



**NMRA DCC Reference Manual**  
*for*  
**QSI Quantum<sup>®</sup> Q1a and Q2**  
**Equipped Locomotives**

Version 4.2.0  
For Firmware Version 7  
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# Digital Command Control Explained

Digital Command Control (DCC) is the standard adopted by the National Model Railroad Association (NMRA) in 1994<sup>1</sup> to allow compatible operation of all locomotives and Command Stations regardless of manufacturer.

DCC differs from Analog control in that DCC applies full voltage to the track at all times and controls the speed and functions of different locomotives by addressing each locomotive separately using assigned locomotive ID numbers. Because each locomotive can be addressed separately, you can independently control speed, lights, and sounds on different locomotives on the same powered track.

DCC provides features and opportunities that are usually not available under conventional Analog Control<sup>2</sup>, but does require you to commit to a new and more complex operating system.

All Quantum equipped locomotives operate using NMRA DCC control. The three most common locomotives are Steam, Diesel and Electric, although others, such as trolleys, powered commuter cars, subways, etc. can be operated under DCC as well.

Quantum equipped locomotives have been designed to operate directly out of the box under NMRA standards for either conventional Analog DC operation or Digital Command Control. There are no switches in the locomotive that need to be set to select the type of control system. The Quantum System responds directly to the type of signal on the track.

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1 The Electrical and Communication Standards were adopted by the NRMA in Portland OR in July, 1994. The basic Recommended Practices (RP's) were accepted in 1995 in Atlanta Georgia and the Service Mode RP's were established in 1996.

2 Quantum systems use an advanced Analog control system called QARC™ (Quantum Analog Remote Control) Technology that does provide many of the same features available in DCC. See the Quantum Analog Reference Manual for details.

# This Manual

This manual is divided into seven parts:

- The first section summarizes how to operate your Quantum locomotive in DCC. Read this and you will quickly have your locomotive up and running.
- The second section summarizes the programming of Configuration Variables (CV's). Read this when you are ready to customize your locomotive's operation.
- The third section describes in detail NMRA standard CV's supported by Quantum locomotives. Skim over this to get a general idea of what it contains. You will often refer to it when you want to solve a particular problem.
- The fourth section outlines in excruciating detail the NMRA standard CV's which assign outputs to function keys. Normally you do not have to be concerned with these CV's, but sometimes this section is important, for example if you ever have to configure your locomotive to operate with a DCC controller having a small number of function keys.
- The fifth section describes in detail CV's that are unique to Quantum locomotives. Skim over this to get an idea of the degree of flexibility built into Quantum locomotives. Refer to this section whenever you want to customize volume levels, change the features that are assigned to function key outputs, configure the behavior of these features, or tweak your locomotive's running performance.
- The sixth section describes in detail additional NMRA standard CV's that you may find useful if you want to fine-tune your locomotive's running performance.
- The appendices describe the sounds and features available in each locomotive type, operation with different DCC Digital Command Stations, troubleshooting and Applications Notes.

Most operations of Quantum equipped locomotives, such as turning the Bell on and off, changing direction, blowing a Horn or a Whistle, are the same across all locomotive types. Special operations for different types of Quantum equipped locomotives are described in the Operation Manuals that come with the locomotives. Any special features included in this Reference Manual will be described in sidebars or notes and in the Appendix section, *Sounds Available in DCC Operation*.

## Please Note

**This reference manual completely describes all features currently available in DCC when operating a Quantum locomotive that has Q1a or Q2 Version 7 firmware. If your locomotive has Version 6 or earlier firmware, use the Quantum DCC Reference Manual Version 3. To determine your software version read the contents of CV 7 (In Ops Mode, set CV 64 to 7 and hear verbal response).**

**Many of the new features described in version 4.1 of this manual are currently available only with Q2 firmware supporting O-Scale and G-Scale locomotives.**

**As new Quantum locomotives are introduced, they may have features not found in earlier locomotives. Check the Operation Manual that came with your locomotive to determine which features apply to your locomotive. This document will evolve over time as new information is added to keep it as complete and current as possible.**

**Although reading the first section, "Locomotive Operation in DCC", will allow you to begin operating your Quantum locomotive immediately, the purpose of this manual is not to teach you how to use DCC. We assume that you already have the working knowledge and experience to operate the different DCC features and program CV's. If you are just getting started in DCC, there are several books listed in Appendix VII to instruct you in the operation of DCC layouts, turnouts, accessories, programming Configuration Variables (CV's), etc.**

# 1 Locomotive Operation in DCC

## 1.1 Getting Started

Although DCC operation can be very complex, it does not have to be. Your Quantum locomotive is factory configured to operate the common and more popular features. The following brief instructions will get you up and running quickly.

To start operating your Quantum equipped locomotive immediately:

- 1) Select locomotive number 3
- 2) Set your controller to 128 (preferred) or 28 (acceptable) speed step range<sup>3</sup>
- 3) Start your locomotive by turning up the throttle

## 1.2 Basic Throttle and Direction Control

When you turn up the throttle, the locomotive starts moving and produces sounds appropriate to its moving state. The Headlight, Mars Light, and Reverse Light change intensity depending on the direction of movement.

When you reduce the throttle setting to zero, the locomotive comes to a complete stop and automatically enters Neutral. You will hear special background sounds appropriate to its resting state. If the locomotive was moving Forward, the Headlight (or operating Mars Light) dims when it stops and enters Neutral. This was common practice for prototype locomotives under Rule 17<sup>4</sup>. You will hear a Short Air Let-off whenever the locomotive enters Neutral.

If you leave your Steam locomotive in Neutral for at least 25 seconds and then slowly turn up the throttle, the locomotive plays Cylinder Cocks sounds as it starts moving. The Cylinder Cocks sounds automatically terminate after 16 repetitions or when the locomotive reaches a speed greater than 12 smph.

The direction of your locomotive changes when you press the direction key. If the locomotive was moving at the time you pressed the direction button, the locomotive slows at a speed determined by the deceleration setting in CV 4, come to a complete stop and then accelerates in the other direction as determined by the CV 3 acceleration setting. CV 3 and CV 4 are described in the section "Programming Configuration Variables".

### Locomotive Directional States

Quantum locomotives have four distinct Directional States:

**Forward (FWD):** If the locomotive is set to the Forward Direction and is moving, it is in the "Forward" state.

**Neutral from Forward (NFF):** If the locomotive is set to the Forward Direction, and the throttle is turned down to zero speed step and the locomotive is stopped, it will be in a Neutral State called "Neutral from Forward".

**Reverse (REV):** If the locomotive is set to the Reverse Direction and is moving, it is in the "Reverse" state.

**Neutral from Reverse (NFR):** If the locomotive is set to the Reverse Direction, and the throttle is turned down to zero speed step and the locomotive is stopped, it will be in a Neutral State called "Neutral from Reverse".

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<sup>3</sup> If you set your controller to 14 speed-step operation without reconfiguring your Quantum system to the same speed steps in CV 29, your Directional Lighting will not operate correctly.

<sup>4</sup> Rule 17, followed by prototype railroads, states: The headlight will be displayed to the front of every train by night, but must be dimmed or concealed when a train turns out to meet another and the entire train has stopped clear of main track, or is standing to meet trains at the end of double track or at junctions.

## 1.3 Throttle Control Modes

There are four ways your locomotive can respond to your throttle.

- **Standard Throttle Control (STC) ::** Under STC, the percentage of full power applied to the motor is directly related to the throttle setting (speed step). Since the power to the motor is constant for a given throttle setting, the locomotive's speed varies depending on the load. The locomotive may easily stall at low speeds from minor gear binding, turnouts, and curves.
- **Calibrated Speed Control (CSC):** Under CSC, the power applied to the motor is varied to maintain constant speed regardless of varying load conditions. The throttle setting (using 128 speed steps specifies the locomotive's speed in 1 smph (scale miles per hour) increments. If your throttle is set at 35, the locomotive tries to maintain 35 smph on level track, up hill, and down hill. If locomotives in a consist differ even slightly in speed calibration, some of the locomotives do all the work while the other locomotives are dragged along.
- **Load Compensated BEMF Speed Control (BEMFSC):** Under BEMFSC, each speed step corresponds to a target BEMF value. The locomotive adjusts the power applied to the motor so that the locomotive's measured BEMF matches the target BEMF.
- **Regulated Throttle Control (RTC)** RTC combines the best of STC and Speed Control. It is the preferred method when multiple heading Quantum locomotives together because it automatically equalizes power between locomotives. Like Speed Control, RTC allows you to run your locomotive at very slow speeds without concern that it will abruptly stop from minor impediments such as misaligned track joints, tight curves, or rough switches. RTC operates your locomotive as though it has huge mass; your locomotive will resist changes in speed once it is moving and will resist starting up quickly if at rest.

For further explanation of these four modes, see CV 56.4: QSI Throttle Mode.

The default mode is RTC. You can change to STC using CV 56.4.

Quantum equipped locomotives will produce labored sounds under acceleration and lighter non-labored sounds under deceleration. The level of labored sounds is proportional to the value of CV 3 plus CV23, and of CV 4 plus CV24 and how much the throttle is increased or decreased. Diesel locomotives produce louder motor sounds under acceleration and softer motor sounds under deceleration. Steam locomotives produce louder chuffs under acceleration and softer chuffs under deceleration.

### Important Legal Notice

BEMF Speed Control and Calibrated Speed Control under DCC operation are not included in your Q1a or Q2 equipped locomotive model. These functions have been declined by model railroad importers of Quantum equipped locomotives because of threats of litigation by Mike's Train House. QSI believes the claim by Mikes Train House is unfounded because these control features were developed by QSI and others and were in use long before Mike's Train House claims to have invented them. QSI does not believe that Quantum Sound System infringes any MTH patent.

## 1.5 Function Keys

Quantum decoders support the 0-12 Function Key standard as now accepted by the NMRA; the old 0-8 standard is not supported.

### 1.5.1 Common Feature Function Key Assignments

The following table lists features that have been pre-assigned to your DCC Function Keys for common operation across the different types of Quantum locomotives. Check the Operation Manual that comes with your locomotive to see which of these common features are offered or what additional custom features have been included.

These common features are described in detail in the following sections.

Notice that some keys operate different features in Forward/Reverse than in Neutral.

<b>F-Key</b>	<b>FWD/REV</b>	<b>NFF/NFR</b>
<b>FL(f)</b> <sup>5</sup>	Headlight,, Reverse Light, and Hazard Light Directional Lighting	Headlight, Reverse Light, and Hazard Light Directional Lighting
<b>FL(r)</b> <sup>6</sup>	Headlight, Reverse Light, and Hazard Light Directional Lighting	Headlight, Reverse Light, and Hazard Light Directional Lighting
<b>F1</b>	Bell on/off (if assigned <sup>7</sup> )	Bell on/off (if assigned)
<b>F2</b>	Horn/Whistle w/ Doppler Shift	Horn/Whistle
<b>F3</b>	Coupler Crash/Coupler Fire	Coupler Arm (Enable) or Coupler Fire
<b>F4</b>	Steam Blower Hiss/ Diesel Fans and Louvers/ Electric Cooling Fans	Steam Blower Hiss/ Diesel Fans and Louvers/ Electric Cooling Fans
<b>F5</b>	Dynamic Brakes	Dynamic Brakes
<b>F6</b>	Doppler Shift	Locomotive Start Up
<b>F7</b>	Squealing Brakes/Flanges and Air Brakes	Steam Cylinder Cocks Arm Diesel Long Air Let-off Electric Long Air Let-off Gas Turbine/Diesel Transition
<b>F8</b>	Audio Mute	Audio Mute
<b>F9</b>	Heavy Load <sup>8</sup>	Shut Down <sup>9</sup> : Disconnect-Standby-Total Shut Down
<b>F10</b>	Status Report (SMPH)	Status Report (ID's, etc.)
<b>F11</b>	Alternate Horn Selection Number Board or Marker Lights on/off	Alternate Horn Selection/ Number Board or Marker Lights on/off
<b>F12</b>	Automatic Cab Lights	Automatic Cab Lights

<sup>5</sup> The FL Key is labeled "F0", "Headlights" "Lights" or "Directional Lighting" on some DCC controllers.

<sup>6</sup> FL(f) and FL(r) activate/deactivate the automatic behavior of the Headlight, Reverse Light, and Hazard Directional Lighting regardless of which direction the train is moving.

<sup>7</sup> If the prototype did not have a bell, the bell feature is not assigned to F1 and no other feature is assigned in its place.

<sup>8</sup> Early Q1 BLI and Lionel locomotives used F9 for Cruise Control, which was only available on locomotives equipped with Speed Control.

<sup>9</sup> There are three stages to Shut Down. You double click the F9 key to advance to each stage.

## 1.6 Automatic Features

Automatic Quantum Features depend on the directional state of the locomotive. Automatic Control can be enabled or disabled by their indicated function keys. The state of each Automatic feature in each direction is shown in the table below for all locomotive types including steam, diesel and electric.

Feature	Function Key	Forward	Neutral from Forward	Reverse	Neutral from Reverse
Headlight	F0 or FL	Bright	Dim <sup>10</sup>	Dim	Dim
Rear Tender Light	F0 or FL	Dim <sup>11</sup>	Dim	Bright	Dim
Mars Light	F0 or FL	Strobing	Steady On	Steady On	Steady On
Ditch Lights	F0 or FL	On	Off	Off	Off
Number Board Lights	F11	On	On	On	On
Marker Lights	F11	On	On	On	On
Cab Lights	F12	Off after 15 seconds	On after 10 seconds.	Off after 15 seconds	On after 10 seconds.
Steam Blowers	F4	Off after 10 seconds.	On after 10 seconds.	Off after 10 seconds.	On after 10 seconds.
Vents & Cooling Fans	F4	On after 20 seconds.	Off after 10 seconds.	On After 20 seconds.	Off after 10 seconds.
Cylinder Cocks <sup>12</sup>	F7	If armed, plays Cylinder Cocks for 16 times or until speed exceeds 12 smph.	Cylinder Cocks armed after 25 seconds.	If armed, plays Cylinder Cocks for 16 times or until speed exceeds 12 smph.	Cylinder Cocks armed after 25 seconds.

When an indicated function key enables an “automatic” light feature, the associated lights operate according to the states shown in the table. For instance, enabling the Automatic Mars Light in Neutral will not cause the Mars Light to strobe since their automatic behavior would have them at a steady-on setting in that directional state; however, if you then entered Forward, the Mars Light would begin to strobe. When an indicated function key disables an “automatic” feature, all lights will be off. For instance, disabling the “Automatic Mars Light” will immediately shut off the Mars Light in any direction and they will not turn on again until the automatic feature is enabled.

**Note:** Use CV 55 to change the behavior of lights from what is shown in the above table and description.

**Note:** Not all automatic features may be included in your locomotive model.

**Note:** Lights and other features can be assigned to function keys and configured to different kinds of operation and initial conditions in CV 53 (Output Feature Assignment) and CV 55 (QSI Feature Configuration). See the Quantum DCC Reference Manual, version 4.

**Note:** Cylinder Cocks can also be armed in Neutral with the F7 key or the F6 Start Up key without having to wait for the 25 time out period.

**Note:** The start up state for directional lighting is “activated”. See CV 55 for further information.

**Note:** Most steam locomotives use a steam-powered generator, called a Dynamo, to supply electricity to the lights. When the lighting system is turned on, the brightness of the headlight increases slowly as the steam generator revs up to full power. Check your Operation Manual to see if your steam model has a Dynamo.

**Note:** If your FL key does not predictably affect the Headlight or Reverse Light, see the troubleshooting section in the Appendix.

<sup>10</sup> If your locomotive has the Mars Light, the Headlight will be off (instead of “Dim”) in all states except Forward where it will be Bright.

<sup>11</sup> Most Quantum 1 and Q1a Reverse Lights cannot be dimmed; they only have bright and off settings. In these cases, “Dim” is equivalent to “Off”.

<sup>12</sup> Cylinder Cocks arming after Start Up and/or after 25 seconds in Neutral can be set using CV 51.2. The settings in this CV apply to both Analog and DCC operation.

## 1.7 Horn/Whistle and Bell Buttons (F2 Key and F1 Key)

Some DCC controllers have separate horn/whistle and bell buttons, in addition to Function Keys assigned to horn/whistle and bell operation. The bell is usually assigned to F1, and the horn is usually assigned to F2.

The F2 key behaves differently than the Horn button.

- Pressing F2 and releasing it will cause the horn/whistle to come on and stay on until you press F2 again.
- Pressing the Horn button will blow the horn/whistle only as long as you hold the button down.

There is no difference in operation between the Bell button and its corresponding function key. Pressing F1 and releasing it will cause the bell to come on and stay on until you press F1 again.

Horns and whistles have start up and shut down effects and a short hoot record for short duration horn/whistle blasts. Some models have an additional fancy ending (playing the horn/whistle). On these models, you can activate the fancy ending by tapping the horn button at the end of the horn blast.

If your locomotive is equipped with Ditch Lights, they will automatically strobe when the horn is being blown, and will continue to strobe until five seconds after the horn signal has stopped<sup>13</sup>.

With Diesel, Electric, and Gas Turbine models, since the prototype horn uses compressed air, you will hear Air Pump sounds turn on after the Horn is operated.

**Note:** If your DCC controller has assigned the Bell to F3, you can reassign your Quantum decoder's F3 to the bell output (see CV 37). Remember to reassign the F1 Function to some other output besides 3 (see CV 35).

## 1.8 Coupler and Coupler Crash Sounds (F3 Key)

There are two ways to use the F3 key.

- 1) In Forward or Reverse, as your locomotive is moving to couple up to a string of cars, press F3 to trigger the crashing sound of a locomotive coupling. Press F3 again as the locomotive is moving out to produce the same sound as the slack is taken up in the cars.
- 2) Press F3 in Neutral to produce uncoupling sounds as you disconnect cars over uncoupler magnets. Press F3 once to produce the sound of the lift bar and coupling pin being raised. This first press also arms the uncoupling sound effect. Press F3 again while moving or in Neutral to produce the sound of the coupler knuckle opening and the air-lines parting.

If you armed the Coupler in Neutral and your locomotive is now in Forward or Reverse, pressing F3 produces the sound of the coupler opening. Thereafter, as the locomotive continues in Forward or Reverse, pressing F3 will produce coupler crash sounds.

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<sup>13</sup> The hold time for strobing Ditch Lights after the horn button is released can be set in CV 55.84.5.

## 1.9 Sound-of-Power™

If CV 3, or CV 23 and CV 4, or CV 24 has been set to non-zero positive values, your locomotive will produce additional labored engine sounds under acceleration and lighter engine sounds under deceleration. The level of labored sounds is proportional to the values for these four CV's, and how much the throttle is increased or decreased. Laboring is different for the three primary types of locomotives:

**Diesel Motor RPM:** Quantum has all eight diesel-motor throttle “notches” found on prototype locomotives. As you increase the throttle, you will hear the RPM's increase for every increase in ten speed steps (at 128 speed step setting). Idle is considered Notch 0 and occurs for speed step 0. Notch 1 ranges from 1 to 10, Notch 2 from 11 to 20, Notch 3 from 21 to 30, etc. If your controller has an option to increment or decrement your throttle set setting by ten speed steps, it is very easy and predicable to set your notch value.

**Steam Exhaust:** Under acceleration the steam exhaust is labored and loud and under decelerating, the steam exhaust is lighter. Also, when starting out after an extended period in Neutral (over 25 seconds), you will hear steam and water vented from the Cylinder Cocks when it starts out. The Cylinder Cocks will vent 16 times or until speed exceeds 12 smph.

**Electric Traction Motors:** Under acceleration, hear the traction motors rev up and strain as the Electric locomotive gains full speed. Under deceleration, the traction motors are not labored and rev down as the locomotive slows.

## 1.10 Dynamic Brakes (F5 Key)

**Diesel Locomotives:** The prototype Dynamic Brakes, found on most diesels, cause the train to slow down by using the traction motors in generator mode. This helps dissipate the energy of a moving train by applying electrical power from the traction motors to a large air-cooled resistor load in the locomotive. These resistor grids can get quite hot and require cooling by fans located on the roofs of the locomotives.

- Pressing F5 in Forward/Reverse will set the Diesel Motor sound to idle at the lowest Sound of Power setting and turn on the powerful Dynamic Brake Cooling Fans.
- Pressing F5 in Neutral does not turn the Dynamic Brake Fans on unless the locomotive is in Disconnect (see F9 “Disconnect” below).

**Electric Locomotives:** Early Electric locomotives did not have Dynamic Brakes. However, the Dynamic Brake function has been included to make Electric locomotives consistent with other Quantum equipped locomotives.

- Pressing F5 in Forward/Reverse will set the Electric Traction Motor Sound-of-Power to the lowest setting allowing these early Electric locomotives to behave consistently<sup>14</sup> with other locomotives that do have Dynamic Brake sounds in multiple unit Consists.
- If an Electric locomotive does have Dynamic Brakes with resistor grids and cooling fans, the locomotive will behave in a similar manner to Diesels.

**Steam Locomotives:** Prototype Steam locomotives do not have Dynamic Brake sounds. However, the Dynamic Brake function has been included to make Steam locomotives consistent with other Quantum equipped locomotives.

- Pressing F5 in Forward/Reverse will set the Steam Exhaust Sound-of-Power to the lowest setting allowing the Steam locomotive to behave consistently<sup>15</sup> with other locomotives that do have Dynamic Brake sounds in multiple unit Consists.

The Dynamic Brakes feature automatically turns off when entering or leaving Neutral, or the speed of the locomotive drops below 8 smph, or if the throttle is turned up. The Dynamic Brakes cannot be turned on in Forward or Reverse unless the locomotive is traveling over 9 smph.

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<sup>14</sup> It would be inconsistent for the Electric Locomotive to be working at full Sound-of-Power while brakes are being applied in other locomotives within the same consist.

<sup>15</sup> It would be inconsistent for the Steam Locomotives to be working at full Sound-of-Power while brakes are being applied in other locomotives within the same consist.



## 1.11 Doppler Shift (F6 in Forward and Reverse)

There are two ways to initiate the Doppler Shift effect.

### 1.11.1 Horn Button Method<sup>16</sup>

- 1) If your controller has a horn button in addition to the F2 key, press the horn button to turn on the Horn/Whistle while the locomotive is moving towards you.
- 2) Wait at least one second while the Horn/Whistle is blowing
- 3) Release and re-press the horn button quickly so the Horn/Whistle does not shut off. You will hear the Horn/Whistle and other locomotive sounds increase in volume and shift in pitch as the locomotive passes by and then reduce in volume.
- 4) Release the horn button or continue blowing long and short blasts. Five to seven seconds after releasing the horn button, the sounds will gradually return to normal.

### 1.11.2 F6 Doppler Shift Operation Method

- 1) Start the Horn/Whistle by pressing and releasing the F2 key.
- 2) Press F6 as the locomotive is moving towards you. The Horn/Whistle and other locomotive sounds increase in volume and shift in pitch as the locomotive passes by and then reduce in volume.
- 3) Press F2 button again to shut off the Horn/Whistle or continue blowing long and short blasts by pressing and re-pressing F2. If you shut off the Horn/Whistle for more than five to seven seconds, the sounds will gradually return to normal.

If the bell was on during DopplerShift, it will automatically turn off prior to the sounds returning to normal.

If Doppler Shift is initiated without the Horn/Whistle blowing, the sounds return to normal soon after the Doppler Shift is finished.

Doppler Shift is speed dependent. The greater the speed, the greater the amount of pitch change as the locomotive passes by. There is no Doppler Shift at speeds less than 15 scale miles per hour (smph); instead you will hear a short air let-off when F6 is pressed.

Try using the F6 key to affect chuffing sounds (sans Whistle or Bell) to create interesting environmental effects.

**Note:** Some base stations produce an intermittent and independent horn signal interruption that causes an unexpected Doppler Shift. If this happens frequently, you may want to disable the horn triggered Doppler Shift by setting CV 51.2 bit 0 to 0.

**Note:** With some Command Stations, using the horn button to activate the Horn/Whistle, and then while this button is held down, pressing F6 causes the Horn/Whistle to shut off instead of causing a Doppler Shift effect.

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<sup>16</sup> This is similar to the method used in Analog DC to trigger a Doppler Shift.

## 1.12 Squealing Brakes and Flanges (F7 in Forward or Reverse)

Quantum locomotives provide automatic Brake Squeal as a locomotive slows to a stop. To enable automatic Squealing Brakes operate the locomotive over 40 smph (64 skph). When the speed is reduced to less than 20 smph (32 skph), squealing Brake sounds will sound automatically.

When the locomotive is moving, you can also manually activate continuous or variable brake sounds when slowing or stopping the locomotive or to simulate the sounds of squealing flanges on curved track.

- 1) Press F7 to start Squealing Brake sounds.
- 2) The Squealing Brakes sounds end automatically, but you can press F7 while the brake squeal is occurring to re-trigger the squealing sounds. This allows you to continue the squealing brake sounds without any dead period for an indefinite period.

The squealing brake sounds will terminate abruptly when the locomotive stops and enters Neutral.

**Note:** If you lower the throttle to speed step 0, pressing F7 will apply Air Brakes instead of activating squealing brake sounds.

## 1.13 Air Brakes (F7 in Forward or Reverse)

If you have selected any non-zero deceleration inertia value in CV 4 and/or CV 24, the F7 key can be used to apply Air Brakes to stop the locomotive more quickly than it would normally stop from the inertia settings<sup>17</sup>. To use Air Brakes:

- Turn the throttle down to speed step 0 on a moving locomotive; this enables the F7 key to act as a brake.
- Press the F7 key. Hear a brief brake squeal sound and air being released from the brake lines continually. The longer the air is released the greater the braking action.
- Press the F7 key again to stop the air release. The train will continue to slow at the last braking value.

**Note:** F7 will apply brakes when set to 1 and stop the air release when set to 0. Depending on the initial setting for F7 when you turn your throttle down to speed step zero, you may need to press the F7 key twice to first apply brakes.

- If you want to apply more braking, press the F7 key again to release more air. When you reach the desired amount of braking, press F7 again to stop the air release.
- Turn up the throttle to any value above 0 to release the brakes; this action resets the locomotive's deceleration to a value determined by the sum of CV 4 and CV 24.
- If the locomotive is in Neutral when the F7 key is pressed, the Cylinder Cocks will arm.<sup>18</sup>

**Note:** If the throttle is set to any speed step except 0, Air Brakes are not enabled; instead the F7 key will now manually activate Squealing Brake/Flange sounds but will not affect the locomotive's deceleration.

**Note:** If the direction state is changed while moving, F7 is enabled to act as a brake without the need to reduce the throttle to speed step 0. After stopping and changing direction, the loco will accelerate back to its original speed. If CV 4 or CV 24 is non-zero, F7 can be used to apply Air Brakes to stop a moving locomotive more quickly than it would normally stop from the inertia settings<sup>19</sup>.

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<sup>17</sup> CV 4 and CV 24 determine the deceleration rate. Applying the brakes increases the deceleration rate temporarily.

<sup>18</sup> If the optional Cylinder Cocks feature is not include in your model, the F7 key will produce a long Air Let-off.

<sup>19</sup> CV 4 and CV 24 determine the deceleration rate. Applying the brakes temporarily increases the rate of deceleration.

## 1.14 Audio Mute (F8 Key)

You can reduce the System Volume to a lower level or increase it back to its original setting using the F8 key. This is useful when you need to reduce the sound to engage in a conversation or to answer the phone.

- 1) Set F8 to “1”. All sounds, including the Whistle, Bells, Motors and Chuff will gradually go off.
- 2) Set F8 to “0”. All sounds, including the Whistle, Bells, Motors and Chuff will gradually return to normal volume.

If you have many locomotives operating at once, you can reduce the volume on all those that are running in the back of the layout and increase the volume of the closest locomotive. The Mute feature changes the sound gradually over a couple of seconds, which allows the sound to increase or decrease realistically as the locomotive approaches or recedes from the observer.

The Mute state is not retained if track power is turned off. On power up the locomotive returns to full system volume.

**Note:** You can set the Mute volume in CV 51.1 if you want to be able to quickly quiet your locomotive without having the sounds turn completely off.

## 1.15 Heavy Load (F9 in Forward or Reverse)

Heavy Load is applied while the train is moving; it maintains the train at a nearly steady speed while allowing you to have control over the sound effects of a working locomotive. Heavy Load represents a train that would take over ten minutes to accelerate to full speed or to bring to a complete stop. It is independent of any inertia values set in CV3, 4, 23, or 24.

Under Heavy Load, changing the throttle will have little effect on the locomotive's speed. Instead you use the throttle to control Sound-of-Power effects. When you approach a grade under Heavy Load, increase the throttle and hear the locomotive produce heavy laboring sounds. When the locomotive goes down a grade, reduce the throttle to hear the locomotive drop to light laboring sounds. You control labored sounds by how much the throttle is increased or decreased from its initial position (where Heavy Load was turned on).

- 1) Press F9 and hear one short hoot when Heavy Load is turned on<sup>20</sup>. You can apply Heavy Load as soon as you start moving, or wait until you are up to speed.
- 2) Press F9 and hear two short hoots when Heavy Load is turned off. Before turning Heavy Load off, return the throttle to its initial setting (where Heavy Load was turned on) to avoid sudden acceleration or deceleration.

Heavy Load can only be turned on or off in Forward or Reverse<sup>21</sup>. If turned on, it will remain on in Neutral. If you want it off when you start out from Neutral, turn it off immediately after increasing the throttle.

Heavy Load is automatically turned off when track power is turned off.

Under RTC and Heavy Load, grades, tight curves or other real loading effects, will have little effect on the speed of the train. But under STC and Heavy Load, grades, curves, loading, etc. will affect the train speed.

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<sup>20</sup> This feedback can be disabled via CV51.2 bit 3.

<sup>21</sup> You can turn Heavy Load on and off in Neutral if you set CV53.x.1 to 179, the Heavy Load feature ID.

## 1.16 Status Report (F10)

Quantum locomotives provide verbal information about a locomotive's current operating state when the locomotive is in Neutral or the locomotive's current speed when the locomotive is moving.

- Press F10 in Neutral; the locomotive will verbally report first its currently enabled long or short DCC address followed by its consist ID if it has one, followed by its Shut Down state (Disconnect, Standby or Shut Down).
- Press F10 in Forward or Reverse; the locomotive will verbally report the locomotive's speed in scale miles per hour (smph) or scale kilometers per hour (skph). (You can select between scale miles per hour (smph) or scale kilometers per hour (skph) in CV56.0.)

**Note:** When a Status Report or Verbal Speedometer Readout begins, the locomotive's sounds will reduce to one half their current volume settings. Locomotive sounds return to normal volume when the report has ended.

**Note:** The Status Report in Forward and Reverse can be configured to also report the Back EMF value and/or motor Pulse Width Modulation (PWM) value. See CV 55.178.0.

**Note:** In a consist, all locomotives will simultaneously report their status when the F10 key is pressed unless disabled in CV 22.

## 1.17 Alternate Horn Selection (F11)

Some prototype steam locomotives had both a steam whistle and an air horn. The whistles worked best in areas where it was necessary for the sound to carry a long way, while the horn was more useful in the city or foggy areas where it was easier to tell the location of the locomotive by its higher pitched sound. Some diesels and electric locomotives used two horns for similar reasons. The Alternate Horn Selection key allows you to choose between two Horn sounds on selected diesel or electric locomotives or between a Whistle and a Horn on steam locomotives.

- Press the Alternate Horn Selection key, F11, to select between the alternate Horn and the primary Horn or the Whistle. Hear a short hoot to indicate which one has been selected.
- Operate the selected Horn or Whistle with the F2 key.

**Note:** The feedback hoots can be disabled/enabled in CV51.2.

**Note:** Setting F11 to "1" selects the primary Horn or the Whistle. Setting F11 to "0" selects the alternate Horn.

## 1.18 Three Stages of Shut Down: Disconnect, Standby and Total Shut Down (F9 in Neutral)

Locomotive Shut Down has three distinct stages, each entered by double-clicking or double-pressing the F9 Key<sup>22</sup>.

### Stage One: Disconnect

- 1) In Neutral, double-press F9 to enter Disconnect. You will hear a Long Air Let-off, which represents the pneumatic reverse lever on a Steam locomotive being placed in the Neutral position or the Diesel transition level being placed in the off or disconnect position. Your locomotive's motor drive is disconnected.
- 2) To leave Disconnect, either double-press the F6 Start Up key as described in the Start Up section or double-press F9 again to reach the next stage of Shut Down, Standby.

A locomotive in Disconnect continues to respond to all function keys.

For a Diesel locomotive in Disconnect, if the throttle is increased or decreased, the motor sounds will rev up and down but the locomotive will not move. If the Dynamic Brakes are activated, the motors sounds will be labored under Sound of Power control as the throttle is increased and decreased. Prototype Diesel Motor/Generator power output is often tested under Dynamic Brake load in disconnect.

For an Electric locomotive in Disconnect, there is no action or sound associated with moving the throttle up and down and no affect from having the Dynamic Brakes activated.

For a Steam locomotive in Disconnect, if the throttle is increased/decreased, the hissing sound of venting steam will get louder/softer but the locomotive will not move. Prototype Steam locomotives would sometimes vent steam in Neutral to clear rust debris from the super-heaters that can affect the throttle.

### Stage Two: Standby

- 1) In Disconnect, double press F9 to enter Standby. You will hear a Long Air Let-off followed by the Directional Lighting turning off. The motor will remain disconnected, while the Air Pumps, automatic Steam Blower/Cooling Fan operation, Number Board Lights and Cab Lights will continue to operate.
- 2) To leave Standby, either double-press the F6 Start Up key described in the Start Up section or double-press F9 again to reach the final stage of Shut Down, Total Shut Down.

In Standby, the locomotive will not respond to the throttle or most function keys<sup>23</sup>. The three exceptions are the F6 Start Up Function Key (described below), the F8 Mute Key (described above) and the F10 Status Key (described above).

Standby in Diesel locomotives, called Low Idle, has more utility than Standby in Steam and Electric locomotives. It allows a Diesel to be left on a siding inactive with only the motor running at its special "Low Idle" sounds. For Steam and Electric locomotives, the locomotive will appear to be completely inactive except for Cab and Number Board lights, occasional Air Pump sounds, and Blower or Fan sounds.

### Stage Three: Total Shut Down

- 1) In Standby, double-press F9 to enter Total Shut Down. You will hear a Long Air Let-off followed by the sounds of a shutdown procedure specific to your type of locomotive.

**Diesel Locomotives:** Low Idle Diesel Motors will return to normal idle sounds. Then the Air Pumps will turn off, as will the Number Board Lights, followed by the sounds of the Cooling Fans shutting off, the Louvers closing, the Diesel Motor(s) shutting down, Cab Lights shutting off, and finally the engineer's door opening and shutting.

**Electric Locomotives:** The Air Pumps will turn off, Cab Lights will turn off, followed by the sounds of the Louvers being closed and the engineer's door being opened and shut.

**Steam Locomotives:** The Air Pumps will turn off, followed by the sounds of Pop Off operating for about ten seconds, the Cab Lights shutting off, and finally the Blower Hiss will die out.

- 2) To leave Total Shut Down, double-press the F6 key.

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<sup>22</sup> Double-clicking ensures that Shut Down stages are not entered or exited accidentally. Doubling-pressing is defined as two F9 presses within two seconds. Note that the F9 key may have to be pressed three times the first time you use it due to the command station and locomotive having different initial states for F9.

<sup>23</sup> Pressing a Function Key will only produce a Short Air Let-off.

In Total Shut Down, the locomotive will not respond to any function keys except the F6 Start Up Function Key (described below) and the F10 Status Key (described above).

Total Shut Down allows you to take a locomotive “off-line” (turn off sounds, lights, ignore throttle and function commands (except turn on)) independent of the operating session; that is, the locomotive will still be “off line” when power is reapplied for the next operating session.

If power is turned off at any stage of Shut Down (Disconnect, Standby or Total Shut Down) or during a Shut Down procedure, the locomotive will remember its last Shut Down stage, and will power up in that Shut Down stage.

If Start Up is initiated during any of the above Shut Down procedures, Shut Down is aborted and the locomotive returns to normal operation.

## 1.19 Start Up (F6 in Neutral)

If your locomotive is in any of the Shut Down stages, you can return your locomotive to normal operation by double-pressing<sup>24</sup> the F6 Key. Start Up will be different for each stage of Shut Down, but always begins with a Long Air Let-off and ends by the locomotive entering normal operation<sup>25</sup>.

### Start Up from Disconnect

- Double press F6 in Disconnect, the locomotive will produce a Long Air Let-off and enter normal operation.

### Start Up from Standby

- Double press F6 in Standby, the locomotive will produce a Long Air Let-off, the Directional Lighting will turn on and then the locomotive will enter normal operation.

### Start Up from Total Shut Down

- Double press F6 in Total Shut Down; the locomotive will produce a Long Air Let-off, and begin a full start up procedure.

**Diesel Locomotives:** The Long Air Let-off is followed by the sound of the engineer's door opening and closing. Cab Lights turn on, Number Boards come on, and Directional Lighting turns on. Then the Vents open and Fans start up, the Diesel Motor or Motors start up, the Air Pumps turn on, and finally the locomotive enters normal operation.

**Electric Locomotives:** The Long Air Let-off is followed by the sound of the engineer's door opening and closing. Cab Lights turn on, Number Boards and Marker Lights turn on, and Directional Lighting turns on. Then the Vents open and Fans start up, the Air Pumps turn on, and finally the locomotive enters normal operation.

**Steam Locomotives:** After the Long Air Let-off, the Dynamo revs up and the Directional Lighting turns on. Then Cab Lights turn on, followed by the Air Pumps and the Steam Blower turning on, and finally the locomotive enters normal operation.

During the Start Up from Total Shut Down procedure, a Quantum locomotive will not respond to any function key. However, if the throttle is turned up, the Start Up procedure abruptly terminates and the locomotive immediately enters normal operation.

**Note:** Whenever a locomotive receives a Start Up command, regardless of whether the locomotive is in a Shut Down stage or operating normally, the locomotive will restore all automatic operations and return all feature function states to their initial states as specified in CV55.

**Note:** Whenever F6 Start Up key is double-pressed in Neutral for a steam locomotive, the Cylinder Cocks<sup>26</sup> will be armed. Cylinder Cocks sounds will play when the throttle is turned up to leave Neutral.

## 1.20 Function Key Operation in Neutral

Some function keys used in Forward and Reverse will have different effects when used in Neutral:

- Pressing F6 results in Doppler shift for a moving locomotive but activates Start Up in Neutral.
- The F7 key produces Squealing Brake Sounds or applies brakes for a moving locomotive but produces a Long Air Let-off in Neutral in Diesels or enables Cylinder Cocks in Steam locomotives.
- Pressing F9 turns on/off the Heavy Load feature in a moving locomotive but activates Shut Down in Neutral.

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<sup>24</sup> Double-pressing ensures that Start Up is not entered or exited accidentally. Doubling-pressing is defined as two F6 presses within two seconds. Note that the F6 Key may have to be pressed three times the first time you use it due to the command station and locomotive having different initial states for F6.

<sup>25</sup> The locomotive enters Neutral with Long Air Let-off if speed step is zero. If speed step is non-zero, the locomotive will enter either forward or reverse.

<sup>26</sup> Not all steam models have Cylinder Cocks feature.

## 2 Programming Configuration Variables

### 2.1 Service Mode Programming<sup>27</sup>

To perform Service Mode Programming, place your locomotive on an isolated track, called a Programming Track, that is electrically insulated from the main line and separately connected to a special output from your Command Station.

There are two advantages to programming in Service Mode.

1. On the Programming Track, no Locomotive Address is required to program your locomotive. This is important if you have forgotten your locomotive's ID numbers or have programmed them incorrectly. This is also why programming must be done on an isolated track section. Otherwise, CV's of all locomotives on your layout would be programmed with the same value.
2. On the Programming Track, the locomotive responds with Service Mode Acknowledgements to command station requests to verify the contents of a CV. In this way the command station is able to read back the current value of a CV. This is important if you want to change a CV by some amount but need to know it's current value before you enter a new value.

Some Command Stations restrict the amount of power that can be delivered to the Programming Track to prevent damage to improperly installed aftermarket decoders. If the decoder were wired correctly, the Programming Track would provide enough power to allow it to be programmed. If the decoder were wired incorrectly and a short circuit occurred, the limited current from the command station would not be enough to damage the decoder, allowing the operator another chance to wire it correctly.

To accommodate command stations that restrict power during Service Mode programming, the Quantum System reduces its power consumption to a minimum by shutting off all lights, sound and other operations during Service Mode operation. Even so, a Quantum Sound Decoder still requires more current than most non-sound decoders. If your Quantum System will not program with your particular command station, you may need to program on the Main (Ops Mode Programming). You can also purchase from Tony's Train Exchange<sup>28</sup>, a simple, inexpensive power booster (PowerPak™ by DCC Specialties) that will allow you to program on the program track with any DCC command station.

**Note:** Some Command Stations will not operate Quantum Systems in Service Mode due to insufficient power output or timing problems. (Check Appendix IIIA for a listing of recommended command stations). If you cannot operate in Service Mode, use Ops Mode programming.

<sup>27</sup> All four methods are supported: Address-Only Mode, Physical Register Addressing Mode, Paged CV Addressing Mode, and Direct CV Addressing Mode.

<sup>28</sup> Tony's Train Exchange; 1-800-978-3472; [info@ttx-dcc.com](mailto:info@ttx-dcc.com).



## 2.2 Operations Mode Programming<sup>29</sup>

Operations Mode Programming is also called Ops Mode Programming or Programming on the Main

In this programming mode, you do not move your locomotive to an isolated programming track. You program it in place on the Main track as you are operating it.

The Quantum System will allow you to program all CV's, including address CV's (CV 1, CV 17 and CV 18), in Operations Mode.

There are advantages and disadvantages to using Operations Mode Programming.

- 1) One disadvantage is that, in Ops Mode, Quantum decoders do not support any advanced acknowledgement mechanism, as defined by the NMRA. If you are using a command station that provides readout for your CV's in Ops Mode, it can only indicate which CV you are addressing and the value you want to program. You will not be able to determine what value is already entered in that CV or that the new value has been accepted and is correct.

**Note:** In Ops Mode, Quantum locomotives do give verbal feedback during CV programming. If CV Verbal Acknowledgement is enabled (see CV 62), the CV number and its new value are announced over the locomotive's sound system when a CV is programmed.

**Note:** In Ops Mode, you can command a Quantum locomotive to speak out the current value of any CV (see CV 64).

- 2) Another disadvantage with Programming on the Main is that you need to address your locomotive with its ID number in order to change its CV values. This could be a problem if you have forgotten your locomotive's ID number. Or you might use the wrong address and program the wrong locomotive. It could happen that you find yourself unable to communicate with your locomotive. If this does happen, you can move your locomotive to a Programming Track and change your locomotive's ID using Service Mode Programming. Or you can do a hardware reset by pulling the reset jumper on the circuit board or by using the Magnetic Wand<sup>30</sup>, which will set the locomotive's ID to short address 3 (See Appendix IIIB).

**Note:** Some command stations do not support programming address CV's on the main. See notes in trouble shooting and related CV's (1, 17, 18, 56.129) for possible solutions to this problem.

- 3) One advantage of programming on the main is that you often can observe an immediate change to your locomotive's behavior when you program a CV. For example, you can hear the System Volume or an individual feature sound volume change immediately after you program its new CV value. In Service Mode, you have to move the locomotive from the Service Mode Programming track to the Main track to see the effect of changing a CV.

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<sup>29</sup> Both the short form and the long form of the CV access instructions are supported.

<sup>30</sup> A magnetically activated switch on the circuit board replaced the jumper on later Quantum equipped locomotives.

## 2.3 List of CV's Supported by Quantum Locomotives

The following table lists all CV's. The third column, labeled "NMRA", indicates whether these CV's are mandatory (M), recommended (R), or optional (O). The fourth column indicates if this CV is supported by QSI and the fifth column indicates the common default value.

CV#	CV Name	NMRA	QSI Supported	Default Value Decimal	Comment
1	Primary Address	M	Y	3	
2	V-Start	R	Y	32	This number may change from locomotive to locomotive.
3	Acceleration Rate	R	Y	0	
4	Deceleration Rate	R	Y	0	
5	V-High	O	Y	1	Either 1 or 0 in this CV will disable V-High
6	V-Mid	O	N	-	
7	Manufacturer Version No.	M	Y	-	See CV 56.254 and CV 56.255 for additional information on Quantum Version numbers.
8	Manufacturer's ID	M	Y	113	
9	Total PWM Period <sup>31</sup>	O	N	-	Not needed with our motor control
10	EMF Feedback Cutout2	O	N	-	Not needed with our BEMF detection.
11	Packet Time-Out Value	R	Y	1	
12	Power Source Conversion	O	N	-	
13	Analog Mode Function Status	O	N	-	
14	Reserved by NMRA for future use	-	-	-	
15	Reserved by NMRA for future use	-	-	-	
16	Reserved by NMRA for future use	-	-	-	
17	Extended Address	O	Y	0	CV 17 and 18 form a paired CV. CV 17 must be written first followed by CV 18
18	Extended Address	O	Y	0	See above.
19	Consist Address	O	Y	0	
20	Reserved by NMRA for future use	-	-	-	
21	Consist Address Active for F1-F8	O	Y	0	
22	Consist Address Active for FL and F9-F12	O	Y	0	
23	Acceleration Adjustment	O	Y	0	
24	Deceleration Adjustment	O	Y	0	
25	Speed Table Selection	O	Y	2	Linear
26	Reserved by NMRA for future use	-	-	-	
27	Reserved by NMRA for future use	-	-	-	
28	Reserved by NMRA for future use	-	-	-	
29	Configuration Data #1	M	Y	6	28 speed step mode. Power Source Conversion enabled.
30	Error Information	O	N	-	May be used in the future but not currently needed.
31	Configuration Data #2	O	N	-	Reserved by NMRA for future use.
32	Configuration Data #3	O	N	-	Reserved by NMRA for future use.
33	Output Location for FL(f)	O	Y	1	By default set to directional lighting.
34	Output Location for FL(r)	O	Y	3	By default set to directional lighting.
35	Output Location for F1	O	Y	4	By default set to bell output.
36	Output Location for F2	O	Y	8	By default set to whistle output.

<sup>31</sup> Changes are not allowed. The PWM is already optimized for Quantum equipped locomotives.

37	Output Location for F3	O	Y	16	By default set to coupler sounds output.
38	Output Location for F4	O	Y	4	By default set to Cooling Fans output.
39	Output Location for F5	O	Y	8	By default set to Dynamic Brakes output.
40	Output Location for F6	O	Y	16	By default set to Doppler output.
41	Output Location for F7	O	Y	32	By default set to Air Brakes output.
42	Output Location for F8	O	Y	64	By default set to Mute output.
43	Output Location for F9	O	Y	16	By default set to Heavy Load output.
44	Output Location for F10	O	Y	32	By default set to Status Report output.
45	Output Location for F11	O	Y	64	By default set to Number Boards output.
46	Output Location for F12	O	Y	128	By default set to Cab Lights output.
47	Reserved by NMRA for future use	-	-		
48	Reserved by NMRA for future use	-	-		
49	QSI Primary Index	O	Y	0	"PI" for short.
50	QSI Secondary Index	O	Y	0	"SI" for short.
51	QSI System Sound Control	O	Y		1-dimensional table[PI]
52	QSI Individual Sound Volume Control	O	Y		1-dimensional table[PI]
53	QSI Function Output Feature Assignment	O	Y		2-dimensional table[PI,SI]
54	Reserved by QSI for future use	-	-		
55	QSI Feature Configuration	O	Y		2-dimensional table[PI,SI]
56	QSI Configuration	O	Y		2-dimensional table[PI,SI]
57	Reserved by QSI for future use	-	-		
58	Odometer	-	-		
59	Reserved by QSI for future use	-	-		
60	Reserved by QSI for future use	-	-		
61	Reserved by QSI for future use	-	-		
62	QSI Control	O	Y	1	Turn on/off programming verbal acknowledgement.
63	Reserved by QSI for future use	-	-		
64	Verbal CV Inquiry	O	Y		Decoder speaks out value of any CV.
65	Kick Start	O	N	-	
66	Forward Trim	O	Y	128	
67	Speed Step 1	O	Y	0	
68	Speed Step 2	O	Y	9	
69	Speed Step 3	O	Y	18	
70	Speed Step 4	O	Y	28	
71	Speed Step 5	O	Y	37	
72	Speed Step 6	O	Y	47	
73	Speed Step 7	O	Y	56	
74	Speed Step 8	O	Y	66	
75	Speed Step 9	O	Y	75	
76	Speed Step 10	O	Y	85	
77	Speed Step 11	O	Y	94	
78	Speed Step 12	O	Y	103	
79	Speed Step 13	O	Y	113	
80	Speed Step 14	O	Y	122	
81	Speed Step 15	O	Y	132	
82	Speed Step 16	O	Y	141	
83	Speed Step 17	O	Y	151	
84	Speed Step 18	O	Y	160	
85	Speed Step 19	O	Y	170	
86	Speed Step 20	O	Y	179	
87	Speed Step 21	O	Y	188	

<b>88</b>	Speed Step 22	O	Y	198	
<b>89</b>	Speed Step 23	O	Y	207	
<b>90</b>	Speed Step 24	O	Y	217	
<b>91</b>	Speed Step 25	O	Y	226	
<b>92</b>	Speed Step 26	O	Y	236	
<b>93</b>	Speed Step 27	O	Y	245	
<b>94</b>	Speed Step 28	O	Y	255	
<b>95</b>	Reverse Trim	O	Y	128	
<b>96</b>	Reserved by NMRA for future use	-	-		
<b>97</b>	Reserved by NMRA for future use	-	-		
<b>98</b>	Reserved by NMRA for future use	-	-		
<b>99</b>	Reserved by NMRA for future use	-	-		
<b>100</b>	Reserved by NMRA for future use	-	-		
<b>101</b>	Reserved by NMRA for future use	-	-		
<b>102</b>	Reserved by NMRA for future use	-	-		
<b>103</b>	Reserved by NMRA for future use	-	-		
<b>104</b>	Reserved by NMRA for future use	-	-		
<b>105</b>	User Identifier #1	O	N		
<b>106</b>	User Identifier #2	O	N		
<b>107</b>	Reserved by NMRA for future use	-	-		
<b>:</b>	:	-	-		
<b>512</b>	Reserved by NMRA for future use	-	-		

## 2.4 Overview of CV Descriptions

The following sections provide detailed descriptions of each CV supported by the Quantum System. Each description includes the default value, a pictorial of the CV data register and sometimes, operational hints or notes about special use and limitations.

The data for each bit shown in the pictorial data registers are classified as:

“**A**” for Address data

“**D**” for general data

“**F**” for Function Designation value

“**Sign**” for plus or minus sign.

“**N/A**” for Not Applicable meaning the user is not to enter data in these bits.

“**Output**” for assigning different Output locations for Function Inputs.

“**P**” for QSI Primary Index values

“**S**” for QSI Secondary Index values

“**V**” for audio volume data

In addition, QSI or NMRA pre-assigned data for individual bits in CV registers are shown as their binary value, “1” or “0”.

### Examples:

#### CV 1: Primary Address Register

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
<b>0</b>	<b>A6</b>	<b>A5</b>	<b>A4</b>	<b>A3</b>	<b>A2</b>	<b>A1</b>	<b>A0</b>

Bits 0-6 are data bits, which specify the locomotive’s seven bit Primary Address. A zero means, “Do not attempt to write a 1 to this bit”.

#### CV 49: Primary Index Register

Bit 7 (MSB)	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0 (LSB)
<b>P7</b>	<b>P6</b>	<b>P5</b>	<b>P4</b>	<b>P3</b>	<b>P2</b>	<b>P1</b>	<b>P0</b>

Bits 0-7 are data bits, which specify any of the possible eight bit Primary Index values.

#### CV 40: F6 Output Location for F6 Register (with Factory Default Features)

Heavy Load (Disconnect- Standby-Total Shut Down)	Mute	Squealing Brakes – Air Brakes (Brake Set)	Doppler (Start Up)	Dynamic Brakes	Blower Hiss/Fans	Coupler Crash Coupler Fire (Coupler Arm)	Horn/Whistle
Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
<b>Output 11</b>	<b>Output 10</b>	<b>Output 9</b>	<b>Output 8</b>	<b>Output 7</b>	<b>Output 6</b>	<b>Output 5</b>	<b>Output 4</b>

The “**Output 4**” means that bit 0 specifies whether Output 4 is controlled by Function Key 6.

Gray background for an Output bit means that it is the default setting.



# 3 CV's 1-29: NMRA Standard CV's

This section describes in detail NMRA standard CV's supported by Quantum locomotives.

## 3.1 CV 1 Primary Address Control

Programs the Short or Primary Address from 1 to 127 decimal.

Default Value:

### CV 1: Primary Address Register

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
<b>0</b>	<b>A6</b>	<b>A5</b>	<b>A4</b>	<b>A3</b>	<b>A2</b>	<b>A1</b>	<b>A0</b>

- Any attempt to set this CV to any value outside the range of 1 to 127 will be ignored and the previous address in this register will remain.
- The Primary Address can be set either in Service Mode or Operations Mode. Remember to change bit 5 of CV 29 to "0" to enable the Primary Address.

**Note:** Some Command Stations will not operate Quantum Systems in Service Mode due to insufficient power output or timing problems. (Check Appendix IIIA for a listing of recommended command stations). If you cannot operate in Service Mode, use Ops Mode programming.

If your command station will not allow setting ID numbers in Ops Mode, use QSI CV 56.129.

## 3.2 CV 2 V-Start

V-Start defines the voltage drive level applied to the motor at the first throttle speed step. Use CV 2 to adjust the responsiveness of your locomotive at low throttle settings.

Default Value:

### CV 2: V-Start Register

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
<b>D7</b>	<b>D6</b>	<b>D5</b>	<b>D4</b>	<b>D3</b>	<b>D2</b>	<b>D1</b>	<b>D0</b>

- CV 2 sets a start voltage for the motor to any value between 0 and 255. A value of 0 provides no offset while a value of 255 provides maximum starting voltage with no throttle range left.

CV 2 specifies how much of the available track voltage will be applied to the motor at the start of the throttle range as defined by the following equation:

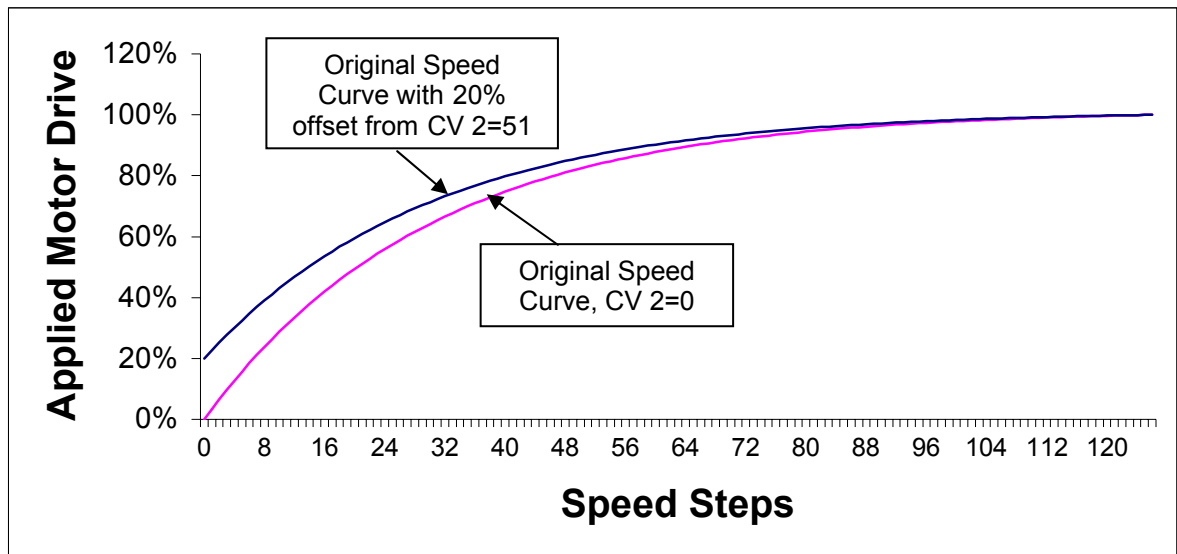
$$\text{Start Voltage} = (\text{Track Voltage}) \times (\text{CV2}/255)$$

- The value of motor drive (as a percentage of total track voltage) is computed according to the formula below:

$$\% \text{ Applied Motor Voltage} = (\text{CV 2} + ((\text{CV5}-\text{CV 2}) * \text{Speed Table Value for speed step}/255)) * (100/255)$$

If CV 5 is less than or equal to CV 2, or CV 5 is set to 0 or 1, then 255 is used for CV 5 in the above equation.

The graph below shows the original curve plus the effect of an offset of 20% (CV 2 = 51 and assuming CV 5, V-High, is set at its maximum value of 255). Note how CV 2 preserves the shape of the original speed curve but compresses it to fit between V-Start and V-High.



- DCC V Start is not related to V Start for Analog Operation.
- V-Start is not used when Throttle Mode = Calibrated Speed Control .
- See CV 5 for more information.



### 3.3 CV 3 Acceleration Rate<sup>32</sup>

Sets the value of Inertia under Acceleration

Default Value:

#### CV 3: Acceleration Rate Register

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
<b>D7</b>	<b>D6</b>	<b>D5</b>	<b>D4</b>	<b>D3</b>	<b>D2</b>	<b>D1</b>	<b>D0</b>

- CV 3 can contain any value between 0 and 255. A value of “0” provides no inertia and gives the fastest response to changes in throttle position.
- The larger the value of CV 3, the more gradually the locomotive increases speed as the throttle is increased. The inertia, in seconds/speed step, is calculated by the formula:

$$\text{Acceleration Inertia (seconds/speed step)} = \frac{(\text{CV 3}) * 0.896}{\text{Number of Speed Steps}}$$

This inertia is independent of which “Number of Speed Steps” is in use (14, 28, or 128). For the same value of CV 3, it will take the same amount of time to go from a dead stop to full speed for a throttle change from minimum to maximum regardless of the speed step choice. The time can vary from a quick response measured in seconds for CV 3=0 to as long as 3.8 minutes (228 seconds) for CV 3 = 255.

- The acceleration rate is the inverse of the inertia formula.

$$\text{Acceleration Rate (speed steps/second)} = \frac{\text{Number of speed steps}}{(\text{CV 3}) * 0.896}$$

- The acceleration and deceleration rate values in CV 3 and CV 4 will apply if you change the direction on a moving locomotive. The locomotive will slow to a stop at a rate set by CV 4 and then accelerate in the opposite direction at a rate set by CV 3.

<sup>32</sup> This NMRA CV is more aptly entitled “Inertia under Acceleration” since higher values for this CV result in higher inertia values but lower acceleration rates. Using the term “Momentum” to describe CV 3 is not correct since a non-moving train has no momentum even if CV 3 is set to the maximum value. Inertia is the property of an object that resists any change to its state of rest or motion.

### 3.4 CV 4 Deceleration Rate<sup>33</sup>

Sets the Inertia under Deceleration.

Default Value:

#### CV 4: Deceleration Register

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
<b>D7</b>	<b>D6</b>	<b>D5</b>	<b>D4</b>	<b>D3</b>	<b>D2</b>	<b>D1</b>	<b>D0</b>

- CV 4 can contain any value between 0 and 255. A value of “0” provides no inertia and gives the fastest response to changes in throttle position.
- The larger the value of CV 4, the more gradually the locomotive slows down as the throttle is decreased. The inertia, in seconds/speed step, is calculated by the formula:

$$\text{Deceleration Inertia (seconds/speed step)} = \frac{(\text{CV 4}) * 0.896}{\text{Number of Speed Steps}}$$

This inertia is independent of which “Number of Speed Steps” is in use (14, 28, or 128). For the same value of CV 4, it will take the same amount of time to go from full speed to a dead stop for a throttle change from maximum to minimum regardless of the speed step choice. The time can vary from a quick response measured in seconds for CV 4=0 to as long as 3.8 minutes (228 seconds) for CV 4 = 255.

- The deceleration rate is the inverse of the above formula.

$$\text{Deceleration Rate (speed steps/second)} = \frac{\text{Number of speed steps}}{(\text{CV 4}) * 0.896}$$

- The acceleration and deceleration rate values in CV 3 and CV 4 will apply if you change the direction of a moving locomotive. The locomotive will slow to a stop at a rate set by CV 4 and then accelerate in the opposite direction at a rate set by CV 3.

<sup>33</sup> This NMRA name is more aptly entitled “Inertia under Deceleration” since higher values for this CV result in higher inertia values but lower deceleration rates. Using the term “Momentum” to describe CV 3 is not correct since a non-moving train has no momentum even if CV 3 is set to the maximum value. Inertia is the property of an object that resists any change to its state of rest or motion.

### 3.5 CV 5 V-High

V-High defines the voltage drive level applied to the motor at maximum throttle. Use CV 5 to reduce the maximum speed of locomotives that operate too fast at maximum throttle.

Default Value:

#### CV 5: V-High Register

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
<b>D7</b>	<b>D6</b>	<b>D5</b>	<b>D4</b>	<b>D3</b>	<b>D2</b>	<b>D1</b>	<b>D0</b>

- CV 5 sets a maximum voltage for the motor to any value between 2 and 255. A value of 0, 1, or 255 provides maximum motor voltage at maximum throttle.

The value of CV 5 determines the maximum motor drive as a fraction of the applied voltage as defined by the following equation:

$$\text{Maximum Motor Voltage} = (\text{Track Voltage}) \times (\text{CV5}/255)$$

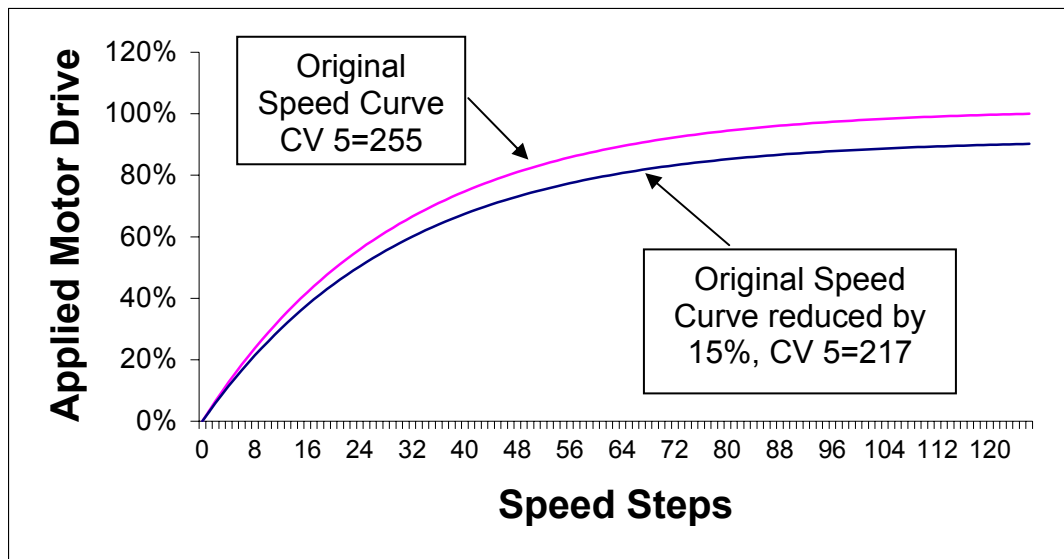
For instance, a value of “200” for CV 5 means that the maximum voltage will be 217/255 or 85% of the applied track voltage.

- The value of motor drive (as a percentage of total track voltage) is computed according to the formula below:

$$\% \text{ Applied Motor Voltage} = (\text{CV 2} + ((\text{CV5}-\text{CV 2}) \times \text{Speed Table Value for speed step}/255)) \times (100/255)$$

If CV 5 is less than or equal to CV 2, or CV 5 is set to 0 or 1, then 255 is used for CV 5 in the above equations.

The graph below shows the effect of only CV 5 (CV 2 = 0) on the original curve. Here a value of CV 5 = 217 reduces the original speed curve by 15% over the entire speed step range. Note how CV 5 preserves the shape of the original speed curve but compresses it to fit between V-Start and V-High.

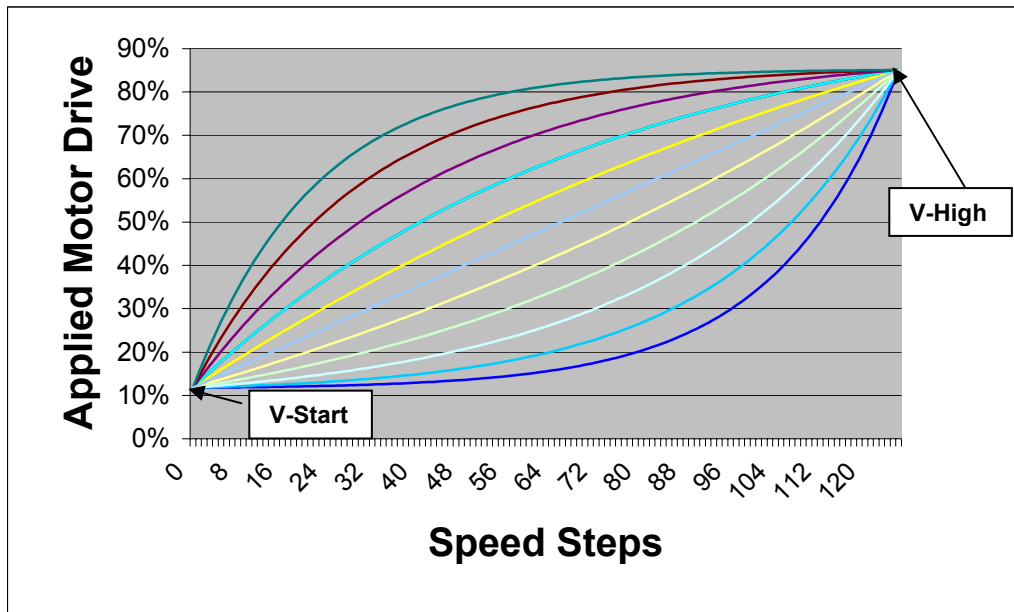


V-High is not related to V Max for Analog Operation.  
V-High is not used when Throttle Mode = Calibrated Speed Control.

## Recommendations for specifying speed curves, V-Start and V-High.

The following is a method we use at QSI to configure a locomotive to match the speed of other locomotives. We use Ops mode programming since it lets us change the locomotive's speed characteristics while the locomotive is operating.

1. Place your locomotive to be configured (call it locomotive A) on a fairly large loop of track. Place your standard locomotive<sup>34</sup> (call it locomotive B) that you use as your speed reference on the same loop of track but on the opposite side. Each locomotive should have a different ID.
2. For both locomotives set CV 56.4 to "0" (STC) or "1" (RTC).
3. For both locomotives set CV 29 bit 4 to "1" to enable speed curves.
4. Run both locomotives at speed step 1.
5. Change locomotive A's CV 2 value until it is moving at the same speed as locomotive B.
6. Run both locomotives at full throttle. You may have to restrain one of the locomotives if they get too close to each other.
7. Change locomotive A's CV 5 value until Locomotive A is moving at the same speed as Locomotive B.
8. Set both locomotives to speed step 64. For locomotive A, choose speed curves from the list of QSI speed curves from CV 25 until both locomotives are running at a similar speed. The speed curves are compressed to fit between V-High and V-Start as shown in the graph below.



Speed Curves with V-Start set to 30 (10% of applied voltage) and V-High set to 217 (85% of applied voltage).

9. If none of the speed curves are acceptable, set CV 25 to 1 and make your own custom speed curve using CV 67 through CV 94. Your custom speed curve will also be compressed to fit within the limits set by V-Start and V-High. Set both locomotives at 28 speed-step selection so your custom changes are at the speed step the locomotive is operating at. Start both locomotives at speed step 1; enter Ops mode programming for Locomotive A and set CV 67 to match Locomotive B speed. Leave Ops mode programming, and set both locomotives to operate at speed step 2, enter Ops mode programming for Locomotive B and set CV 68 to match Locomotive B speed. Repeat this procedure until you have entered speed curve values for all CV's between CV 67 and CV 94.

<sup>34</sup> You may have a number of standard locomotives for different speed classifications. For instance, you might have a standard locomotive for yard operations with a top speed of 35 smph, a standard freight locomotive with a top speed of 65 smph and a third standard locomotive for passenger service with a top speed of 100 smph.

### 3.6 CV 7 Manufacturer's Version Number

This is a read only CV that returns the major version number of the decoder's firmware.

Default Value:

N/A
-----

#### CV 7: Manufacturer's Version Number Register

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
<b>D7</b>	<b>D6</b>	<b>D5</b>	<b>D4</b>	<b>D3</b>	<b>D2</b>	<b>D1</b>	<b>D0</b>

- Production release versions start with 1. If your locomotive has a 1 in this register, your locomotive contains the first version of Quantum HO firmware. A "2" in this register corresponds to the second version of Quantum HO firmware.
- This DCC Reference Manual describes CV's supported by version 7 firmware. If your Quantum locomotive has a value of 1...6 in this CV, version 3.1 of the DCC Reference Manual more accurately describes your locomotive's firmware.

### 3.7 CV 8 Manufacturer's ID

This read-only CV identifies QSI as the manufacturer or developer of the software used in the Quantum System.

Default Value:

<b>113</b>
------------

#### CV 8: Manufacturer's ID Register

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
<b>0</b>	<b>1</b>	<b>1</b>	<b>1</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>1</b>

- The value of this read only register is 113, which is the official NMRA designation for QSI as a manufacturer of DCC decoders.

### 3.8 CV 11 Packet Time-Out Value

The value in CV 11 is the maximum time the decoder will maintain its current speed without receiving a valid DCC packet.

Default Value:

1
---

#### CV 11: Packet Time-Out Value Register

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
N/A	N/A	N/A	D4	D3	D2	D1	D0

- If CV 11 has a non-zero value, and the locomotive receives no DCC packets addressed to the locomotive for that number of seconds then the locomotive will decelerate to a stop at a rate specified by CV 4 and CV 24 and will enter Neutral. The usual Neutral Sounds will then be heard.
- When DCC packets addressed to the locomotive are again received, the locomotive will respond to the DCC packet commands addressed to the locomotive. It will remain in Neutral until a new speed packet is received at which time it will accelerate at the rate set in CV 3 and CV 23.
- A value of zero will disable the time-out function and the locomotive will continue to run at its last speed setting when it stops receiving packets addressed to the locomotive.
- The factory default is “1” which is interpreted as 1 second.
- The maximum value for CV 11 is 20, interpreted as 20 seconds<sup>35</sup>. If any value greater than 20 is written to this CV, the new value is ignored and CV 11 retains its previous value.
- If both Power Source Conversion (CV 29, bit 2) and Packet time-out Value are enabled, Power Source Conversion takes precedence, since it will always have the shorter time-out period.

---

<sup>35</sup> Twenty seconds is the maximum time specified in NMRA Recommended Practice RP-9.2.4.

### 3.9 CV 17, 18 Extended Address

CV 17 and CV 18 together provide a larger (14 bit) range for locomotive ID numbers from 0 to 10,239.

CV 17 Default Value:	0 <sup>36</sup>
CV 18 Default Value	0

#### CV 17: Extended Address Most Significant Byte Register

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
<b>1</b>	<b>1</b>	<b>A13</b>	<b>A12</b>	<b>A11</b>	<b>A10</b>	<b>A9</b>	<b>A8</b>

#### CV 18: Extended Address Least Significant Byte Register

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
<b>A7</b>	<b>A6</b>	<b>A5</b>	<b>A4</b>	<b>A3</b>	<b>A2</b>	<b>A1</b>	<b>A0</b>

- Use CV 17 and CV 18 to assign your locomotive one of 10,240 addresses from 0 to 10,239, although most Command Stations will only allow entering ID's up to 9,999. You can assign your locomotive an address that is identical to the locomotive's cab number, which rarely exceed four digits.
- Your locomotive can have both a Primary Address (CV 1) and an Extended Address. There is overlap in the Primary Address and Extended Address range 1...127 so that a locomotive can have the same number for its Primary Address as it has for its Extended Address. For example, a locomotive can have Primary Address "53" and Extended Address "53". Although the same number, these two addresses are not the same and are treated differently by your locomotive and your Command Station. See your Command Station Instructions to learn how to tell the difference between the two addresses.
- The Extended Address can be set either in Service Mode or Operations Mode. Remember to change bit 5 of Configuration CV 29 to "1" to enable the Extended Address.

#### 3.9.1 Entering Extended Address into CV 17 and CV 18 Directly:

Most modern Command Stations allow the operator to input an Extended Address from 0 to 9999 directly in decimal format without having to individually enter data into CV 17 and CV 18. However, if you have an older Command Station and need to program these CV's directly, the following information will be helpful.

- ◆ CV 17 and CV 18 form a paired CV and it makes a difference how data is entered. CV 17, the most significant byte, must be written first followed by CV 18, the least significant byte. If the order is reversed, the Quantum decoder will not accept the values entered.
- ◆ Bits A15 and A14 must both be assigned "1" which adds 192 to the value of the byte in CV 17. The remaining 6 bits of C17 and the 8 bits of C18 allow addresses to be assigned between 0 and 10,239 inclusive. Any attempt to program an extended ID above 10,239 will be ignored.

To enter CV 17 and CV 18 by direct programming, first divide the decimal address you intend to enter by 256, convert the quotient to binary, add the two leading 1's for bits A14 and A15, and write the result to CV 17. Convert the remainder to binary and write this number to CV 18.

---

36 The default for CV 17 is actually "192" which is an artifact of how these ID numbers are specified by the NRMA where 192 is added to the MSB (Most Significant Byte) of the address you want to enter. If you have a modern Command Station that programs your ID numbers directly, you will enter your ID number equal to the Extended Address you intend to use; however, if you program the extended address CV directly, a zero address must be entered as 192. See example in this section on directly programming CV 17 and CV 18.



**Example1 Decimal Entry: Program CV 17 and CV 18 to Extended Address 5343.**

Divide 5343 by 256 to get 20 as quotient and 223 as remainder.

**Note:** If you use a calculator, you will get 20.8711. Note the integer value  $n = 20$ , which is the quotient.

Add 192 to this quotient to get 212 and store this value in CV 17:

$$\text{CV 17} = n + 192$$

$$\text{CV 17} = 20 + 192 = 212$$

Compute the remaining integer value by multiplying 20 by 256 and subtract from the locomotive value to get remainder and store in CV 18:

$$\text{CV 18} = \text{Locomotive Number} - (n \times 256)$$

$$\text{CV 18} = 5343 - (20 \times 256) = 223$$

Remember to change CV 29, bit 5 to "1" to allow the Extended Address operation (see CV 29).

**Example2 Binary or Hex Entry: Program CV 17 and CV 18 to Extended Address 5343.**

Convert 212 from previous example to binary 11010100 or hex 0xD4. Enter this number in CV 17.

Convert 223 from previous example to binary 11011111 or hex 0xDF and enter in CV 18.

Remember to change CV 29, bit 5 to "1" to allow the Extended Address operation (see CV 29).

To check: Compute  $(\text{CV 17} - 192) \times (256) + \text{CV 18}$  where 192 is the decimal equivalent of CV 17 with only the leading 1's (11000000)

Decimal:  $(212 - 192) \times (256) + 223 = \mathbf{5343}$

Binary:  $(11010100 - 11000000) \times (100000000) + 11011111 = 101001101111 = \mathbf{5343}$  decimal.

Hex:  $(0xD4 - 0xC0) \times 0x100 + 0xDF = 0x14DF = \mathbf{5343}$  decimal, where 0xC0 is the hex equivalent of 192.

The following table shows examples for some common Steam locomotive cab numbers. See if your calculations match the values in the table. After you have calculated your ID numbers, just follow the procedure below to enter your extended ID number.

1. Find out if your command station accepts Decimal, Binary or Hex inputs for CV entries.
2. First enter CV 17 (Most Significant Byte) from the table below as a Decimal, Binary or Hex number shown.
3. Next enter CV 18 (Least Significant Byte) from the table below as a Decimal, Binary or Hex number shown.
4. Change CV 29, bit 5 to "1" to allow operation with your new Extended Address.
5. Read your ID number back from your program track or verbally in Opts Mode to see if you entered the correct number.

### Common Steam Locomotive Numbers

Loco Number	CV 17 (Dec)	CV 18 (Dec)	CV 17 (Hex)	CV 18 (Hex)	CV 17 (Binary)	CV 18 (Binary)
3985	207	145	CF	91	11001111	10010001
611	194	99	C2	63	11000010	01100011
8444	224	252	E0	FC	11100000	11111100
4449	209	97	D1	61	11010001	01100001
3751	206	167	CE	A7	11001110	10100111
261	193	5	C1	5	11000001	00000101
1218	196	194	C4	C2	11000100	11000010
1361	197	81	C5	51	11000101	01010001
700	194	188	C2	BC	11000010	10111100

**Note:** Some command stations will not operate Quantum Systems in Service Mode due to insufficient power output or timing problems. (Check Appendix IIIA for a listing of recommended command stations). If you cannot operate in Service Mode, use Ops mode programming.

If your command station will not allow setting ID numbers in Ops Mode, use QSI CV 56.129 to enter your ID numbers.

### 3.10 CV 19 Consist Address

Sets a locomotive's Consist<sup>37</sup> address in addition to setting the locomotive's direction within the Consist.

Default Value:

0

#### CV 19: Consist Address Register

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
<b>D7</b>	<b>A6</b>	<b>A5</b>	<b>A4</b>	<b>A3</b>	<b>A2</b>	<b>A1</b>	<b>A0</b>

- Bits A0-A6 set the Consist address to any value from 0 to 127.
- Bit D7 sets the locomotive's direction. "0" in D7 sets the locomotive to a normal Forward and "1" sets locomotive to Reverse Direction within the Consist.
- If the address in bits 0-6 is 0, the locomotive is not in a Consist.
- If the seven bit address has a value 1...127, when decoder receives a command packet addressed to this address, the packet will be processed as any other packet except,
  - ◆ The direction bit in a speed/direction or advanced operation packet is inverted if D7=1.
  - ◆ Function Key commands are ignored unless enabled in CV's 21 and 22.
  - ◆ Long Form CV Access instructions will be ignored.
  - ◆ Only Short Form CV Access instructions for CV's 23 and 24 are allowed.
- If a locomotive has the same Consist Address as its Primary Address, it will respond to commands as though it were being addressed by its Primary Address without the restrictions set in CV 21 and CV 22.

---

<sup>37</sup> Consists are also know as Multiple Heading, Lashups or Multiple Unit Trains (MU's) .

### 3.11 CV 21 Consist Address Active for F1-F8<sup>38</sup>

Sets which Function Keys are enabled when a locomotive is addressed by its Consist ID.

Default Value:

0
---

#### CV 21: Consist Address Active for F1-F8 Register

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
<b>F8</b>	<b>F7</b>	<b>F6</b>	<b>F5</b>	<b>F4</b>	<b>F3</b>	<b>F2</b>	<b>F1</b>

- If a “0” is placed in any bit, that function key is disabled when the locomotive is addressed by its Consist ID.
- If a “1” is placed in any bit, that function key is enabled when the locomotive is addressed by its Consist ID.
- This CV is useful for disabling certain features for helper locomotives within the Consist. For instance, only the Lead locomotive should have its Horn/ Whistle and Bell enabled. If the F2 key controls the Horn and the F3 key controls the Bell, then all slave locomotives should have "0" in Bit 1 and Bit 2, while the Lead locomotive should have “1” in these bits.
- The following recommended values are for locomotives that have factory default features assigned to Function Outputs (see CV 53) . Features that are different in the Neutral State are shown with parentheses (i.e. Doppler (Start Up) means Doppler is only operable in Forward and Reverse and Start Up is operable only in Neutral). Features shown that do not indicate a special Neutral Option, will operate in all states (Forward, Neutral and Reverse).

#### Recommended value of CV 21 for a Lead Locomotive in a Consist.

(The QSI default features assignments are shown for Forward/Reverse operation in the top row and for Neutral in parenthesis).

Audio Mute	Brake Squeal and Air Brakes (Arm Cylinder Cocks or long Air Let-Off)	Doppler (Start Up)	Dynamic Brakes	Blower Hiss/Fans	Coupler Crash Coupler Fire (Coupler Arm)	Horn/Whistle	Bell
Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
<b>1</b>	<b>1</b>	<b>1</b>	<b>1</b>	<b>1</b>	<b>0</b>	<b>1</b>	<b>1</b>

#### Recommended value of CV 21 for a Mid<sup>39</sup> Helper Locomotive in a Consist.

(The QSI default features assignments are shown for Forward/Reverse operation in the top row and for Neutral in parenthesis).

Audio Mute	Brake Squeal and Air Brakes (Arm Cylinder Cocks or long Air Let-Off)	Doppler (Start Up)	Dynamic Brakes	Blower Hiss/Fans	Coupler Crash	Horn/Whistle	Bell
Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
<b>1</b>	<b>1</b>	<b>1</b>	<b>1</b>	<b>1</b>	<b>0</b>	<b>0</b>	<b>0</b>

<sup>38</sup> Write bit operation is supported for CV 21.

<sup>39</sup> A Mid Helper is any locomotive between the Lead and the last or End helper in a Consist.

### Recommended value of CV 21 for an End<sup>40</sup> Helper Locomotive in a Consist.

(The QSI default features assignments are shown for Forward/Reverse operation in the top row and for Neutral in parenthesis).

Audio Mute	Brake Squeal and Air Brakes (Arm Cylinder Cocks or long Air Let-Off)	Doppler (Start Up)	Dynamic Brakes	Blower Hiss/Fans	Coupler Crash	Horn/Whistle	Bell
Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
<b>1</b>	<b>1</b>	<b>1</b>	<b>1</b>	<b>1</b>	<b>1</b>	<b>0</b>	<b>0</b>

### 3.12 CV 22 Consist Address Active for FL and F9-F12<sup>41</sup>

Sets whether the FL(r) or FL(f) keys and F9-F12 keys are enabled when a locomotive is addressed by its Consist ID.

Default Value:

#### CV 22: Consist Address Active for FL and F9-F12 Register

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
<b>0</b>	<b>0</b>	<b>F12</b>	<b>F11</b>	<b>F10</b>	<b>F9</b>	<b>FL(r)</b>	<b>FL(f)</b>

- If a "0" is placed in bits 0 through 5, that function key is disabled when the locomotive is addressed by its Consist ID.
- If a "1" is placed in bits 0 through 5, that function key is enabled when the locomotive is addressed by its Consist ID.
- Any "1" placed in bits 6 or 7 will be ignored.
- FL in the Forward Direction is controlled by bit 0, FL in the Reverse Direction is controlled by bit 1.
- This CV and CV 21 are useful for disabling certain features for Helper locomotives within the Consist.
  - ◆ Only the Lead Locomotive should have operational Directional Lighting. Helpers should have their Directional Lighting disabled.
  - ◆ F9, Heavy Load and Shut Down are recommended for all Helper types in a Consist since Heavy Load should apply to all locomotives or none at all; otherwise there would be fighting between locomotives that have Heavy Load enabled and those that do not. Similarly, the F9 Shut Down key should apply to all locomotives in Consist or none at all.
  - ◆ F10, Status Report should be disabled for all Helper types in a Consist since it would be difficult to hear the verbal announcement if more than one locomotive announced its status at the same time.
  - ◆ Features for Function keys 11 and 12 are usually reserved for Number Board Lights and Cab Lights. It is recommended that Cab Lights be disabled and Number Board Lights be enabled. At times F11 and F12 are reserved for custom appliance sounds or operations for the different locomotive types (Steam, Diesel or Electric) such as steam Blow Down, etc. It is recommended that these functions be disabled for all Helper types except the Lead Locomotive to avoid confusion. Check your individual models to determine which features are assigned to F11 and F12.

<sup>40</sup> An End Helper is the last helper in a consist.

<sup>41</sup> Write bit operation is supported for CV 22.

- The following recommended values are for locomotives that have factory default values assigned to FL Outputs (see CV 53). Features that are different in the Neutral State are shown with parentheses; i.e. Heavy Load (Shut Down) means Heavy Load is only operable in Forward and Reverse and Shut Down is operable only in Neutral.

### Recommended value of CV 22 for a Lead Locomotive in a Consist:

N/A	N/A	Cab Lights	Number Board Lights	SMPH Report (Status Report)	Heavy Load (Disconnect-Standby-Total Shut Down)	Directional Lighting	Directional Lighting
N/A	N/A	F12	F11	F10	F9	FL(r)	FL(f)
Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
<b>0</b>	<b>0</b>	<b>0</b>	<b>1</b>	<b>1</b>	<b>1</b>	<b>1</b>	<b>1</b>

### Recommended value of CV 22 for a Mid Helper Locomotive in a Consist:

N/A	N/A	Cab Lights	Number Board Lights	SMPH Report (Status Report)	Heavy Load (Disconnect-Standby-Total Shut Down)	Directional Lighting	Directional Lighting
N/A	N/A	F12	F11	F10	F9	FL(r)	FL(f)
Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
<b>0</b>	<b>0</b>	<b>0</b>	<b>1</b>	<b>0</b>	<b>1</b>	<b>0</b>	<b>0</b>

### Recommended value of CV 22 for an End Helper Locomotive in a Consist:

N/A	N/A	Cab Lights	Number Board Lights	SMPH Report (Status Report)	Heavy Load (Disconnect-Standby-Total Shut Down)	Directional Lighting	Directional Lighting
N/A	N/A	F12	F11	F10	F9	FL(r)	FL(f)
Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
<b>0</b>	<b>0</b>	<b>0</b>	<b>1</b>	<b>0</b>	<b>1</b>	<b>0</b>	<b>0</b>

When making up your consist, remember to have the directional lighting turned off before you assign zeros for bits 0 and 1. Otherwise the directional lighting will be on with no way to turn them off with the FL(r) or FL(f) keys<sup>42</sup>.

The above selections for directional lighting for locomotives in a consist are not ideal for the following reasons:

- You may not want the Lead Locomotive to have an operating Directional Reverse Light since it would only illuminate the locomotive behind it and not the track. The simplest way to have the reverse light off in all motive states is to set CV55.73.1 to 0.
- You may want the End Helper to have an operational reverse facing light (which may be either the End Helper's Reverse Light or Headlight depending on the locomotive's direction within the consist). If the End Helper is facing Forward, set CV55.70.1 to 0, CV55.73.1 to 32, and set bit 0 and bit 1 in CV 22 to 1. If the End Helper is facing Backwards, set CV55.70.1 to 86, CV55.73.1 to 0, and set bit 0 and bit 1 in CV 22 to 1.

With the above changes, the directional lighting in your consist will operate like a single locomotive. That is, the FL key is on, the Lead Locomotive Directional Headlight will be on, all other Helper Headlights will be off, and all Reverse Lights will be off. If the consist is moving in Reverse, only the End Helper Reverse Light will be on and the Lead Locomotive Headlight will either be off or Dim (if the Dim feature is part of the Directional Headlight for your model).

<sup>42</sup> Since the default for directional lighting is off, any helpers that did have their directional lighting on will be set to off if the power is turned off and back on, or if the locomotive is shut down and started using the F9 and F6 keys.

### 3.13 CV 23 Acceleration Adjustment

Increases or decreases the Acceleration from the base Acceleration Rate in CV 3.

Default Value:

#### CV 23: Acceleration Adjustment Register

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
<b>Sign</b>	<b>D6</b>	<b>D5</b>	<b>D4</b>	<b>D3</b>	<b>D2</b>	<b>D1</b>	<b>D0</b>

- CV 23 can have any value from -127 to +127 where positive values will increase the acceleration time and negative values will decrease the acceleration time. A positive value is indicated by a 0 in bit 7 while a "1" indicates a negative value.
- A positive value of CV 23 adds directly to the value of CV 3 by the formula below:  
$$\text{Seconds/speed step} = \frac{(\text{CV 3} + \text{CV 23}) * 0.896}{\text{Number of Speed Steps}}$$
- The purpose of CV 23 is to allow the operator to simulate differing train lengths/loads, most often when operating in Consists. It can, however, apply to single locomotives as well.

### 3.14 CV 24 Deceleration Adjustment

Increases or decreases the Deceleration from the base Deceleration Rate in CV 4.

Default Value:

#### CV 24: Deceleration Adjustment Register

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
<b>Sign</b>	<b>D6</b>	<b>D5</b>	<b>D4</b>	<b>D3</b>	<b>D2</b>	<b>D1</b>	<b>D0</b>

- CV 24 can have any value from -127 to +127 where positive values will increase the deceleration time and negative values will decrease the deceleration time. A positive value is indicated by a 0 in bit 7 while a "1" indicates a negative value.
- A positive value of CV 24 adds directly to the value of CV 4 by the formula below:

$$\text{Seconds/speed step} = \frac{(\text{CV 4} + \text{CV 24}) * 0.896}{\text{Number of Speed Steps}}$$

- The purpose of CV 24 is to allow the operator to simulate differing train lengths/loads, most often when operating in Consists. It can, however, apply to single locomotives as well.



### 3.15 CV 25 Quantum Speed Table Selection

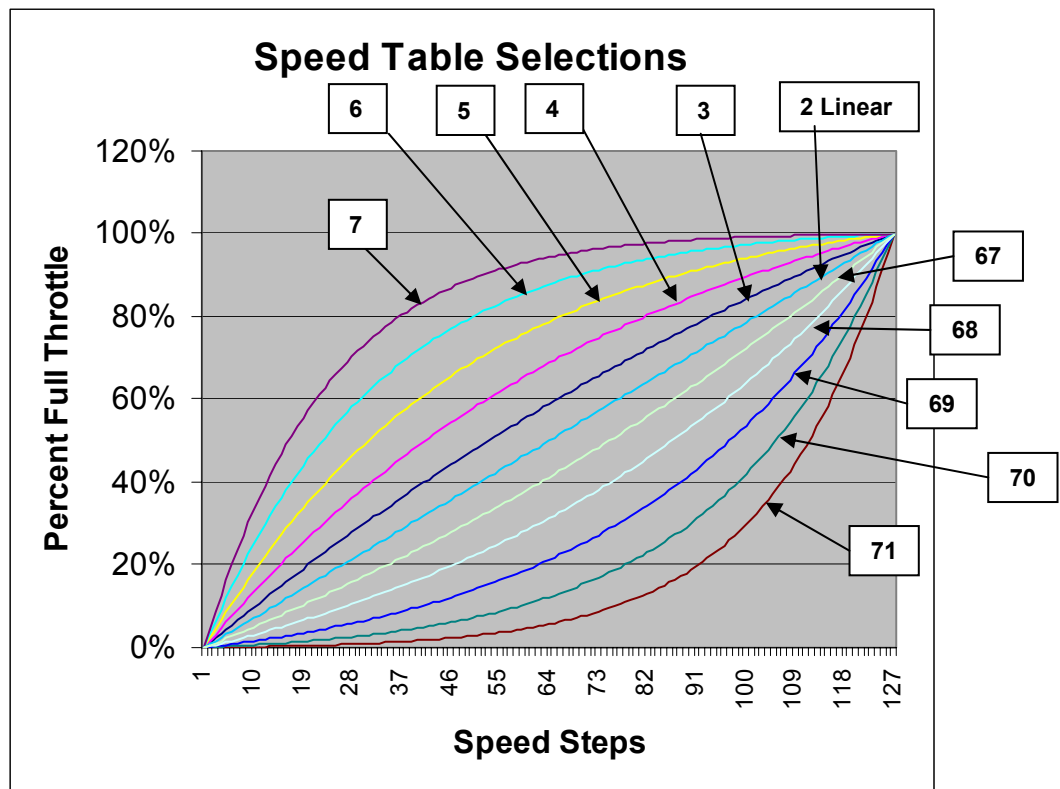
Use this CV to select of one of 11 predefined speed curves..

Default Value:

#### CV 25: Quantum Speed Table Selection Register

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
<b>0</b>	<b>D6</b>	<b>N/A</b>	<b>N/A</b>	<b>N/A</b>	<b>D2</b>	<b>D1</b>	<b>D0</b>

- You can select from 11 predefined speed curves that are shown in the graph below. The upper five convex curves are “fast start” curves while the lower five concave curves are “slow start” curves. The “fast start” curves will compensate for locomotives that are less responsive getting started while the “slow start” curves compensate for locomotives that tend to “rocket out” when the throttle is barely turned on.



- To select a predefined speed curve, set CV 25 to the value associated with the curve in the graph above. Set CV 25 to “0” or “1” to select a User Defined Curve (see CV 67 – 94). Set CV 25 to any other number to select a predefined Linear Curve.
- Bit 4 of CV 29 must be set to “1” to enable any of the above speed curves. If CV 29 bit 4 is set to “0”, then a linear straight-line response is enabled.

#### Additional Information for the Curious Regarding QSI Speed Curves:

- The assignment of bits to this register follows a logical sequence:

- Bits 0-2:** Determines how much curvature. For low values the curves are closer to linear while higher values provide greater curvature. Bits 0-2 set to 000 or 001 indicates that speed table is not used regardless of the setting in bit 6. Bits 0-2 set to 010 indicate a linear speed table.
- Bit 3-5:** Reserved for future QSI expansion of speed curves. Any non-zero value entered for these bits will automatically result in a Linear Response regardless of what is entered in other bits.
- Bit 6:** Determines if it is convex "Fast Start" or concave "Slow Start" curve.  
0 = "Fast Start" Convex Curve  
1 = "Slow Start" Concave Curve
- Bit 7:** This bit specifies the mid-range Speed Step and is not supported by Quantum decoders. Set the value to 0. Either a "1" or a "0" is ignored.

The decimal value for each curve from the table below is shown on the above speed graph.

- Curve Tables in order of value for CV 25

Value of CV 25 (Decimal)	Value of CV 25 Bits 7-0 (Binary)	Resulting Speed Table
<b>Convex "Fast Start" Curves</b>		
0	0 0 0 0 0 0 0 0	Reverts to User Defined Speed Table (CV 67-94)
1	0 0 0 0 0 0 0 1	Reverts to User Defined Speed Table (CV 67-94)
2	0 0 0 0 0 0 1 0	Linear Curve
3	0 0 0 0 0 0 1 1	Fast Start 1 (close to linear)
4	0 0 0 0 0 1 0 0	Fast Start 2
5	0 0 0 0 0 1 0 1	Fast Start 3
6	0 0 0 0 0 1 1 0	Fast Start 4
7	0 0 0 0 0 1 1 1	Fast Start 5 (greatest curvature)
<b>Concave "Slow Start" Curves</b>		
64	0 1 0 0 0 0 0 0	Reverts to Linear Curve
65	0 1 0 0 0 0 0 1	Reverts to Linear Curve
66	0 1 0 0 0 0 1 0	Linear Curve
67	0 1 0 0 0 0 1 1	Slow Start 1 (close to linear)
68	0 1 0 0 0 1 0 0	Slow Start 2
69	0 1 0 0 0 1 0 1	Slow Start 3
70	0 1 0 0 0 1 1 0	Slow Start 4
71	0 1 0 0 0 1 1 1	Slow Start 5 (greatest curvature)

- If any of the "Reverts to User Defined Table" values are set in CV 25, then the user specified speed table programmed into CV's 67-94 will be enabled.
- V-Start and V-High settings will apply to these and all curve tables as described in the sections for CV 2 and CV 5. When selecting a speed table, it is recommended that you first select your V-Start offset based on a linear curve and enter this value into CV 2, particularly for concave "slow start" curves where the V-Start point may not be obvious. Setting V-Start for a linear curve will be much more discernible; then select the type of curve you want.

### 3.16 CV 29 Configuration Data<sup>43</sup>

Each bit in CV 29 controls some basic operational settings for DCC decoders.

Default Value: 00000110 = 6

#### CV 29: Configuration Data Register (with NMRA Assigned Features)

Accessory Decoder	Reserved for Future Use	Extended Addressing	Speed Table Enable	Advanced Decoder Acknowledgement	Power Source Conversion	FL Location	Locomotive Direction
Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
<b>0</b>	<b>N/A</b>	<b>D5</b>	<b>D4</b>	<b>N/A</b>	<b>D3</b>	<b>D2</b>	<b>D1</b>

- Bit 0 = Locomotive Direction:
  - “0” = normal Forward Direction
  - “1” = Reversed Direction.

This bit controls the locomotive’s Forward and Reverse direction. With Bit 0 set to 1, the locomotive will move in the Reverse Direction even though the Command Station indicates a Forward Direction. Directional sensitive functions, such as FL(f) and FL(r) , will also be reversed to be consistent with the locomotive’s Reversed Direction.

- Bit 1 = Speed Steps and FL Location
  - “0” = Bit 4 sets 14 Speed Step Mode.
  - “1” = Bit 4 sets 28 and 128 Speed Step Mode.

In 14 Speed Step Operation, the speed and direction instruction is in one byte of transmitted data that tells the locomotive what direction to go, what speed to travel and whether FL should be “0” or “1”. For 28-speed step operation, the bit used for FL is instead used to double the number of speed steps, so that the light state must be transmitted in a Function Group 1 instruction. Similarly, when using 128 speed step mode, bit 1 of CV 29 must be set to “1”.

- Bit 2 = Power Source Conversion.
  - “0” = Power Source Conversion disabled
  - “1” = Power Source Conversion enabled.

If CV 29 bit 2 is “1”, and a period of approximately 200mSec<sup>44</sup> elapses in which no DCC packet is detected, then the locomotive will convert to Analog power.

If the polarity of the track would result in the locomotive moving in the same direction that it was last moving in DCC mode, then the locomotive will continue to move at the speed corresponding to the last received speed step packet. The usual FWD/REV locomotive sound will be heard.

If the polarity of the track would result in the locomotive moving the opposite direction than it was last moving in DCC mode, then the locomotive will decelerate to a stop at a rate determined by CV 4 and CV 24, and will enter Neutral. The usual Neutral sounds will be heard.

When in Analog mode, switching the polarity of the track will either start the locomotive moving or bring it to a stop.

If the locomotive is moving and the polarity is reversed, the locomotive will decelerate to a stop at a rate determined by CV 4 and CV 24 and will enter Neutral.

<sup>43</sup> Write bit operation is supported for CV 29.

<sup>44</sup> NMRA Spec RP-9.2.4 specifies that Power Source Conversion should take place when DCC packets are absent for more than 30 mSec. However Quantum requires approximately 200mSec to determine the Analog track polarity.

If the locomotive is stopped in Neutral and the polarity is reversed, the locomotive will accelerate at a rate determined by CV 3 and CV 23 to a speed corresponding to the last received speed step packet.

The actual locomotive speed under Analog power may differ from its speed under DCC power depending on the Analog track voltage and whether the locomotive is using Calibrated Speed Control, Regulated Throttle Control, or Standard Throttle Control (e.g. the locomotive may jerk upon switching to analog power).

**NOTE:** This bit must be set to 1 in order for the locomotive to operate on an Analog track. See trouble shooting section.

- Bit 3 = Advanced Decoder Acknowledgement (not used)
- Bit 4 = Speed Table set by configuration variables.
  - “0” Speed Table not used.
  - “1” Speed Table set by CV 25, Quantum Speed Table selection.

When bit 4 of CV 29 is set to “0” a linear Speed Table is used by default.

- Bit 5 = Extended Address Mode enable
  - “0” = The decoder responds to one byte Primary Address (see CV 1).
  - “1” = The decoder responds to a two byte Extended Address (see CV 17 and CV 18)
- Bit 6 = Reserved for NMRA future use.
- Bit 7 = Accessory Decoder
  - “0” = Multifunction locomotive decoder.
  - “1” = Accessory Decoder. .

Quantum decoders are Multifunction Decoders; this bit cannot be changed.

Some command stations make it easy for you to change CV 29 one bit one at a time. Other command stations require you to enter the value of CV 29 as a complete 8-bit byte. The table below shows all the possible combinations of the five programmable bits supported by Quantum locomotives. Where an “X” appears the feature is enabled and the corresponding CV 29 bit is a “1”. The Binary, Decimal, and Hex values are shown for each combination. Choose the features you want enabled and enter the corresponding number into CV 29 using the format recommended by your command station. The default for Quantum decoders is shown in bold type.

## CV 29 Common Settings

Extended Addressing	Speed Tables	Power Conversion	28/ 128 speed step	Reversed Direction	Decimal Value	Binary Value	Hex Value
					0	00000000	0x0
				X	1	00000001	0x1
			X		2	00000010	0x2
			X	X	3	00000011	0x3
		X			4	00000100	0x4
		X		X	5	00000101	0x5
		<b>X</b>	<b>X</b>		<b>6</b>	<b>00000110</b>	<b>0x6</b>
		X	X	X	7	00000111	0x7
	X				16	00010000	0x10
	X			X	17	00010001	0x11
	X		X		18	00010010	0x12
	X		X	X	19	00010011	0x13
	X	X			20	00010100	0x14
	X	X		X	21	00010101	0x15
	X	X	X		22	00010110	0x16
	X	X	X	X	23	00010111	0x17
X					32	00100000	0x20
X				X	33	00100001	0x21
X			X		34	00100010	0x22
X			X	X	35	00100011	0x23
X		X			36	00100100	0x24
X		X		X	37	00100101	0x25
X		X	X		38	00100110	0x26
X		X	X	X	39	00100111	0x27
X	X				48	00110000	0x30
X	X			X	49	00110001	0x31
X	X		X		50	00110010	0x32
X	X		X	X	51	00110011	0x33
X	X	X			52	00110100	0x34
X	X	X		X	53	00110101	0x35
X	X	X	X		54	00110110	0x36
X	X	X	X	X	55	00110111	0x37

# 4 CV's 33-46: Output Locations

## 4.1 Overview

The NMRA standard currently provides for fourteen Function Inputs, which are transmitted to the locomotive decoder to control different Outputs. These fourteen Function Inputs are generally operated by thirteen<sup>45</sup> Function Keys (FL, F1, F2, F3, F4, F5, F6, F7, F8, F9, F10, F11 and F12) on the command station or the hand held throttle. The FL<sup>46</sup> Function Key can produce two different Function Inputs, called FL(r) and FL(f), depending on the direction of the locomotive.

The NMRA standard provides for fourteen Outputs, numbered from 1 to 14.

CV's 33 through 46 specify which Function Input is connected to which Output.

The table below shows Output numbers across the top and Function Inputs along the side. The CV number associated with each Function Input is shown in the first column. Each of these CV's consists of an eight bit register with a "1" or "0" in each bit location, specifying which Outputs are controlled by that Function Input. The default value for each CV is shown.

CV #	Function Inputs	Output Numbers and Pre-assigned Features													
		Cab Lights	Alternate Horn Selection	Status Report	Heavy Load (Shut Down)	Mute	Squealing Brakes Air Brakes (Cylinder Cocks)	Doppler Shift	Dynamic Brakes	Blower Hiss/Fans	Coupler	Horn/Whistle	Bell	Directional Lighting	Directional Lighting
	Outputs	14	13	12	11	10	9	8	7	6	5	4	3	2	1
33	FL(f)							0	0	0	0	0	0	1	1
34	FL(r)							0	0	0	0	0	0	1	1
35	Function 1							0	0	0	0	0	1	0	0
36	Function 2							0	0	0	0	1	0	0	0
37	Function 3							0	0	0	1	0	0	0	0
38	Function 4				0	0	0	0	0	1	0	0			
39	Function 5				0	0	0	0	1	0	0	0			
40	Function 6				0	0	0	1	0	0	0	0			
41	Function 7				0	0	1	0	0	0	0	0			
42	Function 8				0	1	0	0	0	0	0	0			
43	Function 9	0	0	0	1	0	0	0	0						
44	Function 10	0	0	1	0	0	0	0	0						
45	Function 11	0	1	0	0	0	0	0	0						
46	Function 12	1	0	0	0	0	0	0	0						

A "1" with light gray background shows the Output default settings for Quantum decoders. For example, CV 36 has a "1" in the column for Output 4, indicating that Function 2 controls Output 4 which will operate the Whistle or Horn.

Each Input Function can control up to 8 Outputs. The white squares in the table show allowed possible assignments of Outputs for each Function. The dark gray areas indicate where Outputs cannot be assigned. For instance, the F4 key (Function Input 4) can control only Outputs 4-11. You can chose to have the F4 Key operate Output 10 or a combination of Outputs 11, 9, 7, and 6 all at once, but you cannot have it operate Output 12.

<sup>45</sup> Some earlier command stations only support the original NMRA specification of 10 functions using 9 Function Keys.

<sup>46</sup> For Command Stations that do not have an FL key, the F0 Function key usually controls this function.

For many non-sound decoders, the Outputs are literally wires that are connected to different features such as Headlights and Reverse Lights, overhead blinking lights, smoke generators, and couplers. All the Outputs are “hardwired” to the features, meaning you cannot change which feature corresponds to an Output without rewiring the features.

For Sound Decoders like the first Quantum System, only some of the Outputs were “hardwired” to a particular feature. Many of the features require no external wires. Examples of these internal features are bells, whistles, air let-offs, blower hiss, and flange sounds.

On modern decoders, even those features that do require external wires, such as lights and smoke generators, are not necessarily “hardwired” to any particular Output. Outputs are now virtual and can be connected internally by firmware in the Quantum microprocessor to any physical driver, such as a power output for a lamp or a controller for a smoke generator. The connection between a virtual output and a physical feature is called a control port or simply “port”. For consistency with NMRA definitions, virtual outputs are called simply “outputs”.

A virtual output can be connected to more than one port. For example, the Multiple Automatic Lights #1 virtual output is by default connected to the Headlight, Reverse Light, and in some models a Mars Light.

Virtual outputs can be connected to different features depending on the directional state of the locomotive. For example, Output 8 is assigned to Doppler Shift in Forward and Reverse but is assigned to “Locomotive Start Up” in Neutral.

Both of these techniques increase the number of features that can be operated with a limited number of function keys.

The above table shows Common Default Quantum Features Assignments in the second row. Features assignments that operate only in Neutral are shown in parenthesis under the feature that operates in Forward and Reverse. If no Neutral feature is shown, the assigned feature shown will operate in all directional states.

Features are assigned to outputs in CV 53.

Advanced Sound Decoders like the Quantum Decoders allow great flexibility in choosing which function keys operate which features. However, this flexibility can get you into trouble if misused. For technical reasons too complicated to discuss here<sup>47</sup>, we recommend you follow the two rules below to avoid having your decoder behave in a confusing manner.

1. In CV’s 33-46, do not attempt to control the same Output with two or more function keys. This means, in the table above, only one row in each column should have a “1”. Yes, we violated this rule for Output 1 and Output 2, where we have both FL(f) and FL(r) operating the Directional Lighting System. This is an exception, which does work for Directional Lighting using FL(f) and FL(r). In general, it is not a good idea.
2. In CV 53, do not assign the same feature to two or more Outputs.

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<sup>47</sup> See Appendix VI Interaction of Function Keys, Function Groups, Function Inputs and Outputs and Feature Assignments for additional technical explanation.

## 4.2 CV 33 Output Location for FL(f)<sup>48</sup>

This CV specifies whether outputs 1 thru 8 are controlled by FL(f).

A '1' in a bit location specifies the output is controlled by FL(f), while a '0' specifies the output is not controlled by FL(f).

Default Value: 00000011 = 3

### CV 33: Output Location for FL(f) (with Factory Default Features)

Doppler (Start Up)	Dynamic Brakes	Blower-Hiss/Fans	Coupler Crash Coupler Fire (Coupler Arm)	Horn/Whistle	Bell	Directional Lighting <sup>49</sup>	Directional Lighting
Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
<b>Output 8</b>	<b>Output 7</b>	<b>Output 6</b>	<b>Output 5</b>	<b>Output 4</b>	<b>Output 3</b>	<b>Output 2</b>	<b>Output 1</b>

- QSI has pre-assigned default features to each output but any feature can be assigned to any output in CV 53. In CV 53, the default setting for Outputs 1 and 2 is the Directional Lighting System. Therefore, by default FL(f) controls the Directional Lighting System in Forward or Neutral from Forward.
- You can specify that FL(f) controls any of Outputs 2 thru 8 in addition to or instead of Outputs 1 and 2.
- Assuming the default CV 53 settings (shown in the top row)<sup>50</sup>, you can specify that FL(f) controls the following features.

#### Bit 0 Output 1: Directional Lighting

- “0” The Directional Lighting System is unaffected by FL(f).
- “1” The Directional Lighting System is affected by FL(f).

#### Bit 1 Output 2: Directional Lighting

- “0” The Directional Lighting System is unaffected by FL(f).
- “1” The Directional Lighting System is affected by FL(f).

#### Bit 2 Output 3; Bell

- “0” The Bell is unaffected by FL(f).
- “1” The Bell is affected by FL(f).

#### Bit 3 Output 4; Horn/Whistle

- “0” The Horn/Whistle is unaffected by FL(f).
- “1” Horn/Whistle is affected by FL(f).

<sup>48</sup> Write bit operation is supported for CV 33.

<sup>49</sup> The lights used in Directional Lighting are selected in Multiple Lights #1, which is the actual feature assigned to Outputs 1 and 2 (see CV55.136). Depending on your model, different lights may be selected for Multiple Lights #1.

<sup>50</sup> Features that are different in the Neutral state are shown in parentheses



**Bit 4** Output 5: Coupler Crash, Coupler Arm, Coupler Fire

“0” The Coupler Sounds are unaffected by FL(f).

“1” The Coupler Sounds are affected by FL(f).

**Bit 5** Output 6: Steam Locomotive Blower Hiss or Diesel or Electric Loco Vents and Fans

“0” Blower-Hiss/Fans are unaffected by FL(f).

“1” Blower-Hiss/Fans are affected by FL(f).

**Bit 6** Output 7: Dynamic Brakes

“0” Dynamic Brakes are unaffected by FL(f).

“1” Dynamic Brakes are affected by FL(f).

**Bit 7** Output 8: Doppler, Start Up

“0” Doppler shift in Forward/Reverse and Start up in Neutral are unaffected by FL(f).

“1” Doppler shift in Forward/Reverse and Start up in Neutral are affected by FL(f).

### 4.3 CV 34 Output Location for FL(r)<sup>51</sup>

This CV specifies whether outputs 1 thru 8 are controlled by FL(r).

A '1' in a bit location specifies the output is controlled by FL(r), while a '0' specifies the output is not controlled by FL(r).

Default Value: 00000011 = 3

#### CV 34: Output Location for FL(r) (with Factory Default Features)

Doppler (Start Up)	Dynamic Brakes	Blower-Hiss/Fans	Coupler Crash Coupler Fire (Coupler Arm)	Horn/Whistle	Bell	Directional Lighting <sup>52</sup>	Directional Lighting
Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
<b>Output 8</b>	<b>Output 7</b>	<b>Output 6</b>	<b>Output 5</b>	<b>Output 4</b>	<b>Output 3</b>	<b>Output 2</b>	<b>Output 1</b>

- QSI has pre-assigned default features to each output but any feature can be assigned to any output in CV 53. In CV 53, the default setting for Outputs 1 and 2 is the Directional Lighting System. Therefore, by default FL(r) controls the Directional Lighting System in Reverse or Neutral from Reverse.
- You can specify that FL(r) control any of Outputs 3 thru 8 in addition to or instead of Outputs 1 and 2.
- Assuming the default CV 53 settings (shown in the top row)<sup>53</sup>, you can specify that FL(r) control the following features.

**Bit 0** Output 1: Directional Lighting

- “0” The Directional Lighting System is unaffected by FL(r).
- “1” The Directional Lighting System is affected by FL(r).

**Bit 1** Output 2: Directional Lighting

- “0” The Directional Lighting System is unaffected by FL(r).
- “1” The Directional Lighting System is affected by FL(r).

**Bit 2** Output 3; Bell

- “0” The Bell is unaffected by FL(r).
- “1” The Bell is affected by FL(r).

**Bit 3** Output 4; Horn/Whistle

- “0” The Horn/Whistle is unaffected by FL(r).
- “1” Horn/Whistle is affected by FL(r).

<sup>51</sup> Write bit operation is supported for CV 34.

<sup>52</sup> The lights used in Directional Lighting are selected in Multiple Lights #1, which is the actual feature assigned to Outputs 1 and 2 (see CV55.136). Depending on your model, different lights may be selected for Multiple Lights #1.

<sup>53</sup> Features that are different in the Neutral state are shown in parentheses

**Bit 4** Output 5: Coupler Crash, Coupler Arm, Coupler Fire

“0” The Coupler Sounds are unaffected by FL(r).

“1” The Coupler Sounds are affected by FL(r).

**Bit 5** Output 6: Steam Locomotive Blower Hiss or Diesel or Electric Loco Vents and Fans

“0” Blower-Hiss/Fans are unaffected by FL(r).

“1” Blower-Hiss/Fans are affected by FL(r).

**Bit 6** Output 7: Dynamic Brakes

“0” Dynamic Brakes are unaffected by FL(r).

“1” Dynamic Brakes are affected by FL(r).

**Bit 7** Output 8: Doppler, Start Up

“0” Doppler shift in Forward/Reverse and Start up in Neutral are unaffected by FL(r).

“1” Doppler shift in Forward/Reverse and Start up in Neutral are affected by FL(r).

## 4.4 CV 35 Output Location for F1<sup>54</sup>

This CV specifies whether outputs 1 thru 8 are controlled by F1.

A '1' in a bit location specifies the output is controlled by F1, while a '0' specifies the output is not controlled by F1.

Default Value: 00000100 = 4

### CV 35: Output for F1 (with Factory Default Features)

Doppler (Start Up)	Dynamic Brakes	Blower-Hiss/Fans	Coupler Crash Coupler Fire (Coupler Arm)	Horn/Whistle	Bell	Directional Lighting <sup>55</sup>	Directional Lighting
Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
<b>Output 8</b>	<b>Output 7</b>	<b>Output 6</b>	<b>Output 5</b>	<b>Output 4</b>	<b>Output 3</b>	<b>Output 2</b>	<b>Output 1</b>

- QSI has pre-assigned default features to each output but any feature can be assigned to any output in CV 53. In CV 53, the default setting for Output 3 is the Bell. Therefore, by default F1 controls the Bell.
- You can specify that F1 control any of Outputs 1-2 and 4-8 in addition to or instead of Output 3.
- Assuming the default CV 53 settings (shown in the top row)<sup>56</sup>, you can specify that F1 control the following features.

#### Bit 0 Output 1: Directional Lighting

"0" The Directional Lighting System is unaffected by F1.  
 "1" The Directional Lighting System is affected by F1.

#### Bit 1 Output 2: Directional Lighting

"0" The Directional Lighting System is unaffected by F1.  
 "1" The Directional Lighting System is affected by F1.

#### Bit 2 Output 3; Bell

"0" The Bell is unaffected by F1.  
 "1" The Bell is affected by F1.

#### Bit 3 Output 4; Horn/Whistle

"0" The Horn/Whistle is unaffected by F1.  
 "1" Horn/Whistle is affected by F1.

<sup>54</sup> Write bit operation is supported for CV 35.

<sup>55</sup> The lights used in Directional Lighting are selected in Multiple Lights #1, which is the actual feature assigned to Outputs 1 and 2 (see CV55.136). Depending on your model, different lights may be selected for Multiple Lights #1.

<sup>56</sup> Features that are different in the Neutral state are shown in parentheses

**Bit 4** Output 5: Coupler Crash, Coupler Arm, Coupler Fire

“0” The Coupler Sounds are unaffected by F1.

“1” The Coupler Sounds are affected by F1.

**Bit 5** Output 6: Steam Locomotive Blower Hiss or Diesel or Electric Loco Vents and Fans

“0” Blower-Hiss/Fans are unaffected by F1.

“1” Blower-Hiss/Fans are affected by F1.

**Bit 6** Output 7: Dynamic Brakes

“0” Dynamic Brakes are unaffected by F1.

“1” Dynamic Brakes are affected by F1.

**Bit 7** Output 8: Doppler, Start Up

“0” Doppler shift in Forward/Reverse and Start up in Neutral are unaffected by F1.

“1” Doppler shift in Forward/Reverse and Start up in Neutral are affected by F1.

## 4.5 CV 36 Output Location for F2<sup>57</sup>

This CV specifies whether outputs 1 thru 8 are controlled by F2.

A '1' in a bit location specifies the output is controlled by F2, while a '0' specifies the output is not controlled by F2.

Default Value: 00001000 = 8

### CV 36: Output Location for F2 (with Factory Default Features)

Doppler (Start Up)	Dynamic Brakes	Blower-Hiss/Fans	Coupler Crash Coupler Fire (Coupler Arm)	Horn/Whistle	Bell	Directional Lighting <sup>58</sup>	Directional Lighting
Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
<b>Output 8</b>	<b>Output 7</b>	<b>Output 6</b>	<b>Output 5</b>	<b>Output 4</b>	<b>Output 3</b>	<b>Output 2</b>	<b>Output 1</b>

- QSI has pre-assigned default features to each output but any feature can be assigned to any output in CV 53. In CV 53, the default setting for Output 4 is the Whistle or Horn. Therefore, by default F2 controls the Whistle or Horn while locomotive is moving or stopped.
- You can specify that F1 control any of Outputs 1-3 and 5-8 in addition to or instead of Output 4.
- Assuming the default CV 53 settings (shown in the top row)<sup>59</sup>, you can specify that F2 control the following features.

#### Bit 0 Output 1: Directional Lighting

"0" The Directional Lighting System is unaffected by F2.  
 "1" The Directional Lighting System is affected by F2.

#### Bit 1 Output 2: Directional Lighting

"0" The Directional Lighting System is unaffected by F2.  
 "1" The Directional Lighting System is affected by F2.

#### Bit 2 Output 3; Bell

"0" The Bell is unaffected by F2.  
 "1" The Bell is affected by F2.

#### Bit 3 Output 4; Horn/Whistle

"0" The Horn/Whistle is unaffected by F2.  
 "1" Horn/Whistle is affected by F2.

<sup>57</sup> Write bit operation is supported for CV 36.

<sup>58</sup> The lights used in Directional Lighting are selected in Multiple Lights #1, which is the actual feature assigned to Outputs 1 and 2 (see CV55.136). Depending on your model, different lights may be selected for Multiple Lights #1.

<sup>59</sup> Features that are different in the Neutral state are shown in parentheses

- Bit 4** Output 5: Coupler Crash, Coupler Arm, Coupler Fire  
“0” The Coupler Sounds are unaffected by F2.  
“1” The Coupler Sounds are affected by F2.
- Bit 5** Output 6: Steam Locomotive Blower Hiss or Diesel or Electric Loco Vents and Fans  
“0” Blower-Hiss/Fans are unaffected by F2.  
“1” Blower-Hiss/Fans are affected by F2.
- Bit 6** Output 7: Dynamic Brakes  
“0” Dynamic Brakes are unaffected by F2.  
“1” Dynamic Brakes are affected by F2.
- Bit 7** Output 8: Doppler, Start Up  
“0” Doppler shift in Forward/Reverse and Start up in Neutral are unaffected by F2.  
“1” Doppler shift in Forward/Reverse and Start up in Neutral are affected by F2.

## 4.6 CV 37 Output Location for F3<sup>60</sup>

This CV specifies whether outputs 1 thru 8 are controlled by F3.

A '1' in a bit location specifies the output is controlled by F3, while a '0' specifies the output is not controlled by F3.

Default Value:

<b>00010000 = 16</b>
----------------------

### CV 37: Output Location for F3 (with Factory Default Features)

Doppler (Start Up)	Dynamic Brakes	Blower-Hiss/Fans	Coupler Crash Coupler Fire (Coupler Arm)	Horn/Whistle	Bell	Directional Lighting <sup>61</sup>	Directional Lighting
Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
<b>Output 8</b>	<b>Output 7</b>	<b>Output 6</b>	<b>Output 5</b>	<b>Output 4</b>	<b>Output 3</b>	<b>Output 2</b>	<b>Output 1</b>

- QSI has pre-assigned default features to each output but any feature can be assigned to any output in CV 53. In CV 53, the default setting for Output 5 is the Coupler Crash, Coupler Fire and Coupler Arm. Therefore, by default F3 controls the Coupler Sounds.
- You can specify that F3 control any of Outputs 1-4 and 6-8 in addition to or instead of Output 5.
- Assuming the default CV 53 settings (shown in the top row)<sup>62</sup>, you can specify that F3 control the following features.

#### Bit 0 Output 1: Directional Lighting

"0" The Directional Lighting System is unaffected by F3.  
 "1" The Directional Lighting System is affected by F3.

#### Bit 1 Output 2: Directional Lighting

"0" The Directional Lighting System is unaffected by F3.  
 "1" The Directional Lighting System is affected by F3.

#### Bit 2 Output 3; Bell

"0" The Bell is unaffected by F3.  
 "1" The Bell is affected by F3.

#### Bit 3 Output 4; Horn/Whistle

"0" The Horn/Whistle is unaffected by F3.  
 "1" Horn/Whistle is affected by F3.

<sup>60</sup> Write bit operation is supported for CV 37.

<sup>61</sup> The lights used in Directional Lighting are selected in Multiple Lights #1, which is the actual feature assigned to Outputs 1 and 2 (see CV55.136). Depending on your model, different lights may be selected for Multiple Lights #1.

<sup>62</sup> Features that are different in the Neutral state are shown in parentheses



**Bit 4** Output 5: Coupler Crash, Coupler Arm, Coupler Fire

“0” The Coupler Sounds are unaffected by F3.

“1” The Coupler Sounds are affected by F3.

**Bit 5** Output 6: Steam Locomotive Blower Hiss or Diesel or Electric Loco Vents and Fans

“0” Blower-Hiss/Fans are unaffected by F3.

“1” Blower-Hiss/Fans are affected by F3.

**Bit 6** Output 7: Dynamic Brakes

“0” Dynamic Brakes are unaffected by F3.

“1” Dynamic Brakes are affected by F3.

**Bit 7** Output 8: Doppler, Start Up

“0” Doppler shift in Forward/Reverse and Start up in Neutral are unaffected by F3.

“1” Doppler shift in Forward/Reverse and Start up in Neutral are affected by F3.

**Example:** Change F3 to Bell Operation (Output 3), and change F1 to Coupler Sounds (Output 5).

Output 3 is set to Bell by default. Output 5 is set to Coupler Sounds by default.

Set CV 37 (F3) to “4” (bit 2 = output 3 = Bell)

Set CV 35 (F1) to “16” (bit 4 = output 5 = Coupler Sounds)

After these changes, F3 will activate the bell, and F1 will activate Coupler Sounds.

## 4.7 CV 38 Output Location for F4<sup>63</sup>

This CV specifies whether outputs 4 thru 11 are controlled by F4.

A '1' in a bit location specifies the output is controlled by F4, while a '0' specifies the output is not controlled by F4.

Default Value:

**0000100 = 4**

### CV 38: Output Location for F4 Register (with Factory Default Features)

Heavy Load (Disconnect- Standby-Shut Down)	Mute	Squealing Brakes/Flanges /Air Brakes (Cylinder Cocks/ Long Air Let-Off)	Doppler (Start Up)	Dynamic Brakes	Blower- Hiss/Fans	Coupler Crash Coupler Fire (Coupler Arm)	Horn/Whistle
Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
<b>Output 11</b>	<b>Output 10</b>	<b>Output 9</b>	<b>Output 8</b>	<b>Output 7</b>	<b>Output 6</b>	<b>Output 5</b>	<b>Output 4</b>

- QSI has pre-assigned default features to each output but any feature can be assigned to any output in CV 53. In CV 53, the default setting for Output 6 is Blower Hiss/Fans. Therefore, by default F4 controls the Blower Hiss/Fans Sound.
- You can specify that F4 control any of Outputs 4-5 and 7-11 in addition to or instead of Output 6.
- Assuming the default CV 53 settings (shown in the top row)<sup>64</sup>, you can specify that F4 control the following features.

**Bit 0** Output 4; Horn/Whistle

"0" The Horn/Whistle is unaffected by F4.  
 "1" Horn/Whistle is affected by F4.

**Bit 1** Output 5: Coupler Crash, Coupler Arm, Coupler Fire

"0" The Coupler Sounds are unaffected by F4.  
 "1" The Coupler Sounds are affected by F4.

**Bit 2** Output 6: Steam Locomotive Blower Hiss or Diesel or Electric Loco Vents and Fans

"0" Blower-Hiss/Fans are unaffected by F4.  
 "1" Blower-Hiss/Fans are affected by F4.

**Bit 3** Output 7: Dynamic Brakes

"0" Dynamic Brakes are unaffected by F4.  
 "1" Dynamic Brakes are affected by F4.

**Bit 4** Output 8: Doppler, Start Up

"0" Doppler shift in Forward/Reverse and Start up in Neutral are unaffected by F4.  
 "1" Doppler shift in Forward/Reverse and Start up in Neutral are affected by F4.

<sup>63</sup> Write bit operation is supported for CV 38.

<sup>64</sup> Features that are different in the Neutral state are shown in parentheses

**Bit 5** Output 9: Squealing Brakes and Air Brakes, Cylinder Cocks Arm or Long Air Let-off

- "0" Squealing Brakes, Air Brakes in Forward/Reverse and Cylinder Cocks Arm, Long Air Let-off are unaffected by F4.
- "1" Squealing Brakes, Air Brakes in Forward/Reverse and Cylinder Cocks Arm, Long Air Let-off are affected by F4.

**Bit 6** Output 10: Audio Mute

- "0" Audio Mute is unaffected by F4.
- "1" Audio Mute is affected by F4.

**Bit 7** Output 11: Heavy Load, Disconnect-Standby-Total Shut Down

- "0" Heavy Load in Forward/Reverse and Disconnect-Standby-Total Shut Down in Neutral are unaffected by F4.
- "1" Heavy Load in Forward/Reverse and Disconnect-Standby-Total Shut Down in Neutral are affected by F4.

**Note:** Heavy Load has replaced the Cruise Control feature that was available on Lionel HO and early BLI locomotives.

## 4.8 CV 39 Output Location for F5<sup>65</sup>

This CV specifies whether outputs 4 thru 11 are controlled by F5.

A '1' in a bit location specifies the output is controlled by F5, while a '0' specifies the output is not controlled by F5.

Default Value:

00001000 = 8

### CV 39: Output Location for F5 Register (with Factory Default Features)

Heavy Load (Disconnect- Standby-Total Shut Down)	Mute	Squealing Brakes/Flanges /Air Brakes (Cylinder Cocks/ Long Air Let-Off)	Doppler (Start Up)	Dynamic Brakes	Blower- Hiss/Fans	Coupler Crash Coupler Fire (Coupler Arm)	Horn/Whistle
Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
<b>Output 11</b>	<b>Output 10</b>	<b>Output 9</b>	<b>Output 8</b>	<b>Output 7</b>	<b>Output 6</b>	<b>Output 5</b>	<b>Output 4</b>

- QSI has pre-assigned default features to each output but any feature can be assigned to any output in CV 53. In CV 53, the default setting for Output 7 is Dynamic Brakes. Therefore, by default F5 controls the Dynamic Brake Sounds.
- You can specify that F5 control any of Outputs 4-6 and 8-11 in addition to or instead of Output 7.
- Assuming the default CV 53 settings (shown in the top row)<sup>66</sup>, you can specify that F5 control the following features.

**Bit 0** Output 4; Horn/Whistle

"0" The Horn/Whistle is unaffected by F5.  
 "1" Horn/Whistle is affected by F5.

**Bit 1** Output 5: Coupler Crash, Coupler Arm, Coupler Fire

"0" The Coupler Sounds are unaffected by F5.  
 "1" The Coupler Sounds are affected by F5.

**Bit 2** Output 6: Steam Locomotive Blower Hiss or Diesel or Electric Loco Vents and Fans

"0" Blower-Hiss/Fans are unaffected by F5.  
 "1" Blower-Hiss/Fans are affected by F5.

**Bit 3** Output 7: Dynamic Brakes

"0" Dynamic Brakes are unaffected by F5.  
 "1" Dynamic Brakes are affected by F5.

**Bit 4** Output 8: Doppler, Start Up

"0" Doppler shift in Forward/Reverse and Start up in Neutral are unaffected by F5.  
 "1" Doppler shift in Forward/Reverse and Start up in Neutral are affected by F5.

<sup>65</sup> Write bit operation is supported for CV 39.

<sup>66</sup> Features that are different in the Neutral state are shown in parentheses

- Bit 5** Output 9: Squealing Brakes and Air Brakes, Cylinder Cocks Arm or Long Air Let-off
- “0” Squealing Brakes, Air Brakes in Forward/Reverse and Cylinder Cocks Arm, Long Air Let-off are unaffected by F5.
  - “1” Squealing Brakes, Air Brakes in Forward/Reverse and Cylinder Cocks Arm, Long Air Let-off are affected by F5.

- Bit 6** Output 10: Audio Mute
- “0” Audio Mute is unaffected by F5.
  - “1” Audio Mute is affected by F5.

- Bit 7** Output 11: Heavy Load, Disconnect-Standby-Total Shut Down
- “0” Heavy Load in Forward/Reverse and Disconnect-Standby-Total Shut Down in Neutral are unaffected by F5.
  - “1” Heavy Load in Forward/Reverse and Disconnect-Standby-Total Shut Down in Neutral are affected by F5.

**Note:** Heavy Load has replaced the Cruise Control feature that was available on Lionel HO and early BLI locomotives.

## 4.9 CV 40 Output Location for F6<sup>67</sup>

This CV specifies whether outputs 4 thru 11 are controlled by F6.

A '1' in a bit location specifies the output is controlled by F6, while a '0' specifies the output is not controlled by F6.

Default Value:

<b>00010000 = 16</b>
----------------------

### CV 40: F6 Output Location for F6 Register (with Factory Default Features)

Heavy Load (Disconnect- Standby-Total Shut Down)	Mute	Squealing Brakes/Flanges /Air Brakes (Cylinder Cocks/ Long Air Let-Off)	Doppler (Start Up)	Dynamic Brakes	Blower- Hiss/Fans	Coupler Crash Coupler Fire (Coupler Arm)	Horn/Whistle
Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
<b>Output 11</b>	<b>Output 10</b>	<b>Output 9</b>	<b>Output 8</b>	<b>Output 7</b>	<b>Output 6</b>	<b>Output 5</b>	<b>Output 4</b>

- QSI has pre-assigned default features to each output but any feature can be assigned to any output in CV 53. In CV 53, the default settings for Output 8 are Doppler Shift for a moving locomotive and Locomotive Start Up in Neutral. Therefore, by default F6 controls Doppler Shift and Start Up.
- You can specify that F6 control any of Outputs 4-7 and 9-11 in addition to or instead of Output 8.
- Assuming the default CV 53 settings (shown in the top row)<sup>68</sup>, you can specify that F6 control the following features.

**Bit 0** Output 4; Horn/Whistle

"0" The Horn/Whistle is unaffected by F6.  
 "1" Horn/Whistle is affected by F6.

**Bit 1** Output 5: Coupler Crash, Coupler Arm, Coupler Fire

"0" The Coupler Sounds are unaffected by F6.  
 "1" The Coupler Sounds are affected by F6.

**Bit 2** Output 6: Steam Locomotive Blower Hiss or Diesel or Electric Loco Vents and Fans

"0" Blower-Hiss/Fans are unaffected by F6.  
 "1" Blower-Hiss/Fans are affected by F6.

**Bit 3** Output 7: Dynamic Brakes

"0" Dynamic Brakes are unaffected by F6.  
 "1" Dynamic Brakes are affected by F6.

**Bit 4** Output 8: Doppler, Start Up

"0" Doppler shift in Forward/Reverse and Start up in Neutral are unaffected by F6.  
 "1" Doppler shift in Forward/Reverse and Start up in Neutral are affected by F6.

<sup>67</sup> Write bit operation is supported for CV 40.

<sup>68</sup> Features that are different in the Neutral state are shown in parentheses

**Bit 5** Output 9: Squealing Brakes and Air Brakes, Cylinder Cocks Arm or Long Air Let-off.

“0” Squealing Brakes, Air Brakes in Forward/Reverse and Cylinder Cocks Arm, Long Air Let-off are unaffected by F6.

“1” Squealing Brakes, Air Brakes in Forward/Reverse and Cylinder Cocks Arm, Long Air Let-off are affected by F6.

**Bit 6** Output 10: Audio Mute

“0” Audio Mute is unaffected by F6.

“1” Audio Mute is affected by F6.

**Bit 7** Output 11: Heavy Load, Disconnect-Standby-Total Shut Down

“0” Heavy Load in Forward/Reverse and Disconnect-Standby-Total Shut Down in Neutral are unaffected by F6.

“1” Heavy Load in Forward/Reverse and Disconnect-Standby-Total Shut Down in Neutral are affected by F6.

**Note:** Heavy Load has replaced the Cruise Control feature that was available on Lionel HO and early BLI locomotives.

## 4.10 CV 41 Output Location for F7<sup>69</sup>

This CV specifies whether outputs 4 thru 11 are controlled by F7.

A '1' in a bit location specifies the output is controlled by F7, while a '0' specifies the output is not controlled by F7.

Default Value:

<b>00100000 = 32</b>
----------------------

### CV 41: Output Location for F7 Register (with Factory Default Features)

Heavy Load (Disconnect- Standby-Total Shut Down)	Mute	Squealing Brakes/Flanges /Air Brakes (Cylinder Cocks/ Long Air Let-Off)	Doppler (Start Up)	Dynamic Brakes	Blower- Hiss/Fans	Coupler Crash Coupler Fire (Coupler Arm)	Horn/Whistle
Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
<b>Output 11</b>	<b>Output 10</b>	<b>Output 9</b>	<b>Output 8</b>	<b>Output 7</b>	<b>Output 6</b>	<b>Output 5</b>	<b>Output 4</b>

- QSI has pre-assigned default features to each output but any feature can be assigned to any output in CV 53. In CV 53, the default settings for Output 9 are Squealing Brakes plus Air Brakes for a moving locomotive and Cylinder Cocks Arm or a Long Air Let-off for a Brake Set in Neutral. Therefore, by default F7 controls Squealing Brakes or Air Brakes for a moving locomotive and a Cylinder Cocks Arm or Brake Set Sound in Neutral.
- You can specify that F7 control any of Outputs 4-8 and 10-11 in addition to or instead of Output 9.
- Assuming the default CV 53 settings (shown in the top row)<sup>70</sup>, you can specify that F7 control the following features.

**Bit 0** Output 4; Horn/Whistle

"0" The Horn/Whistle is unaffected by F7.  
 "1" Horn/Whistle is affected by F7.

**Bit 1** Output 5: Coupler Crash, Coupler Arm, Coupler Fire

"0" The Coupler Sounds are unaffected by F7.  
 "1" The Coupler Sounds are affected by F7.

**Bit 2** Output 6: Steam Locomotive Blower Hiss or Diesel or Electric Loco Vents and Fans

"0" Blower-Hiss/Fans are unaffected by F7.  
 "1" Blower-Hiss/Fans are affected by F7.

**Bit 3** Output 7: Dynamic Brakes

"0" Dynamic Brakes are unaffected by F7.  
 "1" Dynamic Brakes are affected by F7.

**Bit 4** Output 8: Doppler, Start Up

"0" Doppler shift in Forward/Reverse and Start up in Neutral are unaffected by F7.  
 "1" Doppler shift in Forward/Reverse and Start up in Neutral are affected by F7.

<sup>69</sup> Write bit operation is supported for CV 41.

<sup>70</sup> Features that are different in the Neutral state are shown in parentheses



**Bit 5** Output 9: Squealing Brakes and Air Brakes, Cylinder Cocks Arm or Long Air Let-off

- "0" Squealing Brakes, Air Brakes in Forward/Reverse and Cylinder Cocks Arm, Long Air Let-off are unaffected by F7.
- "1" Squealing Brakes, Air Brakes in Forward/Reverse and Cylinder Cocks Arm, Long Air Let-off are affected by F7.

**Bit 6** Output 10: Audio Mute or

- "0" Audio Mute is unaffected by F7.
- "1" Audio Mute is affected by F7.

**Bit 7** Output 11: Heavy Load, Disconnect-Standby-Total Shut Down

- "0" Heavy Load in Forward/Reverse and Disconnect-Standby-Total Shut Down in Neutral are unaffected by F7.
- "1" Heavy Load in Forward/Reverse and Disconnect-Standby-Total Shut Down in Neutral are affected by F7.

**Note:** Heavy Load has replaced the Cruise Control feature that was available on Lionel HO and early BLI locomotives.

## 4.11 CV 42 Output Location for F8<sup>71</sup>

This CV specifies whether outputs 4 thru 11 are controlled by F8.

A '1' in a bit location specifies the output is controlled by F8, while a '0' specifies the output is not controlled by F8.

Default Value: 01000000 = 64

### CV 42: Output Location for F8 Register (with Factory Default Features)

Heavy Load (Disconnect- Standby-Total Shut Down)	Mute	Squealing Brakes/Flanges /Air Brakes (Cylinder Cocks/ Long Air Let-Off)	Doppler (Start Up)	Dynamic Brakes	Blower- Hiss/Fans	Coupler Crash Coupler Fire (Coupler Arm)	Horn/Whistle
Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
<b>Output 11</b>	<b>Output 10</b>	<b>Output 9</b>	<b>Output 8</b>	<b>Output 7</b>	<b>Output 6</b>	<b>Output 5</b>	<b>Output 4</b>

- QSI has pre-assigned default features to each output but any feature can be assigned to any output in CV 53. In CV 53, the default setting for Output 10 is Audio Mute. Therefore, by default F8 controls Audio Mute.
- You can specify that F8 control any of Outputs 4-9 and 11 in addition to or instead of Output 10.
- Assuming the default CV 53 settings (shown in the top row)<sup>72</sup>, you can specify that F8 control the following features.

**Bit 0** Output 4; Horn/Whistle

"0" The Horn/Whistle is unaffected by F8.  
 "1" Horn/Whistle is affected by F8.

**Bit 1** Output 5: Coupler Crash, Coupler Arm, Coupler Fire

"0" The Coupler Sounds are unaffected by F8.  
 "1" The Coupler Sounds are affected by F8.

**Bit 2** Output 6: Steam Locomotive Blower Hiss or Diesel or Electric Loco Vents and Fans

"0" Blower-Hiss/Fans are unaffected by F8.  
 "1" Blower-Hiss/Fans are affected by F8.

**Bit 3** Output 7: Dynamic Brakes

"0" Dynamic Brakes are unaffected by F8.  
 "1" Dynamic Brakes are affected by F8.

**Bit 4** Output 8: Doppler, Start Up

"0" Doppler shift in Forward/Reverse and Start up in Neutral are unaffected by F8.  
 "1" Doppler shift in Forward/Reverse and Start up in Neutral are affected by F8.

<sup>71</sup> Write bit operation is supported for CV 42.

<sup>72</sup> Features that are different in the Neutral state are shown in parentheses

**Bit 5** Output 9: Squealing Brakes and Air Brakes, Cylinder Cocks Arm or Long Air Let-off

- "0" Squealing Brakes, Air Brakes in Forward/Reverse and Cylinder Cocks Arm, Long Air Let-off are unaffected by F8.
- "1" Squealing Brakes, Air Brakes in Forward/Reverse and Cylinder Cocks Arm, Long Air Let-off are affected by F8.

**Bit 6** Output 10: Audio Mute

- "0" Audio Mute is unaffected by F8.
- "1" Audio Mute is affected by F8.

**Bit 7** Output 11: Heavy Load, Disconnect-Standby-Total Shut Down

- "0" Heavy Load in Forward/Reverse and Disconnect-Standby-Total Shut Down in Neutral are unaffected by F8.
- "1" Heavy Load in Forward/Reverse and Disconnect-Standby-Total Shut Down in Neutral are affected by F8.

**Note:** Heavy Load has replaced the Cruise Control feature that was available on Lionel HO and early BLI locomotives.

## 4.12 CV 43 Output Location for F9<sup>73</sup>

This CV specifies whether outputs 7 thru 14 are controlled by F9.

A '1' in a bit location specifies the output is controlled by F9, while a '0' specifies the output is not controlled by F9.

Default Value:

<b>00010000 = 16</b>
----------------------

### CV 43: Output Location for F9 Register (with Factory Default Features)

Cab Lights <sup>74</sup>	Alternate Horn Selection <sup>75</sup> / Number Board Lights <sup>76</sup>	SMPH Report (Status Report)	Heavy Load (Disconnect- Standby-Total Shut Down)	Mute	Squealing Brakes/Flanges /Air Brakes (Cylinder Cocks/ Long Air Let-Off)	Doppler (Start Up)	Dynamic Brakes
Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
<b>Output 14</b>	<b>Output 13</b>	<b>Output 12</b>	<b>Output 11</b>	<b>Output 10</b>	<b>Output 9</b>	<b>Output 8</b>	<b>Output 7</b>

- QSI has pre-assigned default features to each output but any feature can be assigned to any output in CV 53. In CV 53, the default settings for Output 11 are Heavy Load for a moving locomotive and Disconnect-Standby-Shut Down for a locomotive in Neutral. Therefore, by default F9 controls Heavy Load and Disconnect-Standby-Shut Down.

**Note:** Heavy Load has replaced the Cruise Control feature that was available on Lionel HO and early BLI locomotives.

- You can specify that F9 control any of Outputs 7-10 and 12-14 in addition to or instead of Output 11.
- Assuming the default CV 53 settings (shown in the top row)<sup>77</sup>, you can specify that F9 control the following features.

**Bit 0** Output 7: Dynamic Brakes

- "0" Dynamic Brakes are unaffected by F9.
- "1" Dynamic Brakes are affected by F9.

**Bit 1** Output 8: Doppler, Start Up

- "0" Doppler shift in Forward/Reverse and Start up in Neutral are unaffected by F9.
- "1" Doppler shift in Forward/Reverse and Start up in Neutral are affected by F9.

**Bit 2** Output 9: Squealing Brakes and Air Brakes, Cylinder Cocks Arm or Long Air Let-off

- "0" Squealing Brakes, Air Brakes in Forward/Reverse and Cylinder Cocks Arm, Long Air Let-off are unaffected by F9.
- "1" Squealing Brakes, Air Brakes in Forward/Reverse and Cylinder Cocks Arm, Long Air Let-off are affected by F9.

<sup>73</sup> Write bit operation is supported for CV 43.

<sup>74</sup> Cab Lights are usually selected by default in Multiple Lights #3, which is the actual feature assigned to Output 14 (see CV 55.138). Depending on your model, different lights may be selected for Multiple Lights #3.

<sup>75</sup> Alternate Horn is available only on selected models. Consult your Model's Operation Manual feature list.

<sup>76</sup> Number Board Lights are usually selected by default in Multiple Lights #2, which is the actual feature assigned to Output 13 (see CV 55.137). Depending on your model, different lights may be selected for Multiple Lights #2.

<sup>77</sup> Features that are different in the Neutral state are shown in parentheses

**Bit 3** Output 10: Audio Mute

- "0" Audio Mute is unaffected by F9.
- "1" Audio Mute is affected by F9.

**Bit 4** Output 11: Heavy Load, Disconnect-Standby-Total Shut Down

- "0" Heavy Load in Forward/Reverse and Disconnect-Standby-Total Shut Down in Neutral are unaffected by F9.
- "1" Heavy Load in Forward/Reverse and Disconnect-Standby-Total Shut Down in Neutral are affected by F9.

**Note:** Heavy Load has replaced the Cruise Control feature that was available on Lionel HO and early BLI locomotives.

**Bit 5** Output 12: Speed Report, Status Report

- "0" Speed Report in Forward/Reverse and Status Report in Neutral are unaffected by F9.
- "1" Speed Report in Forward/Reverse and Status Report in Neutral are unaffected by F9.

**Bit 6** Output 13: Number Board Lights

- "0" Alternate Horn Selection or Number Board Lights are unaffected by F9.
- "1" Alternate Horn Selection or Number Board Lights are affected by F9.

**Bit 7** Output 14: Cab Lights

- "0" Cab Lights are unaffected by F9.
- "1" Cab Lights are affected by F9.

## 4.13 CV 44 Output Location for F10<sup>78</sup>

This CV specifies whether outputs 7 thru 14 are controlled by F10.

A '1' in a bit location specifies the output is controlled by F10, while a '0' specifies the output is not controlled by F10.

Default Value:

**00100000 = 32**

### CV 44: Output Location for F10 Register (with Factory Default Features)

Cab Lights <sup>79</sup>	Alternate Horn Selection <sup>80</sup> / Number Board Lights <sup>81</sup>	Speed Report (Status Report)	Heavy Load (Disconnect- Standby-Total Shut Down)	Mute	Squealing Brakes – Air Brakes (Brake Set)	Doppler (Start Up)	Dynamic Brakes
Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
<b>Output 14</b>	<b>Output 13</b>	<b>Output 12</b>	<b>Output 11</b>	<b>Output 10</b>	<b>Output 9</b>	<b>Output 8</b>	<b>Output 7</b>

- QSI has pre-assigned default features to each output but any feature can be assigned to any output in CV 53. In CV 53, the default setting for Output 12 is a Scale Miles Per Hour (smph) or Scale Kilometers Per Hour (skph)<sup>82</sup> Speed Report in Forward/Reverse or Status Report in Neutral. Therefore F10 controls SMPH and Status Report.
- You can specify that F10 control any of Outputs 7-11 and 13-14 in addition to or instead of Output 12.
- Assuming the default CV 53 settings (shown in the top row)<sup>83</sup>, you can specify that F10 control the following features.

#### Bit 0 Output 7: Dynamic Brakes

- “0” Dynamic Brakes are unaffected by F10.
- “1” Dynamic Brakes are affected by F10.

#### Bit 1 Output 8: Doppler, Start Up

- “0” Doppler shift in Forward/Reverse and Start up in Neutral are unaffected by F10.
- “1” Doppler shift in Forward/Reverse and Start up in Neutral are affected by F10.

<sup>78</sup> Write bit operation is supported for CV 44.

<sup>79</sup> Cab Lights are usually selected by default in Multiple Lights #3, which is the actual feature assigned to Output 14 (see CV 55.138). Depending on your model, different lights may be selected for Multiple Lights #3.

<sup>80</sup> Alternate Horn is available only on selected models. Consult your Model's Operation Manual feature list.

<sup>81</sup> Number Board Lights are usually selected by default in Multiple Lights #2, which is the actual feature assigned to Output 13 (see CV 55.137). Depending on your model, different lights may be selected for Multiple Lights #2.

<sup>82</sup> Scale Miles Per Hour or Scale Kilometers Per Hour can be selected in CV 56.0.

<sup>83</sup> Features that are different in the Neutral state are shown in parentheses

- Bit 2** Output 9: Squealing Brakes and Air Brakes, Cylinder Cocks Arm or Long Air Let-off
- “0” Squealing Brakes, Air Brakes in Forward/Reverse and Cylinder Cocks Arm, Long Air Let-off are unaffected by F10.
  - “1” Squealing Brakes, Air Brakes in Forward/Reverse and Cylinder Cocks Arm, Long Air Let-off are affected by F10.
- Bit 3** Output 10: Audio Mute
- “0” Audio Mute is unaffected by F10.
  - “1” Audio Mute is affected by F10.
- Bit 4** Output 11: Heavy Load, Disconnect-Standby-Total Shut Down
- “0” Heavy Load in Forward/Reverse and Disconnect-Standby-Total Shut Down in Neutral are unaffected by F10.
  - “1” Heavy Load in Forward/Reverse and Disconnect-Standby-Total Shut Down in Neutral are affected by F10.
- Note:** Heavy Load has replaced the Cruise Control feature that was available on Lionel HO and early BLI locomotives.
- Bit 5** Output 12: Speed Report, Status Report
- “0” Speed Report in Forward/Reverse and Status Report in Neutral are unaffected by F10.
  - “1” Speed Report in Forward/Reverse and Status Report in Neutral are unaffected by F10.
- Bit 6** Output 13: Number Board Lights
- “0” Alternate Horn Selection or Number Board Lights are unaffected by F10.
  - “1” Alternate Horn Selection or Number Board Lights are affected by F10.
- Bit 7** Output 14: Cab Lights
- “0” Cab Lights are unaffected by F10.
  - “1” Cab Lights are affected by F10.

## 4.14 CV 45 Output Location for F11<sup>84</sup>

This CV specifies whether outputs 7 thru 14 are controlled by F11.

A '1' in a bit location specifies the output is controlled by F11, while a '0' specifies the output is not controlled by F11.

Default Value: 01000000 = 64

### CV 45: Output Location for F11 Register (with Factory Default Features)

Cab Lights <sup>85</sup>	Alternate Horn Selection <sup>86</sup> / Number Board Lights <sup>87</sup>	SMPH Report (Status Report)	Heavy Load (Disconnect-Standby-Total Shut Down)	Mute	Squealing Brakes/Flanges /Air Brakes (Cylinder Cocks/ Long Air Let-Off)	Doppler (Start Up)	Dynamic Brakes
Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
<b>Output 14</b>	<b>Output 13</b>	<b>Output 12</b>	<b>Output 11</b>	<b>Output 10</b>	<b>Output 9</b>	<b>Output 8</b>	<b>Output 7</b>

- QSI has pre-assigned default features to each output but any feature can be assigned to any output in CV 53. In CV 53, the default setting for Output 13 is Number Board Lights. Therefore F11 controls Number Board Lights.
- You can specify that F11 control any of Outputs 7-12 and 14 in addition to or instead of Output 13.
- Assuming the default CV 53 settings (shown in the top row)<sup>88</sup>, you can specify that F11 control the following features.

#### Bit 0 Output 7: Dynamic Brakes

- “0” Dynamic Brakes are unaffected by F11.
- “1” Dynamic Brakes are affected by F11.

#### Bit 1 Output 8: Doppler, Start Up

- “0” Doppler shift in Forward/Reverse and Start up in Neutral are unaffected by F11.
- “1” Doppler shift in Forward/Reverse and Start up in Neutral are affected by F11.

#### Bit 2 Output 9: Squealing Brakes and Air Brakes, Cylinder Cocks Arm or Long Air Let-off

- “0” Squealing Brakes, Air Brakes in Forward/Reverse and Cylinder Cocks Arm, Long Air Let-off are unaffected by F11.
- “1” Squealing Brakes, Air Brakes in Forward/Reverse and Cylinder Cocks Arm, Long Air Let-off are affected by F11.

<sup>84</sup> Write bit operation is supported for CV 45.

<sup>85</sup> Cab Lights are usually selected by default in Multiple Lights #3, which is the actual feature assigned to Output 14 (see CV 55.138). Depending on your model, different lights may be selected for Multiple Lights #3.

<sup>86</sup> Alternate Horn is available only on selected models. Consult your Model's Operation Manual feature list.

<sup>87</sup> Number Board Lights are usually selected by default in Multiple Lights #2, which is the actual feature assigned to Output 13 (see CV 55.137). Depending on your model, different lights may be selected for Multiple Lights #2.

<sup>88</sup> Features that are different in the Neutral state are shown in parentheses



**Bit 3** Output 10: Audio Mute **Error! Bookmark not defined.**

“0” Audio Mute is unaffected by F11.

“1” Audio Mute is affected by F11.

**Bit 4** Output 11: Heavy Load, Disconnect-Standby-Total Shut Down

“0” Heavy Load in Forward/Reverse and Disconnect-Standby-Total Shut Down in Neutral are unaffected by F11.

“1” Heavy Load in Forward/Reverse and Disconnect-Standby-Total Shut Down in Neutral are affected by F11.

**Note:** Heavy Load has replaced the Cruise Control feature that was available on Lionel HO and early BLI locomotives.

**Bit 5** Output 12: Speed Report, Status Report

“0” Speed Report in Forward/Reverse and Status Report in Neutral are unaffected by F11.

“1” Speed Report in Forward/Reverse and Status Report in Neutral are unaffected by F11.

**Bit 6** Output 13: Number Board Lights

“0” Alternate Horn Selection or Number Board Lights are unaffected by F11.

“1” Alternate Horn Selection or Number Board Lights are affected by F11.

**Bit 7** Output 14: Cab Lights

“0” Cab Lights are unaffected by F11.

“1” Cab Lights are affected by F11.

## 4.15 CV 46 Output Location for F12<sup>89</sup>

This CV specifies whether outputs 7 thru 14 are controlled by F12.

A '1' in a bit location specifies the output is controlled by F12, while a '0' specifies the output is not controlled by F12.

Default Value:

<b>10000000 = 128</b>
-----------------------

### CV 46: Output Location for F12 Register (with Factory Default Features)

Cab Lights <sup>90</sup>	Alternate Horn Selection <sup>91</sup> / Number Board Lights <sup>92</sup>	SMPH Report (Status Report)	Heavy Load (Disconnect- Standby-Total Shut Down)	Mute	Squealing Brakes – Air Brakes (Brake Set)	Doppler (Start Up)	Dynamic Brakes
Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
<b>Output 14</b>	<b>Output 13</b>	<b>Output 12</b>	<b>Output 11</b>	<b>Output 10</b>	<b>Output 9</b>	<b>Output 8</b>	<b>Output 7</b>

- QSI has pre-assigned default features to each output but any feature can be assigned to any output in CV 53. In CV 53, the default setting for Output 14 is Cab Lights. Therefore F12 controls Cab Lights.
- You can specify that F12 control any of Outputs 7-13 in addition to or instead of Output 14.
- Assuming the default CV 53 settings (shown in the top row)<sup>93</sup>, you can specify that F12 control the following features.

#### Bit 0 Output 7: Dynamic Brakes

- “0” Dynamic Brakes are unaffected by F12.
- “1” Dynamic Brakes are affected by F12.

#### Bit 1 Output 8: Doppler, Start Up

- “0” Doppler shift in Forward/Reverse and Start up in Neutral are unaffected by F12.
- “1” Doppler shift in Forward/Reverse and Start up in Neutral are affected by F12.

#### Bit 2 Output 9: Squealing Brakes and Air Brakes, Cylinder Cocks Arm or Long Air Let-off

- “0” Squealing Brakes, Air Brakes in Forward/Reverse and Cylinder Cocks Arm, Long Air Let-off are unaffected by F12.
- “1” Squealing Brakes, Air Brakes in Forward/Reverse and Cylinder Cocks Arm, Long Air Let-off are affected by F12.

<sup>89</sup> Write bit operation is supported for CV 46.

<sup>90</sup> Cab Lights are usually selected by default in Multiple Lights #3, which is the actual feature assigned to Output 14 (see CV 55.138). Depending on your model, different lights may be selected for Multiple Lights #3.

<sup>91</sup> Alternate Horn is available only on selected models. Consult your Model's Operation Manual feature list.

<sup>92</sup> Number Board Lights are usually selected by default in Multiple Lights #2, which is the actual feature assigned to Output 13 (see CV 55.137). Depending on your model, different lights may be selected for Multiple Lights #2.

<sup>93</sup> Features that are different in the Neutral state are shown in parentheses

**Bit 3** Output 10: Audio Mute

“0” Audio Mute is unaffected by F12.

“1” Audio Mute is affected by F12.

**Bit 4** Output 11: Heavy Load, Disconnect-Standby-Total Shut Down

“0” Heavy Load in Forward/Reverse and Disconnect-Standby-Total Shut Down in Neutral are unaffected by F12.

“1” Heavy Load in Forward/Reverse and Disconnect-Standby-Total Shut Down in Neutral are affected by F12.

**Note:** Heavy Load has replaced the Cruise Control feature that was available on Lionel HO and early BLI locomotives.

**Bit 5** Output 12: Speed Report, Status Report

“0” Speed Report in Forward/Reverse and Status Report in Neutral are unaffected by F12.

“1” Speed Report in Forward/Reverse and Status Report in Neutral are unaffected by F12.

**Bit 6** Output 13: Number Board Lights

“0” Horn Selection or Number Board Lights are unaffected by F12.

“1” Horn Selection or Number Board Lights are affected by F12.

**Bit 7** Output 14: Cab Lights

“0” Cab Lights are unaffected by F12.

“1” Cab Lights are affected by F12.

# 5 CV's 49-64: QSI Unique CV's

## 5.1 Overview

Many of the available CV's have been reserved by the NMRA to provide standardized and compatible operation by all manufacturers with each other's products.

These standard CV's relate to operations that are common to all DCC products such as ID numbers, speed steps, and acceleration and deceleration rates.

Many model railroad products today, and a much larger number in the future, require manufacturer unique CV's to configure their product's special features. The command structure and protocols for changing and retrieving manufacturer unique CV values are standardized through the NMRA, but the individual manufacturers specify the meaning of the CV values.

The NMRA has provided a number of CV's for manufacturers to use in configuring their own products: CV's 49 through 64, and CV's 112-128.

Instead of filling up the available manufacturer unique CV's in a linear or chronological order, QSI uses an indexing system which organizes these CV's in a meaningful way.

Two of the available manufacturer unique CV's are used as indices to expand some of the remaining CV's into 256 register one-dimensional tables, or into 256x256 register two-dimensional tables.

CV 49 is the Primary Index (PI), and is used for accessing up to 256 registers of a one-dimensional table.

<b>Primary Index CV 49</b>	
<b>0</b>	CV X Register 0
<b>1</b>	CV X Register 1
<b>2</b>	CV X Register 2
<b>3</b>	CV X Register 3
<b>:</b>	CV X Register n
<b>:</b>	
<b>255</b>	CV X Register 255

CV 52 is an example of one of the CV's implemented as a one-dimensional table.

CV 50 is the Secondary Index (SI), and is used together with the Primary Index for accessing up to 256x256 registers of a two-dimensional table.

<b>Primary Index CV 49</b>	<b>Secondary Index CV 50</b>					
	<b>0</b>	<b>1</b>	<b>2</b>	<b>3</b>	<b>.. ..</b>	<b>255</b>
<b>0</b>	CV X Register 0,0	CV X Register 0,1	CV X Register 0,2	CV X Register 0,3	CV X Register 0,m	CV X Register 0,255
<b>1</b>	CV X Register 1,0	CV X Register 1,1	CV X Register 1,2	CV X Register 1,3	CV X Register 1,m	CV X Register 1,255
<b>2</b>	CV X Register 2,0	CV X Register 2,1	CV X Register 2,2	CV X Register 2,3	CV X Register 2,m	CV X Register 2,255
<b>3</b>	CV X Register 3,0	CV X Register 3,1	CV X Register 3,2	CV X Register 3,3	CV X Register 3,m	CV X Register 3,255

:	CV X Register n,0	CV X Register n,1	CV X Register n,2	CV X Register n,3	CV X Register n,m	CV X Register n,255
<b>255</b>	CV X Register 255,0	CV X Register 255,1	CV X Register 255,2	CV X Register 255,3	CV X Register 255,m	CV X Register 255,255

CV 53 is an example of one of the CV's implemented as a two-dimensional table.

## 5.2 CV 49 QSI Primary Index

Use CV 49 to specify the Primary Index for a CV that is implemented as a one-dimensional or two-dimensional array.

Default Value:

### CV 49: Primary Index Register (PI)

Bit 7 (MSB)	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0 (LSB)
<b>P7</b>	<b>P6</b>	<b>P5</b>	<b>P4</b>	<b>P3</b>	<b>P2</b>	<b>P1</b>	<b>P0</b>

- CV 49 is used as an index into a table of up to 256 related values.

Primary Index	Table of Values
0	Value[0]
1	Value[1]
2	Value[2]
3	Value[3]
...	...

- For example, CV 49 is used as an index for CV 52 which contains the volume levels for up to 256 Individual Sounds.

Primary Index	Table of Volume Levels
0	Volume Level for Sound[0]
1	Volume Level for Sound[1]
2	Volume Level for Sound[2]
3	Volume Level for Sound[3]
...	...

- In this document the terms CV 49 and Primary Index mean the same thing. PI is the abbreviation for Primary Index.
- We use a shorthand notation to simplify description of a CV that is composed of a one-dimensional table of values. The elements of the table are referred to as CV NN.PI, where NN is the CV number, and PI is the Primary Index. For example, Individual Sound Volume 5 is written CV 52.5. During verbal acknowledgement or during CV Numeric Verbal Readout (CV 64) from the locomotive, it is spoken out as "CV five two point five".

## 5.3 CV 50 QSI Secondary Index

Use CV 50 to specify the Secondary Index for a CV that is implemented as a two-dimensional array.

Default Value:

0

### CV 50: Secondary Index Register (SI)

Bit 7 (MSB)	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0 (LSB)
<b>S7</b>	<b>S6</b>	<b>S5</b>	<b>S4</b>	<b>S3</b>	<b>S2</b>	<b>S1</b>	<b>S0</b>

- CV 50 is used along with CV 49 as an index into a two-dimensional table of up to 256x256 related values. CV 49 is the row index and CV 50 is the column index.

Primary Index	Secondary Index				...
	0	1	2	3	
0	Value[0,0]	Value[0,1]	Value[0,2]	Value[0,3]	...
1	Value[1,0]	Value[1,1]	Value[1,2]	Value[1,3]	...
2	Value[2,0]	Value[2,1]	Value[2,2]	Value[2,3]	...
3	Value[3,0]	Value[3,1]	Value[3,2]	Value[3,3]	...
...	...	...	...	...	...

- For example, CV 53 uses CV 49 as a row index (1...14) and CV 50 as a column index (0...1) to assign different QSI Features to each of fourteen outputs for two states: Forward/Reverse, and NFF/NFR.

Primary Index	Secondary Index	
	0	1
1	Feature Assigned to Output 1 in FWD/REV	Feature Assigned to Output 1 in NFF/NFR
2	Feature Assigned to Output 2 in FWD/REV	Feature Assigned to Output 2 in NFF/NFR
3	Feature Assigned to Output 3 in FWD/REV	Feature Assigned to Output 3 in NFF/NFR
...	...	...
14	Feature Assigned to Output 14 in FWD/REV	Feature Assigned to Output 14 in NFF/NFR

- In this document the terms CV 50 and Secondary Index mean the same thing. SI is the abbreviation for Secondary Index.
- We use a shorthand notation to simplify description of a CV that is composed of a two-dimensional table of values. The elements of the table are referred to as CV NN.PI.SI, where NN is the CV number, PI is the Primary Index, and SI is the Secondary Index. For example, the CV for output 4 in neutral is written CV 53.4.1. During verbal acknowledgement or during CV Numeric Verbal Readout (CV 64) from the locomotive, it is spoken out as "CV five three point four point one".

## 5.4 CV 51.PI QSI System Sound Control

Use CV 51 to control your Quantum locomotive's System Volume, Mute Volume and Special Sound Effects CV51 is implemented as a one-dimensional array, with CV 49 used as an index to these CV 51 registers.

### 5.4.1 CV 51.0 Operations Mode System Volume (PI = 0)

Use CV 51.0 to change the System Volume.

Default Value: 

127
-----

#### CV 51.0: Ops Mode System Volume Register

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
<b>0</b>	<b>V6</b>	<b>V5</b>	<b>V4</b>	<b>V3</b>	<b>V2</b>	<b>V1</b>	<b>V0</b>

- Set CV 49 to "0" to specify the Primary Index for **Operations Mode System Volume**.
- The System Volume can be set to any value between 0 (no sound) and 127 (100%). The upper bit is reserved and should be 0. The default Operations Mode Volume is 127 (**100%**). A "0" in this CV will reduce all sound effects to zero volume.
- The Operations Mode System Volume is the overall sound volume when the locomotive is in normal operation on the main (Operations Mode). When you change the Operations Mode System Volume on the main, you will immediately hear the change in volume.
- All sound is turned off in Service Mode because of the limited power usually available for the programming track. You can program the System Volume in Service Mode, but you won't hear the change in volume until you enter Operations Mode.

**Note:** The system volume in this CV is the same system volume used during conventional Analog operation. Changing this CV changes the system volume in Analog DC, and changing the system volume in Analog DC changes the value of this CV.

Example: Set the Operations Mode System volume to 64 (50% of max).
--

- |  |
|--|
| <ol style="list-style-type: none"><li>1. Set CV 49 to 0.</li><li>2. Set CV 51 to 64.</li></ol> |
|--|



## 5.4.2 CV 51.1 Operations Mode Mute Volume (PI = 1)

Use CV 51.0 to change the Mute Volume.. Mute is one of the Quantum features that can be turned on and off by a Function Key. When Mute is “On”, the overall volume reduces to the volume set by CV 51.1.

Default Value:

0

### CV 51.1: Ops Mode Mute Volume Register

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
<b>0</b>	<b>0</b>	<b>V5</b>	<b>V4</b>	<b>V3</b>	<b>V2</b>	<b>V1</b>	<b>V0</b>

- Set CV 49 to “1” to specify the Primary Index for **Operations Mode Mute Volume**.
- The Mute Volume can be set to any value between 0 (no sound) and 63 (50%). If the Mute Volume is set over 50% of the System Volume set in CV 51.0, the applied Mute Volume will be 50% of the System Volume setting. The upper bit is reserved and should be 0. A “0” in this CV will mute all sound effects to zero volume.
- The default Mute Volume is 0 (**0%**).
- The Mute Volume applies when the locomotive is in normal operation on the main (Operations Mode). When you change the Mute Volume on the main and “Mute” has been turned “On” by its assigned Function Key, you will immediately hear the change in volume.
- If you program the Mute Volume in Service Mode, you won’t hear the change in Mute volume until you enter Operations Mode and activate the Mute feature.

Example: Set the Operations Mode Mute Volume to 32 (25% of max).

- 1) Set CV 49 to 1.
- 2) Set CV 51 to 32.

### 5.4.3 CV 51.2 Special Sound Effects Enable<sup>94</sup> (PI = 2)

Use CV 51.2 to enable/disable special sound effects.

Default Value:

**Depends on Locomotive**

#### CV 51.2: Special Sound Effects Enable Register

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Reserved for future use	Reserved for future use	Cylinder Cocks Armed after 25 seconds in NFF/NFR	Cylinder Cocks Armed on Startup	Heavy Load On/Off Feedback	Alternate Horn Selection Feedback	Coded Horn for Gas Turbine Start Up <sup>95</sup>	Horn Triggered Doppler

- Write 2 to CV 49 to specify the Primary Index for **Special Sound Effects Enable**.
- Set data in Bit 0 as follows:
  - “0” = Horn triggered Doppler effect is disabled.
  - “1” = Horn triggered Doppler effect is enabled. (Default)

If Horn Triggered Doppler is enabled, you can obtain a Doppler effect by first blowing the Horn for a least one second. Any time thereafter, briefly interrupt the horn signal by releasing the function key and reapplying to produce the Doppler effect.
- Set data in Bit 1 as follows:
  - “0” = Coded Horn triggered Gas Turbine Start Up is disabled.
  - “1” = Coded Horn triggered Gas Turbine Start Up is enabled. (Default)

If Coded Horn triggered Gas Turbine Start Up is enabled, then 4 short horn blasts in neutral will cause the Gas Turbine decoder to transition from Diesel to Turbine operation or from Turbine to Diesel operation.
- Set data in Bit 2 as follows:
  - “0” = Alternate Horn Selection Feedback is disabled.
  - “1” = Alternate Horn Selection Feedback is enabled. (Default)

If Alternate Horn Selection Feedback is enabled, then the newly selected Horn sounds a short hoot when it is selected. Only certain models have an Alternate Horn.
- Set data in Bit 3 as follows:
  - “0” = Heavy Load On/Off Feedback is disabled.
  - “1” = Heavy Load On/Off Feedback is enabled. (Default)

If Heavy Load On/Off Feedback is enabled, a single horn hoot is played when Heavy Load is turned on. When Heavy Load is turned off, two horn hoots are played.
- Set data in Bit 4 as follows:
  - “0” = Cylinder Cocks are not automatically armed as a result of a Startup (F6) operation.
  - “1” = Cylinder Cocks are automatically armed as a result of a Startup (F6) operation. (Default)

If this bit is “1” and a Startup (F6) operation occurs, Cylinder Cocks sounds play when the locomotive starts moving in FWD/REV. The Cylinder Cocks sounds automatically terminate after 16 repetitions or when the locomotive reaches a speed greater than 12 smph.
- Set data in Bit 5 as follows:

<sup>94</sup> Write bit operation is supported for Special Sound Effects Enable.

<sup>95</sup> See Gas Turbine Operation in Appendix II for further explanation of this feature.

“0” = Cylinder Cocks are not automatically armed after 25 seconds in NFF/NFR.

“1” = Cylinder Cocks are automatically armed after 25 seconds in NFF/NFR. (Default)

If this bit is “1” and the locomotive remains in neutral for at least 25 seconds, Cylinder Cocks sounds play when the locomotive starts moving in FWD/REV. The Cylinder Cocks sounds automatically terminate after 16 repetitions or when the locomotive reaches a speed greater than 12 smph.

- All other bits are reserved. Any data entered in these bits is ignored.

Example: Set Special Sound Effects according to Feature Table below.
Set CV 49 to 2.
Set CV 51 to value indicated for the combination of features you want.

Cylinder Cocks Armed after 25 seconds in NFF/NFR	Cylinder Cocks Armed on Startup	Heavy Load On/Off Feedback	Std/Alt Horn Select Feedback	Coded Horn for Gas Turbine Start Up	Horn Triggered Doppler	Decimal Value	Binary Value	Hex Value
						0	00000000	00
					X	1	00000001	01
				X		2	00000010	02
				X	X	3	00000011	03
			X			4	00000100	04
			X		X	5	00000101	05
			X	X		6	00000110	06
			X	X	X	7	00000111	07
		X				8	00001000	08
		X			X	9	00001001	09
		X		X		10	00001010	0A
		X		X	X	11	00001011	0B
		X	X			12	00001100	0C
		X	X		X	13	00001101	0D
		X	X	X		14	00001110	0E
		X	X	X	X	15	00001111	0F
	X					16	00010000	10
	X				X	17	00010001	11
	X			X		18	00010010	12
	X			X	X	19	00010011	13
	X		X			20	00010100	14
	X		X		X	21	00010101	15
	X		X	X		22	00010110	16
	X		X	X	X	23	00010111	17
	X	X				24	00011000	18
	X	X			X	25	00011001	19
	X	X		X		26	00011010	1A
	X	X		X	X	27	00011011	1B
	X	X	X			28	00011100	1C
	X	X	X		X	29	00011101	1D
	X	X	X	X		30	00011110	1E
	X	X	X	X	X	31	00011111	1F
X						32	00100000	20
X					X	33	00100001	21
X				X		34	00100010	22
X				X	X	35	00100011	23
X			X			36	00100100	24
X			X		X	37	00100101	25
X			X	X		38	00100110	26
X			X	X	X	39	00100111	27
X		X				40	00101000	28
X		X			X	41	00101001	29
X		X		X		42	00101010	2A
X		X		X	X	43	00101011	2B
X		X	X			44	00101100	2C
X		X	X		X	45	00101101	2D
X		X	X	X		46	00101110	2E
X		X	X	X	X	47	00101111	2F
X	X					48	00110000	30
X	X				X	49	00110001	31
X	X			X		50	00110010	32
X	X			X	X	51	00110011	33
X	X		X			52	00110100	34
X	X		X		X	53	00110101	35
X	X		X	X		54	00110110	36
X	X		X	X	X	55	00110111	37
X	X	X				56	00111000	38
X	X	X			X	57	00111001	39
X	X	X		X		58	00111010	3A
X	X	X		X	X	59	00111011	3B
X	X	X	X			60	00111100	3C
X	X	X	X		X	61	00111101	3D
X	X	X	X	X		62	00111110	3E
X	X	X	X	X	X	63	00111111	3F

## 5.4.4 CV 51.5 Automatic Mute Timeout Value (PI = 5)

Use this CV to specify the number of seconds of "idle time" after which the locomotive automatically mutes its sounds.

Default Value:

0
---

### CV 51.5: Automatic Mute Timeout Value Register

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
<b>D7</b>	<b>D6</b>	<b>D5</b>	<b>D4</b>	<b>D3</b>	<b>D2</b>	<b>D1</b>	<b>D0</b>

- Each unit represents 10 seconds. The maximum value is 255, which represents 2550 seconds or 42 minutes and 30 seconds.
- If the number of specified seconds of idle time is exceeded, the locomotive's sounds are automatically reduced to the Mute Volume specified in CV51.1. If the locomotive's sounds are already muted via the Mute function, the locomotive's sounds will not change in volume.
- If the value of this CV is "0", this timeout is disabled. Sounds are not automatically muted.
- Idle time is defined as the period of time during which the locomotive is in neutral and receives only Speed packets with speed step "0".
- If the locomotive receives a Speed packet with speed step > 0, or any non speed packet such as a Function packet or Configuration Variable Access packet, then the idle time is immediately reset and the sounds return to their previous volume.
- Idle time also includes the case where the locomotive receives no valid packets addressed specifically to its Primary, Extended, or Consist address. This overlaps with the condition which triggers the CV11 Packet Timeout, but CV51.5 is independent of CV11 and vice versa. Either or both timeouts may be enabled and do not interfere with each other.

Example 1: Suppose CV11 = "10" and CV51.5 = "6". Suppose the locomotive enters neutral (speed step 0) and the locomotive receives no packets other than Speed "0" packets. After 60 seconds of this, the locomotive's sounds are reduced to the CV51.1 Mute Volume.

Example 2: Suppose CV11 = "10" and CV51.5 = "6". The locomotive's speed corresponds to the last received Speed packet specifying speed step "30". The locomotive does not receive any valid packets addressed to one of its addresses. After 10 seconds of this the CV11 Packet Timeout Value is exceeded and the locomotive automatically slows to a stop and enters neutral, but the locomotive's sounds do not change in volume. After the locomotive comes to a stop and after 60 additional seconds of receiving no valid packets addressed to one of its addresses, the locomotive's sounds are reduced to the CV51.1 Mute Volume.

Example: Set the Automatic Mute Timeout Value to 10 (100 seconds).
--

- |                     |
|---------------------|
| 3) Set CV 49 to 5.  |
| 4) Set CV 51 to 10. |

## 5.5 CV 52.PI QSI Individual Sound Volume Control

Use CV 52 to specify volume levels for individual Quantum sounds.

### CV 52.PI: Individual Sound Volume Registers

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>V3</b>	<b>V2</b>	<b>V1</b>	<b>V0</b>

- CV 52 is implemented as a one-dimensional table of up to 256 Individual Sound Volume registers, with CV 49 used as an index to these registers.

Primary Index	Table of Volume Levels
0	Volume Level for Sound[0]
1	Volume Level for Sound[1]
2	Volume Level for Sound[2]
3	Volume Level for Sound[3]
...	...

- To change the volume level of an individual sound, do the following:
  - Set CV 49 to the identifier for the individual sound (see table next page).
  - Set data in Bits 0-3 of CV 52 as follows:
    - “0” = No sound
    - “1 – 15” = Sets volume level from the lowest level at “1” to the highest level at “15”
- 4 bits of volume level are used, providing 16 volume levels. The volume levels correspond to 2db increments.
- All other bits are reserved. Data in bits 4-7 are not used. Any data entered in these bits will be ignored.

Example: Set the bell volume to the 6<sup>th</sup> volume level and then set the Horn/Whistle volume to 10<sup>th</sup> level (i.e. set CV 52.8 to 6 followed by setting CV 52.0 to 11)

- Set CV 49 to 8 to select the Bell sound.
- Set CV 52 to 6 to select the 6th volume level for the Bell.
- Set CV 49 to 0 to select the Horn/Whistle sound.
- Set CV 52 to 10 to select the 10th volume level for the Horn/Whistle.

Example: For dual Air Pump Steam Locomotives, turn the volume off on one pump to create single pump action.

- Set CV 49 to 17 to select the second pump sound.
- CV 52 to zero to select no volume.

## 5.5.1 Individual Sound Identifiers

Primary Index (CV 49 value)	Sound	Typical Default Levels <sup>96</sup>
0	Horn/Whistle <sup>97</sup>	11
8	Bell	11
10	Chuff/Diesel Motor/Traction Motor <sup>98</sup>	11
11	Chuff 2 (Articulated Steam Locomotives Only)	11
13	Gas Turbine Whoosh	11
14	Turbo	11
15	Cylinder Cocks or Gas Turbine Whine	11
16	Air Pump 1	11
17	Air Pump 2 (Steam Locomotives Only)	11
19	Steam Blower Hiss/ Fans <sup>99</sup>	8/11
21	Long Air Let-off	11
22	Short Air Let-off	11
24	Squealing Brakes	11
26	Steam Dynamo/Diesel Generator	11
28	Dynamic Brakes Fans	11
29	Boiler Pop-off	11
30	Blow down	11
31	Injector	11
34	Coupler Sounds	11
37	Air Brakes	11
40	Alternate Horn Volume	11

<sup>96</sup> Default levels for individual sounds may be set to different levels at the factory then are shown here depending on the acoustic nature of each locomotive. Check the value of your default settings in your individual locomotive's instruction manual.

<sup>97</sup> Whistle in Steam Locomotives; Horn in Diesel and Electric Locomotives.

<sup>98</sup> Chuff in Steam Locomotives; Diesel Motor in Diesel Locomotives; Traction Motor in Electric Locomotives.

<sup>99</sup> Steam Blower in Steam Locomotives; Cooling Fans in Diesel and Electric Locomotives.

## 5.6 CV 53.PI.SI Output Feature Assignment

Use CV 53 to assign QSI features to the 14 decoder outputs.

### CV 53.PI.SI: Output Feature Assignment Register

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
<b>D7</b>	<b>D6</b>	<b>D5</b>	<b>D4</b>	<b>D3</b>	<b>D2</b>	<b>D1</b>	<b>D0</b>

- CV 53 is implemented as a two-dimensional table of 14x2 registers, with CV 49 used as a row index to these registers, and CV 50 used as a column index.

Primary Index (CV 49)	Secondary Index (CV 50)	
	0	1
1	Feature Assigned to Output 1 in FWD/REV	Feature Assigned to Output 1 in NFF/NFR
2	Feature Assigned to Output 2 in FWD/REV	Feature Assigned to Output 2 in NFF/NFR
3	Feature Assigned to Output 3 in FWD/REV	Feature Assigned to Output 3 in NFF/NFR
4	Feature Assigned to Output 4 in FWD/REV	Feature Assigned to Output 4 in NFF/NFR
5	Feature Assigned to Output 5 in FWD/REV	Feature Assigned to Output 5 in NFF/NFR
6	Feature Assigned to Output 6 in FWD/REV	Feature Assigned to Output 6 in NFF/NFR
7	Feature Assigned to Output 7 in FWD/REV	Feature Assigned to Output 7 in NFF/NFR
8	Feature Assigned to Output 8 in FWD/REV	Feature Assigned to Output 8 in NFF/NFR
9	Feature Assigned to Output 9 in FWD/REV	Feature Assigned to Output 9 in NFF/NFR
10	Feature Assigned to Output 10 in FWD/REV	Feature Assigned to Output 10 in NFF/NFR
11	Feature Assigned to Output 11 in FWD/REV	Feature Assigned to Output 11 in NFF/NFR
12	Feature Assigned to Output 12 in FWD/REV	Feature Assigned to Output 12 in NFF/NFR
13	Feature Assigned to Output 13 in FWD/REV	Feature Assigned to Output 13 in NFF/NFR
14	Feature Assigned to Output 14 in FWD/REV	Feature Assigned to Output 14 in NFF/NFR

- To change an output assignment, do the following:
  - Set CV 49 to the decoder Output Number (1...14).
  - Set CV 50 to the Locomotive State (0 for Forward/Reverse, 1 for Neutral (NFF/NFR).
  - Set CV 53 to the QSI Feature Identification Number (see table next page)
- Certain features can only be assigned to an output for a specific state.
- Never assign the same feature to two or more outputs; it is unclear what the effect will be since both outputs may have different states. For instance, if you assign the Blower Hiss to Output 5 and to Output 7, and Output 5 is off but Output 7 is on, would Blower Hiss be on or off?



**Example:** Set Long Air Let-Off to Output 5 to operate in Forward and Reverse and set Short Air Let-Off to Output 5 to operate in Neutral (i.e. set CV 53.5.0 to 9 and set CV 53.5.1 to 10).

- 1) Set Primary Index CV 49 to "5" to select output 5.
- 2) Set Secondary Index CV 50 to "0" to select Forward/Reverse.
- 3) Set CV 53 to "9" (00000101) which is Long Air Let-Off Feature ID Number.
- 4) Set Secondary Index CV 50 to "1" to select Neutral. (CV 49 is already set to output 5.)
- 5) Set CV 53 to "10" (00001010) for Short Air Let-Off.

Now the Function key mapped to output 5 will produce a Short Air-Let-Off when the locomotive is in Neutral, and a Long Air Let-Off when the locomotive is moving in Forward and Reverse.

## 5.6.1 QSI Feature Identification Numbers used with CV 53

The following table lists the QSI Features that may be assigned to function key outputs.

The third column shows the directional states (All, Forward/Reverse, Neutral) for which the feature may be assigned to an output. Some features, like Blower Hiss or Mute, apply to all states; some features, like Doppler and Squealing Brakes, only apply to a moving locomotive; some features, like Pop-off or Blow-Down, only apply to Neutral. The Quantum System allows you to assign, say, Squealing Brakes to Output 7 in Neutral but when the F5 Key is pressed to activate this feature in Neutral, it will produce no effect.

Feature	Feature ID	Allowed Directional States	Comments
Air Brakes	<b>176</b>	FWD/REV	See section "1.13 Air Brakes (F7 in Forward or Reverse)".
Alternate Horn Selection	<b>2</b>	All	This selects between the primary warning device be it either Horn or Whistle and an alternate Horn. Each time you make a selection, you hear a short hoot that identifies the Horn or Whistle selected. To disable feedback, see CV 51.2.
Arm Cylinder Cocks	<b>6</b>	NFF/NFR	Explicitly arms Cylinder Cocks. If Cylinder Cocks are armed, Cylinder Cocks sounds play when the locomotive begins moving in FWD/REV. The Cylinder Cocks sounds automatically terminate after 16 repetitions or when the locomotive reaches a speed greater than 12 smph. See CV 51.2.
Automatic Ditch Lights	<b>84</b>	All	When Automatic Ditch Lights is activated, the Ditch Lights intensity changes automatically in response to changes to the locomotive's directional state. See CV 55.84.x.
Automatic Front Cab Lights	<b>116</b>	All	When Automatic Front Cab Lights is activated, the Front Cab Lights intensity changes automatically in response to changes to the locomotive's directional state. See CV 55.116.x.
Automatic Front Marker Lights	<b>104</b>	All	When Automatic Front Marker Lights are activated, the Front Marker Light intensity changes automatically in response to changes to the locomotive's directional state. See CV 55.104.x.
Automatic Front Number Board Lights	<b>100</b>	All	When Automatic Front Number Board Lights is activated, Front Number Board Light intensity changes automatically in response to changes to the locomotive's directional state. See CV 55.100.x.
Automatic Front Step Lights	<b>112</b>	All	When Automatic Front Step Lights is activated, Front Step Light intensity changes automatically in response to changes to the locomotive's directional state. See CV 55.112.x.
Automatic Headlight	<b>70</b>	All	If Automatic Headlight is activated, the Headlight intensity changes automatically in response to changes to the locomotive's directional state. See CV 55.70.x.
Automatic Mars Light	<b>76</b>	All	If Automatic Mars Light is activated, the Mars Light intensity changes automatically in response to changes to the locomotive's directional state. See CV 55.76.x.

Automatic Rear Cab Lights	<b>118</b>	All	When Automatic Rear Cab Lights is activated, Rear Cab Lights turn off in Forward/Reverse after 15 seconds and turn on in Neutral after 10 seconds. See CV 55.118.x.
Automatic Rear Marker Lights	<b>106</b>	All	When Automatic Rear Marker Lights is activated, the Rear Marker Light intensity changes automatically in response to changes to the locomotive's directional state. See CV 55.108.x.
Automatic Rear Number Board Lights	<b>102</b>	All	When Automatic Rear Number Board Lights is activated, Rear Number Board Light intensity changes automatically in response to changes to locomotive's directional state. See CV 55.102.x.
Automatic Rear Step Lights	<b>114</b>	All	When Automatic Rear Step Lights is activated, Rear Step Light intensity changes automatically in response to changes to the locomotive's directional state. See CV 55.114.x.
Automatic Reverse Light	<b>73</b>	All	When Automatic Reverse Light is activated, the Reverse Light intensity changes automatically in response to changes in the locomotive's directional state. See CV 55.73.x.
Bell	<b>3</b>	All	When on, the bell rings continuously. Some bells have both start up and shut down sounds. See section "1.7 Horn and Bell Buttons (F2 Key and F1 Key)". See also CV 55.3.x.
Blow down	<b>13</b>	NFF/NFR	Blow Down produces a sound sequence of venting water, steam and residue that collects at the bottom of the boiler. The length of the Blow Down sequence is random. Blow Down sounds are produced automatically in Neutral at random intervals so there is no need to assign this feature to a function key output unless you really want to.
Blower Hiss	<b>8</b>	All	See section "1.9 Steam Blower Hiss and Cooling Fans (F4 Key)".
Cooling Vents and Fans	<b>8</b>	All	See section "1.9 Steam Blower Hiss and Cooling Fans (F4 Key)".
Coupler	<b>211</b>	All	See section "1.8 Coupler and Coupler Crash Sounds (F3 Key)".
GasTurbine/Diesel Transition	<b>24</b>	NFF/NFR	Selects between Diesel mode and Turbine mode for the UP Gas Turbine Locomotive.
Dim Ditch Lights	<b>86</b>	All	Explicitly switches the Ditch Lights from Bright to be Dim. See CV 55.84.x.
Dim Headlight	<b>72</b>	All	Explicitly switches the Headlight from Bright to Dim. See CV 55.70.x.
Dim Mars Light	<b>78</b>	All	Explicitly switches the Mars Light from Bright to Dim. See CV 55.76.x.
Dim Reverse Light	<b>75</b>	All	Explicitly switches the Reverse light from Bright to Dim. See CV 55.73.x.
Disconnect/Standby/Total Shut Down	<b>145</b>	NFF/NFR	See section "1.17 Three Stages of Shut Down: Disconnect, Standby and Total Shut Down (F9 in Neutral)".
Ditch Lights	<b>85</b>	All	Explicitly turns the Ditch Lights On or Off. See CV 55.84.x.
Doppler Shift	<b>65</b>	FWD/REV	See section "1.11 Doppler Shift (F6 in Forward and Reverse)".

Dynamic Brakes	<b>5</b>	FDW/REV and Disconnect	See section "1.10 Dynamic Brakes (F5 Key)".
Flanges/Squealing Brakes	<b>215</b>	FWD/REV	See section "1.12 Squealing Brakes and Flanges (F7 in Forward or Reverse)".
Flanges/Squealing Brakes + Air Brakes	<b>216</b>	FWD/REV	This feature is a combination of Flanges/Squealing Brakes, 215, and Air Brakes, 176. If assigned to a function key and pressed when Air Brakes would not normally be functional (i.e. throttle at some non-zero setting), squealing brakes would still be heard.
Front Cab Lights	<b>117</b>	All	Explicitly turns the Front Cab Lights On or Off. See CV 55.116.x.
Front Marker Lights	<b>105</b>	All	Explicitly turns the Front Marker Lights On or Off. See CV 55.104.x.
Front Number Board Lights	<b>101</b>	All	Explicitly turns the Front Number Board Lights On or Off. See CV 55.100.x.
Front Step Lights	<b>113</b>	All	Explicitly turns the Front Step Lights On or Off. See CV 55.112.x.
Grade Crossing	<b>154</b>	FWD/REV	Plays a grade crossing scenario consisting of four horn blasts: two long blasts, one short blast, and one long blast.
Headlight	<b>71</b>	All	Explicitly turns the Headlight On or Off. See CV 55.70.x.
Heavy Load	<b>179</b>	All	See section "1.15 Heavy Load (F9 in Forward or Reverse)".
Horn	<b>1</b>	All	See section "1.7 Horn and Bell Buttons (F2 Key and F1 Key)".
Injector	<b>14</b>	NFF/NFR	When triggered, Injector produces a sound sequence of water being injected into the boiler. This can happen in any directional state but it is more obvious in Neutral. The length of the Injector sequence is random. Injector sounds are produced automatically in Neutral at random intervals so there is no need to assign this feature to a function key output unless you really want to.
Long Air Let-off	<b>9</b>	All	When triggered, Long Air Let-off produces an air release sound of about 1.5 seconds. Use a Long Air Let-off to simulate operating some steam appliances like power reverse or applying the brakes in Neutral on any locomotive.
Mars Light	<b>77</b>	All	Explicitly turn the Mars Light On or Off. See CV 55.76.x.
Multiple Automatic Lights #1	<b>136</b>	All	The Multiple Automatic Lights #1 feature allows you to activate more than one automatic light feature with a single function key. See CV 55.136.x.
Multiple Automatic Lights #2	<b>137</b>	All	The Multiple Automatic Lights #2 feature allows you to activate more than one automatic light feature with a single function key. See CV 55.137.x.
Multiple Automatic Lights #3	<b>138</b>	All	The Multiple Automatic Lights #3 feature allows you to activate more than one automatic light feature with a single function key. See CV 55.138.x.

Mute	<b>64</b>	All	See section "1.14 Audio Mute (F8 Key)".
None	<b>0</b>	All	If this feature is assigned to a function key output, pressing the function key does nothing.
Pop-off	<b>12</b>	NFF/NFR	When triggered, Pop Off produces a sound sequence of steam being ejected from the boiler. This can happen in any directional state but it is more obvious in Neutral. The length of the Pop Off sequence is random. Pop Off sounds are produced automatically in Neutral at random intervals so there is no need to assign this feature to a function key output unless you really want to.
Rear Cab Lights	<b>119</b>	All	Explicitly turns the Rear Number Board Lights On or Off. See CV 55.118.x.
Rear Marker Lights	<b>107</b>	All	Explicitly turns the Rear Marker Lights On or Off. See CV 55.106.x.
Rear Number Board Lights	<b>103</b>	All	Explicitly turns the Rear Number Board Lights On or Off. See CV 55.102.x.
Rear Step Lights	<b>115</b>	All	Explicitly turns the Rear Step Lights On or Off. See CV 55.114.x.
Reverse Light	<b>74</b>	All	Explicitly turns the Reverse light On or Off. See CV 55.73.x.
Short Air Let-off	<b>10</b>	All	When triggered, Short Air Let-off produces an air release sound of about 1 second. Use a Short Air Let-off to simulate operating some locomotive appliances or as a place holder feature for unused function keys.
Start Up	<b>144</b>	NFF/NFR	See section "1.18 Start Up (F6 in Neutral)".
Status Report	<b>178</b>	All	See section "1.16 Status Report (F10)".
Strobe Ditch Lights	<b>87</b>	All	Explicitly turns on or off Ditch Lights strobe. See CV 55.84.x.
Strobe Mars Light	<b>79</b>	All	Explicitly turns on or off Mars Light strobe. See CV 55.76.x.
Whistle	<b>1</b>	All	See section "1.7 Horn and Bell Buttons (F2 Key and F1 Key)".

**Note:** Do not confuse the above table with the Individual Sound Identifiers Table shown in CV 52. The above table lists ID's of Features while CV 52 table lists ID's of Individual Sounds.

## 5.6.2 CV 53 Factory Default Settings

Primary Index (PI) (CV 49 Value)		Secondary Index (SI) (CV 50 Value)	
		0	1
		Forward/Reverse only	Neutral only
1	Output 1	Multiple Automatic Lights #1 (136)	Multiple Automatic Lights #1 (136)
2	Output 2	Multiple Automatic Lights #1 (136)	Multiple Automatic Lights #1 (136)
3	Output 3	Bell (3)	Bell (3)
4	Output 4	Horn/Whistle (1)	Horn/Whistle (1)
5	Output 5	Coupler (211)	Coupler (211)
6	Output 6	Blower Hiss/Fans (8)	Blower Hiss/Fans (8)
7	Output 7	Dynamic Brakes (5)	Dynamic Brakes (5)
8	Output 8	Doppler Shift (65)	Start Up (144)
9	Output 9	Squealing Brakes + Air Brakes (216)	Long Air Let-off (9) or Arm Cylinder Cocks (6)
10	Output 10	Mute (64)	Mute (64)
11	Output 11	Heavy Load (179)	Disconnect/Standby/ Shut Down (145)
12	Output 12	Status Report (178)	Status Report (178)
13	Output 13	Alternate Horn Selection (2) Multiple Automatic Lights #2 (137)	Alternate Horn Selection (2) Multiple Automatic Lights #2 (137)
14	Output 14	Multiple Automatic Lights #3 (138)	Multiple Automatic Lights #3 (138)

## 5.7 CV 55.PI.SI QSI Feature Configuration

Use CV 55 to configure the behavior of Quantum features.

CV 55 is implemented as a two-dimensional array of registers. with both CV 49 and CV 50 used to access these registers. The CV 49 Primary Index corresponds to QSI feature ID numbers.

### 5.7.1 CV 55.3.SI Bell

#### 5.7.1.1 CV 55.3.0 Maximum Bell Index

This read-only CV contains the number of prototypical bell sounds available in your Quantum Decoder.

Default Value:

<b>Depends on Locomotive</b>
------------------------------

#### CV 55.3.0: Maximum Bell Index

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
<b>D7</b>	<b>D6</b>	<b>D5</b>	<b>D4</b>	<b>D3</b>	<b>D2</b>	<b>D1</b>	<b>D0</b>

- In Service Mode, to determine the number of bells available:
  - 1) Set CV 49 to 3.
  - 2) Set CV 50 to 0.
  - 3) Then read back CV 55.
- In Ops Mode, to determine the number of bells available:
  - 1) Set CV 49 to 3.
  - 2) Set CV 50 to 0.
  - 3) Then set CV 64 to 55 to hear a verbal response.

### 5.7.1.2 CV 55.3.1 Bell Select

Your Quantum Decoder may have more than one type of prototypical bell sound. Use CV 55.3.1 to choose from the available bell sounds.

Default Value:

<b>1</b> <sup>100</sup>
-------------------------

#### CV 55.3.1: Bell Select

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
<b>D7</b>	<b>D6</b>	<b>D5</b>	<b>D4</b>	<b>D3</b>	<b>D2</b>	<b>D1</b>	<b>D0</b>

- Use CV 55.3.0 to determine “N”, the number of prototypical bell sounds available.
- Set CV 55.3.1 to a number from “0” to “N”. Selection “1” is the original prototypical bell for this model; selection “0” is “Feedback Bell<sup>101</sup>”.
- If you set CV 55.3.1 to a value larger than “N”, the decoder will revert to “0”, the “Feedback Bell”.
- If you set CV 55.3.1 to 1...N in Ops Mode, and the locomotive’s bell is ringing, the newly selected prototypical bell will begin ringing immediately.

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<sup>100</sup> The default for some European models is 0, because their prototype did not have a bell.

<sup>101</sup> Feedback Bells produce a single light “ding” when turning the bell on and a double “ding” when shutting the bell off. This bell type is suitable for locos that are not intended to have bells but need a bell sound to indicate that the bell state is on or off.



### 5.7.3 CV 55.70.SI Headlight

Three features can be assigned to function keys to control headlight operation:

Feature ID	Feature Name	Use
70	Automatic Headlight Activate	Activate/Deactivate Automatic Control of the Headlight
71	Headlight On	Explicitly turn the Headlight On/Off
72	Headlight Dim	Explicitly specify the Headlight be Dim/Bright

The headlight intensity (Off, Dim\*, Bright) can be controlled automatically or explicitly.

#### Automatic Control

When the Feature 70 function state is 1, automatic control is activated. The headlight intensity changes automatically in response to changes to the locomotive's motive state.

Forward	Neutral from Forward	Reverse	Neutral from Reverse
Bright	Dim*	Dim*	Dim*

The automatic behavior can be configured in CV 55.70.1.

Feature 70 has precedence over Features 71 and 72. When the Feature 70 function state is 1, the Feature 71 and 72 function states are ignored.

#### Explicit Control

When the Feature 70 function state is 0, automatic control is deactivated. The headlight intensity reverts to the Feature 71 and 72 function states.

Feature 72 Function State	Feature 71 Function State	Intensity
X	0	Off
0	1	Bright
1	1	Dim*

Feature 70 has precedence over Features 71 and 72. If the Feature 70 function state changes to 1, because of a Feature 70 function key press or a start up operation, automatic control is re-activated.

Feature 71 has precedence over Feature 72. If the Feature 71 function state is 0, the Feature 72 function state is ignored.

\* If the headlight cannot be dimmed, then Dim = Off.

### 5.7.3.1 CV 55.70.0 Headlight Initial State

Use this CV to specify the startup state function states for the Headlight features.

Default Value:

1

#### CV 55.70.0: Headlight Initial State

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Reserved	Reserved	Reserved	Reserved	Reserved	Feature 72 Function State	Feature 71 Function State	Feature 70 Function State

- Default value = 00000001 binary = 01 hex = 1 decimal (Automatic Control Activated).
- Bit 0 is the initial state of the Automatic Headlight Activate (Feature 70) function.
- Bit 1 is the initial state of the Headlight On (Feature 71) function.
- Bit 2 is the initial state of the Headlight Dim (Feature 72) function.
- A write to this CV in operations mode causes the Feature 70, 71 and 72 function states to be immediately set to the new values.
- A start up operation causes the Feature 70, 71 and 72 function states to be set to the values in this CV.

### 5.7.3.2 CV 55.70.1 Automatic Headlight Configuration

Use this CV to configure the Automatic Headlight behavior.

Default Value:

<b>86</b>
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#### CV 55.70.1: Automatic Headlight Configuration

NFR		REV		NFF		FWD	
Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Intensity	Intensity	Intensity	Intensity	Intensity	Intensity	Intensity	Intensity

- Default value = 01010110 binary = 56 hex = 86 decimal.
- Bits 0,1 specify the headlight intensity in FWD, bits 2,3 the intensity in NFF, bits 4,5 the intensity in REV, and bits 6,7 the intensity in NFR.

Bit 1 Bit 3 Bit 5 Bit 7	Bit 0 Bit 2 Bit 4 Bit 6	Intensity
0	0	Off
0	1	Dim*
1	0	Bright
1	1	Reserved

- The default settings specify the following behavior:

FWD	NFF	REV	NFR
Bright	Dim*	Dim*	Dim*

\* If the headlight cannot be dimmed, then Dim = Off.

### 5.7.3.3 CV 55.70.10 Headlight Dim Intensity

For models with a dimmable Headlight, this CV controls its dim intensity.

Default Value:

<b>Depends on Locomotive</b>
------------------------------

#### CV 55.70.10: Headlight Dim Intensity

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
<b>D7</b>	<b>D6</b>	<b>D5</b>	<b>D4</b>	<b>D3</b>	<b>D2</b>	<b>D1</b>	<b>D0</b>

- The default value is dependent on the model.
- Valid values are 0...255, 0 being least intense (off) and 255 being most intense (bright).
- In Ops mode, with the Headlight dimmed, you can observe the Headlight intensity change as you change the value of CV 55.70.10.

### 5.7.3.4 CV 55.70.SI Headlight Examples

**Example 1:** I want the automatic headlight to be bright in all four motive states, NFF, REV and NFR as well as FWD.

Solution: Set CV 55.70.1 to 10101010 binary = AA hex = 170 decimal.

**Example 2:** How will the headlight behave if I set CV 55.70.0 to 00000111 binary = 07 hex = 7 decimal?

Answer: The automatic headlight is initially activated and the headlight intensity is controlled by the CV 55.70.1 settings. If the automatic headlight is deactivated, for example, by pressing FL so that the FL function state is 0, then the Feature 71 function state turns the headlight on, and the Feature 72 function state makes the headlight dim.

**Example 3:** I want explicit headlight on/off control at all times. At startup I want the headlight off until I turn it on with a function key. When the headlight is on, it should be bright.

Solution: First set CV 55.70.0 to 0. Next remove the automatic headlight feature from multiple automatic lights #1 by setting CV 55.136.0 bit 0 to 0. Finally in CV 53 assign feature 71 to a function output.

**Example 4:** Same as example 3, but I want to explicitly dim the headlight as well. When I first turn the headlight on, it should be dim.

Solution: First set CV 55.70.0 to 00000100 binary = 04 hex = 4 decimal. Next remove the automatic headlight feature from multiple automatic lights #1 by setting CV 55.136.0 bit 0 to 0. Finally in CV 53 assign feature 71 to a function output and feature 72 to a second function output.

**Example 5:** I want explicit control over whether the headlight is bright or dim, but the headlight will always be on. On startup the headlight should be dim.

Solution: First set CV 55.70.0 to 00000110 binary = 05 hex = 5 decimal. Next remove the Automatic Headlight feature from Multiple Automatic Lights #1 by setting CV 55.136.0 bit 0 to 0. Finally in CV 53 assign feature 72 to a function output. You do not need to assign feature 71 to a function output.

## 5.7.4 CV 55.73.SI Reverse Light

Three features can be assigned to function keys to control reverse light operation:

Feature ID	Feature Name	Use
73	Automatic Reverse Light Activate	Activate/Deactivate Automatic Control of the Reverse Light
74	Reverse Light On	Explicitly turn the Reverse Light On/Off
75	Reverse Light Dim	Explicitly specify the Reverse Light be Dim/Bright

The reverse light intensity (Off, Dim\*, Bright) can be controlled automatically or explicitly.

### Automatic Control

When the Feature 73 function state is 1, automatic control is activated. The reverse light intensity changes automatically in response to changes to the locomotive's motive state.

Forward	Neutral from Forward	Reverse	Neutral from Reverse
Dim*	Dim*	Bright	Dim*

The automatic behavior can be configured in CV 55.73.1.

Feature 73 has precedence over Features 74 and 75. When the Feature 73 function state is 1, the Feature 74 and 75 function states are ignored.

### Explicit Control

When the Feature 73 function state is 0, automatic control is deactivated. The reverse light intensity changes in response to Feature 74 and 75 function key presses.

Feature 75 Function State	Feature 74 Function State	Intensity
X	0	Off
0	1	Bright
1	1	Dim*

If the Feature 73 function state changes to 1, because of a Feature 73 function key press or a start up operation, automatic control is re-activated.

Feature 74 has precedence over Feature 75. If the Feature 74 function state is 0, the Feature 75 function state is ignored.

\* If the reverse light cannot be dimmed, then Dim = Off.

### 5.7.4.1 CV 55.73.0 Reverse Light Initial State

Use this CV to specify the startup state function states for the Reverse Light features.

Default Value:

1

#### CV 55.73.0: Reverse Light Initial State

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Reserved	Reserved	Reserved	Reserved	Reserved	Feature 75 Function State	Feature 74 Function State	Feature 73 Function State

- Default value = 00000001 binary = 01 hex = 1 decimal (Automatic Control Activated).
- Bit 0 is the initial state of the Automatic Reverse Light Activate (Feature 73) function.
- Bit 1 is the initial state of the Reverse Light On (Feature 74) function.
- Bit 2 is the initial state of the Reverse Light Dim (Feature 75) function.
- A write to this CV in operations mode causes the Feature 73, 74 and 75 function states to be immediately set to the new values.
- A start up operation causes the Feature 73, 74 and 75 function states to be set to the values in this CV.

### 5.7.4.2 CV 55.73.1 Automatic Reverse Light Configuration

Use this CV to configure the Automatic Reverse Light behavior.

Default Value:

<b>101</b>
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#### CV 55.73.1: Automatic Reverse Light Configuration

NFR		REV		NFF		FWD	
Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Intensity	Intensity	Intensity	Intensity	Intensity	Intensity	Intensity	Intensity

- Default value = 01100101 binary = 65 hex = 101 decimal.
- Bits 0,1 specify the reverse light intensity in FWD, bits 2,3 the intensity in NFF, bits 4,5 the intensity in REV, and bits 6,7 the intensity in NFR.

Bit 1 Bit 3 Bit 5 Bit 7	Bit 0 Bit 2 Bit 4 Bit 6	Intensity
0	0	Off
0	1	Dim*
1	0	Bright
1	1	Reserved

- The default settings specify the behavior:

FWD	NFF	REV	NFR
Dim*	Dim*	Bright	Dim*

\* If the reverse light cannot be dimmed, then Dim = Off.



### 5.7.4.3 CV 55.73.10 Reverse Light Dim Intensity

For models with a dimmable Reverse Light, this CV controls its dim intensity.

Default Value:

<b>Depends on Locomotive</b>
------------------------------

#### CV 55.73.10: Reverse Light Dim Intensity

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
<b>D7</b>	<b>D6</b>	<b>D5</b>	<b>D4</b>	<b>D3</b>	<b>D2</b>	<b>D1</b>	<b>D0</b>

- The default value is dependent on the model.
- Valid values are 0...255, 0 being least intense (off) and 255 being most intense (bright).
- In Ops mode, with the Reverse Light dimmed, you can observe the Reverse Light intensity change as you change the value of CV 55.73.10.

#### 5.7.4.4 CV 55.73.SI Reverse Light Examples

**Example 1:** I want the automatic reverse light to be bright in all four motive states, NFF, REV and NFR as well as FWD.

Solution: Set CV 55.73.1 to 10101010 binary = AA hex = 170 decimal.

**Example 2:** How will the reverse light behave if I set CV 55.73.0 to 00000111 binary = 07 hex = 7 decimal?

Answer: The automatic reverse light is initially activated and the reverse light intensity is controlled by the CV 55.73.1 settings. If the automatic reverse light is deactivated, for example, by pressing FL so that the FL function state is 0, then the Feature 74 function state turns the reverse light on, and the Feature 75 function state makes the reverse light dim.

**Example 3:** I want explicit reverse light on/off control at all times. At startup I want the reverse light off until I turn it on with a function key. When the reverse light is on, it should be bright.

Solution: First set CV 55.73.0 to 0. Next remove the automatic reverse light feature from multiple automatic lights #1 by setting CV 55.136.0 bit 1 to 0. Finally in CV 53 assign Feature 74 to a function output.

**Example 4:** Same as example 3, but I want to explicitly dim the reverse light as well. When I first turn the reverse light on, it should be dim.

Solution: First set CV 55.73.0 to 00000100 binary = 04 hex = 4 decimal. Next remove the automatic reverse light feature from multiple automatic lights #1 by setting CV 55.136.0 bit 1 to 0. Finally in CV 53 assign Feature 74 to a function output and Feature 75 to a second function output.

## 5.7.5 CV 55.76.SI Mars Light

Four features can be assigned to function keys to control mars light operation:

Feature ID	Feature Name	Use
76	Automatic Mars Light Activate	Activate/Deactivate Automatic Control of the Mars Light
77	Mars Light On	Explicitly turn the Mars Light On/Off
78	Mars Light Dim	Explicitly specify the Mars Light be Dim/Bright
79	Mars Light Strobe	Explicitly turn on/off Mars Light strobe

The mars light intensity (Off, Dim, Bright, Strobe) can be controlled automatically or explicitly.

### Automatic Control

When the Feature 76 function state is 1, automatic control is activated. The mars light intensity changes automatically in response to changes to the locomotive's motive state.

Forward	Neutral from Forward	Reverse	Neutral from Reverse
Strobe	Dim	Dim	Dim

The automatic behavior can be configured in CV 55.76.1, CV 55.76.2, CV 55.76.3, and CV 55.76.4.

Feature 76 has precedence over Features 77, 78 and 79. When the Feature 76 function state is 1, the Feature 77, 78 and 79 function states are ignored.

### Explicit Control

When the Feature 76 function state is 0, automatic control is deactivated. The Mars Light intensity changes in response to Feature 77, 78 and 79 function key presses.

Feature 79 Function State	Feature 78 Function State	Feature 77 Function State	Intensity
x	X	0	Off
0	0	1	Bright
0	1	1	Dim
1	X	1	Strobe

Feature 76 has precedence over Features 77, 78 and 79. If the Feature 76 function state changes to 1, because of a Feature 76 function key press or a start up operation, automatic control is re-activated.

Feature 77 has precedence over Features 78 and 79. If the Feature 77 function state is 0, the Feature 78 and 79 function states are ignored.

Feature 79 has precedence over Feature 78. If the Feature 79 function state is 1, the Feature 78 function state is ignored.

### 5.7.5.1 CV 55.76.0 Mars Light Initial State

Use this CV to specify the startup state function states for the Mars Light features.

Default Value:

1
---

#### CV 55.76.0: Mars Light Initial State

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Reserved	Reserved	Reserved	Reserved	Feature 79 Function State	Feature 78 Function State	Feature 77 Function State	Feature 76 Function State

- Default value = 00000001 binary = 01 hex = 1 decimal (Automatic Control Activated).
- Bit 0 is the initial state of the Automatic Mars Light Activate (Feature 76) function.
- Bit 1 is the initial state of the Mars Light On (Feature 77) function.
- Bit 2 is the initial state of the Mars Light Dim (Feature 78) function.
- Bit 3 is the initial state of the Mars Light Strobe (Feature 79) function.
- A write to this CV in operations mode causes the Feature 76, 77, 78 and 79 function states to be immediately set to the new values.
- A start up operation causes the Feature 76, 77, 78 and 79 function states to be set to the values in this CV.

### 5.7.5.2 CV 55.76.1 Automatic Mars Light FWD Configuration

Use this CV to configure how the Automatic Mars Light behaves when the locomotive is in forward.

Default Value:

3
---

#### CV 55.76.1: Automatic Mars Light FWD Configuration

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Reserved	Reserved	Reserved	Reserved	Reserved	Reserved	Intensity	Intensity

- Default value = 00000011 binary = 03 hex = 3 decimal (strobe).
- Bits 0 and 1 specify the mars light intensity.

Bit 1	Bit 0	Intensity
0	0	Off
0	1	Dim
1	0	Bright
1	1	Strobe

### 5.7.5.3 CV 55.76.2 Automatic Mars Light NFF Configuration

Use this CV to configure how the Automatic Mars Light behaves when the locomotive is in neutral from forward.

Default Value:

1
---

#### CV 55.76.2: Automatic Mars Light NFF Configuration

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Reserved	Reserved	Reserved	Reserved	Reserved	Reserved	Intensity	Intensity

- Default value = 00000001 binary = 01 hex = 1 decimal (dim).
- Bits 0 and 1 specify the mars light intensity.

Bit 1	Bit 0	Intensity
0	0	Off
0	1	Dim
1	0	Bright
1	1	Strobe

### 5.7.5.4 CV 55.76.3 Automatic Mars Light REV Configuration

Use this CV to configure how the Automatic Mars Light behaves when the locomotive is in reverse.

Default Value:

1
---

#### CV 55.76.3: Automatic Mars Light REV Configuration

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Reserved	Reserved	Reserved	Reserved	Reserved	Reserved	Intensity	Intensity

- Default value = 00000001 binary = 01 hex = 1 decimal (dim).
- Bits 0 and 1 specify the mars light intensity.

Bit 1	Bit 0	Intensity
0	0	Off
0	1	Dim
1	0	Bright
1	1	Strobe

### 5.7.5.5 CV 55.76.4 Automatic Mars Light NFR Configuration

Use this CV to configure how the Automatic Mars Light behaves when the locomotive is in neutral from reverse.

Default Value:

1
---

#### CV 55.76.4: Automatic Mars Light NFR Configuration

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Reserved	Reserved	Reserved	Reserved	Reserved	Reserved	Intensity	Intensity

- Default value = 00000001 binary = 01 hex = 1 decimal (dim).
- Bits 0 and 1 specify the mars light intensity.

Bit 1	Bit 0	Intensity
0	0	Off
0	1	Dim
1	0	Bright
1	1	Strobe



### 5.7.5.6 CV 55.76.10 Mars Light Dim Intensity

For models with a Mars Light, this CV controls its dim intensity.

Default Value:

<b>Depends on Locomotive</b>
------------------------------

#### CV 55.76.10: Mars Light Dim Intensity

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
<b>D7</b>	<b>D6</b>	<b>D5</b>	<b>D4</b>	<b>D3</b>	<b>D2</b>	<b>D1</b>	<b>D0</b>

- The default value is dependent on the model.
- Valid values are 0...255, 0 being least intense (off) and 255 being most intense (bright).
- In Ops mode, with the Mars Light dimmed, you can observe the Mars Light intensity change as you change the value of CV 55.76.10.

### 5.7.5.7 CV 55.76.SI Mars Light Examples

**Example 1:** I want the automatic mars light to be bright (not strobing) in all four motive states, NFF, REV and NFR as well as FWD.

Solution: Set CV 55.76.1...4 to 00000010 binary = 02 hex = 2 decimal.

**Example 2:** How will the mars light behave if I set CV 55.76.0 to 00001111 binary = 0F hex = 15 decimal?

Answer: The automatic mars light is initially activated and the mars light intensity is controlled by the CV 55.76.1...4 settings. If the automatic mars light is deactivated, for example, by pressing FL so that the FL function state is 0, then the Feature 77 function state turns the mars light on, and the Feature 79 function state makes the mars light strobe.

**Example 3:** I want explicit mars light on/off control at all times. At startup I want the mars light off until I turn it on with a function key. When the mars light is on, it should strobe.

Solution: First set CV 55.76.0 to 00001000 binary = 08 hex = 8 decimal. Next remove the automatic mars light feature from multiple automatic lights #1 by setting CV 55.136.0 bit 2 to 0. Finally in CV 53 assign Feature 77 to a function output.

**Example 4:** Same as example 3, but I want to explicitly dim and strobe the mars light as well. When I first turn the mars light on, it should be dim.

Solution: First set CV 55.76.0 to 00000100 binary = 04 hex = 4 decimal. Next remove the automatic mars light feature from multiple automatic lights #1 by setting CV 55.136.0 bit 2 to 0. Finally in CV 53 assign Feature 77 to a function output, Feature 78 to a second function output, and Feature 79 to a third function output.

**Example 5:** I want to explicitly dim and strobe the mars light, but the mars light should be always on. On startup, the mars light should be dim.

Solution: First set CV 55.76.0 to 00000110 binary = 05 hex = 5 decimal. Next remove the Automatic Mars Light feature from Multiple Automatic Lights #1 by setting CV 55.136.0 bit 2 to 0. Finally in CV 53 assign Feature 78 to a function output and Feature 79 to a second function output. You do not need to assign Feature 77 to a function output.

## 5.7.6 CV 55.84.SI Ditch Lights

Four features can be assigned to function keys to control ditch lights operation:

Feature ID	Feature Name	Use
84	Automatic Ditch Lights Activate	Activate/Deactivate Automatic Control of the Ditch Lights
85	Ditch Lights On	Explicitly turn the Ditch Lights On/Off
86	Ditch Lights Dim	Explicitly specify the Ditch Lights be Dim/Bright
87	Ditch Lights Strobe	Explicitly turn on/off Ditch Lights strobe

The ditch lights intensity (Off, Dim, Bright, Strobe) can be controlled automatically or explicitly.

### Automatic Control

When the Feature 84 function state is 1, automatic control is activated. The ditch lights intensity changes automatically in response to changes to the locomotive's motive state.

Forward	Neutral from Forward	Reverse	Neutral from Reverse
Bright	Off	Off	Off

The automatic behavior can be configured in CV 55.84.1, CV 55.84.2, CV 55.84.3, and CV 55.84.4.

Feature 84 has precedence over Features 85, 86 and 87. When the Feature 84 function state is 1, the Feature 85, 86 and 87 function states are ignored.

### Explicit Control

When the Feature 84 function state is 0, automatic control is deactivated. The ditch lights intensity changes in response to Feature 85, 86 and 87 function key presses.

Feature 87 Function State	Feature 86 Function State	Feature 85 Function State	Intensity
X	X	0	Off
0	0	1	Bright
0	1	1	Dim*
1	X	1	Strobe

Feature 84 has precedence over Features 85, 86 and 87. If the Feature 84 function state changes to 1, because of a Feature 84 function key press or a start up operation, automatic control is re-activated.

Feature 85 has precedence over Features 86 and 87. If the Feature 85 function state is 0, the Feature 86 and 87 function states are ignored.

Feature 87 has precedence over Feature 86. If the Feature 87 function state is 1, the Feature 86 function state is ignored.

\* If the ditch lights cannot be dimmed, then Dim = Off.

### 5.7.6.1 CV 55.84.0 Initial State

Use this CV to specify the startup state function states for the Ditch Lights features.

Default Value:

1

#### CV 55.84.0: Ditch Lights Initial State

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Reserved	Reserved	Reserved	Strobe with Horn	Feature 87 Function State	Feature 86 Function State	Feature 85 Function State	Feature 84 Function State

- Default value = 00000001 binary = 01 hex = 1 decimal (Automatic Control Activated).
- Bit 0 is the initial state of the Automatic Ditch Lights Activate (Feature 84) function.
- Bit 1 is the initial state of the Ditch Lights On (Feature 85) function.
- Bit 2 is the initial state of the Ditch Lights Dim (Feature 86) function.
- Bit 3 is the initial state of the Ditch Lights Strobe (Feature 87) function.
- If bit 4 = 1, under explicit control the ditch lights strobe when the horn blows. Note that if the ditch lights are already strobing, no change in Ditch Lights behavior will be observed when the horn blows. Bit 4 is applied even if the Feature 85 function state is 0, but is ignored if the Feature 84 function state is 1.
- A write to this CV in operations mode causes the Feature 84, 85, 86 and 87 function states to be immediately set to the new values.
- A start up operation causes the Feature 84, 85, 86 and 87 function states to be set to the values in this CV.

### 5.7.6.2 CV 55.84.1 Automatic Ditch Lights FWD Configuration

Use this CV to configure how the Automatic Ditch Lights behave when the locomotive is in forward.

Default Value:

6
---

#### CV 55.84.1: Automatic Ditch Lights FWD Configuration

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Reserved	Reserved	Reserved	Reserved	Reserved	Strobe with Horn	Intensity	Intensity

- Default value = 00000110 binary = 06 hex = 6 decimal (bright, strobe with horn).
- Bits 0 and 1 specify the ditch lights intensity.

Bit 1	Bit 0	Intensity
0	0	Off
0	1	Dim*
1	0	Bright
1	1	Strobe

- If bit 2 = 1, the ditch lights strobe when the horn blows. Note that if the Intensity = Strobe, no change in ditch lights behavior will be observed when the horn blows.

\* If the ditch lights cannot be dimmed, then Dim = Off.

### 5.7.6.3 CV 55.84.2 Automatic Ditch Lights NFF Configuration

Use this CV to configure how the Automatic Ditch Lights behave when the locomotive is in neutral from forward.

Default Value:

0
---

#### CV 55.84.2: Automatic Ditch Lights NFF Configuration

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Reserved	Reserved	Reserved	Reserved	Reserved	Strobe with Horn	Intensity	Intensity

- Default value = 00000000 binary = 00 hex = 0 decimal (off).
- Bits 0 and 1 specify the ditch lights intensity.

Bit 1	Bit 0	Intensity
0	0	Off
0	1	Dim*
1	0	Bright
1	1	Strobe

- If bit 2 = 1, the ditch lights strobe when the horn blows. Note that if the Intensity = Strobe, no change in ditch lights behavior will be observed when the horn blows.

\* If the ditch lights cannot be dimmed, then Dim = Off.

### 5.7.6.4 CV 55.84.3 Automatic Ditch Lights REV Configuration

Use this CV to configure how the Automatic Ditch Lights behave when the locomotive is in reverse.

Default Value:

0
---

#### CV 55.84.3: Automatic Ditch Lights REV Configuration

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Reserved	Reserved	Reserved	Reserved	Reserved	Strobe with Horn	Intensity	Intensity

- Default value = 00000000 binary = 00 hex = 0 decimal (off).
- Bits 0 and 1 specify the ditch lights intensity.

Bit 1	Bit 0	Intensity
0	0	Off
0	1	Dim*
1	0	Bright
1	1	Strobe

- If bit 2 = 1, the ditch lights strobe when the horn blows. Note that if the Intensity = Strobe, no change in ditch lights behavior will be observed when the horn blows.

\* If the ditch lights cannot be dimmed, then Dim = Off.

### 5.7.6.5 CV 55.84.4 Automatic Ditch Lights NFR Configuration

Use this CV to configure how the Automatic Ditch Lights behave when the locomotive is in neutral from reverse.

Default Value:

0

#### CV 55.84.4: Automatic Ditch Lights NFR Configuration

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Reserved	Reserved	Reserved	Reserved	Reserved	Strobe with Horn	Intensity	Intensity

- Default value = 00000000 binary = 00 hex = 0 decimal (off).
- Bits 0 and 1 specify the ditch lights intensity.

Bit 1	Bit 0	Intensity
0	0	Off
0	1	Dim*
1	0	Bright
1	1	Strobe

- If bit 2 = 1, the ditch lights strobe when the horn blows. Note that if the Intensity = Strobe, no change in ditch lights behavior will be observed when the horn blows.

\* If the ditch lights cannot be dimmed, then Dim = Off.



### 5.7.6.6 CV 55.84.5 Ditch Lights Strobe Hold Time

Use this CV to specify the number of seconds the ditch lights continue to strobe after a horn blast ends.

Default Value:

<b>5</b>
----------

#### CV 55.84.5: Ditch Lights Strobe Hold Time

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Reserved	Reserved	Reserved	Hold Time	Hold Time	Hold Time	Hold Time	Hold Time

- Default value = 00000101 binary = 05 hex = 5 decimal.
- Valid values are 0...31 seconds.

### 5.7.6.7 CV 55.84.10 Ditch Lights Dim Intensity

For models with dimmable Ditch Lights, this CV controls the dim intensity.

Default Value:

<b>Depends on Locomotive</b>
------------------------------

#### CV 55.84.10: Ditch Lights Dim Intensity

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
<b>D7</b>	<b>D6</b>	<b>D5</b>	<b>D4</b>	<b>D3</b>	<b>D2</b>	<b>D1</b>	<b>D0</b>

- The default value is dependent on the model.
- Valid values are 0...255, 0 being least intense (off) and 255 being most intense (bright).
- In Ops mode, with the Ditch Lights dimmed, you can observe the Ditch Lights intensity change as you change the value of CV 55.84.10.

### 5.7.6.8 CV 55.84.SI Ditch Lights Examples

**Example 1:** I want the automatic ditch lights to be bright (not strobing) in all four motive states, NFF, REV and NFR as well as FWD. I want the ditch lights to strobe when the horn blows in both FWD and REV.

Solution: Set CV 55.84.1 and CV 55.84.3 to 00000110 binary = 06 hex = 6 decimal. Set CV 55.84.2 and CV 55.84.4 to 00000010 binary = 02 hex = 2 decimal.

**Example2:** I want the automatic ditch lights to be off in all four motive states. But I want the ditch lights to strobe when the horn blows in both FWD and REV.

Solution: Set CV 55.84.1 and CV 55.84.3 to 00000100 binary = 04 hex = 4 decimal. Set CV 55.84.2 and CV 55.84.4 to 0.

**Example 3:** How will the ditch lights behave if I set CV 55.84.0 to 00011111 binary = 1F hex = 31 decimal?

Answer: The automatic ditch lights are initially activated and the ditch lights intensity is controlled by the CV 55.84.1...4 settings. If the automatic ditch lights are deactivated, for example, by pressing FL so that the FL function state is 0, then the Feature 85 function state turns the ditch lights on, and the Feature 87 function state makes the ditch lights strobe.

**Example 4:** I want explicit ditch lights on/off control at all times. At startup I want the ditch lights off until I turn them on with a function key. When the ditch lights are on, they should be bright (not strobing).

Solution: First set CV 55.84.0 to 0. Next remove the automatic ditch lights feature from multiple automatic lights #1 by setting CV 55.136.0 bit 4 to 0. Finally in CV 53 assign Feature 85 to a function output.

**Example 5:** Same as example 4, but I want to explicitly dim and strobe the ditch lights as well. When I first turn the ditch lights on, they should be bright.

Solution: First set CV 55.84.0 to 0. Next remove the automatic ditch lights feature from multiple automatic lights #1 by setting CV 55.136.0 bit 4 to 0. Finally in CV 53 assign Feature 85 to a function output, Feature 86 to a second function output, and Feature 87 to a third function output.

**Example 6:** I want to explicitly strobe the ditch lights, but when not strobing the ditch lights should be always bright.

Solution: First set CV 55.84.0 to 00000010 binary = 02 hex = 2 decimal. Next remove the Automatic Ditch Lights feature from Multiple Automatic Lights #1 by setting CV 55.136.0 bit 4 to 0. Finally in CV 53 assign Feature 87 to a function output. You do not need to assign Feature 85 to a function output.

**Example7:** Similar to example 2, I want the automatic ditch lights to be off in all four motive states. But I want the ditch lights to strobe when the horn blows in FWD only. Further, I want this behavior even if FL is 0.

Solution: First set CV 55.84.0 to 1. Then set CV 55.84.1 to 00000100 binary = 04 hex = 4 decimal. Set CV 55.84.2, CV 55.84.3 and CV 55.84.4 to 0. Finally remove the Automatic Ditch Lights feature from Multiple Automatic Lights #1 by setting CV 55.136.0 bit 4 to 0.

### 5.7.7 CV 55.100.SI Front Number Board Lights

Two features can be assigned to function keys to control front number board lights operation:

Feature ID	Feature Name	Use
100	Automatic Front Number Board Lights Activate	Activate/Deactivate Automatic Control of the Front Number Board Lights
101	Front Number Board Lights On	Explicitly turn the Front Number Board Lights On/Off

The front number board lights intensity (Off, On) can be controlled automatically or explicitly.

#### Automatic Control

When the Feature 100 function state is 1, automatic control is activated. The front number board lights intensity changes automatically in response to changes to the locomotive's motive state.

The default rules for automatic control are simple: the front number board lights are on regardless of the locomotive's motive state.

The automatic control can be configured in CV 55.100.1.

Feature 100 has precedence over Feature 101. When the Feature 100 function state is 1, the Feature 101 function state is ignored.

#### Explicit Control

When the Feature 100 function state is 0, automatic control is deactivated. The front number board lights intensity changes in response to Feature 101 function key presses.

Feature 101 Function State	Intensity
0	Off
1	On

Feature 100 has precedence over Feature 101. If the Feature 100 function state changes to 1, because of a Feature 100 function key press or a start up operation, automatic control is re-activated.

### 5.7.7.1 CV 55.100.0 Front Number Board Lights Initial State

Use this CV to specify the startup state function states for the Front Number Board Lights features.

Default Value:

1
---

#### CV 55.100.0: Front Number Board Lights Initial State

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Reserved	Reserved	Reserved	Reserved	Reserved	Reserved	Feature 101 Function State	Feature 100 Function State

- Default value = 00000001 binary = 01 hex = 1 decimal (Automatic Control Activated).
- Bit 0 is the initial state of the Automatic Front Number Board Lights Activate (Feature 100) function.
- Bit 1 is the initial state of the Front Number Board Lights On (Feature 101) function.
- A write to this CV in operations mode causes the Feature 100 and 101 function states to be immediately set to the new values.
- A start up operation causes the Feature 100 and 101 function states to be set to the values in this CV.

### 5.7.7.2 CV 55.100.1 Automatic Front Number Board Lights Configuration

Use this CV to configure the Automatic Front Number Board Lights behavior.

Default Value:

85
----

#### CV 55.100.1: Automatic Front Number Board Lights Configuration

NFR		REV		NFF		FWD	
Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Reserved	1 = On	Reserved	1 = On	Reserved	1 = On	Reserved	1 = On

- Default value = 01010101 binary = 55 hex = 85 decimal.
- If bit 0 = 1, the front number board lights are on in FWD.
- If bit 2 = 1, the front number board lights are on in NFF.
- If bit 4 = 1, the front number board lights are on in REV.
- If bit 6 = 1, the front number board lights are on in NFR.

### 5.7.7.3 CV 55.100.SI Front Number Board Lights Examples

**Example 1:** I want the automatic front number board lights to be on in FWD and REV, but off in NFF and NFR.

Solution: Set CV 55.100.1 to 00010001 binary = 11 hex = 17 decimal.

**Example 2:** How will the front number board lights behave if I set CV 55.100.0 to 00000011 binary = 03 hex = 3 decimal?

Answer: The automatic front number board lights are initially activated and the front number board lights intensity is controlled by the CV 55.100.1 settings. If the automatic front number board lights are deactivated, for example, by pressing F11 so that the F11 function state is 0, then the Feature 101 function state turns the front number board lights on.

**Example 3:** I want explicit front number board lights on/off control at all times. At startup I want the front number board lights off until I turn them on with a function key.

Solution: First set CV 55.100.0 to 0. Next remove the automatic front number board lights feature from multiple automatic lights #2 by setting CV 55.137.0 bit 0 to 0. Finally in CV 53 assign Feature 101 to a function output.

**Example 4:** I want the front number board lights to be on at all times. But I don't want them to be affected by function key presses.

Solution: First set CV 55.100.0 to 00000010 binary = 02 hex = 2 decimal. Then remove the automatic front number board lights feature from multiple automatic lights #2 by setting CV 55.137.0 bit 0 to 0.

**Example 5:** I want the front number board lights to be on automatically in FWD and NFF and off automatically in REV and NFR. But I don't want them to be affected by function key presses.

Solution: First set CV 55.100.0 to 00000001 binary = 01 hex = 1 decimal. Then set CV55.100.1 to 00000101 binary = 05 hex = 5 decimal. Finally remove the automatic front number board lights feature from multiple automatic lights #2 by setting CV 55.137.0 bit 0 to 0.

## 5.7.8 CV 55.102.SI Rear Number Board Lights

Two features can be assigned to function keys to control rear number board lights operation:

Feature ID	Feature Name	Use
102	Automatic Rear Number Board Lights Activate	Activate/Deactivate Automatic Control of the Rear Number Board Lights
103	Rear Number Board Lights On	Explicitly turn the Rear Number Board Lights On/Off

The rear number board lights intensity (Off, On) can be controlled automatically or explicitly.

### Automatic Control

When the Feature 102 function state is 1, automatic control is activated. The rear number board lights intensity changes automatically in response to changes to the locomotive's motive state.

The default rules for automatic control are simple: the rear number board lights are on regardless of the locomotive's motive state.

The automatic control can be configured in CV55.102.1.

Feature 102 has precedence over Feature 103. When the Feature 102 function state is 1, the Feature 103 function state is ignored.

### Explicit Control

When the Feature 102 function state is 0, automatic control is deactivated. The rear number board lights intensity changes in response to Feature 103 function key presses.

Feature 103 Function State	Intensity
0	Off
1	On

Feature 102 has precedence over Feature 103. If the Feature 102 function state changes to 1, because of a Feature 103 function key press or a start up operation, automatic control is re-activated.



### 5.7.8.1 CV 55.102.0 Rear Number Board Lights Initial State

Use this CV to specify the startup state function states for the Rear Number Board Lights features.

Default Value:

1

#### CV 55.102.0: Rear Number Board Lights Initial State

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Reserved	Reserved	Reserved	Reserved	Reserved	Reserved	Feature 103 Function State	Feature 102 Function State

- Default value = 00000001 binary = 01 hex = 1 decimal (Automatic Control Activated).
- Bit 0 is the initial state of the Automatic Rear Number Board Lights Activate (Feature 102) function.
- Bit 1 is the initial state of the Rear Number Board Lights On (Feature 103) function.
- A write to this CV in operations mode causes the Feature 102 and 103 function states to be immediately set to the new values.
- A start up operation causes the Feature 102 and 103 function states to be set to the values in this CV.

### 5.7.8.2 CV 55.102.1 Automatic Rear Number Board Lights Configuration

Use this CV to configure the Automatic Rear Number Board Lights behavior.

Default Value:

85
----

#### CV 55.102.1: Automatic Rear Number Board Lights Configuration

NFR		REV		NFF		FWD	
Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Reserved	1 = On	Reserved	1 = On	Reserved	1 = On	Reserved	1 = On

- Default value = 01010101 binary = 55 hex = 85 decimal (On in all motive states).
- If bit 0 = 1, the rear number board lights are on in FWD.
- If bit 2 = 1, the rear number board lights are on in NFF.
- If bit 4 = 1, the rear number board lights are on in REV.
- If bit 6 = 1, the rear number board lights are on in NFR.

### 5.7.8.3 CV 55.102.SI Rear Number Board Lights Examples

**Example 1:** I want the automatic rear number board lights to be on in FWD and REV, but off in NFF and NFR.

Solution: Set CV 55.102.1 to 00010001 binary = 11 hex = 17 decimal.

**Example 2:** How will the rear number board lights behave if I set CV 55.102.0 to 00000011 binary = 03 hex = 3 decimal?

Answer: The automatic rear number board lights are initially activated and the rear number board lights intensity is controlled by the CV 55.102.1 settings. If the automatic rear number board lights are deactivated, for example, by pressing F11 so that the F11 function state is 0, then the Feature 103 function state turns the front number board lights on.

**Example 3:** I want explicit rear number board lights on/off control at all times. At startup I want the rear number board lights off until I turn them on with a function key.

Solution: First set CV 55.102.0 to 0. Next remove the automatic rear number board lights feature from multiple automatic lights #2 by setting CV 55.137.1 bit 0 to 0. Finally in CV 53 assign Feature 103 to a function output.

## 5.7.9 CV 55.104.SI Front Marker Lights

Two features can be assigned to function keys to control front marker lights operation:

Feature ID	Feature Name	Use
104	Automatic Front Marker Lights Activate	Activate/Deactivate Automatic Control of the Front Marker Lights
105	Front Marker Lights On	Explicitly turn the Front Marker Lights On/Off

The front marker lights intensity (Off, On) can be controlled automatically or explicitly.

### Automatic Control

When the Feature 104 function state is 1, automatic control is activated. The front marker lights intensity changes automatically in response to changes to the locomotive's motive state.

The default rules for automatic control are simple: the front marker lights are on regardless of the locomotive's motive state.

The automatic control can be configured in CV 55.104.1.

Feature 104 has precedence over Feature 105. When the Feature 104 function state is 1, the Feature 105 function state is ignored.

### Explicit Control

When the Feature 104 function state is 0, automatic control is deactivated. The front number board lights intensity changes in response to Feature 105 function key presses.

Feature 105 Function State	Intensity
0	Off
1	On

Feature 104 has precedence over Feature 105. If the Feature 104 function state changes to 1, because of a Feature 104 function key press or a start up operation, automatic control is re-activated.

### 5.7.9.1 CV 55.104.0 Front Marker Lights Initial State

Use this CV to specify the startup state function states for the Front Marker Lights features.

Default Value:

1

#### CV 55.104.0: Front Marker Lights Initial State

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Reserved	Reserved	Reserved	Reserved	Reserved	Reserved	Feature 105 Function State	Feature 104 Function State

- Default value = 00000001 binary = 01 hex = 1 decimal (Automatic Control Activated).
- Bit 0 is the initial state of the Automatic Front Marker Lights Activate (Feature 104) function.
- Bit 1 is the initial state of the Front Marker Lights On (Feature 105) function.
- A write to this CV in operations mode causes the Feature 104 and 105 function states to be immediately set to the new values.
- A start up operation causes the Feature 104 and 105 function states to be set to the values in this CV.

### 5.7.9.2 CV 55.104.1 Automatic Front Marker Lights Configuration

Use this CV to configure the Automatic Front Marker Lights behavior.

Default Value:

85
----

#### CV 55.104.1: Automatic Front Marker Lights Configuration

NFR		REV		NFF		FWD	
Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Reserved	1 = On	Reserved	1 = On	Reserved	1 = On	Reserved	1 = On

- Default value = 01010101 binary = 55 hex = 85 decimal (On in all motive states).
- If bit 0 = 1, the front marker lights are on in FWD.
- If bit 2 = 1, the front marker lights are on in NFF.
- If bit 4 = 1, the front marker lights are on in REV.
- If bit 6 = 1, the front marker lights are on in NFR.

### 5.7.9.3 CV 55.104.SI Front Marker Lights Examples

**Example 1:** I want the automatic front marker lights to be on in FWD and REV, but off in NFF and NFR.

Solution: Set CV 55.104.1 to 00010001 binary = 11 hex = 17 decimal.

**Example 2:** How will the front marker lights behave if I set CV 55.104.0 to 00000011 binary = 03 hex = 3 decimal?

Answer: The automatic front marker lights are initially activated and the front marker lights intensity is controlled by the CV 55.104.1 settings. If the automatic front marker lights are deactivated, for example, by pressing F11 so that the F11 function state is 0, then the Feature 105 function state turns the front marker lights on .

**Example 3:** I want explicit front marker lights on/off control at all times. At startup I want the front marker lights off until I turn them on with a function key.

Solution: First set CV 55.104.0 to 0. Next remove the automatic front marker lights feature from multiple automatic lights #2 by setting CV 55.137.2 bit 0 to 0. Finally in CV 53 assign Feature 105 to a function output.

## 5.7.10 CV 55.106.SI Rear Marker Lights

Two features can be assigned to function keys to control rear marker lights operation:

Feature ID	Feature Name	Use
106	Automatic Rear Marker Lights Activate	Activate/Deactivate Automatic Control of the Rear Marker Lights
107	Rear Marker Lights On	Explicitly turn the Rear Marker Lights On/Off

The rear marker lights intensity (Off, On) can be controlled automatically or explicitly.

### Automatic Control

When the Feature 106 function state is 1, automatic control is activated. The rear marker lights intensity changes automatically in response to changes to the locomotive's motive state.

The default rules for automatic control are simple: the rear marker lights are on regardless of the locomotive's motive state.

The automatic control can be configured in CV 55.106.1.

Feature 106 has precedence over Feature 107. When the Feature 106 function state is 1, the Feature 107 function state is ignored.

### Explicit Control

When the Feature 106 function state is 0, automatic control is deactivated. The front number board lights intensity changes in response to Feature 107 function key presses.

Feature 107 Function State	Intensity
0	Off
1	On

Feature 106 has precedence over Feature 107. If the Feature 106 function state changes to 1, because of a Feature 106 function key press or a start up operation, automatic control is re-activated.



### 5.7.10.1 CV 55.106.0 Rear Marker Lights Initial State

Use this CV to specify the startup state function states for the Rear Marker Lights features.

Default Value:

1

#### CV 55.106.0: Rear Marker Lights Initial State

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Reserved	Reserved	Reserved	Reserved	Reserved	Reserved	Feature 107 Function State	Feature 106 Function State

- Default value = 00000001 binary = 01 hex = 1 decimal (Automatic Control Activated).
- Bit 0 is the initial state of the Automatic Rear Marker Lights Activate (Feature 106) function.
- Bit 1 is the initial state of the Rear Marker Lights On (Feature 107) function.
- A write to this CV in operations mode causes the Feature 106 and 107 function states to be immediately set to the new values.
- A start up operation causes the Feature 106 and 107 function states to be set to the values in this CV.

### 5.7.10.2 CV 55.106.1 Automatic Rear Marker Lights Configuration

Use this CV to configure the Automatic Rear Marker Lights behavior.

Default Value:

85
----

#### CV 55.106.1: Automatic Rear Marker Lights Configuration

NFR		REV		NFF		FWD	
Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Reserved	1 = On	Reserved	1 = On	Reserved	1 = On	Reserved	1 = On

- Default value = 01010101 binary = 55 hex = 85 decimal (“On” in all motive states).
- If bit 0 = 1, the rear marker lights are on in FWD.
- If bit 2 = 1, the rear marker lights are on in NFF.
- If bit 4 = 1, the rear marker lights are on in REV.
- If bit 6 = 1, the rear marker lights are on in NFR.

### 5.7.10.3 CV 55.106.SI Rear Marker Lights Examples

**Example 1:** I want the automatic rear marker lights to be on in FWD and REV, but off in NFF and NFR.

Solution: Set CV 55.106.1 to 00010001 binary = 11 hex = 17 decimal.

**Example 2:** How will the rear marker lights behave if I set CV 55.106.0 to 00000011 binary = 03 hex = 3 decimal?

Answer: The automatic rear marker lights are initially activated and the rear marker lights intensity is controlled by the CV 55.106.1 settings. If the automatic rear marker lights are deactivated, for example, by pressing F11 so that the F11 function state is 0, then the Feature 107 function state turns the rear marker lights on.

**Example 3:** I want explicit rear marker lights on/off control at all times. At startup I want the rear marker lights off until I turn them on with a function key.

Solution: First set CV 55.106.0 to 0. Next remove the automatic rear marker lights feature from multiple automatic lights #2 by setting CV 55.137.2 bit 1 to 0. Finally in CV 53 assign Feature 107 to a function output.

## 5.7.11 CV 55.112.SI Front Step Lights

Two features can be assigned to function keys to control front step lights operation:

Feature ID	Feature Name	Use
112	Automatic Front Step Lights Activate	Activate/Deactivate Automatic Control of the Front Step Lights
113	Front Step Lights On	Explicitly turn the Front Step Lights On/Off

The front step lights intensity (Off, On) can be controlled automatically or explicitly.

### Automatic Control

When the Feature 112 function state is 1, automatic control is activated. The front step lights intensity changes automatically in response to changes to the locomotive's motive state.

The default rules for automatic control are simple: the front step lights are on regardless of the locomotive's motive state.

The automatic control can be configured in CV 55.112.1.

Feature 112 has precedence over Feature 113. When the Feature 112 function state is 1, the Feature 113 function state is ignored.

### Explicit Control

When the Feature 112 function state is 0, automatic control is deactivated. The front number board lights intensity changes in response to Feature 113 function key presses.

Feature 113 Function State	Intensity
0	Off
1	On

Feature 112 has precedence over Feature 113. If the Feature 112 function state changes to 1, because of a Feature 112 function key press or a start up operation, automatic control is re-activated.

### 5.7.11.1 CV 55.112.0 Front Step Lights Initial State

Use this CV to specify the startup state function states for the Front Step Lights features.

Default Value:

1

#### CV 55.112.0: Front Step Lights Initial State

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Reserved	Reserved	Reserved	Reserved	Reserved	Reserved	Feature 113 Function State	Feature 112 Function State

- Default value = 00000001 binary = 01 hex = 1 decimal (Automatic Control Activated).
- Bit 0 is the initial state of the Automatic Front Step Lights Activate (Feature 112) function.
- Bit 1 is the initial state of the Front Step Lights On (Feature 113) function.
- A write to this CV in operations mode causes the Feature 112 and 113 function states to be immediately set to the new values.
- A start up operation causes the Feature 112 and 113 function states to be set to the values in this CV.

### 5.7.11.2 CV 55.112.1 Automatic Front Step Lights Configuration

Use this CV to configure the Automatic Front Step Lights behavior.

Default Value:

85
----

#### CV 55.112.1: Automatic Front Step Lights Configuration

NFR		REV		NFF		FWD	
Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Reserved	1 = On	Reserved	1 = On	Reserved	1 = On	Reserved	1 = On

- Default value = 01010101 binary = 55 hex = 85 decimal (On in all motive states).
- If bit 0 = 1, the front step lights are on in FWD.
- If bit 2 = 1, the front step lights are on in NFF.
- If bit 4 = 1, the front step lights are on in REV.
- If bit 6 = 1, the front step lights are on in NFR.

### 5.7.11.3 CV 55.112.SI Front Step Lights Examples

**Example 1:** I want the automatic front step lights to be on in NFF and NFR and off in FWD and REV.

Solution: Set CV 55.112.1 to 01000100 binary = 44 hex = 68 decimal.

**Example 2:** How will the front step lights behave if I set CV 55.112.0 to 00000011 binary = 03 hex = 3 decimal?

Answer: The automatic front step lights are initially activated and the front step lights intensity is controlled by the CV 55.112.1 settings. If the automatic front step lights are deactivated, for example, by pressing F11 so that the F11 function state is 0, then the Feature 113 function state turns the front step lights on.

**Example 3:** I want explicit front step lights on/off control at all times. At startup I want the front step lights off until I turn them on with a function key.

Solution: First set CV 55.112.0 to 0. Next remove the automatic front step lights feature from multiple automatic lights #2 by setting CV 55.137.2 bit 6 to 0. Finally in CV 53 assign Feature 113 to a function output.

## 5.7.12 CV 55.114.SI Rear Step Lights

Two features can be assigned to function keys to control rear step lights operation:

Feature ID	Feature Name	Use
114	Automatic Rear Step Lights Activate	Activate/Deactivate Automatic Control of the Rear Step Lights
115	Rear Step Lights On	Explicitly turn the Rear Step Lights On/Off

The rear step lights intensity (Off, On) can be controlled automatically or explicitly.

### Automatic Control

When the Feature 114 function state is 1, automatic control is activated. The rear step lights intensity changes automatically in response to changes to the locomotive's motive state.

The default rules for automatic control are simple: the rear step lights are on regardless of the locomotive's motive state.

The automatic control can be configured in CV 55.114.1.

Feature 114 has precedence over Feature 115. When the Feature 114 function state is 1, the Feature 115 function state is ignored.

### Explicit Control

When the Feature 114 function state is 0, automatic control is deactivated. The front number board lights intensity changes in response to Feature 115 function key presses.

Feature 115 Function State	Intensity
0	Off
1	On

Feature 114 has precedence over Feature 115. If the Feature 114 function state changes to 1, because of a Feature 115 function key press or a start up operation, automatic control is re-activated.



### 5.7.12.1 CV 55.114.0 Rear Step Lights Initial State

Use this CV to specify the startup state function states for the Rear Step Lights features.

Default Value:

1

#### CV 55.114.0: Rear Step Lights Initial State

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Reserved	Reserved	Reserved	Reserved	Reserved	Reserved	Feature 115 Function State	Feature 114 Function State

- Default value = 00000001 binary = 01 hex = 1 decimal (Automatic Control Activated).
- Bit 0 is the initial state of the Automatic Rear Step Lights Activate (Feature 114) function.
- Bit 1 is the initial state of the Rear Step Lights On (Feature 115) function.
- A write to this CV in operations mode causes the Feature 114 and 115 function states to be immediately set to the new values.
- A start up operation causes the Feature 114 and 115 function states to be set to the values in this CV.

### 5.7.12.2 CV 55.114.1 Automatic Rear Step Lights Configuration

Use this CV to configure the Automatic Rear Step Lights behavior.

Default Value:

85
----

#### CV 55.114.1: Automatic Rear Step Lights Configuration

NFR		REV		NFF		FWD	
Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Reserved	1 = On	Reserved	1 = On	Reserved	1 = On	Reserved	1 = On

- Default value = 01010101 binary = 55 hex = 85 decimal (On in all motive states).
- If bit 0 = 1, the rear step lights are on in FWD.
- If bit 2 = 1, the rear step lights are on in NFF.
- If bit 4 = 1, the rear step lights are on in REV.
- If bit 6 = 1, the rear step lights are on in NFR.

### 5.7.12.3 CV 55.114.SI Rear Step Lights Examples

**Example 1:** I want the automatic rear step lights to be on in NFF and NFR and off in FWD and REV.

Solution: Set CV 55.114.1 to 01000100 binary = 44 hex = 68 decimal.

**Example 2:** How will the rear step lights behave if I set CV 55.114.0 to 00000011 binary = 03 hex = 3 decimal?

Answer: The automatic rear step lights are initially activated and the rear step lights intensity is controlled by the CV 55.114.1 settings. If the automatic rear step lights are deactivated, for example, by pressing F11 so that the F11 function state is 0, then the Feature 115 function state turns the rear step lights on.

**Example 3:** I want explicit rear step lights on/off control at all times. At startup I want the rear step lights off until I turn them on with a function key.

Solution: First set CV 55.114.0 to 0. Next remove the automatic rear step lights feature from multiple automatic lights #2 by setting CV 55.137.2 bit 7 to 0. Finally in CV 53 assign Feature 115 to a function output.

### 5.7.13 CV 55.116.SI Front Cab Lights

Two features can be assigned to function keys to control front cab lights operation:

Feature ID	Feature Name	Use
116	Automatic Front Cab Lights Activate	Activate/Deactivate Automatic Control of the Front Cab Lights
117	Front Cab Lights On	Explicitly turn the Front Cab Lights On/Off

The front cab lights intensity (Off, On) can be controlled automatically or explicitly.

#### Automatic Control

When the Feature 116 function state is 1, automatic control is activated. The front cab lights intensity changes automatically in response to changes to the locomotive's motive state.

The default rules for front cab light automatic control are:

Forward	Neutral from Forward	Reverse	Neutral from Reverse
Off after 15 seconds	On after 10 seconds	Off after 15 seconds	On after 10 seconds

The automatic control can be configured in CV 55.116.1.

Feature 116 has precedence over Feature 117. When the Feature 116 function state is 1, the Feature 117 function state is ignored.

#### Explicit Control

When the Feature 116 function state is 0, automatic control is deactivated. The front cab lights intensity changes in response to Feature 117 function key presses.

Feature 117 Function State	Intensity
0	Off
1	On

Feature 116 has precedence over Feature 117. If the Feature 116 function state changes to 1, because of a Feature 116 function key press or a start up operation, automatic control is re-activated.

### 5.7.13.1 CV 55.116.0 Front Cab Lights Initial State

Use this CV to specify the startup state function states for the Front Cab Lights features.

Default Value:

1

#### CV 55.116.0: Front Cab Lights Initial State

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Reserved	Reserved	Reserved	Reserved	Reserved	Reserved	Feature 117 Function State	Feature 116 Function State

- Default value = 00000001 binary = 01 hex = 1 decimal (Automatic Control Activated).
- Bit 0 is the initial state of the Automatic Front Cab Lights Activate (Feature 116) function.
- Bit 1 is the initial state of the Front Cab Lights On (Feature 117) function.
- A write to this CV in operations mode causes the Feature 116 and 117 function states to be immediately set to the new values.
- A start up operation causes the Feature 116 and 117 function states to be set to the values in this CV.

### 5.7.13.2 CV 55.116.1 Automatic Front Cab Lights Configuration

Use this CV to configure the Automatic Front Cab Lights behavior.

Default Value:

68
----

#### CV 55.116.1: Automatic Front Cab Lights Configuration

NFR		REV		NFF		FWD	
Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Reserved	1 = On	Reserved	1 = On	Reserved	1 = On	Reserved	1 = On

- Default value = 01000100 binary = 44 hex = 68 decimal. (On in NFF and NFR.)
- If bit 0 = 1, the front cab lights are on in FWD.
- If bit 2 = 1, the front cab lights are on in NFF. If the front cab lights were already on in FWD, they remain on in NFF. If they were off in FWD, they come on after 10 seconds.
- If bit 4 = 1, the front cab lights are on in REV.
- If bit 6 = 1, the front cab lights are on in NFR. If the front cab lights were already on in REV, they remain on in NFR. If they were off in REV, they come on after 10 seconds.

### 5.7.13.3 CV 55.116.SI Front Cab Lights Examples

**Example 1:** I want the automatic front cab lights to be on in all motive states FWD, NFF, REV and NFR.

Solution: Set CV 55.116.1 to 01010101 binary = 55 hex = 85 decimal.

**Example 2:** How will the front cab lights behave if I set CV 55.116.0 to 00000011 binary = 03 hex = 3 decimal?

Answer: The automatic front cab lights are initially activated and the front cab lights intensity is controlled by the CV 55.116.1 settings. If the automatic front cab lights are deactivated, for example, by pressing F12 so that the F12 function state is 0, then the Feature 117 function state turns the front cab lights on.

**Example 3:** I want explicit front cab lights on/off control at all times. At startup I want the front cab lights off until I turn them on with a function key.

Solution: First set CV 55.116.0 to 0. Next remove the automatic front cab lights feature from multiple automatic lights #3 by setting CV 55.138.3 bit 0 to 0. Finally in CV 53 assign Feature 117 to a function output.

## 5.7.14 CV 55.118.SI Rear Cab Lights

Two features can be assigned to function keys to control rear cab lights operation:

Feature ID	Feature Name	Use
118	Automatic Rear Cab Lights Activate	Activate/Deactivate Automatic Control of the Rear Cab Lights
119	Rear Cab Lights On	Explicitly turn the Rear Cab Lights On/Off

The rear cab lights intensity (Off, On) can be controlled automatically or explicitly.

### Automatic Control

When the Feature 118 function state is 1, automatic control is activated. The rear cab lights intensity changes automatically in response to changes to the locomotive's motive state.

The default rules for rear cab light automatic control are:

Forward	Neutral from Forward	Reverse	Neutral from Reverse
Off after 15 seconds	On after 10 seconds	Off after 15 seconds	On after 10 seconds

The automatic control can be configured in CV 55.118.1.

Feature 118 has precedence over Feature 119. When the Feature 118 function state is 1, the Feature 119 function state is ignored.

### Explicit Control

When the Feature 118 function state is 0, automatic control is deactivated. The rear cab lights intensity changes in response to Feature 119 function key presses.

Feature 119 Function State	Intensity
0	Off
1	On

Feature 118 has precedence over Feature 119. If the Feature 118 function state changes to 1, because of a Feature 118 function key press or a start up operation, automatic control is re-activated.



### 5.7.14.1 CV 55.118.0 Rear Cab Lights Initial State

Use this CV to specify the startup state function states for the Rear Cab Lights features.

Default Value:

1

#### CV 55.118.0: Rear Cab Lights Initial State

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Reserved	Reserved	Reserved	Reserved	Reserved	Reserved	Feature 119 Function State	Feature 118 Function State

- Default value = 00000001 binary = 01 hex = 1 decimal (Automatic Control Activated).
- Bit 0 is the initial state of the Automatic Rear Cab Lights Activate (Feature 118) function.
- Bit 1 is the initial state of the Rear Cab Lights On (Feature 119) function.
- A write to this CV in operations mode causes the Feature 118 and 119 function states to be immediately set to the new values.
- A start up operation causes the Feature 118 and 119 function states to be set to the values in this CV.

### 5.7.14.2 CV 55.118.1 Automatic Rear Cab Lights Configuration

Use this CV to configure the Automatic Rear Cab Lights behavior.

Default Value:

68

#### CV 55.118.1: Automatic Rear Cab Lights Configuration

NFR		REV		NFF		FWD	
Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Reserved	1 = On	Reserved	1 = On	Reserved	1 = On	Reserved	1 = On

- Default value = 01000100 binary = 44 hex = 68 decimal. (On in NFF and NFR.)
- If bit 0 = 1, the rear cab lights are on in FWD.
- If bit 2 = 1, the rear cab lights are on in NFF. If the rear cab lights were already on in FWD, they remain on in NFF. If they were off in FWD, they come on after 10 seconds.
- If bit 4 = 1, the rear cab lights are on in REV.
- If bit 6 = 1, the rear cab lights are on in NFR. If the rear cab lights were already on in REV, they remain on in NFR. If they were off in REV, they come on after 10 seconds.

### 5.7.14.3 CV 55.118.SI Rear Cab Lights Examples

**Example 1:** I want the automatic rear cab lights to be on in all motive states FWD, NFF, REV and NFR.

Solution: Set CV 55.118.1 to 01010101 binary = 55 hex = 85 decimal.

**Example 2:** How will the rear cab lights behave if I set CV 55.118.0 to 00000011 binary = 03 hex = 3 decimal?

Answer: The automatic rear cab lights are initially activated and the rear cab lights intensity is controlled by the CV 55.118.1 settings. If the automatic rear cab lights are deactivated, for example, by pressing F12 so that the F12 function state is 0, then the Feature 119 function state turns the rear cab lights on.

**Example 3:** I want explicit rear cab lights on/off control at all times. At startup I want the rear cab lights off until I turn them on with a function key.

Solution: First set CV 55.118.0 to 0. Next remove the automatic rear cab lights feature from multiple automatic lights #3 by setting CV 55.138.3 bit 1 to 0. Finally in CV 53 assign Feature 119 to a function output.

## 5.7.15 CV 55.136.SI Multiple Automatic Lights #1

The Multiple Automatic Lights #1 feature allows you to activate more than one automatic light feature with a single function key. Select which lights you want to activate in CV 55.136.0 ... CV 55.136.2, and assign Feature 136 to a function output in CV 53.

By default, Feature 136 is assigned to outputs 1 and 2 (FL(f) and FL(r)) in CV 53.

By default, Multiple Automatic Lights #1 controls the automatic Headlight, Reverse Light, Front and Rear Mars Lights, and Ditch Lights.

### CV 55.136.0 Multiple Automatic Lights #1 Configuration Byte 0

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Reserved	Reserved	Reserved	Ditch Lights (84)	Reserved	Mars Light (76)	Reverse Light (73)	Headlight (70)

- Default value = 11111111 binary = FF hex = 255 decimal.

### CV 55.136.1 Multiple Automatic Lights #1 Configuration Byte 1

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Rear Step Lights (114)	Front Step Lights (112)	Reserved	Reserved	Rear Marker Lights (106)	Front Marker Lights (104)	Rear Number Board Lights (102)	Front Number Board Lights (100)

- Default value = 00000000 binary = 00 hex = 0 decimal.

### CV 55.136.2 Multiple Automatic Lights #1 Configuration Byte 2

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Reserved	Reserved	Reserved	Reserved	Reserved	Reserved	Rear Cab Lights (118)	Front Cab Lights (116)

- Default value = 00000000 binary = 00 hex = 0 decimal.

**Example:** My DCC controller has limited number of function keys and I want to be able to turn all the lights on and off with a single function key, F0. What can I do to accomplish this?

Solution: Set CV 55.136.1 to 255 and set CV 55.136.2 to 255. Since the Multiple Automatic Lights #1 feature is assigned to F0 by default, F0 will now activate or deactivate all the automatic lights. You can also set CV 55.137.1 to 0 and CV 55.138.2 to 0 if you wish, but unless you have F9...F12 on your controller, this should not be necessary.

## 5.7.16 CV 55.137.SI Multiple Automatic Lights #2

The Multiple Automatic Lights #2 feature allows you to activate more than one automatic light feature with a single function key. Select which lights you want to activate in CV 55.137.0 ... CV 55.137.2, and assign Feature 137 to a function output in CV 53.

By default, Feature 137 is assigned to output 13 (F11) in CV 53.

By default, the Multiple Automatic Lights #2 feature controls the automatic Front and Rear Number Board Lights, Front and Rear Marker Lights, and Front and Rear Step Lights.

### CV 55.137.0 Multiple Automatic Lights #2 Configuration Byte 0

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Reserved	Reserved	Reserved	Ditch Lights (84)	Reserved	Mars Light (76)	Reverse Light (73)	Headlight (70)

- Default value = 00000000 binary = 00 hex = 0 decimal.

### CV 55.137.1 Multiple Automatic Lights #2 Configuration Byte 1

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Rear Step Lights (114)	Front Step Lights (112)	Reserved	Reserved	Rear Marker Lights (106)	Front Marker Lights (104)	Rear Number Board Lights (102)	Front Number Board Lights (100)

- Default value = 11111111 binary = FF hex = 255 decimal.

### CV 55.137.2 Multiple Automatic Lights #2 Configuration Byte 2

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Reserved	Reserved	Reserved	Reserved	Reserved	Reserved	Rear Cab Lights (118)	Front Cab Lights (116)

- Default value = 00000000 binary = 00 hex = 0 decimal.

### 5.7.17 CV 55.138.SI Multiple Automatic Lights #3

The Multiple Automatic Lights #3 feature allows you to activate more than one automatic light feature with a single function key. Select which lights you want to activate in CV 55.138.0 ... CV 55.138.2, and assign Feature 138 to a function output in CV 53.

By default, Feature 138 is assigned to output 14 (F12) in CV 53.

By default, Multiple Automatic Lights #3 controls the automatic Front and Rear Cab Lights.

#### CV 55.138.0 Multiple Automatic Lights #3 Configuration Byte 0

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Reserved	Reserved	Reserved	Ditch Lights (84)	Reserved	Mars Light (76)	Reverse Light (73)	Headlight (70)

- Default value = 00000000 binary = 00 hex = 0 decimal.

#### CV 55.138.1 Multiple Automatic Lights #3 Configuration Byte 1

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Rear Step Lights (114)	Front Step Lights (112)	Reserved	Reserved	Rear Marker Lights (106)	Front Marker Lights (104)	Rear Number Board Lights (102)	Front Number Board Lights (100)

- Default value = 00000000 binary = 00 hex = 0 decimal.

#### CV 55.138.2 Multiple Automatic Lights #3 Configuration Byte 2

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Reserved	Reserved	Reserved	Reserved	Reserved	Reserved	Rear Cab Lights (118)	Front Cab Lights (116)

- Default value = 11111111 binary = FF hex = 255 decimal.

## 5.7.18 CV 55.178.SI Status Report

By default, Feature 178 is assigned to output 12 (F10) in CV 53.

By default, the Status Report announces the speed in scale MPH or scale KPH in forward and reverse.

### 5.7.18.1 CV 55.178.0 Status Report Configuration

Use this CV to select the type of information announced in the status report.

Default Value:

1

#### CV 55.178.0: Status Report Configuration

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Reserved	Reserved	Reserved	Scale Miles	Internal Temp	PWM	BEMF	Scale MPH

- Default value = 00000001 binary = 01 hex = 1 decimal.
- If bit 0 = 1, the Scale MPH or Scale KPH is announced in FWD/REV. You can select between SMPH and SKPH in CV56.0.
- If bit 1 = 1, the BEMF is announced in FWD/REV. The spoken BEMF value is preceded by a spoken 'B'.
- If bit 2 = 1, the PWM is announced in FWD/REV. The spoken PWM value is preceded by a spoken 'D'.
- If bit 3 = 1, the Internal Temperature<sup>102</sup> is announced in degrees Celsius. The spoken temperature value is followed by the spoken phrase "degrees C". See CV56.32.0 for temperature calibration information.
- If bit 4 = 1, the Odometer<sup>103</sup> distance traveled is announced in scale miles followed by the word "miles". If you want the distance reported in kilometers, set CV56.0 bit 1 to "1". See CV58.1.x for more information on the odometer feature.

<sup>102</sup> The Internal Temperature feature is currently only available with Q2 O-Scale and G-Scale firmware.

<sup>103</sup> The Odometer feature is currently only available with Q2 O-Scale and G-Scale firmware.

## 5.8 CV 56.PI.SI QSI Configuration

Use CV 56 to access Quantum Configuration settings.

CV 56 is implemented as a two-dimensional table of registers. Some rows of this table have only one register and require the use of CV 49 only. Other rows require both CV 49 and CV 50 to select the configuration registers.

### 5.8.1 CV 56.0: QSI System Configuration (PI = 0)

Use this CV to configure the Quantum system.

Default  
Value:

<b>0</b> <sup>104</sup>
-------------------------

#### CV 56.0: QSI System Configuration Register

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
D7	0	D5	D4	D3	0	D1	D0

#### Bit 0 Sounds on Power Up

“0” On power up, the locomotive’s sound system will turn on only when a valid DCC Ops Mode packet addressed to the locomotive is received.

“1” On power up, the locomotive’s sound system will turn on when any valid DCC Ops Mode packet is received.

#### Bit 1 Selects between Imperial and Metric Units.

“0” Selects “Imperial Units”. The locomotive’s speed is reported in scale miles per hour (smph). Under Calibrated Speed Control (see CV 56.4), each speed step increment is equal to 1 smph. “Imperial Units” is the default for models of US prototypes.

“1” Selects “Metric Units”. The locomotive’s speed is reported in scale kilometers per hour (skph). Under Calibrated Speed Control, each speed step increment is equal to 1 skph. “Metric Units” is the default for models of non-US prototypes.

#### Bit 3 Selects BEMF synchronized chuff calibration mode<sup>105</sup>.

“0” BEMF synchronized chuffs calibration mode “Off” (default).

“1” BEMF synchronized chuffs calibration mode “On”. In this mode the locomotive maintains a constant speed at each speed step and, in place of normal chuffing sounds, produces a single short air release sound once per wheel revolution. Cylinder Cocks sounds are turned off to make it easier to hear the air release sound. It is now easy to adjust CV56.13 Chuff Interval Trim to obtain exactly one air release per wheel revolution.

#### Bit 4 Selects between BEMF synchronized and CAM<sup>106</sup> synchronized chuffs on Steam locomotives.

“0” Synchronize chuffs using BEMF (default).

“1” Synchronize chuffs using a Chuff CAM.

#### Bit 5 Odometer<sup>107</sup> Mode

<sup>104</sup> The default for models of non-US prototypes is 2, selecting for Metric Units.

<sup>105</sup> The BEMF synchronized chuff calibration is currently available only in Q2 firmware.

<sup>106</sup> Chuff CAMs are currently supported only in Q2 O-Scale and G-Scale locomotives.



“0” BEMF mode (default).  
“1” CAM mode.

**Bit 7** Reed Switch Disable

“0” Normal Reed Switch operation is in effect (default).  
“1” The Reed Switch is ignored for all operations except powerup reset to factory defaults.

All other bits (2,3,6) are ignored.

---

<sup>107</sup> The Odometer feature is currently only available with Q2 firmware.

## 5.8.2 CV 56.4: QSI Throttle Mode (PI = 4)

Use this CV to specify how your Quantum Locomotive interprets throttle position.

Default  
Value:

1
---

### CV 56.4: QSI Throttle Mode Register

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
0	0	0	0	0	0	D1	D0

- Set data in bits 0 and 1 as follows:
  - “0” = Standard Throttle Control (STC).
  - “1” = Regulated Throttle Control (RTC)<sup>108</sup>
  - “2” = Load Compensated BEMF Speed Control (BEMFSC)<sup>109</sup>.
  - “3” = Calibrated Speed Control (CSC)
- All other bits are reserved and should be set to 0.
- Default is “1”, Regulated Throttle Control.

**Standard Throttle Control (STC)** is the common way to control the power delivered to a locomotive’s motor. Under STC, the throttle setting (speed step) explicitly determines the percentage of full power applied to the motor as specified in a speed table. Because the power applied to the motor is constant for a given throttle setting, the speed of the locomotive will change under load, such as climbing grades, pulling a heavy train, binding wheels or gears, and poor track conditions. In addition, the speed of the locomotive will vary as a result of changes in track voltage caused by power pack resistance, track resistance, inconsistent or intermittent pickups, and changes in motor load current.

**Calibrated Speed Control (CSC)** uses internal motor control electronics to vary the power applied to the motor in an attempt to maintain the same speed regardless of varying load or track voltage conditions. In 128 speed step mode, the locomotive’s speed in scale miles per hour (smph) is equal to the throttle setting<sup>110</sup>. Default resolution is in 1-smph increments. If your throttle is set at 35, the locomotive will go 35 smph. In 14 or 28 speed step mode, you need to multiply your throttle settings by 9 and 4.5 respectively to determine the locomotive’s speed.

If CV 56.0 bit 1 is set to 1, the locomotive’s speed in scale kilometers per hour (skph) is equal to the throttle setting.

Although some prototype locomotives can achieve 128 miles per hour, most were not designed for these speeds. Increasing the speed step above the fastest speed obtainable by your model locomotive will not produce additional speed increase. Your model’s top speed is also limited by the track voltage. If your command station cannot supply sufficient voltage, at high speed steps the locomotive will run slower than the throttle indicates.

CSC is a big improvement over STC, but may not work well when locomotives are in Consists or are used as mid train helpers or pushers and the locomotives are slightly mismatched in speed calibration. A locomotive that tends to go slightly faster than 35 smph tries to pull the locomotive that tends to go slightly slower than 35 smph up to speed and applies more power to do so. The locomotive that tends to go slightly slower than 35 smph tries to slow the locomotive that tends to go slightly faster than 35 smph and reduces power to do so. The result is that the slightly faster locomotive does all the pulling work while the slightly slower locomotive is dragged along.

Under CSC, the following CV’s have no meaning and are not used: CV 2 (V-Start), CV 5 (V-High), CV 25 (Speed Table Selection), CV 66 (Forward Trim), CV 95 (Reverse Trim), and CV 67 – CV 94 (User Defined Speed Tables).

<sup>108</sup> CV56.4 = 1 was the setting for Speed Control, and CV 56.4 = 2 was the setting for RTC on early Quantum 1 factory equipped locomotives.

<sup>109</sup> Both CSC and BEMFSC are not available in Q1a or Q2 firmware due to threatened litigation from Mike’s Train House (MTH) ®.

<sup>110</sup> Because of the way the NMRA has set up speed steps, the actual scale speed is 1 smph less than the speed step (i.e. Speed Step 2 = 1 smph, Speed Step 3 = 2 smph, etc.). Most Command Stations display the throttle setting as 1 less than the speed step (i.e. Speed Step 2 = Throttle Setting 1, Speed Step 3 = Throttle Setting 2, etc.) For those command stations, the throttle setting is equal to scale miles per hour.

**Load Compensated BEMF Speed Control (BEMFSC):** This is a non-calibrated speed control technique where each speed step corresponds to a specific BEMF target value. The speed control circuitry adjusts the power applied to the motor in order to minimize the difference between the measured BEMF and the target BEMF.

BEMFSC has the same problem with locomotives in a consist as does CSC.

The following CV's are used to determine the BEMF target value: CV 2 (V-Start), CV 5 (V-High), CV 25 (Speed Table Selection), CV 66 (Forward Trim), CV 95 (Reverse Trim), and CV 67 – CV 94 (User Defined Speed Tables).

**Regulated Throttle Control (RTC)** combines the best of both Standard Throttle Control and Speed Control. The locomotive still uses speed control circuitry to maintain the locomotive's speed but the speed is allowed to increase or decrease slowly in response to loading. When the locomotive encounters an uphill grade, it decreases speed slowly in response to the extra loading. If a locomotive encounters a tight curve or if it has to climb a bad track joint at low speed, it passes through or over these obstacles with little change in speed, just like the prototype. In RTC as in STC, the speed step is a requested power setting, but in RTC the locomotive acts like it weighs thousands of pounds in response to changing loads or layout conditions.

This "intrinsic mass" is not the same as the inertia settings specified in CV 3, CV 4, CV 23, and CV 24, where the locomotive responds to throttle increases and decreases slowly over time. Even with these CV's set to large values, in STC the locomotive would still stop suddenly if it encountered a minor obstacle at slow speeds since there is no Inertial Control circuitry to maintain its motion.

RTC provides an advantage when operating Consists. If the locomotives in a consist are slightly mismatched in speed and experience unequal loading, the RTC firmware in each locomotive responds to automatically equalize the loading.

RTC applies a little more power to the locomotive that tends to run slightly slower, and applies a little less power to the locomotive that tends to run slightly faster. As a result, all the locomotives in the consist tend to work together rather than fight each other.

RTC uses all the standard CV's pertaining to the throttle, including CV 2 (V-Start), CV 5 (V-High), CV 25 (Speed Table Selection), CV 66 (Forward Trim), CV 95 (Reverse Trim), and CV 67 – CV 94 (User Defined Speed Tables).

**Example:** Select Regulated Throttle Control

1. Set CV 49 to 4.
2. Set CV 56 to 1.

### 5.8.3 CV 56.5: Regulated Throttle Control (RTC) Minimum Back EMF (PI = 5)

Use this CV to specify the minimum speed under Regulated Throttle Control.

Default Value:

Depends on Locomotive

#### CV 56.5: Regulated Throttle Control Minimum BEMF

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
0	0	0	D4	D3	D2	D1	D0

- For models 100...999, the data range is from 0 to 7. Bits 3...7 are ignored. For models 1000...9999, the data range is 0 to 31. Bits 5...7 are ignored.
- The locomotive will operate at a speed corresponding to this minimum Back EMF until the speed table value corresponding to the throttle position exceeds V-Start at which time the locomotive will gain speed.
- If the value of this CV is 0, the locomotive does not maintain a minimum speed. The locomotive may not move at very low speed steps.
- If your locomotive runs very smoothly under RTC at speed step one, you may consider lowering the RTC Minimum BEMF value. If your locomotive exhibits non-smooth, jerky behavior at speed step one, you may want to increase the RTC Minimum BEMF value until operation is smooth.
- Before setting the minimum Back EMF, make sure that V-Start, CV2, is not affecting the minimum speed at speed step 1. At QSI, we set V-Start to provide minimum speed between speed step 1 and speed step 8<sup>111</sup> in the following way.

#### Setting CV 2 for Best RTC Minimum Speed Performance at Lower Speed Steps

1. Place locomotive on a level section of track at least a few feet in length.
2. Set V-Start, CV 2, to 0.
3. Set locomotive Throttle Mode to STC in CV 56.4.
4. Set throttle to speed step 8. Unless your track voltage is very high, your locomotive should be stopped.
5. Increase CV2 in increments until the locomotive starts to move.
6. Decrease CV2 until the locomotive stops. Use this value for your CV2 setting.
7. Return to RTC in CV 56.4.

With this CV 2 setting, notice that your locomotive's minimum speed is maintained between speed step 0 and speed step 8. If the locomotive does not increase at speed step 9, you may want to increase CV 2 slightly. See Appendix VI for additional information on operating your locomotive at minimum speed under RTC.

<sup>111</sup> Speed step 8 is an arbitrary choice. It maintains a reasonable speed step range that ensures that variations in track voltage settings, locomotive wear-in and others factors do not prevent the locomotive from obtaining a minimum speed at lower speed steps.

## 5.8.4 CV 56.9: BEMF to Scale MPH Trim<sup>112</sup> (PI = 9)

Use this CV to change the mapping of BEMF to scale MPH.

Default Value:

128

### CV 56.9: BEMF to Scale MPH Trim Register

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
<b>D7</b>	<b>D6</b>	<b>D5</b>	<b>D4</b>	<b>D3</b>	<b>D2</b>	<b>D1</b>	<b>D0</b>

This CV determines the relationship between the measured BEMF of the motor and the speed of the locomotive in smph. The content of this CV is interpreted as “X / 128”, which means a CV value of 128 is equivalent to a Trim Factor of 1.0.

The locomotive announces the speed of the locomotive in Forward or Reverse in a verbal status report. You can trigger the status report by pressing F10. The locomotive’s speed can be announced in either scale miles per hour or scale kilometers per hour. To have scale kilometers per hour announced, set CV56.0 bit 1 to “1”.

The factory default value for CV56.9 is “128” which represents “1.0”. If your locomotive is reporting speeds that are too slow or too fast, you can correct this by increasing or decreasing the value of this CV.

For example, suppose that your locomotive reports that it is moving 30 mph, but that you measure its speed by some other means to be 35 mph. To correct this, set CV56.9 to “149”. The “149” is arrived at by the following calculation:

$$\begin{aligned} &(\text{Measured\_Speed} / \text{Reported\_Speed}) * \text{Current\_CV56.9} \\ &(35 / 30) * 128 \\ &1.167 * 128 \\ &149 \end{aligned}$$

Suppose that now the locomotive reports that it is going 36 mph when it is actually going 35 mph. You can further adjust the mapping by setting CV56.9 to “145” according to the calculation:

$$\begin{aligned} &(\text{Measured\_Speed} / \text{Reported\_Speed}) * \text{Current\_CV56.9} \\ &(35 / 36) * 149 \\ &0.972 * 149 \\ &145 \end{aligned}$$

### 5.8.4.1 Calibrating BEMF to SMPH

Here are three ways you can calibrate your locomotive’s BEMF to SMPH mapping. Two methods involve measuring your locomotive’s actual speed and comparing with the locomotive’s reported speed. One method involves comparing the actual distance the locomotive travels with the distance it reports it travels.

#### Using a Commerical Speedometer

Measure your locomotive’s speed using a device similar to one available from [http://www.tonystrains.com/products/tdp-assoc\\_speed.htm](http://www.tonystrains.com/products/tdp-assoc_speed.htm)

For best results get your locomotive up to the desired speed and put the locomotive into “Heavy Load” by pressing F9. Under Heavy Load the locomotive acts as if it has enormous inertia and will speed up or slow down very little under varying track conditions.

Have the locomotive report its speed from time to time. You may want to write these numbers down and compute an average.

<sup>112</sup> This CV is currently available only in Q2 firmware.

Adjust CV56.9 as discussed above until the measured speed matches the locomotive's reported speed.

## Using a Stopwatch

Use a tape measure to measure a distance on your layout. Mark a start point and a stop point.

For best results get your locomotive up to the desired speed and put the locomotive into "Heavy Load" by pressing F9. Under Heavy Load the locomotive acts as if it has enormous inertia and will speed up or slow down very little under varying track conditions.

Have the locomotive report its speed from time to time. You may want to write these numbers down and compute an average.

When the locomotive passes the start point, start the stopwatch. When the locomotive passes the stop point, stop the stopwatch. Calculate the locomotive's speed as:

$$\text{Distance\_Traveled} / \text{Time}$$

Remember to convert your "Distance\_Traveled" to miles and the "Time" to hours and multiply by the appropriate scale factor for your model (e.g., "29" for Aristocraft G-Scale).

For example, if the Distance\_Traveled is 40 feet 6 inches and the Time is 1 minute 30 seconds, then the SMPH for 1:29 Scale is:

$$\begin{aligned} & \text{Distance\_Traveled} / \text{Time} \\ & (40.5 \text{ feet} * 29 * (1 \text{ mile} / 5280 \text{ feet})) / (90 \text{ seconds} * (1 \text{ minute} / 60 \text{ seconds}) * (1 \text{ hour} / 60 \text{ minutes})) \\ & (40.5 * 29) / 5280 / (90 / 3600) \\ & (40.5 * 29 * 3600) / (90 * 5280) \\ & 8.897 \text{ SMPH} \end{aligned}$$

The longer your calibration course, the more accurate your calculated speed will be. If you have a small layout, measure the distance for one trip around the layout and run your locomotive 10 times around the layout, starting the stopwatch at the start of the first trip and stopping the stopwatch at the end of the tenth trip.

Adjust CV56.9 as discussed above until your measured speed matches the locomotive's reported speed.

## Using the Locomotive's Odometer

Using this method you compare the measured distance traveled against the locomotive's reported distance traveled. When using this method, the Odometer mode must be "BEMF" (CV56.0 bit 5 = '0').

(1) Mark a start point and a stop point on your layout.

(2) Use a tape measure to measure the distance to be traveled through the calibration course. The longer the calibration course, the more accurate the calibration will be. If you have a small layout, measure the distance for one trip around the layout and run your locomotive 10 times around the layout.

(3) Convert the measured length to scale miles and save as "Measured\_Scale\_Distance". For example, for a G-Scale locomotive (scale 1:29), suppose the measured length around your layout is 60 feet 3¼ inches and the calibration course is 10 times around the layout. Then

$$\begin{aligned} \text{Measured\_Scale\_Distance} &= (60.27 \text{ feet} * 10) * (1 \text{ mile} / 5280 \text{ feet}) * 29.0 \\ \text{Measured\_Scale\_Distance} &= 3.31 \text{ scale miles} \end{aligned}$$

(4) Move the locomotive to the start point.

(5) Reset the odometer to "0" by writing "0" to CV58.1.0 (see note 3).

(6) Start the locomotive and run it through the calibration course. Stop the locomotive at the stop point.

(7) Have the locomotive report the distance traveled (see notes 1, 2 and 3). Save this value as "Reported\_Distance".

(8) Read out the current trim factor in CV56.9. Save this as "Old\_Trim".

(9) Calculate the new trim factor as shown:

$$\text{New\_Trim} = (\text{Measured\_Scale\_Distance} / \text{Reported\_Distance}) * \text{Old\_Trim}$$

(10) Set CV56.9 to the value of "New\_Trim".

(11) Repeat steps 4 thru 10 if desired.

Note 1: To have the locomotive speak out the odometer value in scale miles or scale kilometers, set CV55.178.0 bit 4 to "1". Then press the F10 key. If you want the odometer value in scale kilometers, set CV56.0 bit 1 to "1".

Note 2: You can also have the locomotive speak out the odometer value by writing 58 to CV64.1.0. (CV64 is the CV Numeric Verbal Readout).

Set CV49 to "1"  
Set CV50 to "0"  
Set CV64 to "58"

Note 3: Version 1.1.0.1 and later versions of QuantumCVManager make this easy to do. Just select the Decoder menu item "Odometer..." to display the Odometer dialog box. There is one button for odometer read out and a second button for resetting the odometer.

## 5.8.5 CV 56.10: Speed Step to Scale MPH Scale Factor (PI = 10)

Use this CV to change the mapping of speed step to scale MPH under Calibrated Speed Control (CSC).

Default Value:

64

### CV 56.10: Speed Step to Scale MPH Scale Factor Register

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
<b>D7</b>	<b>D6</b>	<b>D5</b>	<b>D4</b>	<b>D3</b>	<b>D2</b>	<b>D1</b>	<b>D0</b>

- This CV determines the relationship between speed steps and smph for CSC. The content of this CV is interpreted as "X / 64", which means a CV value of 64 is equivalent to a Scale Factor of 1.0. Some examples are:

CV 56.10	Scale Factor	Slowest possible speed at Speed Step 2	Fastest possible speed at Speed Step 127.
<b>32 (0x20)</b>	0.5	0.5 smph	63 smph
<b>64 (0x40)</b>	1.0	1 smph	126 smph
<b>128 (0x80)</b>	2.0	2 smph	252 smph

- Change the Scale Factor if you want a more active throttle range for a locomotive under CSC.
- A Scale Factor less than 1.0 makes sense when the top speed of the locomotive is much less than 126 smph. For example, suppose a locomotive has a top speed of 60 smph. With a Scale Factor of 1.0, all speed steps from 61 through 127 will result in a speed of 60 smph. If the Scale Factor is set to 0.5, then the top speed of 60 smph will correspond to speed steps 121 and above.
- A Scale Factor greater than 1.0 make sense when the top speed of the locomotive is much greater than 126 smph. For example, suppose a locomotive has a top speed of 200 smph. With a Scale Factor of 1.0 the locomotive would only go up to 126 smph. If the Scale Factor were set to 2.0, then the top speed of 200 smph would be obtained at speed steps 101 and above.
- The advantage of a Scale Factor of "1.0" is that you easily know the locomotive's speed if you have a command station that displays the current speed step.
- The Scale Factor can also be used to increase the accuracy of locomotive's speed. For example, if your locomotive runs at 34 smph when it should run at 35 smph, you could increase the scale factor slightly to  $(35/34) * 64 = 66$ .
- Adjusting the Scale Factor when trying to match locomotives in Consists when all are operating under CSC is another possibility.
- This CV has no effect under Standard Throttle Control, Regulated Throttle Control, or Load Compensated BEMF Speed Control.



## 5.8.6 CV 56.12: Chuff Interval Scale Factor<sup>113</sup> (PI = 12)

Use this CV to adjust the time between BEMF synchronized chuffs.

Default Value:

32

### CV 56.12: Chuff Interval Scale Factor Register

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
<b>D7</b>	<b>D6</b>	<b>D5</b>	<b>D4</b>	<b>D3</b>	<b>D2</b>	<b>D1</b>	<b>D0</b>

- This byte specifies a scale factor used to determine the amount of time between BEMF synchronized chuffs. This is inversely related to the chuff rate or the number of chuffs per wheel revolution; the larger the scale factor (more time between chuffs), the slower the chuff rate (fewer chuffs per wheel revolution). The content of this CV is interpreted as "X / 32", which means a CV value of 32 is equivalent to a scale factor of 1.0.
- Some examples of different scale factors are:

CV 56.12	Scale Factor	Chuffs Per Wheel Revolution
<b>32 (0x20)</b>	1.0	4
<b>43 (0x2B)</b>	1.3	3
<b>64 (0x40)</b>	2.0	2
<b>128 (0x80)</b>	4.0	1

- To calculate the scale factor for a desired number of chuffs per wheel revolution, use the formula Scale Factor = (4 / N) \* 32, where N is the number of chuffs per revolution.
- Use this scale factor to fine-tune the chuff rate. For example, if your locomotive chuffs a little slower than four per revolution, you can decrease the scale factor to 31 (0.97) to slightly increase the number of chuffs per revolution. Or if your locomotive chuffs a little faster than four per revolution, you can increase the scale factor to 33 (1.03) to slightly decrease the number of chuffs per revolution. If your locomotive supports CV56.13, use CV56.13 instead of this CV for fine-tuning the chuff rate.

**Note:** We recommend that you set the chuff rate at some speed value greater than 2 smph.

<sup>113</sup> All QSI equipped steam locomotives since 1-July-04 support CV 56.12 Chuff Interval Scale Factor and it is available on all version 6 software which includes all Life Like and the BLI PRR K4, C&O Texas and all following models.

## 5.8.6 CV 56.13: Chuff Interval Trim<sup>114</sup> (PI = 13)

Use this CV to adjust the time between BEMF synchronized chuffs.

Default Value:

128

### CV 56.13: Chuff Interval Trim Register

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
<b>D7</b>	<b>D6</b>	<b>D5</b>	<b>D4</b>	<b>D3</b>	<b>D2</b>	<b>D1</b>	<b>D0</b>

- This byte specifies a scale factor used to determine the amount of time between BEMF synchronized chuffs. This is inversely related to the chuff rate or the number of chuffs per wheel revolution; the larger the scale factor (more time between chuffs), the slower the chuff rate (fewer chuffs per wheel revolution). The content of this CV is interpreted as “X / 128”, which means a CV value of 128 is equivalent to a scale factor of 1.0.
- Use this scale factor to fine-tune the chuff rate. For example, if your locomotive chuffs a little slower than four per revolution, you can decrease the scale factor to 127 (0.992) to slightly increase the number of chuffs per revolution. Or if your locomotive chuffs a little faster than four per revolution, you can increase the scale factor to 129 (1.008) to slightly decrease the number of chuffs per revolution.
- Set CV56.0 bit 3 to “1” to turn on BEMF synchronized chuff calibration mode to make it easier to adjust the chuff rate.
- If you find that one value of CV56.13 gives good synchronized chuff at one speed, but at another speed a different value of CV56.13 is required, see the Q2Upgrade User Manual for a procedure for calibrating the chuff rate for multiple values of CV56.13.
- This CV is similar to CV56.12 Chuff Interval Scale Factor. The resolution is greater in CV56.13 but the range is less. CV56.12 is a coarse adjustment while CV56.13 is a fine adjustment. In locomotives that support both CV56.12 and CV56.13, both CV’s are applied. For example, if CV56.12 is “40” and CV56.13 is “144”, then the resulting scale factor applied to the chuff interval is:

$$\begin{aligned} &40/32 * 144/128 \\ &1.25 * 1.125 \\ &1.40625 \end{aligned}$$

**Note:** We recommend that you trim the chuff rate at some speed value greater than 2 smph.

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<sup>114</sup> CV56.13 is currently available only in Q2 firmware.

## 5.8.7 CV 56.18-21.SI: Quantum PID Parameters

PID parameters are used to control the amount of power applied to the motor of QSI locomotives when operating under Regulated Throttle Control, Calibrated Speed Control, or Load Compensated BEMF Speed Control.

“PID” is an acronym standing for “Proportional, Integral, Differential”.

Because model locomotives behave differently at different speeds, we use four different sets of PID parameters within four different speed ranges. Since BEMF is directly proportional to speed, we classify these speed ranges in terms of BEMF ranges.

There are two PID parameters that you can set for each BEMF range. We do not allow changing the Integral term.

### 5.8.7.1 CV 56.18.SI PID Parameters for Very Slow Speed (PI=18, SI = 0,2)

Default Values:

**Depends on Locomotive**

#### CV 56.18.0: Proportional Gain for BEMF ≤ 7

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
<b>D7</b>	<b>D6</b>	<b>D5</b>	<b>D4</b>	<b>D3</b>	<b>D2</b>	<b>D1</b>	<b>D0</b>

- Use this configuration byte to control Proportional Gain for very slow speeds for:  $0 < \text{BEMF} \leq 7$ . For Q2 firmware, this range is  $0 < \text{BEMF} \leq \text{CV56.5} + 5$ .
- Valid values are 0 to 255.

#### CV 56.18.2: Differential Gain for BEMF ≤ 7

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
<b>D7</b>	<b>D6</b>	<b>D5</b>	<b>D4</b>	<b>D3</b>	<b>D2</b>	<b>D1</b>	<b>D0</b>

- Use this configuration byte to control Differential Gain for very slow speeds for:  $0 < \text{BEMF} \leq 7$ . For Q2 firmware, this range is  $0 < \text{BEMF} \leq \text{CV56.5} + 5$ .
- Valid values are 0 to 255.

### 5.8.7.2 CV 56.19.SI PID Parameters for Slow Speed (PI=19, SI = 0,2)

Default Values:

Depends on Locomotive
-----------------------

#### CV 56.19.0: Proportional Gain for: $7 < \text{BEMF} \leq 54$ .

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
<b>D7</b>	<b>D6</b>	<b>D5</b>	<b>D4</b>	<b>D3</b>	<b>D2</b>	<b>D1</b>	<b>D0</b>

- Use this configuration byte to control Proportional Gain for slow speeds for:  $7 < \text{BEMF} \leq 54$ . For Q2 firmware, this range is  $\text{CV}56.5 + 5 < \text{BEMF} \leq 54$ .
- Valid values are 0 to 255.

#### CV 56.19.2: Differential Gain for: $7 < \text{BEMF} \leq 54$ .

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
<b>D7</b>	<b>D6</b>	<b>D5</b>	<b>D4</b>	<b>D3</b>	<b>D2</b>	<b>D1</b>	<b>D0</b>

- Use this configuration byte to control Differential Gain for slow speeds for:  $7 < \text{BEMF} \leq 54$ . For Q2 firmware, this range is  $\text{CV}56.5 + 5 < \text{BEMF} \leq 54$ .
- Valid values are 0 to 255.

### 5.8.7.3 CV 56.20.SI PID Parameters for Medium Speed (PI=20, SI = 0,2)

Default Values:

Depends on Locomotive
-----------------------

#### CV 56.20.0: Proportional Gain for: $54 < \text{BEMF} \leq 108$ .

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
<b>D7</b>	<b>D6</b>	<b>D5</b>	<b>D4</b>	<b>D3</b>	<b>D2</b>	<b>D1</b>	<b>D0</b>

- Use this configuration byte to control Proportional Gain for medium speeds for:  $54 < \text{BEMF} \leq 108$ .
- Valid values are 0 to 255.

#### CV 56.20.2: Differential Gain for: $54 < \text{BEMF} \leq 108$ .

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
<b>D7</b>	<b>D6</b>	<b>D5</b>	<b>D4</b>	<b>D3</b>	<b>D2</b>	<b>D1</b>	<b>D0</b>

- Use this configuration byte to control Differential Gain for medium speeds for:  $54 < \text{BEMF} \leq 108$ .
- Valid values are 0 to 255.

#### 5.8.7.4 CV 56.21.SI PID Parameters for High Speed (PI=21, SI = 0,2)

Default Values:

Depends on Locomotive
-----------------------

##### CV 56.21.0: Proportional Gain for: 108 < BEMF.

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
<b>D7</b>	<b>D6</b>	<b>D5</b>	<b>D4</b>	<b>D3</b>	<b>D2</b>	<b>D1</b>	<b>D0</b>

- Use this configuration byte to control Proportional Gain for high speeds for: 108 < BEMF.
- Valid values are 0 to 255.

##### CV 56.21.2: Differential Gain for: 108 < BEMF.

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
<b>D7</b>	<b>D6</b>	<b>D5</b>	<b>D4</b>	<b>D3</b>	<b>D2</b>	<b>D1</b>	<b>D0</b>

- Use this configuration byte to control Differential Gain for high speeds for: 108 < BEMF.
- Valid values are 0 to 255.

### 5.8.7.5 Setting PID Parameters for Quantum Equipped Model Locomotives:

- Make sure your locomotive is in the best possible mechanical condition. RTC can improve the operation of a well-tuned locomotive but it cannot compensate for locomotives that have serious mechanical problems. Set CV 56.4 to "0" to select Standard Throttle Control and operate your model at slow speed over a level piece of straight track at the minimum sustainable speed. Note any gear bind or "catching". If the locomotive always slows down at the same wheel position, you may need to make mechanical adjustments. With a steam locomotive, look for any mechanical problems with the valve gear. Lubricate all moving joints with appropriate non-corrosive oil and lube the gearbox. Check your electrical pickups and clean the wheels to ensure consistent power to the motor.
- Make sure your test conditions are consistent.
- If you are using a test track or a different layout to set PID parameters, set the DCC track voltage to match the layout you intend to use for normal operation. When we calibrate motor control and throttle CV's at QSI, we set our track at 16 volts with only the test locomotive on the track and in Neutral.
- Use a flat oval of track that is consistently powered in all sections (i.e. Track voltage should be the same at all locations). Make sure track does not have misaligned track joints or turnouts that can slow the locomotive.
- Reset All CV's.
- Set Status Report (F10) to both smph and BEMF (set CV 55.178.0 to 3). Speed will be announced first followed by the BEMF value. The BEMF report will be preceded by "B" to distinguish it from the speed report.
- Set minimum BEMF to 3 (set CV 56.5 to 3). This CV specifies the slowest speed the locomotive will travel in RTC.
- Set CV 56.4 to "0" to select STC.
- While in STC, with the throttle set to speed step = 8 (126 speed step range), increase CV 2 until locomotive moves, and then decrease CV 2 until locomotive stops. This will ensure that the low-end speed on your model is not being affected by CV 2 during the PID setting procedure. This will likely be the value of CV 2 you will retain in your model after you have set all your PID parameters.
- Set CV 56.4 to 1 to select RTC and adjust PID parameters:
  - 1) **Very Slow Speed PID's:** Set your locomotive to Speed Step 1. Change CV 56.18.0 and CV 56.18.2 to achieve optimal performance.
  - 2) **Slow Speed PID's:** Increase your throttle until the Status Report (F10 key) announces a BEMF value between 20 and 56. Change CV 56.19.0 and CV 56.19.2 to achieve optimal performance.
  - 3) **Medium Speed PID's:** Increase your throttle until the Status Report (F10 key) announces a BEMF between 56 and 125. Change CV 56.20.0 and CV 56.20.2 to achieve optimal performance.
  - 4) **High Speed PID's:** Increase your throttle until the Status Report (F10 key) announces a BEMF greater than 125. Change CV 56.21.0 and CV 56.21.2 to achieve optimal performance
- Transient Response Test: Does the locomotive stop smoothly in DCC when the throttle is changed from full throttle to zero throttle quickly? If it overshoots (i.e. slows, speeds up, and then slows again when you lower the throttle quickly and the locomotive slows to its new speed), then PID parameters need to be re-adjusted (see Hints below).
- It is also a good idea to test your PID settings under Analog operation to see if there is any overshoot or surging when the throttle is changed from full to just below V-Start quickly. RTC problems under DC operation almost always appear in DCC, although they can have different characteristics.
- Set New Minimum BEMF: Adjust CV 56.5 for the best possible low speed performance in RTC. If your locomotive runs very smoothly and has good Very Slow Speed PID parameters, the minimum BEMF can be reduced to 1 to achieve the ultimate low-end speed.

### 5.8.7.6 General Hints for Setting PID Parameters:

Choosing the correct PID parameters is more an art form than a science. Here are some general rules based on our experience that will get you close to the best performance.

1. We usually set the Proportional term (P) between 4 and 16. High values can cause overshooting, or surging when the throttle is changed quickly and low terms can result in poor response time. Higher values of P are generally used at the "Very Slow Speed" and "Slow Speed" BEMF ranges. We have seldom set P above 20 for the "High Speed" range.
2. The Differential term (D) is usually set between 1 and 100 with some notable exceptions as high as 150. The very high values for D are best at the "Very Slow Speed" range, while moderate D values are better at the higher BEMF ranges (10 to 60). High values of D help at slow speeds since this term compensates for rapid changes in speed that can occur from gear binding or minor obstacles such as misaligned track joints. At higher speed, high values of D are less significant since the flywheel momentum will often keep the locomotive moving despite minor gear issues. Too high a value of D will result in surging. This effect is sometimes very subtle. Carefully watch your train for any slight changes in steady-state speed as it moves around that track oval. Too high a Proportional term can also cause steady-state surging.
3. If your locomotive fails the "Transient Response" test, try lowering the Proportional terms and increase the Differential terms for the Slow Speed, Medium Speed and High Speed ranges. Adjustments of the Differential term for Very Low Speed will probably have no effect on transient performance. Try to bring the differential terms closer to the same value for the three top ranges. Do the same for the Proportional term. You will probably have the best luck with the Differential term in adjusting transient performance. The larger the Differential term, the less overshoot or surging the locomotive will do as it slows to it lower speed or stops. However, a large Differential term can result in steady state surging at some speeds. Always go back and check your steady state speed performance after optimizing your transient behavior.

In some cases it is best to ignore all the above. We have seen locomotives that do not fit neatly into the above set of rules. You may want to experiment using your own intuition, knowledge, and methodology. If you do obtain a good set of PID parameters, please let us know or publish for the rest of the railroad community.



## 5.8.8 CV 56.24.SI: Wheel Diameter<sup>115</sup> (PI = 24,SI = 0,1)

Use this CV to specify the locomotive's wheel diameter to 0.001 of an inch.

Default Value: 

<b>NA</b>
-----------

The wheel diameter requires 2 bytes. CV56.24.0 is the least significant byte, and CV56.24.1 is the most significant byte.

### CV 56.24.0: Wheel Diameter Low Byte Register

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
<b>D7</b>	<b>D6</b>	<b>D5</b>	<b>D4</b>	<b>D3</b>	<b>D2</b>	<b>D1</b>	<b>D0</b>

### CV 56.24.1: Wheel Diameter High Byte Register

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
<b>D7</b>	<b>D6</b>	<b>D5</b>	<b>D4</b>	<b>D3</b>	<b>D2</b>	<b>D1</b>	<b>D0</b>

The wheel diameter = low byte + (high byte \* 256). This 16 bit number represents the wheel diameter in units of 0.001 inch.

For example, a value of 930 represents a diameter of 0.930 inches. You would set CV56.24.0 to "162" and CV56.24.1 to "3", according to the calculation

$$\text{Low byte} = 930 \text{ modulo } 256 = 162$$

$$\text{High byte} = 930 / 256 = 3$$

This CV is used with CV56.25 Locomotive Scale when calculating the distance the locomotive has traveled when the odometer mode = "CAM".

---

<sup>115</sup> The CAM Odometer feature and this CV is currently only available with Q2 O-Scale and G-Scale firmware.

## 5.8.9 CV 56.25.SI: Locomotive Scale<sup>116</sup> (PI = 25,SI = 0,1)

Use this CV to specify the locomotive's scale.

Default Value: 

<b>NA</b>
-----------

The locomotive scale requires 2 bytes. CV56.25.0 is the least significant byte, and CV56.25.1 is the most significant byte.

### CV 56.25.0: Locomotive Scale Low Byte Register

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
<b>D7</b>	<b>D6</b>	<b>D5</b>	<b>D4</b>	<b>D3</b>	<b>D2</b>	<b>D1</b>	<b>D0</b>

### CV 56.25.1: Locomotive Scale High Byte Register

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
<b>D7</b>	<b>D6</b>	<b>D5</b>	<b>D4</b>	<b>D3</b>	<b>D2</b>	<b>D1</b>	<b>D0</b>

The locomotive scale = low byte + (high byte \* 256). This 16 bit number represents the locomotive scale in units of 0.01.

For example, a value of 2900 represents a scale of 29.00. You would set CV56.25.0 to "84" and CV56.25.1 to "11", according to the calculation

Low byte = 2900 modulo 256 = 84  
High byte = 2900 / 256 = 11

This CV is used with CV56.24 Wheel Diameter when calculating the distance the locomotive has traveled when the odometer mode = "CAM".

---

<sup>116</sup> The CAM Odometer feature and this CV is currently only available with Q2 O-Scale and G-Scale firmware.

## 5.8.10 CV 56.32.0: Room Temperature<sup>117</sup> (PI = 32,SI = 0)

Use this CV to specify the room temperature in degrees Celsius.

Default Value:

NA

### CV 56.32.0: Room Temperature Register

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
<b>D7</b>	<b>D6</b>	<b>D5</b>	<b>D4</b>	<b>D3</b>	<b>D2</b>	<b>D1</b>	<b>D0</b>

When this CV is written a flag is set to read the Internal Temperature at the next powerup and store the value read in long term memory. The stored value is then used to calibrate future Internal Temperature readings.

Note: after setting this CV power off your locomotive and let it set for several minutes to cool down. Then power the locomotive up at which time the Internal Temperature will be calibrated for the room temperature value in CV56.32.0.

The internal temperature can be read out as part of the F10 status report by setting CV55.178.0 bit 3 to "1".

The locomotive's firmware continuously monitors the internal temperature. If the internal temperature exceeds 90 degrees Celsius, the horn hoots, and a high temperature motor shutdown is executed. The locomotive stops and the internal temperature is announced every 10 seconds. After a high temperature shutdown occurs, the locomotive must be powered off before normal operation can resume.

---

<sup>117</sup> The internal temperature feature is currently only available in G-Scale and O-Scale locomotives.

## 5.8.10 CV 56.128: Reset to Factory Default (PI = 128)

Use this CV to reset CV's to factory default values.

Default Value: 

<b>NA</b>
-----------

### CV 56.128: Reset to Factory Default Register

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
<b>D7</b>	<b>D6</b>	<b>D5</b>	<b>D4</b>	<b>D3</b>	<b>D2</b>	<b>D1</b>	<b>D0</b>

- Use the Secondary Index to select a range of CV's. Only those CV's in the selected range will be reset; those CV's outside the range are left unchanged.

SI	Reset Operations:
<b>51</b>	Reset CV 51, System Sound Control
<b>52</b>	Reset CV 52, Individual Sounds
<b>53</b>	Reset CV 53, Function Output Mappings
<b>55</b>	Reset CV 55, QSI Feature Configuration
<b>56</b>	Reset CV 56, QSI Configuration
<b>58</b>	Reset CV 58, Odometer
<b>253</b>	Reset all standard NMRA CV's
<b>254</b>	Reset all QSI CV's
<b>255</b>	Reset all CV's

- Write the QSI Manufacturer Number, 113, to CV 56, to execute the reset operation.
- In Operations Mode you will hear "Reset" spoken when the reset operation completes.

**Note:** "Reset all CV's" may not work correctly in Service Mode on some command stations, because the command station may turn off the track power before the operation is complete. If this happens, reset CV's in separate groups or use Ops Mode Programming.

#### Example: Reset Quantum decoder to original factory defaults (i.e. Reset all CV's)

- Set CV 49 to 128.
- Set CV 50 to 255.
- Set CV 56 to 113. In Ops Mode, you will hear "Reset" when reset is completed.

#### Example: Reset the Individual Sound Volumes to factory defaults

- Set CV 49 to 128.
- Set CV 50 to 52.
- Set CV 56 to 113.

## 5.8.11 CV 56.129: Locomotive ID Access (PI = 129)

Default Value:

N/A

### CV 56.129: Locomotive ID Access Register

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
<b>D7</b>	<b>D6</b>	<b>D5</b>	<b>D4</b>	<b>D3</b>	<b>D2</b>	<b>D1</b>	<b>D0</b>

- Use this index with CV 56 if your controller will not allow you to program your locomotive's ID on the main, and programming on the programming track is impossible due to insufficient power from your command station.
- This feature is only supported during Operations Mode programming. It will not work during Service Mode programming.
- Use CV 50 to select between Short Address (CV 50 = 1), High Byte Extended Address (CV 50 = 17) and Low Byte Extended Address (CV 50 = 18).
- When CV 56.129.1 is written, the data byte is written to CV 1. If programming acknowledgement is enabled, you will hear "CV 1 equals <short address>". The data byte must be in the range 1 to 127.
- When CV 56.129.17 is written, the data byte is merely stored in temporary memory. There is no verbal program announcement. The data byte must be in the range of 0xC0 to 0xE7.
- When CV 56.129.18 is written, the two data bytes are written to CV 17 and CV 18, making the locomotive's ID the 2 byte address consisting of the byte written to CV 56.129.17 and the byte written to CV 56.129.18. If you want to verify the full address in Ops Mode, set CV 64 to 17 (or 18) and hear "CV 17 (or 18) equals <long address>".

**Note:** When programming the Extended Address, you must set CV 56.129.17 before you set CV 56.129.18.

See the CV 17 and CV 18 documentation for description of how to compute and enter the MSB (most significant byte) and the LSB (least significant byte) of your Extended Addresses.

### Step-by-Step procedure for entering your short (Primary) address in CV 56.129 in Ops Mode.

- 1) Find out if your command station accepts Decimal, Binary or Hex<sup>118</sup> inputs for CV entries.
- 2) Set CV 49 to 129.
- 3) Set CV 50 to 1.
- 4) Set CV 56 to your short address. Hear the address spoken back.
- 5) Change CV 29, bit 5 to "0" to allow operation with your new primary address (see CV 29).

**Example:** Set your locomotive's ID to the short address "23".

1. Set CV 49 to 129 decimal (10000001, 0x81).
2. Set CV 50 to 1.
3. Set CV 56 to 23 decimal (00010111, 0x17). Hear "CV One equals two, three". At this point, the locomotive must be selected as 23 to proceed to step 4.

If you were using the extended addressing to do steps 1-3, then set CV 29 to 34 decimal (00000010, 0x02) for Primary Address Enable and 28/128 Speed Step.

Your locomotive's short ID is now 23 and ready to operate.

<sup>118</sup> Hex and Binary numbers are not shown in the following examples. If you require Hex or Binary, use the conversion table in Appendix IX.

## Step-by-Step procedure for entering your long (Extended) Address in CV 56.129 in Ops Mode.

1. Find out if your command station accepts Decimal, Binary or Hex inputs for CV entries.
2. Determine the MSB and LSB for your Extended Address (See CV 17/18 instructions and example).
3. Set CV 49 to 129.
4. Set CV 50 to 17.
5. Enter CV 17 (Most Significant Byte) as a Decimal, Binary or Hex number required by your command station. You will hear no verbal response.
6. Next enter CV 18 (Least Significant Byte) as a Decimal, Binary or Hex number. Hear the new full address spoken back.
7. Change CV 29, bit 5 to "1" to allow operation with your new Extended Address (see CV 29).

The following table shows examples for some common train numbers. Just follow the procedure above when entering CV 17 and CV 18.

ID Number	CV 17 (MSB) (Dec)	CV 18 (LSB) (Dec)	CV 17 (MSB) (Hex)	CV 18 (LSB) (Hex)	CV 17 (MSB) (Binary)	CV 18 (LSB) (Binary)
<b>3985</b>	207	145	CF	91	11001111	10010001
<b>3989</b>	207	149	CF	95	11001111	10010101
<b>3708</b>	206	124	CE	7C	11001110	01111100

### Example 1: Set your locomotive's long address to "3985" (Also see example under CV 17 and 18.)

1. Set CV 49 to 129 decimal (10000001, 0x81).
2. Set CV 50 to 17 decimal (00010001, 0x11).
3. Set CV 56 to 207 decimal (11001111, 0xCF), which is the MSB for your address (you will hear no verbal feedback).
4. Set CV 50 to 18 decimal (00010010, 0x12).
5. Set CV 56 to 145 decimal (10010001, 0x91), which is the LSB for your address. Hear "CV one, seven equals three, nine, eight, five".
6. Set CV 29 to 34 decimal (00100010, 0x22) for Extended Address Enable and 28/128 Speed Step.

Your locomotive's Long ID is now 3985 and ready to operate.

### Example 2: Set your locomotive's long address to "5344" (See example under CV 17 and 18.)

1. Set CV 49 to 129 decimal (10000001, 0x81).
2. Set CV 50 to 17 decimal (00010001, 0x11).
3. Set CV 56 to 212 decimal (11010100, 0xD4), which is the MSB for your address (you will hear no verbal feedback).
4. Set CV 50 to 18 decimal (00010010, 0x12).
5. Set CV 56 to 224 decimal (11100000, 0xE0), which is the LSB for your address. Hear "CV one, seven equals five, three, four, four".
6. Set CV 29 to 34 decimal (00100010, 0x22) for Extended Address Enable and 28/128 Speed Step.

Your locomotive's Long ID is now 5344 and ready to operate.

## 5.8.12CV 56.254: About Quantum Decoder (PI = 254)

Use this CV in Service Mode to read back information about your Quantum locomotive. Use CV 50 to select among the data bytes to retrieve.

Default Value: 

<b>NA</b>
-----------

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
<b>D7</b>	<b>D6</b>	<b>D5</b>	<b>D4</b>	<b>D3</b>	<b>D2</b>	<b>D1</b>	<b>D0</b>

- Information from this CV is retrieved in Service Mode as a response to VERIFY\_BYTE or VERIFY\_BIT operations.
- To select which byte of information to retrieve, write data to CV 50 as follows:
  - “2” = Retrieve Hardware Profile High Byte.
  - “3” = Retrieve Hardware Profile Low Byte.
  - “4” = Retrieve Product Model High Byte.
  - “5” = Retrieve Product Model Low Byte.
  - “6” = Retrieve Firmware Minor Version Number.
  - “8” = Retrieve Firmware Build Number.
  - “10” = Retrieve Firmware Build Date.Month (1...12).
  - “11” = Retrieve Firmware Build Date.Day (1...31).
  - “12” = Retrieve Firmware Build Date.Year (02 = 2002).
  - “14” = Retrieve Firmware Sound Set Number Low Byte.
  - “15” = Retrieve Firmware Sound Set Number High Byte.
  - “16” = Retrieve Firmware Last Modified Date.Month (1...12).
  - “17” = Retrieve Firmware Last Modified Date.Day (1...31).
  - “18” = Retrieve Firmware Last Modified Date.Year (02 = 2002).
- The Firmware Major Version Number can be retrieved from CV 7, Manufacturer’s Version Number.

### Example: Retrieve the Product Model

1. Write 254 to CV 49.
2. Write 4 to CV 50.
3. Read back CV 56. Save the returned value as H.
4. Write 5 to CV 50.
5. Read back CV 56. Save the returned value as L.
6. The Product Model = (H \* 256) + L.

### 5.8.13 CV 56.255: Play Build Information (PI = 255)

Use this CV in Ops Mode to hear the locomotive speak out information about its firmware.

Default Value:

NA

#### CV 56.255: Play Build Information Register

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
0	0	0	0	0	D3	D1	D0

- Write data to CV 56 as follows:
  - “0” = Play Product Model. You will hear the Product Model number (e.g. “300” or “400”). This identifies the locomotive model and the sounds programmed into the software.
  - “1” = Play Firmware Version. You will hear three sets of numbers separated by the word “point”. The first number is the major version number, the second is the minor version number, and the third is the build number (e.g. “seven point one point five” means Major Version 7, Minor Version 1, Build Number 5).
  - “2” = Play Firmware Build Date. This is the date the software was created. You will hear three sets of numbers, each separated by a pause. The first number set is the month, followed by the day of the month, followed by the year (e.g. “six” pause “one five” pause “zero two” means June 15, 2002).
  - “3” = Play Hardware Profile number.
  - “4” = Play Sound Set number. This number identifies variations on the sounds programmed into the software for a model. The original firmware for a model has Sound Set number “0”.
  - “5” = Play Firmware Last Modified Date. This is the date the software was modified by a program such as Q2Upgrade. You will hear three sets of numbers, each separated by a pause. The first number set is the month, followed by the day of the month, followed by the year (e.g. “six” pause “one five” pause “zero two” means June 15, 2002).
- Any value other than 0..5 will be ignored and there will be no verbal output.

**Note:** While the Build Information is playing, all incoming DCC packets are ignored, so wait until the locomotive stops speaking before writing another CV.

#### Example: Play Firmware Version

7. Write 255 to CV 49.
8. Write 1 to CV 56.
9. Hear Version spoken out: for Major Version 7, Minor Version 1, Build Number 6, you would hear “seven point one point six”.



## 5.9 CV 58.1.SI Odometer<sup>119</sup>

This CV is used to read back or read out the odometer value. It is also used to reset the odometer to 0.

Default Value:

0

### CV 58.1.0: Odometer Byte 0 (Least Significant Byte) Register

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
<b>D7</b>	<b>D6</b>	<b>D5</b>	<b>D4</b>	<b>D3</b>	<b>D2</b>	<b>D1</b>	<b>D0</b>

### CV 58.1.1: Odometer Byte 1 Register

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
<b>D7</b>	<b>D6</b>	<b>D5</b>	<b>D4</b>	<b>D3</b>	<b>D2</b>	<b>D1</b>	<b>D0</b>

### CV 58.1.2: Odometer Byte 2 (Most Significant Byte) Register

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
<b>D7</b>	<b>D6</b>	<b>D5</b>	<b>D4</b>	<b>D3</b>	<b>D2</b>	<b>D1</b>	<b>D0</b>

All Q2 locomotives have a BEMF driven on-board odometer. The average BEMF reading each second is converted to Scale Miles Per Hour (SMPH) and added to a total stored in long term memory.

Q2 steam locomotives may be equipped with a Chuff CAM. This CAM signals the decoder processor at each of 4 positions of a wheel revolution, thus providing 4 chuffs per revolution. This CAM can also be used as an on-board odometer, given that the diameter of the wheel (CV56.24.0-1) and the locomotive scale (CV56.25.0-1) are known.

BEMF odometer mode is the default. If your locomotive has a Chuff CAM, you can select the CAM odometer mode, by setting CV56.0 bit 5 to "1".

### 5.9.1 Odometer Reset

Reset the odometer to "0" by writing "0" to CV58.1.0.

Set CV49 to "1"  
Set CV50 to "0"  
Set CV58 to "0"

Actually, a write of any value to CV58.1.0, CV58.1.1, or CV58.1.2 will reset the odometer to "0".

In Ops Mode, the locomotive will respond by saying "Reset".

The odometer is also reset to "0" when all CV's are reset to factory default values.

### 5.9.2 Ops Mode Odometer Read Out

In Ops mode you can have the locomotive verbally read out the odometer value. There are two ways to do this.

(1) Make the odometer reading part of the F10 status report by setting CV55.128.0 bit 4 to "1". Then whenever you press F10, the locomotive will speak out the odometer value.

(2) Write "58" to CV64.1.0. (CV64 is the CV Numeric Verbal Readout).

<sup>119</sup> The Odometer feature is currently only available with Q2 O-Scale and G-Scale firmware.

Set CV49 to "1"  
Set CV50 to "0"  
Set CV64 to "58"

By either way, the locomotive speaks out either the scale miles or the scale kilometers traveled, to the nearest 0.01 of a scale mile or scale kilometer. The default is "miles". If you want the locomotive to speak out the scale kilometers traveled, set CV56.0 bit 1 to "1".

### 5.9.3 Service Mode Odometer Read Back

The raw odometer value can be read back in DCC Service Mode. These three CV's contain the raw odometer value:

CV58.1.0 byte\_0 (low order byte)  
CV58.1.1 byte\_1  
CV58.1.2 byte\_2 (high order byte)

The raw odometer value is thus

$$\text{Raw Odometer Value} = \text{byte\_0} + (\text{byte\_1} * 256) + (\text{byte\_2} * 256 * 256)$$

The number of scale miles this represents depends on the Odometer Mode (CV56.0 bit 5).

### 5.9.4 BEMF Odometer Mode (CV56.0 bit 5 = "0")

For BEMF odometer mode, the number of scale miles is

$$\text{Miles} = \text{Raw Odometer Value} / 3600$$

From this we can calculate the maximum number of scale miles before the odometer rolls over.

$$\text{Max\_Miles} = 16777215 / 3600 = 4660.33$$

To convert to kilometers, multiply the miles by 1.609.

$$\text{Kilometers} = \text{Miles} * 1.609$$

### 5.9.5 CAM Odometer Mode (CV56.0 bit 5 = "1")

For CAM odometer mode, the number of scale miles is

$$\text{Miles} = (\text{Raw Odometer Value} * \text{Diameter} * \text{Scale} * \text{PI}) / (4 * 12 * 5280)$$

The "4" is needed because there are 4 CAM ticks per wheel revolution. The "12" is needed because there are 12 inches per foot. The "5280" is needed because there are 5280 feet per mile. "PI" is 3.1415926.

Diameter is the Wheel Diameter read back from CV56.24.0 (low byte) and CV56.24.1 (high byte). The diameter is

$$\text{Diameter} = \text{low byte} + (\text{high byte} * 256)$$

This number represents the wheel diameter in units of 0.001 inch. For example a value of "1000" represents a diameter of 1.0 inches.

Scale is the Locomotive Scale read back from CV56.25.0 (low byte) and CV56.25.1 (high byte). The scale is

$$\text{Scale} = \text{low byte} + (\text{high byte} * 256)$$

This number represents the locomotive scale in units of 0.01. For example, a value of 2900 represents a scale of 29.0.

Thus, we have

Diameter = (CV56.24.0 value + (CV56.24.1 value \* 256)) / 1000  
Scale = (CV56.25.0 value + (CV56.25.1 value \* 256)) / 100  
Miles = (Raw Odometer Value \* Diameter \* Scale \* PI) / (4 \* 12 \* 5280)

The maximum number of scale miles before the odometer rolls over depends on the wheel diameter and the locomotive scale.

Max\_Miles = (16777215 \* Diameter \* Scale \* PI) / (4 \* 12 \* 5280)

To convert to kilometers, multiply the miles by 1.609.

Kilometers = Miles \* 1.609

## 5.10 CV 62 QSI Control<sup>120</sup>

Use this CV to control Programming Verbal Acknowledgement and CV Numeric Readout.

Default Value:

1

### CV 62: QSI Control Register

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
0	0	0	0	0	D2	0	D0

- Bit 0 = Programming Verbal Acknowledgement Enable
  - “0” = disable Programming Verbal Acknowledgement.
  - “1” = enable Programming Verbal Acknowledgement.

If Programming Verbal Acknowledgement is enabled, and you write a value to a CV, the locomotive announces the CV number and its new value. For example, if you set CV 2 to 18, the locomotive will respond with the spoken message “C V two equals one eight”.

If you write a value to a QSI unique CV that uses a Primary Index, the locomotive announces the CV number followed by the Primary Index followed by the new value. For example, if you set CV 52.8 to 9, the locomotive will respond with the spoken message “C V five two point eight equals nine”.

If you write a value to a QSI unique CV that uses a Primary Index and a Secondary index, the locomotive announces the CV number followed by the Primary Index followed by the Secondary Index followed by the new value. For example, if you set CV 53.12.0 to 104, the locomotive will respond with the spoken message “C V five three point one two point zero equals one zero four”.

If you hear a verbal response like “C V three one” but not followed by “equals” and a value, that means that the CV, in this case CV 31, is not implemented.

**Note:** During the time a Programming Verbal Acknowledgement is playing, all incoming DCC packets are ignored. If your DCC controller attempts to program several CV’s at a time, the second, third, etc. CV’s may not be programmed. You should disable Programming Verbal Acknowledgement when using this kind of controller.

- Bit 2 = CV Numeric Readout Control:
  - “0” = announce both the CV number and the CV value (default).
  - “1” = announce only the CV value.

This bit is used to specify whether or not the decoder announces the CV number as well as the CV value for a CV64 operation.

For example, suppose the value of CV2 is “32”. If this bit were “0”, and you wrote “2” to CV64, you would hear “C V two equals three two”. If this bit were “1”, you would hear “three two”.

Programming Verbal Acknowledgement and CV Numeric Readout are available only during Ops Mode. In Service Mode, there is not sufficient track power to run the Quantum Sound System.

The overall System Volume determines the volume for these verbal responses. If you cannot hear the Ops Mode verbal responses, you will need to turn up the System Volume (see CV 51.0).

If you cannot hear verbal responses during Ops Mode programming, check to see if you have activated the Mute feature.

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<sup>120</sup> Write bit operation is supported for CV 62.

**Example:** To Disable Programming Verbal Acknowledgement

1. Set CV 62 to 0.

**Example:** To Disable Programming Verbal Acknowledgement and specify CV Numeric Readout of the CV Value only.

1. Set CV 62 to 4.



## 5.11 CV 64 CV Numeric Verbal Readout (Verbal CV Inquiry)

Use this CV to hear the locomotive speak the value of any CV as a decimal number. This works only in Operations Mode.

Default Value:

NA

### CV 64: Numeric Verbal Readout Register

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
<b>D7</b>	<b>D6</b>	<b>D5</b>	<b>D4</b>	<b>D3</b>	<b>D2</b>	<b>D1</b>	<b>D0</b>

- To hear the locomotive speak the value of a Standard NMRA CV:
  - Write the number of the CV to CV 64.
  - The decoder will respond something like “C V three five equals four”.
  - If the decoder responds something like “C V three one” but not followed by “equals” and a value, that means that the CV, in this case CV 31, is not implemented.
- To hear the locomotive speak the value of a QSI Unique CV:
  - Determine the Primary Index for the value you want to know. If a Primary Index is required, write the Primary Index number to CV 49.
  - Determine the Secondary Index for the value you want to know. If a Secondary Index is required, write the Secondary Index number to CV 50.
  - Write the number of the QSI CV to CV 64.
  - The decoder will respond something like “C V five two point eight equals five”.
  - If the decoder responds something like “C V five two point 1” but does not follow this with “equals and a value, this means that the CV, in this case CV 52.1, is not implemented.”
- Writing either 17 or 18 to CV 64 will produce a verbal response indicating the full value of the Extended Address.
- The overall System Volume determines the volume for these verbal responses. If you cannot hear the Ops Mode verbal responses, you will need to turn up the System Volume (see CV 51.0).
- If you cannot hear verbal responses during Ops Mode programming, check to see if you have activated the Mute feature.
- CV62 bit 2 controls whether decoder speaks out the CV number as well as the CV value.

**Note:** While the Verbal Readout is playing, all incoming DCC packets are ignored, so wait until the locomotive stops speaking before writing another CV.

**Example:** Hear the current setting for CV 2 V-Start.

- Write 2 to CV 64.
- Hear the value spoken out: if the value of CV 2 were “32”, you would hear “C V two equals three two”.

**Example:** Hear the current setting of the bell volume.

- Set CV 49 to 8. (The Individual Sound Identifier for Bell is “8”; see table in CV 52)
- Set CV 64 to 52.
- Hear the Bell volume spoken out: if the bell volume were 13, you would hear “C V five two point eight equals one three”.

# 6 CV's 66-95: NMRA Standard CV's

This section describes in detail additional NMRA standard CV's supported by Quantum locomotives.

## 6.1 CV 66 Forward Trim

Forward Trim specifies a scale factor by which a voltage drive level should be multiplied when the controller is driving the unit in the Forward Direction.

Default Value:

### CV 66: Forward Trim Register

Bit 7 (MSB)	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0 (LSB)
<b>D7</b>	<b>D6</b>	<b>D5</b>	<b>D4</b>	<b>D3</b>	<b>D2</b>	<b>D1</b>	<b>D0</b>

- The Forward Trim factor preserves the same curve shape as specified in the speed table but allows a simple multiplying factor to scale it larger or smaller for “trimming” its speed behavior in Forward. This allows making fine adjustments to match the speed of other locomotives, and to match the locomotive’s Reverse speed characteristics.
- The multiplying scale factor is  $n/128$  where “n”, the Forward Trim Factor, can be any number entered into CV 66 from 0 to 255. If  $n = 128$ , then multiplying scale factor is 1 resulting in no change to the speed curve.
- If Forward Trim Factor is “0”, then Forward Trim is not implemented.
- If Forward Trim Factor is between 1 and 128 than the voltage applied to the motor is decreased by a multiplying factor that varies from .00775 to .99225.
- If Forward Trim Factor is between 130 and 255 than the voltage applied to the motor is increased by a multiplying factor that varies from 1.0078 to 1.977.
- CV 66 only applies if the speed tables are activated in CV 29 by setting bit 4 = 1.



## 6.2 CV 67-94 User Defined Speed Table

Use CV's 67–94 to specify a custom speed table that is suitable for your locomotive.

### CV 67-94: User Defined Speed Registers

Bit 7 (MSB)	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0 (LSB)
<b>D7</b>	<b>D6</b>	<b>D5</b>	<b>D4</b>	<b>D3</b>	<b>D2</b>	<b>D1</b>	<b>D0</b>

- The speed table consists of 28 data points for each of 28 speed steps. A value of 255 means full voltage applied to the motor while a value of 0 means no additional voltage applied to the motor over the V-Start voltage (CV 2).
- If you select 14 speed steps, every other data value is used. If you select 128 speed steps, extra points will be interpolated between each of the 28 data points to provide a smooth curve consisting of 255 points.
- The User Defined Speed Table must be enabled by setting CV 29 bit 5 to 1 and CV 25 bit 1 to 0 or 1.
- Default Values:

CV #	Speed Step	Default Value
CV 67	Speed Step 1	0
CV 68	Speed Step 2	9
CV 69	Speed Step 3	18
CV 70	Speed Step 4	28
CV 71	Speed Step 5	37
CV 72	Speed Step 6	47
CV 73	Speed Step 7	56
CV 74	Speed Step 8	66
CV 75	Speed Step 9	75
CV 76	Speed Step 10	85
CV 77	Speed Step 11	94
CV 78	Speed Step 12	103
CV 79	Speed Step 13	113
CV 80	Speed Step 14	122
CV 81	Speed Step 15	132
CV 82	Speed Step 16	141
CV 83	Speed Step 17	151
CV 84	Speed Step 18	160
CV 85	Speed Step 19	170
CV 86	Speed Step 20	179
CV 87	Speed Step 21	188
CV 88	Speed Step 22	198
CV 89	Speed Step 23	207
CV 90	Speed Step 24	217
CV 91	Speed Step 25	226
CV 92	Speed Step 26	236
CV 93	Speed Step 27	245
CV 94	Speed Step 28	255

## 6.3 CV 95 Reverse Trim

Reverse Trim specifies a scale factor by which a voltage drive level should be multiplied when the controller is driving the unit in the Reverse direction.

Default Value:

128

### CV 95: Reverse Trim Registers

Bit 7 (MSB)	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0 (LSB)
<b>D7</b>	<b>D6</b>	<b>D5</b>	<b>D4</b>	<b>D3</b>	<b>D2</b>	<b>D1</b>	<b>D0</b>

- The Reverse Trim factor preserves the same curve shape as specified in the speed table but allows a simple multiplying factor to scale it larger or smaller for “trimming” its speed behavior in Reverse. This allows making fine adjustments to match the speed of other locomotives, and to match the locomotive’s Forward speed characteristics.
- The multiplying scale factor is  $n/128$  where “n”, the Reverse Trim Factor, can be any number entered into CV 66 from 0 to 255.
- If the Reverse Trim Factor is “0”, then Reverse Trim is not implemented.
- If the Reverse Trim Factor is between 1 and 128 then the voltage applied to the motor is decreased by a multiplying factor that varies from .00775 to .99225.
- If the Reverse Trim Factor is between 130 and 255 then the voltage applied to the motor is increased by a multiplying factor that varies from 1.0078 to 1.977.
- CV 95 only applies if the speed tables are activated in CV 29 by setting bit 4 = 1.

# Appendix I

## Sounds Available in DCC Operation

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### Steam Sounds

#### 1.1 Automatic Sounds

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**Steam Chuff:** The familiar steam chuff comes from steam exhausted from the steam chest through the smoke stack, which creates a powerful draft to feed the fire. QSI Quantum chuffing produces four distinct chuff sounds per drive wheel setting a rhythm recognized by all steam fans.

**Articulated Chuff:** Articulated or Duplex steam locomotives have two sets of steam Chuff sounds that will go gradually in and out of synchrony. Most articulated locomotives had less weight over the front engine, which resulted in more slippage, causing the two engines to run at slightly different speeds.

**Cylinder Cocks:** When a steam locomotive sits idle for an extended period of time, water collects in the steam chest. Since water is not compressible, the fireman will open special cocks on the steam cylinders to allow the water to be ejected as the piston moves. As the locomotive moves out, clouds of steam and water are propelled out on either side of the locomotive in such a flurry that it sometimes obscures the wheels and valve gear of the engine. Hear the sounds of Cylinder Cocks on the model as the locomotive starts out after it has been idle in Neutral for at least 25 seconds. The Cylinder Cocks sounds are synchronized to the Chuff and shorten in duration as the loco's speed is increased. Under automatic Cylinder Cocks control, the Cylinder Cocks sounds terminate when the locomotive's speed reaches 12 smph or after 16 Cylinder Cocks sounds occur.

**Blower or Steam Locomotive Hiss:** On a moving locomotive, the steam from the steam chest venting through the smoke-stack draws air through the fire box, keeping the fire healthy. When the locomotive is sitting still, blowers are often turned on to vent steam through the smoke stack to maintain the draft. Blowers were often turned off soon after the locomotive started out. The QSI Steam Blower sound on steam locomotives will turn on gradually followed by a continual steam hiss. The turning on and off of Steam Blower Sounds is automatic and depends on the direction state.

**Air Pumps:** When a locomotive is sitting still, the pumps come on at a steady beat to replace air lost from the brake air release and from pneumatically operated appliances. Once the pressure is up, the pumps only turn on occasionally to maintain pressure. Large steam locomotives may have more than one pump operating independently.

**Appliance Air Release:** Compressed air is used on locomotives for operating various appliances like the reversing mechanisms common on large steam locomotives. When a large steam locomotive comes to a stop, you will hear a Long Air Let-off as the power reverse is moved to the center Neutral Position. You will also hear a Long Air Let-off or Short Air Let-off at various times.

**Brake Squeal:** You can hear the brakes squeal on prototype locomotives when they are moving slowly. This sound can become quite loud when the wheels are just about to stop turning. Listen for automatic Squealing Brake sounds at slow speeds and the final distinctive squealing sounds as the Quantum equipped Steam Locomotive slows to a stop.

**Steam Pop-off:** If there is too much steam in the boiler, special pop-off valves or "safeties" on top of the locomotive release the excess pressure in a fury of hissing steam that often will blow for 30' or more above the locomotive. This happens most often when the locomotive is sitting still, since the fire continues to build up steam that is not used. The Quantum Pop-off sound comes on for random lengths, at random times in Neutral.

**Steam Water Injector:** The water used to make steam is replaced by water injectors operating at high pressure to overcome the elevated pressure in the boiler. The sound of rushing water and steam hiss ends with a distinctive valve shut off. This sound comes on for random lengths of time and occurs randomly when the locomotive is in Neutral.

**Steam Boiler Blow Down:** As water evaporates, minerals and other residues settle to the bottom of the boiler. The fireman opens a valve to vent this material through a large pipe under the side of the cab onto the ground. Quantum's Blow Down sound occurs at random in Neutral for varying lengths of time.

## 1.2 Controllable Sounds

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**Whistle:** The Quantum System uses authentic locomotive sounds whenever possible. All Quantum Whistles are engineered by QSI sound experts to give you the most authentic effects. If you blow the Whistle briefly, you will produce a realistic short Whistle sound or “hoot”. Some locomotive models have special Whistle Endings to allow the whistle to be “played” when desired.

**Bell:** Steam locomotives may have either pull bells or pneumatic operated mechanical bells. With pull bells you will hear a different sound as the bell swings backward and forward producing the familiar ding-dong effect. Pneumatic bells produce a very repetitive ring and often at a much faster ring rate than a pull bell. During turn-on in Neutral, you will hear the pneumatic clapper gain greater throw with each stroke until it finally strikes the Bell. During shut down in Neutral, you will hear the Bell sound fade out for either pneumatic or pull Bells.

**Horn:** Steam locomotives sometimes had both a whistle and a horn. Whistles were used when sound needed to carry a long way such as in country areas or large yards where whistle blasts were used for communication. Horns were useful in the city or in foggy areas where the pitch of the horn made it easier to locate a moving locomotive. If your model has an alternate Horn, Alternate Horn Selection is assigned to function key F11. The Quantum System uses authentic locomotive sounds, whenever possible. If you blow the Horn briefly, you will produce a realistic short Horn sound or “hoot”. Some Quantum Sound sets have special Horn Ending, which can be “played” by tapping the horn button immediately after finishing horn operation.

**Doppler Run-by:** The locomotive sounds get louder as the train approaches, then immediately drop to a much lower pitch and lower volume as the train passes by. With a little practice you can activate the Doppler Effect exactly when and where you want. Doppler pitch change is based on the speed of the locomotive, so the sounds change more dramatically when the locomotive is running faster. After the Doppler shift has occurred and the Whistle is no longer being blown, the Bell shuts off automatically and locomotive sounds return to normal.

**Flanges :** When a train enters a curve, the flanges on the wheels tend to ride up on the inside of the rail and usually squeal. Recreate this squealing effect by pressing and releasing the Squealing Brake/Flanges function key quickly and repeatedly as necessary.

**Air Brakes:** When prototype train brakes are applied, air is released from the brake lines to reduce the pressure. The more the pressure is reduced, the greater the braking. You will hear a continual air release sound from the steam locomotive model as braking is continually increased. The longer the air is released, the quicker the steam locomotive model will slow down. Once all the pressure is released, the locomotive will continue at maximum braking which can still require a long stopping distance depending on your Load settings.

**Dynamic Brakes:** Steam Locomotives do not have Dynamic Brakes. When steam locomotives are operated today, they are often coupled to a diesel to provide dynamic brakes on down grades. If a Quantum Steam locomotive is coupled to a Quantum Diesel, and Dynamic Brakes are activated, the Diesel Dynamic Brake effect will start up and the Steam locomotive labored chuffing will reduce at the same time. Since prototype dynamic brakes are relatively ineffective at low speeds, the Dynamic Brakes will shut off automatically below 8 smph and Steam Locomotive Chuff will return to normal.

**Coupler:** To give you the most authentic coupler sounds, QSI has identified three distinct types of coupler activity. The first is when the coupler is Armed where you will hear the clanking sound of the coupler lift bar and coupler pin raising. The next is Firing the coupler, where you will hear the opening of the coupler and the hiss of the air-lines parting. The third is when the locomotive couples up to its load of cars, and you hear the Coupler Crash as all the cars bunch together from the impact.

**Locomotive Shut Down (Extended):** A Long Air Let-Off will first occur followed by the steam Dynamo revving down and the Directional lights shutting off. The Air Pumps will turn off, followed by the sounds of Pop Off<sup>121</sup> Operating for about ten seconds and finally the Blower Hiss will shut off.

**Locomotive Start Up (Extended):** The Dynamo will rev up while the Headlight comes on gradually, then the Cab Lights (if available) will turn on, followed by the Air Pumps, the Steam Blower will turn on and then the locomotive will enter normal operation.

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<sup>121</sup> Some Steam Locomotives may not produce a Pop-Off effect during shut down.

## Diesel Sounds

### 2.1 Automatic Sounds

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**Diesel Motor Rev:** The Quantum System allows Diesel Motors to be operated with all eight notches corresponding to the throttle notches used on the prototype. As the throttle is turned up, the Diesel Motor RPM will increase in fixed increments until the maximum RPM occurs at notch 8.

**Diesel Motor Start:** Separate sound records are used for diesel starting. Depending on the model, this could be the sound of an electric motor starter similar to a truck or from compressed air (called an air start). Both types of starting have very distinctive sounds. If the diesel model has two motors, both motors will start independently, one after the other.

**Diesel Motor Shut Down:** Separate sound records are used for diesel stopping sounds. If the diesel model has two motors, both motors will shut down independently, one after the other.

**Extended Start Up and Shut Down:** It takes time to startup or shutdown a prototype locomotive. To model this, the Quantum system uses additional sound records of the engineer's entering and leaving the cab, vents opening and closing, lights turn on or off at different times along with the sounds of the diesel motor starting up or shutting down.

**Diesel Turbo:** Turbo appliances are used to improve the locomotive's horsepower by pumping air into the intake manifold under pressure. The power to operate the turbo comes from the diesel motors exhaust pressure, which causes the turbo high pitch whine to lag the revving of the motor. Quantum Systems use a separate sound for the turbo to allow it to lag behind revving the motor up and to "hang" for a few seconds when the motor is revved down.

**Vents and Cooling Fans:** The enormous diesel motors and generators enclosed in the diesel cab need ventilation to stay cool. All diesel locomotives have powerful cooling fans on the roof to draw outside air through louvers on the sides of the locomotive, which is then blown across large radiators. You will also hear the sounds of louvers opening before the fans start. When cooling fans shut down, you will hear the louvers close after the fans have quit.

**Air Pumps:** When a locomotive is sitting still, the pumps come on in a steady beat to replace the air lost from the brake air release or from air-operated appliances. Once the pressure is up, the pumps only turn on occasionally to maintain the pressure. Diesel Air Pumps are operated directly from the motor and are quite noticeable when turned on in a non-moving locomotive. You will hear the Air Pumps come on soon after the horn is operated to maintain the air pressure.

**Appliance Air Release:** Compressed air is used on locomotives for operating various appliances. You will hear either a Short Air Let-off or Long Air Let-off at various times.

**Brake Squeal:** You can hear the brakes squeal on prototype locomotives when they are moving slowly. This sound can become quite loud when the wheels are just about to stop turning. Listen for automatic Squealing Brake sounds at slow speeds and the final distinctive squealing sounds as the Quantum equipped Diesel locomotive slows to a stop.

**Quick Locomotive Start Up.** All diesel locomotives have a quick Start Up and Shut Down effect when a locomotive is selected. Protracted turn-on effects are available when locomotives are in Total Shut Down (see Controllable Sounds below).

### 2.2 Controllable Sounds

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**Horn:** The Quantum system uses authentic locomotive sounds whenever possible. All Quantum Horns are engineered by QSI sound experts to give you the most authentic effects. If you blow the horn briefly, you will produce a realistic short horn sound or "hoot". Some quantum sound sets have special Horn Endings, which can be "played" by tapping the Horn button immediately after finishing horn operation.

**Alternate Horn:** Some diesel locomotives had two horns, such as a country horn and city horn. If your model has an alternate Horn, Alternate Horn Selection is assigned to function key F11.

**Bell:** North American Diesel locomotives usually have pneumatically operated mechanical bells. During turn-on in Neutral, you will hear the pneumatic clapper gain greater throw with each stroke until it finally strikes the bell. During shutdown in Neutral, you will hear a Short Air Let-off followed by the bell sound fade out as the pneumatic clapper slows down, just like the prototype.

**Doppler Run-by:** The locomotive's sounds get louder as the train approaches, then immediately drop to a much lower pitch and lower volume as the train passes by. With a little practice you can activate the Doppler Effect exactly when and where you want. Doppler pitch change is based on the speed of the locomotive, so the sounds change more dramatically when the locomotive is running faster. After the Doppler shift has occurred and the horn is no longer being blown, the Bell shuts off automatically and the locomotive sounds return to normal.

**Flanges:** When a train enters a curve, the flanges on the wheels ride up on the inside of the rail and usually squeal. Recreate this squealing effect by pressing and releasing the Squealing Brake/Flanges function key quickly and repeatedly as necessary.

**Air Brakes:** When prototype trains brakes are applied, air is released from the brake lines to reduce the pressure. The more the pressure is reduced, the greater the braking. You will hear a continual air release sound from the diesel locomotive model as braking is continually increased. The longer the air is released, the quicker the diesel locomotive model will slow down. Once all the pressure is released, the locomotive will continue at maximum braking which can still require a long stopping distance depending on your Load settings.

**Dynamic Brakes:** Prototype electric traction motors can act as motors or generators depending on whether they are using power or generating power. When used as generators, the traction motors are disconnected from taking power from the locomotive's prime mover, and instead are connected to large resistor grids in the roof. By increasing the resistive load on the traction motors, the traction motors become harder to turn and act as brakes for the locomotive. The electric power generated by turning the traction motors is dissipated as heat in the resistor grid. These resistor arrays get quite hot and require cooling. When Dynamic Brakes are turned on in the Quantum equipped Diesel locomotive, the Diesel Motor sound drops to notch 1 and the Dynamic Brake cooling fan sounds come on. Since dynamic brakes are relatively ineffective at low speeds, the Dynamic Brakes sounds will shut off automatically below 8 smph (13 skph).

**Coupler:** To give you the most authentic coupler sounds, QSI has identified three distinct types of coupler activity. The first is when the coupler is Armed where you will hear the clanking sound of the coupler lift bar and coupler pin raising. The next is Firing the coupler, where you hear the opening of the coupler and the hiss of the air-lines parting. The third sound occurs when the locomotive couples up to its load of cars, and you hear the Coupler Crash as all of the cars bunch together from the impact.

**Low Idle** Low Idle is used on prototype locomotives to maintain a warm and ready locomotive with a minimum of fuel consumption. The special Low Idle sound has a lower base throb and is less harsh than the normal idle.

## Electric Locomotive Sounds

### 3.1 Automatic Sounds

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**Traction Motor Whine:** Although both Diesels and Electric locomotives have Traction Motors, Electric locomotives do not have loud diesel motors drowning out the sounds of the Traction Motors. You will hear the Traction Motors when Electric locomotive starts out, especially if the Cooling Fan Volume is turned down to a lower value. Like the prototype, the Quantum Traction Motor Whine pitch increases and decreases with the speed of the locomotive. It is not affected by track voltage, only the speed.

**Traction Motor Cooling Fans:** The Electric Traction Motors get quite hot from the enormous current supplied to their circuits. All Electric locomotives have powerful Cooling Fans that can create so much draft the access panel doors cannot be opened when the Cooling Fans are operating at full power. It is not surprising that these fans can easily be heard in idling and operating locomotives. You will also hear the sounds of louvers opening before the fans start. When Cooling Fans shut down, you will hear the louvers close.

**Extended Start Up and Shut Down:** It takes time to startup or shutdown a prototype locomotive. To model this, the Quantum system uses additional sound records of the engineer entering and leaving the cab, vents opening and closing, lights turning on or off at different times along with the sounds of the Electric Air Pumps starting up or shutting down.

**Air Pumps:** When a locomotive is sitting still, the pumps come on in a steady beat to replace the air lost from the brake air releases and air operated appliances. Once the pressure is up, the pumps only turn on occasionally to maintain the pressure. Air pumps are electrically operated and are quite noticeable if the fans are turned down or off. In Forward, you will hear the Air Pumps come on soon after the Horn is operated to maintain the air pressure.

**Appliance Air Release:** Compressed air is used on locomotives for operating various appliances. You will hear either a Short Air Let-off or Long Air Let-off at various times.

**Brake Squeal:** You can hear the brake squeal on prototype locomotives when the locomotive is moving slowly. This sound can become quite loud when the wheels are just about to stop turning. Listen at slow speeds for automatic Squealing Brake sounds and the final distinctive squealing sounds as the Quantum equipped Electric Locomotive slows to a stop.

### 3.2 Controllable Sounds

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**Horn:** The Quantum system uses authentic locomotive sounds whenever possible. All Quantum horns are engineered by QSI sound experts to give you the most authentic effects. If you blow the horn briefly, you will produce a realistic short horn sound or "hoot". Some Quantum sound sets have special Horn endings which can be "played" by tapping the Horn button immediately after finishing horn operation.

**Alternate Horn:** Some electric locomotives had two horns, such as a country horn and city horn. If your model has a alternate Horn, Alternate Horn Selection is assigned to function key F11.

**Bell:** North American Electric locomotives and Diesel locomotives, as well as larger Steam locomotives, usually have pneumatically operated mechanical bells. Small Steam locomotives often have hand-pulled bells. During turn-on in Neutral, you will hear the pneumatic clapper gain greater throw with each stroke until it finally strikes the Bell. During shutdown in Neutral, you will hear a Short Air Let-off followed by the Bell sound fade out.

**Doppler Run-by:** The locomotive sounds get louder as the train approaches, then immediately drop to a much lower pitch and lower volume as the train passes by. With a little practice you can activate the Doppler Effect exactly when and where you want. Doppler pitch change is based on the speed of the locomotive, so the sounds change more dramatically when the locomotive is running faster. After the Doppler shift has occurred and the horn is no longer being blown, the Bell shuts off automatically and the locomotive sounds return to normal.

**Flanges :** When a train enters a curve, the flanges on the wheels tend to ride up on the inside of the rail and squeal. Recreate this squealing effect by pressing and releasing the Squealing Brakes/Flanges function key quickly and repeatedly as necessary.

**Air Brakes:** When a prototype trains brakes are applied, air is released from the brake lines to reduce the pressure. The more the pressure is reduced, the greater the braking. You will hear a continual air release sound from the Electric Locomotive model as braking is continually increased. The longer the air is released, the quicker the Electric locomotive model will slow down. Once all the pressure is released, the locomotive will continue at maximum braking which can still require a long stopping distance depending on your Load settings.

**Regenerative or Dynamic Brakes:** Prototype electric traction motors can act as motors or generators depending on whether they are using power or generating power. When they are generating power, they are hard to turn and can act as brakes. Under dynamic brakes, the power generated from the traction motors is dissipated as heat in large resistor grids, usually located on the top of the locomotive. High volume fans are used to keep the resistor grids from overheating. In regenerative braking, the power from the traction motors is sent back into the electrical distribution system through the overhead wires. In this case, resistor grids and their cooling fans are not required and less power is dissipated in the locomotive. In fact, the power generated from a moving train under regenerative braking can be used by other locomotives on the distribution system. If no such locomotives are present or requiring power, the regenerative power is fed back through the substations into the commercial power grid, which allows the railroad to deduct the power generated from their electrical bill. If the commercial power company does not allow power to be supplied to its power grid from the railroad, then dynamic brakes might be employed instead.

When Dynamic or Regenerative Brakes are turned on in a Quantum equipped Electric Locomotive, the Electric Motor Sound-of-Power drops to its lowest setting and Traction Motor Cooling Fans turn on and Fans for the resistor grid also come on (if dynamic brakes are used). Since dynamic or regenerative brakes are relatively ineffective at low speeds, the Dynamic or Regenerative Brake sounds on the model will shut off automatically below 8 smph (13 skph).

**Coupler:** To give you the most authentic coupler sounds, QSI has identified three distinct types of coupler activity. The first is when the coupler is Armed where you will hear the clanking sound of the coupler lift bar and coupler pin raising. The next is Firing the coupler where you will hear the opening of the coupler and the hiss of the air-lines parting. The third is when the locomotive couples up to its load of cars, and you hear the Coupler Crash as all the cars bunch together from the impact.

**Extended Start Up and Shut Down:** It takes time to startup or shutdown a prototype locomotive. To model this, the Quantum system uses additional sound records of the engineer entering and leaving the cab, vents opening and closing, lights turning on or off at different times along with the sounds of the Electric Air Pumps starting up or shutting down.



## Gas Turbine Sounds

### 4.1 Automatic Sounds

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**Diesel Motor Rev:** The diesel used in the prototype was a Cummings 250 horsepower motor. In Diesel mode in RTC, the Gas Turbine top speed is limited to 25 smph. Quantum decoders allow the Diesel Motor to be operated over eight notches corresponding to the throttle notches used on most prototype diesels. As the throttle is turned up, the Diesel Motor RPM will increase in fixed increments until the maximum RPM occurs at notch 8. All eight notches are evenly distributed between 0 and 80 speed step. Although the locomotive will not exceed 25 smph, the motor can still be revved through all notches.

**Turbine Whoosh:** The U.P. Gas Turbine produced an almost deafening roar that seemed to drown out all but the horn. It was sometimes referred to as “The Big Blow” since its dominant sound was that of furiously rushing exhaust gas. We have modeled this effect by synthesizing this sound in the Quantum system until it sounded exactly like the prototype gas turbine. We have coupled this effect to our Sound of Power™ concept to provide labored Turbine Whoosh when the locomotive is under load.

**Turbine Whine:** Some witnesses to the prototype Gas Turbine maintain there is no Turbine Whine, such as the sound that a jet airplane would make. However, other witnesses say that there was a discernable whine as the turbine was revving up that could still be barely heard at idle. We have included a separate whine sound in the Quantum System, which can easily be heard during the transition from diesel to turbine sounds, and which is almost buried in the Turbine Whoosh sound when the turbine is “on the line”.

**Vents and Cooling Fans:** The Cummings diesel motor and generator enclosed in the Gas Turbine cab need ventilation to stay cool. All diesel locomotives have powerful cooling fans on the roof to draw outside air through louvers on the sides of the locomotive. When Cooling Fans start, you will also hear the sounds of Louvers opening. When Cooling Fans shut down, you will hear the Louvers close after the fans have quit.

**Air Pumps:** When a locomotive is sitting still, the pumps come on in a steady beat to replace the air lost from the brake air release or any other air operated appliances. Once the pressure is up, the pumps only turn on occasionally to maintain the pressure. Air Pumps are operated directly from the Diesel Motor or from two electric motors when the turbine is “on the line”. Air Pumps are quite noticeable when turned on in a non-moving locomotive in Diesel Mode. You will also hear the Air Pumps come on soon after the Horn is operated to maintain the air pressure.

**Appliance Air Release:** Compressed air is used on locomotives for operating various appliances. You will hear either a Short Air Let-off or Long Air Let-off at various times.

**Brake Squeal:** You can hear the brake squeal on prototype locomotives when they are moving slowly. This sound can become quite loud when the wheels are just about to stop turning. Listen for automatic Squealing Brake sounds at slow speeds and the final distinctive squealing sounds as the Quantum equipped Gas Turbine locomotive slows to a stop.

**Quick Locomotive Start Up.** If the locomotive is in Diesel Mode, the diesel motor will start quickly when the Gas Turbine is powered up or addressed. If the locomotive is in Turbine Mode, it will quickly enter Turbine Mode when operated. Extended turn-on effects occur if locomotive is started from Total Shutdown.

### 4.2 Controllable Sounds

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**Air Horns:** The horn used for the Gas Turbine is a single chime horn usually found on early F units. Some commercial videotapes of the Gas Turbine have dubbed a multi-chime horn in for sound effects and do not represent the actual locomotive horn. In addition, the Gas Turbine horn includes a special short horn blast. If you blow the horn briefly, you will produce a realistic short horn sound or “hoot”.

**Bells:** Diesels and electric locomotives, and larger steam locomotives, usually have pneumatically operated mechanical bells and so does the Gas Turbine. Pneumatic bells can be as distinctive as pull bells. They are characterized by their tone, clapper rep rate and their location in the locomotive. In addition, it often takes time to get the clapper up to speed on the prototype or to shut down. When the Quantum Bell is turned on in Neutral, you will hear the wheezy sound of the pneumatic clapper starting up before the bell starts to ring and you will hear the bell fade out with soft rings along with the Short Air Let-off sound associated with turning this appliance off.

**Transition from Diesel to Turbine and Ignition:** Starting the gas turbine was a complex procedure which required considerable time for the turbine to be at full power. We have shortened the amount of time to start the turbine in the model but preserved much of the important procedures necessary to bring the turbine “on the line”.

This includes first ramping up the diesel locomotive one notch to start the turbine rotating to the point where it would fire. The firing of the gas turbine model sounds a bit like lighting a large industrial gas furnace. At this point the turbine starts revving up with its distinctive whine coupled with a low level Whoosh. The diesel is then revved up further followed by the turbine whine and whoosh increasing up to the point where the diesel disconnects and returns to idle. Shortly after this, the turbine is ramped up to full power where the Whoosh or roar now dominates the Turbine Whine.

**Transition from Turbine to Diesel:** Turning off the turbine was almost as complex as turning it on. The diesel is first ramped up to engage the turbine at full RPM. The turbine is dropped down to idle and the turbine throttle is reduced to zero. The Diesel Motor is maintained at full power to allow the turbine to cool over about 40 seconds; during this period, the Turbine Whoosh is first reduced to off while the Turbine Whine is gradually reduced to zero. After the turbine is completely shut down, the Diesel Motor returns to idle.

**Doppler Run-by:** On prototype locomotives sounds get louder as the train approaches, then immediately drop to a much lower pitch and lower volume as the train passes by. With a little practice you can change the pitch to occur exactly when and where you want. Doppler pitch change is based on the speed of the locomotive, so the sounds change more dramatically when the locomotive is running faster. After the Doppler shift has occurred and the horn is no longer being blown, the bell shuts off automatically and locomotive sounds return to normal.

**Flanges or Extended Brakes:** When a train enters a curve, the flanges on the wheels tend to ride up on the inside of the rail and squeal. Recreate this squealing effect by pressing and releasing the Brake Sound function key button quickly and repeatedly as necessary. Or for slow stops, use the same function key to produce long protracted squealing brake sounds.

**Air Brakes:** When prototype train brakes are applied, air is released from the brake lines to reduce the pressure. The more the pressure is reduced, the greater the braking. You will hear a continual air release sound from the diesel locomotive model as braking is continually increased. The longer the air is released, the quicker the gas turbine locomotive model will slow down. Once all the pressure is released, the locomotive will continue at maximum braking, which can still require a long stopping distance depending on your Load settings.

**Dynamic Brakes:** Electric motors can act as motors or generators depending on whether they are using power or generating power. When used as generators, the traction motors are disconnected from taking power from the locomotive's prime mover, and instead are connected to large resistor grids in the roof. By increasing the resistive load on the traction motors, the traction motors become harder to turn and act as brakes for the locomotive. The electric power generated by turning the traction motors is dissipated as heat by the resistor grid. These resistor arrays get quite hot and require cooling. When Dynamic Brakes are turned on under Diesel operation, the Diesel Motor sound drops to notch 1 and the Dynamic Brake cooling fan sounds come on. Under Turbine operation, the Turbine sound will drop to its lowest Sound of Power setting but since the Turbine Whoosh stays relatively constant and loud, it may be difficult to hear the Dynamic Brake sounds. Since dynamic brakes are relatively ineffective at low speeds, the Dynamic Brakes will shut off automatically below 8 smph (13 skph).

**Coupler Sounds:** To give you the most authentic coupler sounds, QSI has identified three distinct types of coupler activity. The first is when the coupler is Armed where you will hear the clanking sound of the coupler lift bar and coupler pin raising. The next is Firing the coupler, where you hear the opening of the coupler with the hiss of the air-lines parting. The third sound occurs when the locomotive couples up to its load of cars, and you hear the Coupler Crash as all the cars bunch together from the impact.

**Low Idle:** Low Idle is used on prototype locomotives to maintain a warm and ready locomotive with a minimum of fuel consumption. The special Low Idle sound has a lower base throb and is less harsh than the normal idle.

**Locomotive Shut Down (Extended):** The Air Pumps will turn off, as will Directional Lighting, followed by the sounds of the Cooling Fans shutting off, the Louvers closing, the Diesel Motors shutting down and finally, the engineer's door opening and closing.

**Locomotive Start Up (Extended):** The engineer's door will open and close, followed by vents opening, the Diesel Motor starting up, the Air Pumps starting up, and the locomotive entering normal operation.

# Appendix II

## Gas Turbine Operation

### Prototype Design and Operation

#### Introduction

The Veranda Gas Turbines were powerful locomotives, developing 4,500 horsepower with 138,000 lbs of tractive effort at start up. As a point of comparison, the N & W J 4-8-4 steam locomotive provided 80,000 lbs, and the largest steam locomotive, the UP Big Boy, provided 135,000 lbs of tractive effort. The popular GP series diesels were rated at 2000 hp with a maximum of 65,000 lbs of tractive effort. The gigantic UP DD40AX Centennials come close with 134,000 lbs of tractive effort. Later large two-unit turbines developed over 8,500 horsepower but the Veranda retained its distinction of having the largest internal combustion engine in a single power unit.

The Verandas were designed for freight operation with a top speed of 65 mph.

The advantage of all gas turbines for Union Pacific was their ability to operate on inexpensive heavy oil called "Bunker C" that was readily available on long UP desert lines. The chief disadvantages of gas turbines were their lower efficiency than diesels particularly at low speeds and their tendency towards corrosion. The Bunker C caused both fouling and corrosion of the turbine blades over time and the heavy oil was difficult to handle. Turbines carried their own steam boilers to preheat the Bunker C to 240 degrees to be suitable for combustion in the turbines. These problems combined with the increasing price of Bunker C and competition from new more efficient and powerful diesels, caused the demise of the Gas Turbines. However, the UP Verandas were a success story. They performed well for the UP from 1952 to when they were retired in the early sixties. The more advanced two unit turbines served the UP up to December of 1969 when the last gas turbine was retired.

#### Design and Description

The Veranda Gas Turbine used two different methods to power the locomotive; a 4500 horsepower gas turbine and a 250 horsepower diesel motor.

**Diesel Motor:** this was a Cummings Diesel Motor that powered three different machines:

1. **Diesel Generator:** The diesel generator, in turn, had three different functions:
  - a) Provide electrical power to charge batteries and power for d-c auxiliaries when turbine power was shut down.
  - b) To motor one of the main traction generators to crank turbine for starting.
  - c) To power two of the eight traction motors low power locomotive movement in the yard (hostling). During hostling, there was no battery charging or air compressor operation.
2. **Diesel Alternator:** This was belt driven from the diesel motor to provide three-phase a-c auxiliary power to run the radiator-fan motors, starting fuel-pump motor, and water booster-pump motor until turbine is up to idling speed.
3. **Air Compressor:** This was also belt driven from the diesel motor to pump up main reservoir air pressure until the two motor driven air compressors take over during battery charging. This is primarily intended for use during hostling and turbine cranking.

The diesel motor was not used to provide additional power during normal operation or when starting the locomotive from a dead stop.

**Gas Turbine:** This was the main power plant rated at 4,500 horsepower. It is an oil burning, axial flow gas turbine. It delivers power through a single reduction gearbox to drive four traction generators, an auxiliary generator and a turbine alternator.

The traction generators are excited by four amplidyne exciters and furnish power to eight traction motors. Power is controlled in 20 steps by the main handle of the master controller. There are four independent power circuits, each consisting of a traction generator and two traction motors. The following connections are obtained during locomotive operation:

1. Series-connected traction motors, full field.
2. Series-connected traction motors, shunted fields.
3. Parallel-connected traction motors, full field.
4. Parallel-connected traction motors, shunt fields.

**Transitions are automatically controlled as a function of locomotive speeds.**

While the field current was determined as a function of speed, the series parallel connection of the motors was determined by selection handle. The choices of the selection handle were OFF at the left followed by motor position, M1, motoring position M2, and BRAKE to the right.

The turbine alternator is a three-phase, six-pole machine driven by the turbine and supplies power to the a-c auxiliary system.

The auxiliary generator driven by the turbine furnishes power for d-c auxiliaries and battery charging when turbine is running and "on the line".

## Operation

The Turbine Control Switch, TC, has four positions and along with the Turbine Control Switch Light, controls and monitors diesel-motor and turbine operations.

### Starting the Diesel Motor (TC1):

1. Move TC switch to position 1 and all necessary switches and breakers must be closed.
2. Close battery switch BVS.
3. Close breaker TB1 – Turbine generator, Diesel Start.
4. Close breaker TB3 – Coolant pump.
5. Close breaker TB12 – Diesel alternate field (this breaker should normally be left closed). The following sequence will happen:
  - Coolant water pressure switch picks up.
  - Battery charge timing relay, **T-BC**, picks up.
  - Fuel pressure relay, **FPR** picks up.
  - **MF TEMP** lamp lights.
  - **LUB PRS** lamp lights.
  - Sequence relay, **T-SQ**, picks up.
  - Fuel dump solenoid valve, **FDSV**, is energized.

Momentarily depress the locomotive-start button, **ES**.

- a) The diesel crank timing relay, T-DC, picks up and remains closed for 20 seconds. Engine cranks for 20 seconds and fires within this period.
- b) Ten seconds later battery charging power is supplied from diesel generator.
- c) After battery charging commences, the motor driven train air compressors run to supply main reservoir air. Also the diesel alternator is excited to furnish ac auxiliary power to necessary ac auxiliaries only. At this time, lights can be turned on.

**Note:** The turbines diesel did not have an air start. It was also started from the batteries.

The diesel motor can now be used to do hostling of the locomotive. Because of the notoriously inefficient operation of the gas turbine power plant at idle and low speeds, hostling was usually done using the diesel motor. To move the locomotive using the diesel motor:

- 1) Close propulsion control breaker, TB4.
- 2) Move reverse handle to FORWARD or REVERSE.
- 3) Move Selector Handle to M1 position.

**Note:** When operating the diesel, the selector handle connects motors in series, M1, or in parallel, M2. Maximum diesel RPM in M2 is 843 rpm.

- 4) Advance throttle to 1<sup>st</sup> and then to 2<sup>nd</sup> notches.
- 5) To increase speed above 10 mph, move throttle handle to IDLE, then move Selector Handle to motoring position, M2, and again advance throttle handle to notch 1 and then to 2.

**Note:** The UP operation manuals do not seem to indicate the top speed in M2. Using the speed ratios for an F7 between series and parallel connections gives a speed ratio of 2.79 independent of gear ratios. I would guess the same holds true for the Turbine diesel. This would give a top speed of about 28 mph.

**Note:** In the Mighty Turbine video and on independent recordings, there is a high pitch whine when the motor is idling. Since it does not seem likely that the diesel motor would have a turbo and the turbine is not running, this is likely the sound of the gearbox.

## **Turbine Cranking (TC2)**

When Turbine Control Switch, **TCS**, indicating lamp (green) on engineer's instrument panel lights, **TC** Switch can be advanced to **Position 2**, at which time the following occurs in the sequence listed below which takes about 3-5 minutes:

- TCS lamp goes out.
- Battery charging and motor driven air compressors nullified.
- Diesel generator is coupled to traction generators G4 to crank turbine (with diesel engine operating at idling speed).
- When turbine reaches 10-15 percent of speed (about 700 rpm), a limited amount of diesel fuel is admitted to turbine.
- Ignition is turned on.
- Atomizing air is fed to turbine.
- Turbine fires.
- Generator main field is weakened.
- Diesel engine governor is advanced to top speed.
- Turbine accelerates toward top speed.
- Generator G4 uncouples from diesel generator and turbine operates at IDLE speed.
- Diesel engine returns to IDLE speed and diesel generator reconnected for battery charging and air compressor operation.
- Turbine alternator furnishes power to traction motor blower motors, amplidyne drive motors, main lube pump motor.

## **Fuel Transfer (TC3)**

When TCS green indicator lamp again goes on after the above 3-5 minute sequence finishes, TC switch can be moved to position 3. The following then occurs over about one minute:

- Turbine auxiliary generator (dc) takes over battery charging function and supplies control power. Air compressors come on line.
- Fuel transfer mechanism operates progressively to transfer fuel from diesel oil to "Bunker C" within 40 seconds.

## Turbine “ON THE LINE”

When **TCS** green indicator lamp relights after the 1-minute sequence above, **TC** Switch can be moved to position 4.

- Diesel motor shuts down.
- Turbine alternator takes over to supply auxiliary ac power to all ac motors.
- Turbine is “on the line” and locomotive is ready for operation.

### Setting Turbine Speeds

Under normal conditions, turbine speed is adjusted for idle speed of 5,175 rpm using rheostat R# while having the turbine running in TC4, TH, IDLE, RH OFF and SR OFF. To adjust top speed, install reverse handle, throttle up to notch 13 slowly and adjust rheostat, R14A. Top speed is 6900 plus or minus 70 rpm.

### Moving the Locomotive Under Gas Turbine Power”

- Move reverse handle to FORWARD or REVERSE, depending on direction desired.
- Move selector handle to MOTORING position **M1** or **M2** position as required.

**Note:** The Selector Handle sets the turbine at idle in motor position, M1, or full turbine operation, M2.

- Make sure handbrake is released
- Advance throttle handle as quickly as possible to the position that starts locomotive. Observe limitations of loadmeter and do not permit notching guide pointer to make prolonged indications in the RED band. Reduce throttle position if necessary.
- Operate locomotive according to loadmeter and notching guide limitations.

### Stopping the Locomotive”

- Move throttle handle to IDLE and apply air brakes.
- If leaving engineers position, move selector and reverse handles to OFF.

### Dynamic Brakes”

- When Selector Handle is moved to Brake, the turbine goes to idle and dynamic brakes are applied. Resistor grid cooling fans come on automatically.

### Reversing the Locomotive

- Bring locomotive to a full stop.
- Move reverse handle to opposite direction.
- Release brakes.
- Continue operation according to *Moving the Locomotive Under Gas Turbine Power* described above.

### Shutting Down the Locomotive

- Turn turbine control switch, **TC**, to position 1. Diesel motor automatically starts and gas turbine shuts down in approximately 4½ minutes.

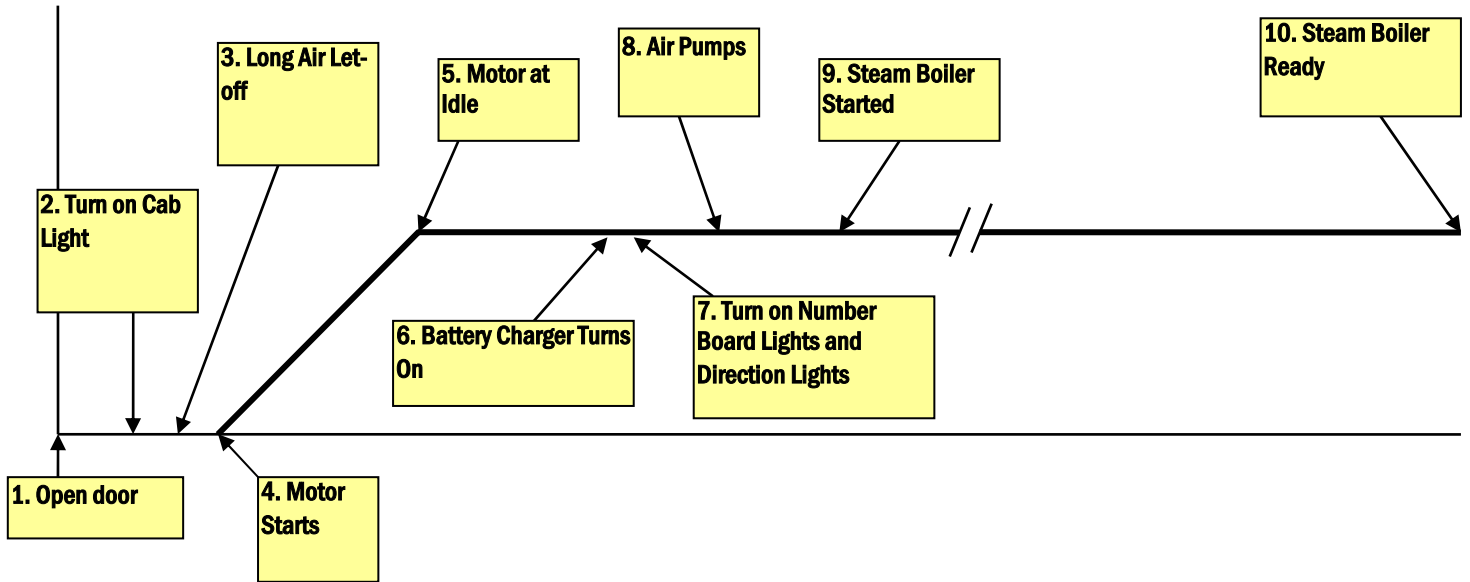
**Note:** When fuel was cut to the turbine, without power, it probably took only about thirty seconds to completely stop. However, the diesel was allowed to operate to run the turbine with just air moving through the blades. I understand this was done to prevent heat damage to the blades. Assume that the diesel motor continued at full speed for about forty minutes followed by the diesel shutting down to idle, followed by the turbine winding down to off.

### Leaving the Locomotive

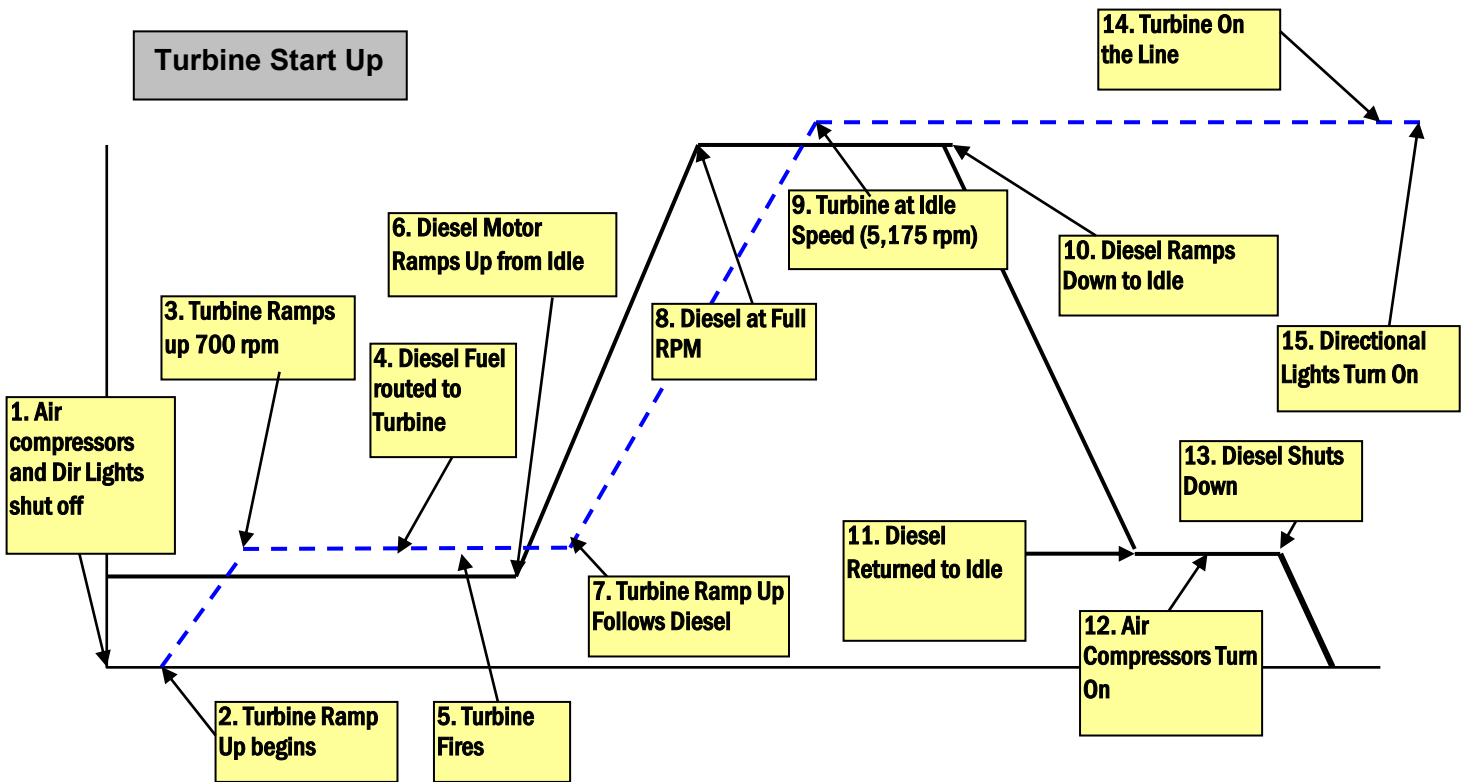
- Set handbrake and close windows and doors.
- Move throttle handle to OFF.
- Move selector handle to OFF.
- Move reverse handle to OFF and remove handle.

Approximate Prototype Event and Timing Graphs

### Diesel Start Up

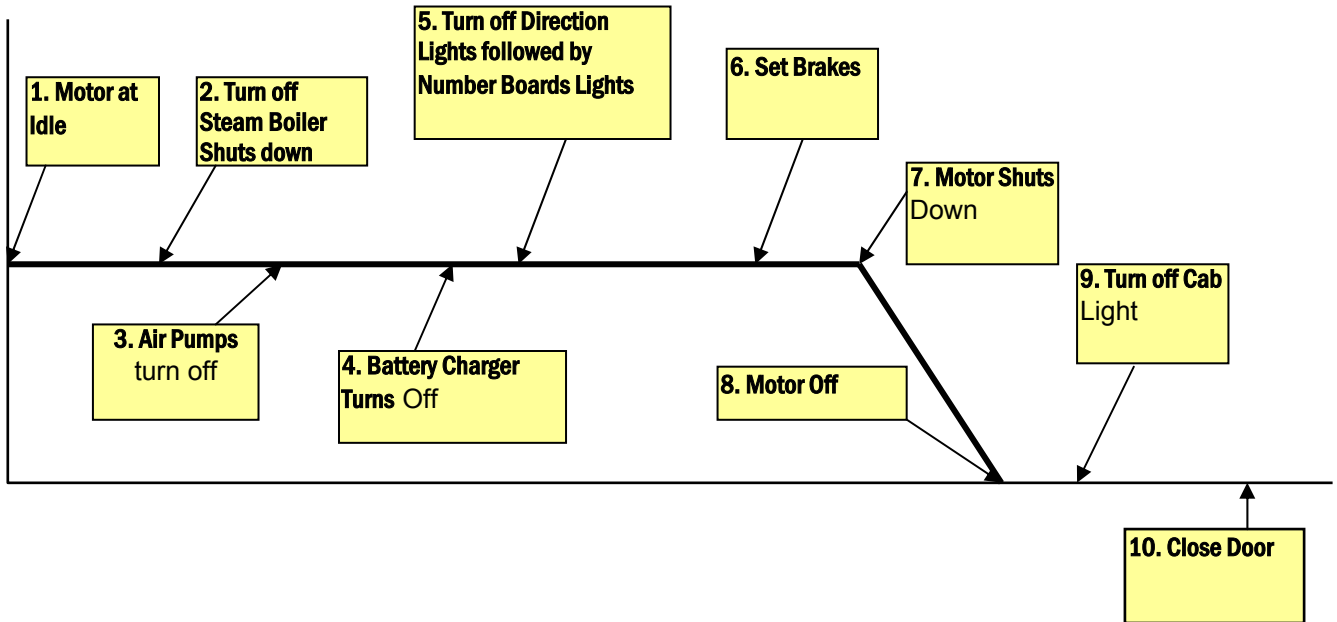


### Turbine Start Up

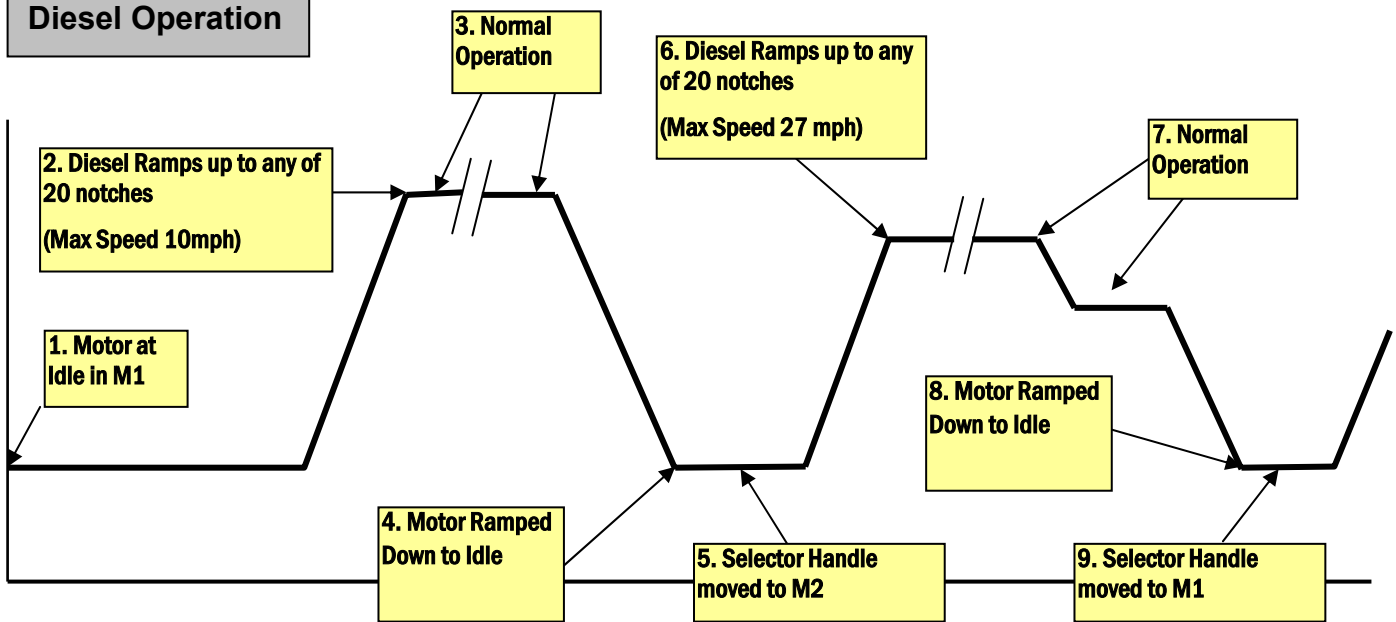




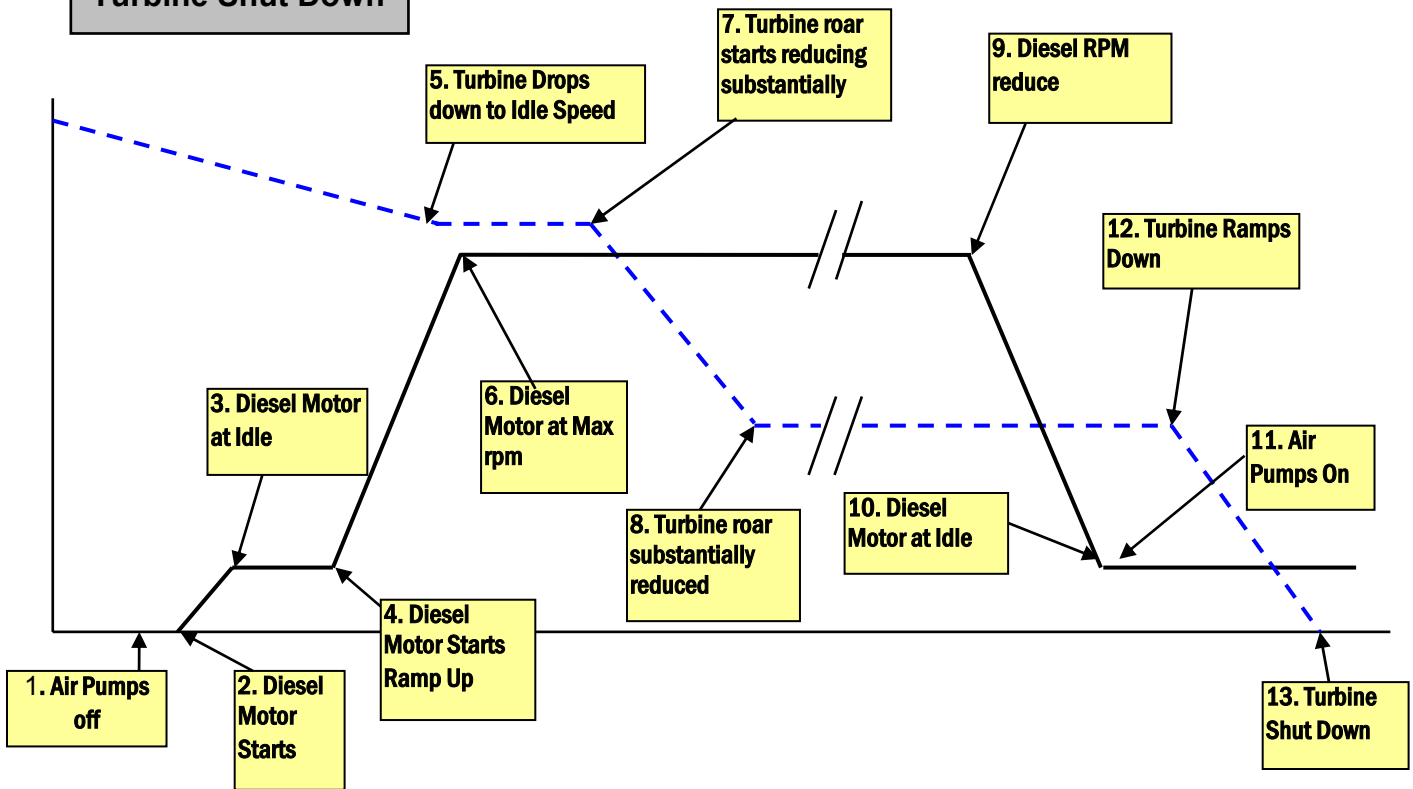
## Diesel Shut Down



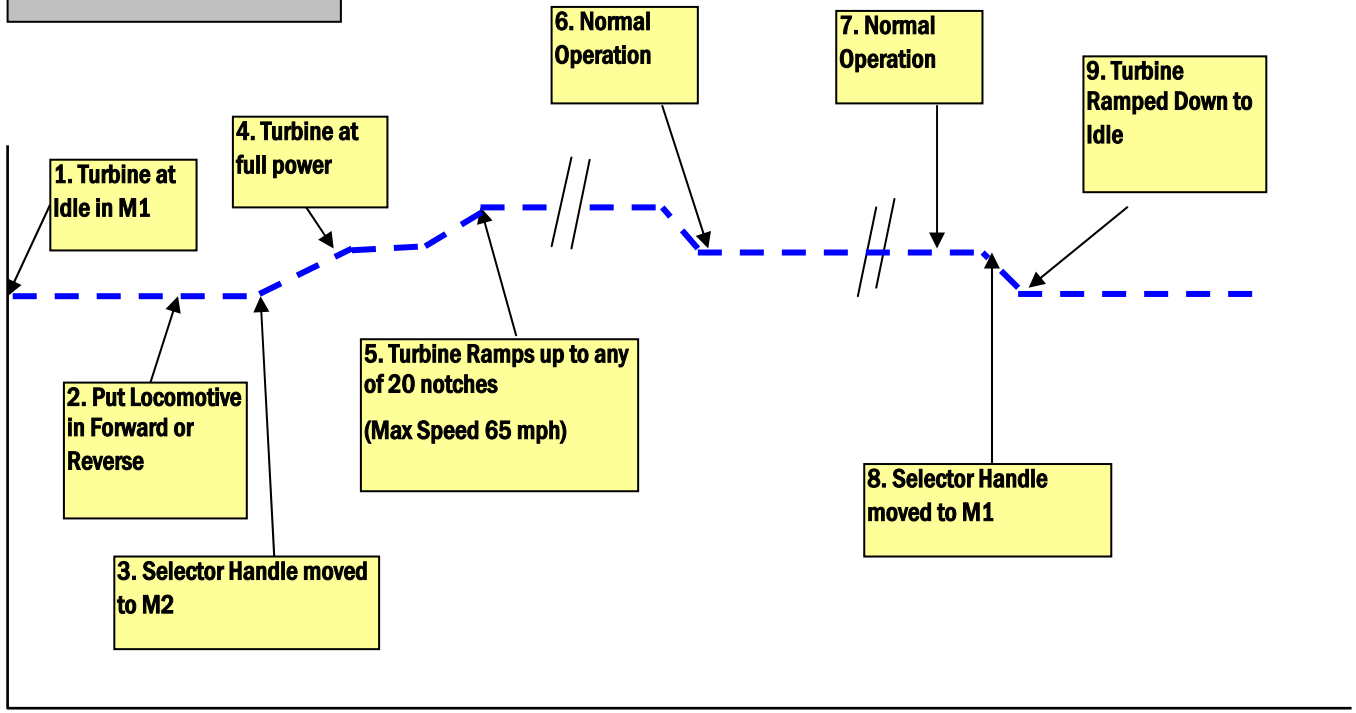
## Diesel Operation



## Turbine Shut Down



## Turbine Operation



# DCC Operation for Quantum Gas Turbine

## Introduction

The Gas Turbine will initially start and operate as a standard diesel locomotive except that the speed is limited to 25 smph to model the lower power of the prototype locomotive when operated with the small 250 hp Cummings diesel.

These steps will allow you to start operating your Quantum equipped gas turbine locomotive immediately using any DCC system that is compatible with the applicable NMRA DCC specifications.

1. Select locomotive number 3.
2. Set your DCC controller to 128 (preferable) or 28 (acceptable) speed step range.
3. Start your locomotive immediately by pressing the F6 DCC function key<sup>122</sup> to hear the diesel Start Up sounds. Number Board Lights will be on and Directional Lighting System (Headlight, Locomotive Reverse Light and Tender Reverse Light, Mars Light) will be on. Use the FL or FO key to turn on/off the Directional Lighting System.
4. Increase the throttle to leave Neutral and start the locomotive moving. The locomotive will start out slowly due to special Quantum Inertial Control™ that resists rapid increases or decreases in speed. When you reduce the throttle to zero, you will hear a Short Air Let-off when the locomotive stops moving indicating that it has entered Neutral; a Long Air Let-off will occur about one second later, followed by Air Pumps and other background sounds<sup>123</sup>.

The direction of your locomotive will change when you press the direction key on your DCC throttle.

### Locomotive Inertia Effects

Your new locomotive is pre-programmed at the factory to use Regulated Throttle Control (RTC) in DCC operation. A model locomotive under RTC operates as though it has the mass and inertia of a prototype locomotive. As a result, your locomotive will resist starting up too quickly if at rest and will resist changes in speed once moving. It takes a little practice to learn to move the throttle slowly and wait until the locomotive responds. If you prefer that your locomotive respond almost immediately to the throttle, it may be reprogrammed to use Standard Throttle Control (STC) in CV 56.4.

**Note:** Under RTC, in Diesel Mode, the locomotive will only travel up to 25 smph<sup>124</sup>; any speed setting above 25 smph in Diesel Mode will not increase speed but will cause the motor sounds to be more labored.

The direction of your locomotive will change when you press the direction key on your DCC throttle.

## Function Keys

The following table lists features that have been pre-assigned to your DCC function keys. Operation of these keys can be different in the Neutral state (locomotive stopped) and the Motive states (locomotive moving in Forward or Reverse). After you have selected your locomotive, simply press any of the function keys listed below to produce the described effects.

Function Key*	Forward and Reverse	Neutral
F0 or FL or Headlight	Directional Head, Reverse and Mars Lights on/off**	Directional Head, Reverse and Mars Lights on/off
F1	Bell on/off	Bell on/off
F2	Horn or horn with Doppler Effect (see below)	Horn on/off
F3	Coupler Crash/Coupler Fire	Coupler Arm or Coupler Fire
F4	Cooling Fans on/off	Cooling Fans on/off
F5	Dynamic Brake function on/off	Dynamic Brake function on/off (in "Disconnect" only)
F6	Initiate Doppler Effect	Start Up
F7	Squealing Brake/Flanges and Air Brakes	Toggle Diesel or Gas Turbine modes
F8	Audio Mute on/off	Audio Mute on/off

\*\*Directional Headlight, Reverse and Mars Lights are assigned to Multiple Automatic Lights #1.

<sup>122</sup> It does not need to be F6; any function or speed command for a locomotive that is not in Shut Down will activate the locomotive.

<sup>123</sup> Neutral sounds also include Cooling Fans with Vents opening and closing that turn on and off randomly.

<sup>124</sup> Because of the limited power of the Cummings diesel, top speed for a prototype in Diesel mode was less than 25 mph. Quantum operation under Regulated Throttle Control (RTC) will also limit the top speed to 25 smph (see Regulated Throttle Control on Page 5)

Function Key*	Forward and Reverse	Neutral
F9	Heavy Load on/off	Disconnect/ Standby/ Shut Down
F10	Locomotive's Speed Report	Status Report
F11	Multiple Automatic Lights <sup>125</sup> #2	Multiple Automatic Lights #2
F12	Multiple Automatic Lights #3	Multiple Automatic Lights #3

\* Quantum supports the new NMRA 0-12 function key standard; the old 0-8 standard is not supported.

If you have a DCC command station that supports only the older 0 to 8 function key standard, you will have no way to initiate Shut Down in Neutral with these pre-assigned feature to function key mappings. There is an interim solution to this problem; Swap the features assigned to the F4 and F9 outputs in Neutral by doing the following:

Set CV49 to 6, set CV50 to 1, and set CV53 to 145. Now F4 in Neutral controls Shut Down.

Set CV49 to 11, set CV50 to 1, and set CV53 to 8. Now F9 in Neutral controls Diesel Cooling Fans.

## Automatic Features

Automatic Quantum Features depend on the directional state of the locomotive. Automatic Control can be enabled or disabled by their indicated function keys. The state of each Automatic feature in each direction is shown in the table below.

Feature	Function Key	Forward	Neutral from Forward	Reverse	Neutral from Reverse
Headlight	F0 or FL	Bright	Off	Off	Off
Reverse Lights	F0 or FL	Off	Off	Bright	Off
Mars Light	F0 or FL	Strobing	Steady On	Steady On	Steady On
Number Board Lights		On	On	On	On
Marker Lights		On	On	On	On
Vents & Cooling Fans	F4	Off	On at Random Times	Off.	On at Random Times

When an indicated function key enables an “automatic” light feature, the associated lights operate according to the states shown in the table. For instance, enabling the Automatic Reverse Light in Forward will not cause the Reverse Light to turn on since its automatic behavior would have them off in that directional state; however, if you then entered Reverse, the Automatic Reverse Light would turn on. When an indicated function key disables an “automatic” feature, all lights will be off. For instance, disabling “Automatic Reverse Light” will immediately shut off the operating Reverse Light and it will not turn on again until the automatic feature is enabled.

**Note:** Reverse Light operation applies simultaneously to both the Locomotive Rear and the Tender Reverse Lights. These lamps are wired together when the tender is plugged in and are not under separate Quantum control.

**Note:** Use CV 55 to change the behavior of lights from what is described in the above table.

**Note:** Lights and other features can be assigned to function keys and configured to different kinds of operation and initial conditions in CV 53 (Output Feature Assignment) and CV 55 (QSI Feature Configuration). See the Quantum DCC Reference Manual, version 4.

# Changing between Diesel and Gas Turbine Mode

## Changing From Diesel Mode to Turbine Mode

The Gas Turbine locomotive comes from the factory in Diesel Mode. Because of the limited power from the diesel motor in the prototype, the model will be limited to 25 smph or less in Diesel Mode. To achieve full power from your model for mainline operation, you will need to change to Turbine Mode. There are two ways to do this.

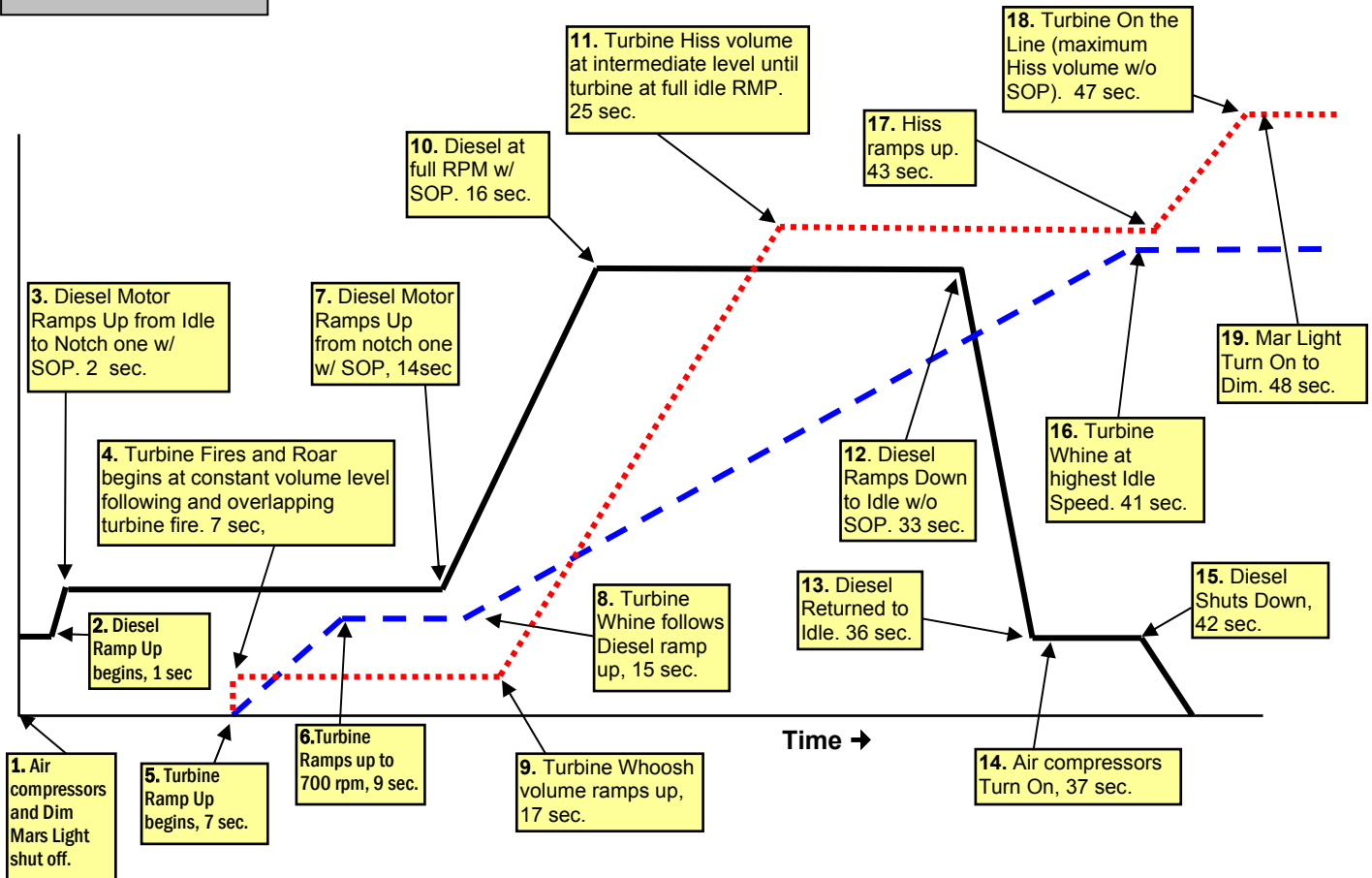
- Press the horn button four times to produce four short horn hoots in Neutral.
- Press the F7 key in Neutral.

The locomotive will go through a complex Turbine Start Up scenario as depicted in the graph below. At the start of the transition to Turbine Mode, the Mars Light will change from Dim to Off. When the transition scenario is completed, the Mars light will change from Off back to Dim.

**Note:** Turbine fire is a distinctive sound that sounds like a giant gas furnace being ignited.

<sup>125</sup> No lights are currently assigned to Multiple Lights #2 or #3 features and hence F11 and F12 will have no affect. See CV 55 in DCC Reference Manual, Version 4, for more information on Multiple Lights.

## Turbine Start



There are three operations shown.

- The solid black lines show the volume and rpm operation of the diesel motor.
- The dotted blue line with large dashes shows the volume and rpm of the Turbine Whine.
- The dotted red line with small dashes shows the volume of the Turbine Whoosh.

The yellow boxes indicate major events in the transition to Turbine Mode. The timing shown in each box indicates the number of seconds since the transition command was sent to start Turbine Mode.

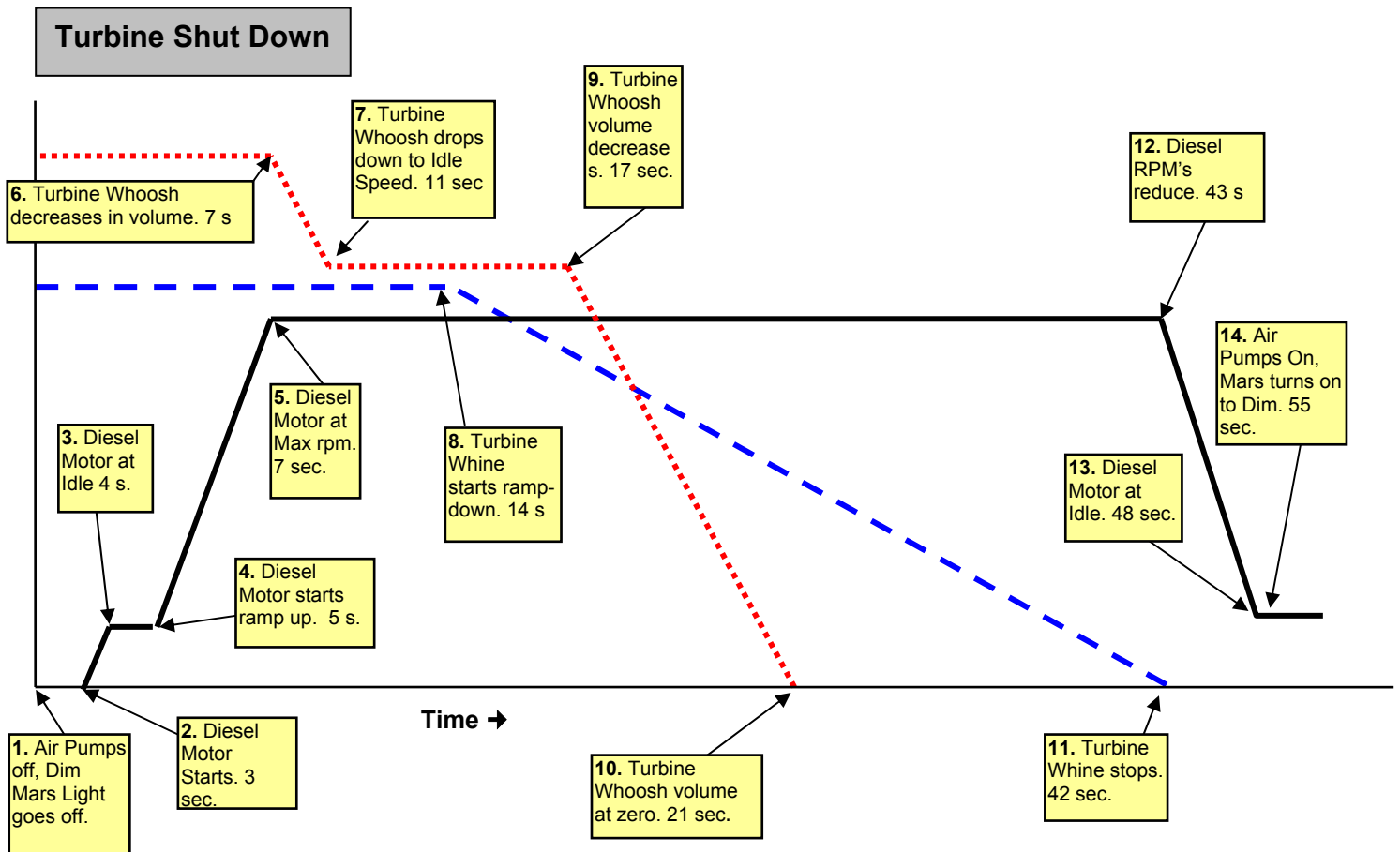
**Note:** Turbine fire is a distinctive sound that sounds like a giant gas furnace being ignited.

## Changing from Turbine to Diesel Mode Diesel Mode to Turbine Mode (F7)

There are two ways to return to Diesel Mode from Turbine Mode.

- Press the horn button four times to produce four short horn hoots in Neutral.
- Press the F7 key in Neutral.

The locomotive will go through a complex Turbine shut down scenario as depicted in the graph below. At the start of the transition to Diesel Mode, the Mars Light will change from Dim to Off. When the transition scenario is completed, the Mars light will change from Off back to Dim.



**Notes:** The following is a list of operational issues when changing between Diesel and Turbine Mode:

- F7 must be set to “1” in Neutral to activate transitions between diesel to turbine or turbine to diesel. If F7 is already set to 1, set to 0 and then set to 1.
- After the Turbine whoosh starts reducing, the Diesel locomotive will continue at maximum RPM for 36 seconds to model the Turbine cool down process.
- Cooling fans and vent opening sounds only occur in Diesel Mode.
- Mars Light, Air Pumps, Cooling Fans and other Neutral Sounds will be suspended during transition from Turbine Mode to Diesel Mode or from Diesel Mode to Turbine Mode, like the prototype.
- If locomotive is in Turbine Mode or Diesel Mode when power is shut off, the engine will power up in the same Mode when power is reapplied.
- If locomotive is at any point in transition from Turbine to Diesel Mode, it will power up in full Diesel Mode when power is reapplied with standard rapid diesel start up sounds.
- If locomotive is in Turbine Mode or in transition from Diesel to Turbine Mode when power is shut off, Turbine sounds will sequence through rapid turn on operation instead of artificially and abruptly producing full Turbine sounds when power is reapplied.
- If the locomotive is in any point in the transition from Diesel Mode to Turbine Mode, and the throttle is turned up to leave Neutral, the locomotive will terminate Diesel/Turbine transition and rapidly enter full Turbine operation in Turbine Mode.
- If the locomotive is at any point in the transition from Turbine Mode to Diesel Mode, and the throttle is turned up to leave Neutral, locomotive will terminate Turbine/Diesel transition and enter Diesel Mode.
- A power cycle or a Software Reset will not change from Diesel Mode to Turbine Mode or from Turbine Mode to Diesel Mode. A Hardware Reset using the jumper will always return the locomotive to Diesel Mode.

- It is disallowed to move back and forth between Turbine and Diesel Mode when the locomotive is in transition between either Mode. The transition process must be completed before another transition can be initiated.
- Transition from Diesel to Turbine Mode or transition from Turbine to Diesel Mode will only happen in Neutral. Neither the Turbine/Diesel transition by a coded horn (four short horn hoots) or the F7 key will have any affect on changing modes in Forward or Reverse.
- If the locomotive was in Turbine Mode, it will return to Diesel Mode prior to any shutdown operation (F9). The locomotive will start up and stay in Diesel Mode when Start Up (F6) is activated after any shutdown operation. To return to Turbine Mode the transition from Diesel to Turbine Mode must be activated.
- The coded horn Turbine/Diesel Mode toggle can be disabled in DCC in CV 52.2 bit 1. Enable =1 (default) and Disable =0.

## Sound-of-Power™

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Your Gas Turbine locomotive will produce labored sounds under acceleration and lighter sounds under deceleration but only if CV 3, or CV 23 and CV 4, or CV 24 are set to non-zero positive values. The level of labored sounds is proportional to the values for these four CV's, and how much the throttle is increased or decreased. Labored sounds will be heard in either Diesel or Turbine Mode.

**Diesel Motor RPM:** Quantum has eight motor throttle “notches” found on most prototype diesel locomotives. As you increase the throttle, you will hear the RPM's increase for every increase in ten speed steps (at 128 speed step setting). Idle is considered Notch 1 and occurs for speed step 0. Notch 2 ranges from 1 to 10, Notch 3 from 11 to 20, Notch 4 from 21 to 30, etc. If your controller has an option to increment or decrement your throttle set setting by ten speed steps, it is very easy and predicable to set your notch value.

**Turbine Whine and Whoosh** will change with the throttle only slightly over the entire throttle range since the turbine was often run near full RMP at all times. Although the changes in Turbine sound are not as dramatic as changes in diesel RPM's or volume, they are nevertheless quite noticeable.

## Coupler and Coupler Crash Sounds (F3)

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There are two ways to use the F3 key.

- As your locomotive is about to couple up to a string of cars, press the F3 key to trigger the crashing sound of locomotive coupling. Use the F3 key again as the engine moves out to trigger the same sound as the slack is taken up in the cars.
- Use the F3 key in Neutral to produce uncoupling sounds as you disconnect cars over uncoupler magnets. Press the F3 key once to produce the sound of the lift bar and coupling pin being raised. This first press also arms the uncoupling sound effect. Press the F3 key again while moving or in Neutral to trigger the sound of the coupler knuckle opening and air-lines parting.

## Horn and Bell Buttons (F2, F1)

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Some DCC controllers have separate horn and bell buttons along with function keys assigned to horn and bell operation. The bell is usually assigned to F1 and the horn is usually assigned to F2. The F2 key behaves differently than using the horn button.

- Pressing the F2 key and releasing it will cause the horn command to come on and stay on, until you press F2 again.
- Pressing the horn button will send the horn command only as long as you hold the button down.

Pressing the F1 key and releasing it will cause the Bell to come on and stay on, until you press F1 again. There is no difference in operation between the bell button and its corresponding function key.

**Note:** Since the prototype used compressed air for horn operation, you will hear the Air Pump sounds turn on after the Horn is operated.

## Doppler Operation (F6)

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With DCC, you can trigger the Doppler Effect by quickly interrupting the horn signal in the same way as described under Analog Operation. Or, you can use the function key (F6) assigned to the Doppler Effect.

- Start the Horn and/or Bell by pressing and releasing their function keys.
- Press F6 to hear the Doppler shift. A few seconds after the horn button is turned off with the F2 key the locomotive sounds return to normal.

**Note:** If you do not turn on either Horn or Bell, the Doppler shift will still occur but will be less dramatic.

**Note:** If the Bell was on, it will shut off prior to sounds returning to normal.

## Squealing Brake and Flange Sounds (F7)

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Quantum provides automatic brake squeal as a locomotive slows to a stop. The operator can also control squealing sounds for continuous and variable brake sounds for protracted stops or to simulate the sounds of squealing wheel flanges on curved track.

- To enable Automatic Squealing Brakes, operate the locomotive over 40 smph (64 skph). Squealing brakes sounds will then sound automatically when the speed is reduced to less than 20 smph (32 skph).

- Pressing the F7 key when the locomotive is moving at any speed will manually activate Squealing Brake sounds, and repeated pressings while the Squealing Brake sounds are occurring will continue the sounds uninterrupted.

**Note:** If you slow the locomotive too quickly, the brake sounds will terminate abruptly when the locomotive stops and enters Neutral.

**Note:** If you lower your throttle to speed step 0 on a moving locomotive, the F7 key will apply Air Brakes to slow the locomotive. See next section.

## Dynamic Brakes (F5)

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The prototype Gas Turbine locomotive has dynamic brakes that cause the train to slow down by using the traction motors in generator (rather than motor) mode. This method of braking dissipates the energy of a moving train by converting it to electrical power, which is then applied to a large air-cooled resistor load in the locomotive.

- Pressing the F5 key in Forward or Reverse will set the locomotive Diesel Motor or Turbine sound to idle at the lowest Sound of Power setting and turn on the powerful Dynamic Brake cooling fans.
- Pressing the F5 key in Neutral and Disconnect (see Shut Down above), will turn on the Dynamic Brake Fans while Diesel Motor sounds remain at idle.

Dynamic Brakes automatically turn off when entering or leaving Neutral, when locomotive speed drops below 7 smph (11 skph)<sup>126</sup>, or when the throttle is turned up. Dynamic Brakes cannot be turned on in Forward or Reverse unless the locomotive is traveling over 8 smph (13 skph).

**Note:** In contrast to Air Brakes (F7), Dynamic Brakes do not increase the deceleration rate specified by CV 4 and CV 24.

**Note:** Dynamic Brakes sounds will be barely audible over the Turbine roar in Turbine Mode.

**Note:** Mute Volume can be programmed in CV 51.1.

## Three Stages of Shut Down: 1. Disconnect, 2. Standby, 3. Total Shut Down (F9)

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Locomotive Shut Down has three distinct stages that you can control. Each stage is entered by double pressing the F9 key<sup>127</sup>. If the locomotive is in Turbine Mode, any shut down operation will automatically return it in Diesel Mode prior to the shut down operation.

### Stage One: Disconnect

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- Double press the F9 key in Neutral to enter Disconnect. You will hear a Long Air Let-off. The motor drive will be disabled. If the locomotive was in Turbine Mode, it will return to Diesel Mode. The DCC throttle can be moved up and down without the locomotive moving. As the throttle is moved up or down, you will hear the Diesel Motor rev up and down in proportion to the throttle setting.
- To leave Disconnect, either double press the F6 Start Up key, as described in the Start Up section or double press the F9 key again to reach Standby, the next stage of Shut Down.

**Note:** In Disconnect, you can also turn on the Dynamic Brakes (see description of Dynamic Brakes below) to create Sound-of-Power as the throttle is moved up and down. Engineers on prototype diesels use dynamic brakes to load the motor-generator to test its output efficiency while the locomotive remains stationary.

### Stage Two: Standby

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- Double press the F9 key while in Disconnect to enter Standby. You will hear a Long Air Let-off followed by a special “Low Idle” sound. The Directional Lighting and optional Ditch Lights or Mars Light will shut down.

**Note:** The motor will remain disconnected, while the Air Pumps, automatic Cooling Fan operation, Number Board Lights and Marker Lights will continue to operate. In Standby, the locomotive will not respond to throttle or function keys<sup>128</sup>. The three exceptions are the F6 Start Up Key, the F8 Mute Key and the F10 Status Key.

- To leave Standby, either double press the F6 Start Up Key, as described in the Start Up section, or double press the F9 key again to reach the final stage of Shut Down: Total Shut Down.

**Note:** Standby is ideal for leaving your locomotive running on a siding. Besides hearing the Low Idle diesel motor sounds, the locomotive will not respond to accidentally changing the throttle setting or pressing the function keys.

### Stage Three: Total Shut Down

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Total Shut Down allows the operator to take the locomotive “off line” (turn off sounds, lights, ignore throttle settings and function commands) independent of the operating session: the locomotive will still be “off line” when power is reapplied for the next operating session, regardless of whether the next session is Analog (conventional DC) or DCC.

<sup>126</sup> Dynamic Brakes on prototype locomotives are less effective and are seldom used at low speeds.

<sup>127</sup> Double pressing ensures that Shut Down stages are not entered or exited accidentally. Double pressing is defined as two F9 commands sent within two seconds. Note that the F9 key may have to be pressed three times, due to the DCC command station and locomotive having different initial states for F9.

<sup>128</sup> Pressing a function key will only produce a Short Air Let-off.



- Double press the F9 in Standby to enter Total Shut Down. You will hear a Long Air Let-off. The Air Pumps will turn off, followed by the sounds of the Cooling Fans shutting off, the louvers closing, the Diesel Motor shutting down. A few seconds later you will hear the engineer's door open and then shut.

**Note:** In Total Shut Down, the locomotive will not respond to throttle or function keys. The two exceptions are the F6 Start Up Key (described below) and the F10 Status Key.

- To leave Total Shut Down, double press the F6 key.

**Note:** If power is turned off at any stage of Shut Down (Disconnect, Standby or Total Shut Down) or during a Shut Down procedure, the locomotive will remember the last Shut Down stage it was at during power down, and the locomotive will power up in the same stage. If Start Up is initiated during any of the above Shut Down procedures, Shut Down is aborted, and locomotive will return to normal Diesel Mode operation.

## Start Up (F6)

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If Gas Turbine locomotive is in any stage of Shut Down, you can return it to normal operation by double pressing<sup>129</sup> the F6 key. Start Up will be different for each stage of Shut Down, but all will start up with a Long Air Let-off and will enter normal Diesel Mode operation.

**Start Up from Disconnect:** If you double press the F6 key in Disconnect, the locomotive will produce a Long Air Let-off, Dynamic Brakes will shut off (if on) and the locomotive will enter normal Diesel Mode operation.

**Start Up from Standby:** If you double press the F6 key in Standby, the locomotive will produce a Long Air Let-off, Directional Lighting will turn on, the Diesel Motor sound will change from the special Low Idle to regular Idle, and the locomotive will enter normal Diesel Mode operation.

**Start Up from Total Shut Down:** If you double press the F6 key in Total Shut Down, the locomotive will produce a Long Air Let-off, you will hear the engineer's door opening and closing, and see the Mars Light will turn on steady. These actions are followed by the sounds of vents opening, the Diesel Motor starting up, the Air Pumps starting up, followed by a Long Air Let-off and the locomotive entering normal Diesel Mode operation.

**Note:** During the Start Up procedure, none of the DCC function keys are active. However, if the throttle is turned up from zero during any of the above Start Up procedures, the Start Up procedure will abort and the locomotive will enter normal operation.

## Mute (F8)

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The Quantum System allows you to reduce the System Volume to a lower level or increase it back to its original setting using the F8 function key. This capability is useful when you need to reduce the sound to engage in a conversation or to answer the phone. If you have many trains operating at once, you can reduce the volume on all those that are running in the background of the layout and increase the volume of the closest locomotive. The Mute feature changes the sound gradually over a second or two, which allows the sound to increase or decrease realistically as the locomotive approaches or recedes from the observer.

- Press the F8 key in Neutral or Forward/Reverse to gradually decrease or increase the locomotive's volume.

**Note:** Mute state is not maintained if power is turned off and then turned back on; the locomotive will return to full system volume setting.

**Note:** Mute Volume can be programmed in CV 51.1.

## Function Key Operation in Neutral

---

Some function keys used in Forward and Reverse will have different effects when used in Neutral:

- The F7 key produces Squealing Brake Sounds for a moving locomotive but produces Diesel/Turbine transitions in Neutral.
- Pressing F6 results in Doppler shift for a moving locomotive but activates Start Up in Neutral.
- Pressing F9 enables Heavy Load in a moving locomotive but activates Shut Down in Neutral.

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<sup>129</sup> Double pressing ensures that Start Up is not entered accidentally. Double pressing is defined as two F6 commands sent within two seconds. Note that the F6 key may have to be pressed three times, due to the DCC command station and locomotive having different initial states for F6.

# DCC Programming for the Gas Turbine

Most DCC command stations currently available will program Quantum equipped locomotives in Service Mode<sup>130</sup> on a programming track or Operations (Ops) Mode on the main track. In Service Mode, your locomotive (if queried) will report back CV values to your command station. In Ops Mode, reports are verbal using the locomotive sound system.

## Changing the System Volume Electronically in CV 51.0

You can change the volume either manually (as described in the *Special Operation and Troubleshooting* section) or electronically using QSI CV 51.0 in DCC. To change volume in Service or Ops Mode, do the following:

- Set CV 49 to 0.<sup>131</sup>
- Enter the System Volume in CV 51. The System Volume can be set to any value between 0 (no sound) and 127 (100%). The default System Volume is 127.

**Note:** When you change the System Volume in Ops Mode, you will immediately notice the change in volume.

**Note:** System Volume changes in DCC also apply to Analog and vice-versa.

## Changing the Mute Volume Electronically in CV 51.1

To change the Mute Volume in Service or Ops Mode, do the following:

- Set CV 49 to 1.
- Enter the Mute Volume in CV 51. The System Volume can be set to any value between 0 (no sound) and 63 (100%). The default Mute Volume is 0.

**Note:** When you change the Mute Volume in Ops Mode, and the locomotive is muted, you will immediately notice the change in Mute Volume.

**Note:** The effective Mute Volume level will be the smaller of the Mute Volume setting or one-half the current System Volume. In other words, the effective Mute Volume will never be more than one half of the System Volume.

## Enable/Disable Doppler Shift from Whistle Signal Interrupt and Enable/Disable Turbine/Diesel Transition from Coded Horn (CV 51.2)

- Set CV 49 to 2.
- Set CV 51 to the value indicated in the table below. An “X” in the table indicates that the feature will be enabled. The default is 3 (both features are enabled).

Doppler from Horn Signal	Turbine Transition from Coded Horn	Decimal Value	Binary Value	Hex Value
		0	00000000	00
X		1	00000001	01
	X	2	00000010	02
X	X	3	00000011	03

## Changing Individual Sound Volumes (CV 52.X<sup>132</sup>)

To change the volume of individual sounds listed in the table on the next page do the following:

- Set CV 49 to the Primary Index for the individual sound from the table below.
- Enter Volume level in CV 52 as follows: “0” = No sound, “1 – 15” = Sets volume from the lowest value at “1”, the highest volume at “15”. The volume levels are in 2db increments.

<sup>130</sup> If your DCC command station will not program in Service Mode, check with the command station manufacturer; some companies will give you a free upgrade. Also, see Special Operation and Troubleshooting on page 215.

<sup>131</sup> In Ops Mode, you will hear the value spoken out when changing the value of a CV.

<sup>132</sup> ‘X’ refers to the value in column 1 of the table, the Primary Index number put into CV 49.

### Individual Sound Volumes for CV52.PI

Primary Index entered into CV 49	Sound	Default
0	Horn	11
8	Bell	11
10	Diesel Motor	11
13	Turbine Whoosh	11
15	Turbine Whine	11
16	Air Pump	11
19	Diesel Motor Cooling Fans and Vents	11
21	Long Air Let-off	11
22	Short Air Let-off	11
24	Squealing Brakes	11
28	Dynamic Brakes	11
34	Coupler Sounds	11
37	Air Brakes	11

## Standard Throttle Control, Speed Control and Regulated Throttle Control Options (CV 56.4)

- Set CV 49 to 4.
- Set CV 56 to 0 for Standard Throttle Control; 1 for Regulated Throttle Control. The default is 1.  
**Note:** CV 2, CV3, CV4, CV 5 and speed tables apply to both Standard and Regulated Throttle Control.

## Reset All<sup>133</sup> CV's to Factory Default Values (CV 56.128.255)

**Note:** This does not affect Analog settings, except for volumes.

- Set CV 49 to 128.
- Set CV 50 to 255.
- Set CV 56 to 113<sup>134</sup>. In Ops mode, you will hear "Reset" when reset is completed.

## Special Procedure for Short or Extended Address Programming (CV 56.129)

If you cannot program your Short or Extended ID number in Service Mode and your DCC command station prevents you from setting either of these addresses in Ops Mode (using CV 1, or CV 17 and CV 18) use the following alternative procedures to program your locomotive's ID's.

### Alternate Procedure for Entering Short (Primary) Address in CV 56.129.1 in Ops Mode

- Set CV 49 to 129.
- Set CV 50 to 1.
- Set CV 56 to your Short Address (1 or 2 digits). Hear the address spoken back ("CV 1 = XX").
- If necessary, set CV 29, bit 5 to '0' (or set CV 29 to 6 which is factory default<sup>135</sup>) to enable your new Primary Address.

### Procedure for Entering your Long (Extended) Address in CV 56.129 in Ops Mode.

- Determine the value of CV 17 and CV 18 for your Extended Address from the ID Table on the next page or follow instructions under CV 17 and CV 18 in the *Quantum DCC Reference Manual (Version 3)* to calculate a different ID number.
- Set CV 49 to 129.
- Set CV 50 to 17.
- Set CV 56 to the value of CV 17 from the table. Hear the value of CV17 spoken out ("CV 56.129.17 = X").
- Set CV 50 to 18.
- Set CV 56 to the value of CV 18 from the table. Hear the value of CV18 spoken out ("CV 56.129.18 = X").<sup>136</sup>
- If necessary, set CV 29, bit 5 to '1' (or set CV 29 to 38<sup>137</sup>) to allow operation with your new Extended Address.

<sup>133</sup> Consult the DCC Reference manual to learn how to reset different groups of CV's.

<sup>134</sup> "113" is QSI's Manufacturer's ID Number assigned by the NMRA.

<sup>135</sup> See Table on Page 22 for additional options for CV29 with bit 5 set to "0".

<sup>136</sup> If you want to verify your extended address, set CV 64 to 17 (or 18) to hear the full address spoken out.

<sup>137</sup> Entering "38" leaves the other configuration settings in CV 29 at factory default, but changes the ID to Extended Address type. Also see table on next page for other choices.

**Gas Turbine Extended Address values for CV 17 and CV 18 for Different Cab Numbers.**

Loco Cab Number	CV 17 (Dec)	CV 18 (Dec)	CV 17 (Hex)	CV 18 (Hex)	CV 17 (Binary)	CV 18 (Binary)
61	192	61	C0	3D	11000000	00111101
64	192	64	C0	40	11000000	01000000
66	192	66	C0	42	11000000	01000010
71	192	71	C0	47	11000000	01000111
73	192	73	C0	49	11000000	01001001
75	192	75	C0	4B	11000000	01001011

**Note:** When you select your locomotive with a two digit ID as an extended address, you may need to enter leading zeros to distinguish it from a Primary (short) ID on some command stations (e.g. 0062 instead of 62).

## Disable/Enable Verbal Announcements (CV 62)

In Ops Mode, the Quantum System will automatically speak out the value of the CV that you enter.

To disable, set CV 62 to 0 (no verbal response); to enable, set CV 62 to 1 (hear “CV 62 equals 1”). Default is “Enabled”.

## CV Inquiry with Verbal Feedback in Ops Mode (CV 64)<sup>138</sup>

To inquire about the current value of any CV through Verbal Feedback in Ops Mode:

- Set CV 64 to the CV you wish to query. Hear the verbal message “CV ‘X’ equals ‘Y’”, where ‘X’ is the CV number and ‘Y’ is the value.

**Note:** If the CV has a Primary Index such as QSI CV n.PI (where n is the CV number and PI is the Primary Index), set CV 49 to PI before you set CV 64 to n. For example, if you want to inquire about the Diesel Motor Volume, which is CV 52.10, set CV 49 to 10 and set CV 64 to 52. You will hear, “CV five two point one zero equals ‘Y’ (where ‘Y’ is the current volume setting). If the CV has both a Primary and Secondary Index, such as CV n.PI.SI where SI is the Secondary Index, set CV 50 to SI in addition to setting CV 49 to PI before you set CV 64 to n. .

**Note:** If you enter either ‘17’ or ‘18’ in CV 64, you will hear the full one to four digit Extended Address ID number spoken out.

**Note:** Disabling Verbal Announcements (CV 62) will not disable CV Inquiry (CV 64).

## Common NMRA Configuration Values (CV 29)

Each bit in CV 29 controls some basic operational setting for DCC decoders, including Extended Addressing, Speed Table Enable, Power Source Conversion, Lighting Operation, Locomotive Direction, and others. Quantum default for CV 29 is 6.

The following table provides some of the more common values for CV 29 for the features indicated.

Extended Addressing	Speed Tables	Power Conversion	28/128 Speed Steps	Reversed Direction	Decimal Value	Binary Value	Hex Value
			X		2	00000010	2
		X	X		6	00000110	6
	X		X		18	00010010	12
	X	X	X		22	00010110	16
X			X		34	00100010	22
X		X	X		38	00100110	26
X	X		X		50	00110010	32
X	X	X	X		54	00110110	36
			X	X	3	00000011	3
		X	X	X	7	00000111	7
	X		X	X	19	00010011	13
	X	X	X	X	23	00010111	17
X			X	X	35	00100011	23
X		X	X	X	39	00100111	27
X	X		X	X	51	00110011	33
X	X	X	X	X	55	00110111	37

For more information, download the Quantum DCC Reference Manual (Version 3) from <http://www.qsindustries.com>.

<sup>138</sup> This option is not disabled by CV 62.

## Special Operation and Troubleshooting

With some Command Stations, using the horn button to activate the Horn, and, while this button is held down, activating the F6 Doppler key, will cause the Horn to shut off instead of causing a Doppler shift effect.

We have experienced intermittent and independent horn signal interruption with some DCC command stations, causing unexpected Doppler shifts. If this happens frequently, you can disable the Horn Triggered Doppler (CV 51.2).

### Manual Volume Adjustment (Analog and DCC)

To adjust the volume by hand:

- Locate the removable hatch on the top of your Lionel Gas Turbine locomotive and remove it using your fingernail. It is located in the center of the roof and is held in place magnetically. Manual Volume Control (blue potentiometer) is located towards the front with the Reset Jumper directly behind.
- Use a small screwdriver to turn the potentiometer clockwise to increase volume or turn it counterclockwise to decrease the volume.

**Note:** Volume can also be adjusted digitally using the programming methods described in the programming sections of this manual. However, if you turn the volume down using the Manual Volume Control, you will not be able to increase the volume using programming above the level set by the potentiometer.



### Using the Quantum Reset Jumper to Return Your Locomotive to Factory Default Values (Analog and DCC)

In case your locomotive's sound and control system misbehaves and turning the power off and back on does not return it to normal operation, you can reset your locomotive to original factory values.

- Turn off the power.
- Use small needle nose pliers to pull the jumper up and out.
- Reapply power; after a few seconds you hear three Horn hoots in quick succession.

Turn power off, reinstall the jumper. The locomotive has now been returned to original factory defaults for all DCC and Analog values.

### Program Track Operation (DCC)

Your locomotive conforms to NMRA standards for program track operation. However, the Quantum System requires more current to operate than standard DCC decoders and may not respond to the limited program track power from some command stations. If you are unable to program in Service Mode on your program track, all CV's in your locomotive can be programmed in Ops Mode. You can also purchase from Tony's Train Exchange®<sup>139</sup>, a simple, inexpensive power booster (PowerPak™ by DCC Specialties) that will allow you to program on the program track with any DCC command station.

### Reasons why Your Locomotive is Silent or will not Start (Analog and DCC)

In case your locomotive remains silent after power up and turning the power off for 15 seconds does not return it to normal operation, try the following suggestions to bring your locomotive back to normal sound operation.

- Make sure the locomotive has not been Muted with the F8 key.
- Check to see if your volume potentiometer or digital sound has been turned all the way down.
- You may have shut your locomotive down in DCC using the F9 key, **which will also shut it down in Analog**. Go back to DCC operation and start your locomotive with the F6 key. Once started, you can return to DC or DCC operation.
- If the above methods do not start your locomotive, use the jumper to reset your locomotive to factory default values as described above.

<sup>139</sup> Tony's Train Exchange; 1-800-978-3427; www.tonystrains.com.

# Appendix III A

## Recommended DCC Command Stations

Command Station	Recommended	Will Support Service Mode w/ Quantum	Comments <sup>140</sup>
NCE™	Yes	Yes (See Comments)	Horn and Bell buttons are available but bell button assigned to F3 (see QSI CV 37 example). Newer NCEs apparently support programming track but older command stations do not. Programming on the main is easy and straightforward. NCE currently only supports F0-F8.
Wangrow™	Yes	No	Horn and Bell buttons are available but bell button assigned to F3 (see QSI CV 37 example). No Service Mode but programming on the main is easy and straightforward.
Digitrax™	Yes	Yes	<p>F0 = Lights, F1 = Bell, F2 = Horn. DT300 will operate in Service mode but will not read back value. Long address is automated with the DT300 and DT400 throttles, which properly writes CVs 18, 17, and 29. Click to the 4-digit mode, set address, and answer yes to the enable 4 digit address prompt. It also automatically resets CV 29 if you return to 2-digit address.</p> <p>An exception is the obsolete DT100 throttle, which will only program Quantum decoders in Ops Mode. Use QSI CV 56.129 to program either CV 1 or CV 17/18. Note that the DT100 only programs in hex, except for addresses, which are in decimal. This makes it easy to enter address in Ops mode.</p> <p>We have qualified the following Digitrax systems with Quantum decoders (all support F0-F12):            Super Chief with DT400            Zephyr with DT400            DCS100 with DT400            Chief with DT400</p> <p>See Digitrax for more information on QSI compatibility at <a href="http://www.digitrax.com">www.digitrax.com</a>.</p>
MRC™	Yes	No	MRC does not provide a separate programming function. All programming is done in Ops mode with no acknowledgement feedback. A resistor is included to limit current for a Programming Track, which may limit the current below the allowable level for Quantum decoder programming. For the Quantum system, the resistor may be left out. For other decodes, the user should follow the MRC instructions.
Lenz™ LZ100, LV200, LZV100	Yes	Yes (See Comments)	F0 = Lights, F1 = Bell, F2 = Horn. Lenz will program in Service mode providing that a suitable resistor is added in series to the Programming Track (LV100 requires 20 ohms and LV200 requires 10 ohms). Note that CV 1, 17 and 18

<sup>140</sup> Many comments and opinions regarding operation with different command stations are the result of user's letters to QSI or comments on various railroad web forums. QSI is not responsible for the accuracy of these comments, which are included here only as a starting point for the customer to verify to his own satisfaction the compatibility of these products for use with the QSI Quantum System.

			cannot be programmed on the main in the standard way (see QSI CV 56.129 for alternative way to program ID numbers). Newer Lenz does support F0-F12 Function Keys.
Atlas <sup>TM</sup>	Yes	Yes (See Comments)	Early models of the Atlas command station had some problems with programming. Reports from Atlas on their recent versions indicate no problems. Limited number of function keys available.
CVP <sup>TM</sup>	Yes	Yes	EZ DCC. Works with wireless hand held throttle as well as standard command station.
Zimo <sup>TM</sup>	Yes	Yes	All products work with Quantum decoders.

# Appendix III B

## Programming a Long Address on Digitrax

### Select the Loco's Short Address (Usually 3)

- Press "Loco" then "3" then "Enter".

### Program "On the main" the new Long Address.

- Press "PROG" until "Po" and the Loco's address is shown on the LCD.
- Press right turn knob down until it reads "ad4 = ???"
- Type in desired four digit address and press "Enter". Loco verbally responds with "CV 18 = XXXX" where XXXX is the four digit address.

Once the long address is programmed, you must enable the locomotive to use it.

### Enable the Long Address.

- Next, press the right turn knob until it reads "ad2 = 000"
- Scroll with left knob until you get to "029 = ???"; turn right knob until readout = "029 = 034"; press Enter, locomotive says "CV 29 = 34".
- Press "Exit" to leave program mode.

### Select Loco with the new Long Address.

- Press "LOCO" and enter new long address to run locomotive.

## Returning to the Short Address

### Select the Loco's Long Address (The value you programmed above)

- Press "Loco" then the Long Address then "Enter".

### Program "On the main" to Enable the Short Address.

- Press "PROG" until "Po" and the Loco's address is shown on the LCD.
- Scroll with left knob until you get "CV29 = ???"; scroll with right knob until you get "029 = 002"; press Enter; locomotive verbally responds with "CV 29 = 2".
- Press "Exit" to leave program mode.

### Select Loco with the Short Address.

- Press "LOCO" and enter Short Address to run locomotive.



# Appendix III C

## Programming a Long Address on North Coast Engineering (NCE)

### Select the Loco's Short Address (Usually 3)

- Press "Loco" then "3" then "ENTER".

### Program "On the main" the new Long Address.

- Press the "Program" button. Display reads "Program on Main".
- Press "ENTER".
- Display shows current "003" I.D. on the display.....Press "ENTER"
- Press 1 for Address. Display shows "Set ADDR"
- Press "1" to set Long Address.
- Enter four digit address. Press "Enter" Hear "CV 18 equals XXXX" where XXXX is the four digit address you entered.
- You are now back in Run Mode. Select loco 3. Press "ENTER".
- Once the long address is programmed, you must enable the locomotive to use it.

### Enable the Long Address.

- Press the "Program" button. Display reads "Program on Main".
- Press "ENTER".
- Display shows current 003 I.D. on the display. Press "ENTER"
- Press "3" for Configuration. Display shows "ENTER=NORM 1=REV".
- Progress through and set each variable until you reach "ADDRESS?".
- Enter "1" for "LONG" address. This enables using the long address.
- Leave Ops Mode Programming by pressing the red "Emergency Stop" button.
- Select locomotives long address and operate.

You are now out of program mode and have completed "the Long Address" sequence.

## Returning to the Short Address

### Select the Loco's Long Address (The value you programmed above)

- Press "Loco" then enter the Loco's Long Address (The value you programmed above) then press "Enter".

### Program "On the main" to Enable the Short Address.

- Press the "Program" button. Display reads "Program on Main".
- Press "ENTER"
- Display shows current Long Address I.D. on the display. Press "Enter"

- Press “3” for Configuration. Display shows “ENTER=NORM 1=REV”.
- Progress through each variable until you reach “ADDRESS?”.
- Press “ENTER” for “SHORT” address. This enables using the short address.
- Leave Ops Mode Programming by pressing the red “Emergency Stop” button.
- Select locomotives short address and operate.

The above procedure was evaluated with an upgraded<sup>141</sup> NCE POWER PRO series of DCC command stations. If the above procedure does not work properly, contact NCE to see if they can upgrade your software.

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<sup>141</sup> NCE Software Version 1.3, December, 21, 2004.

# Appendix IV

## DCC Troubleshooting

### Operations Mode

My headlight does come on when I start my locomotive but mysteriously goes off whenever I blow the horn or turn on the bell. Also, if I try to turn off the headlight, it sometimes requires two pressings for the F0 or FL key.	Pressing the horn or toggling the bell will cause your command station to send out a Function Group One command, which contains the lighting information. Not all command stations automatically send this information unless FL, F1, F2, F3 or F4 is pressed. Regarding turning off the lighting with the F0 key, the state for the light may already be off at the base station but not sent. When you press the F0 key, it toggles the lights on and sends that command and hence the lights stay on. It takes a second press of the F0 key to send another command to turn off the lights. See Appendix VII, <i>Different types of Feature Operation from Function Commands</i> .
My brakes,, bell, air release, or other sounds come on sometimes for no apparent reason while operating my locomotive.	See above. Some functions may already be turned on but not sent. When you request any function, the entire function group that contains that function will be sent and this may trigger other features already enabled within that group. Hence, you might request the light be turned on and hear squealing brakes or the bell turn on or off. If your base station display shows the toggled condition for each of the function keys, you can determine which feature will turn on or off when a Function Group One or a Function Group Two is sent.
My locomotive makes no sounds except an air release when power is applied and will not operate.	You have your locomotive in Shut Down. Double press the F6 Start-Up key to start your locomotive.
My locomotive runs but makes no sounds.	You have Mute on or have turned down your System Volume or individual feature sound volumes. You may have a broken wire to the speakers or a faulty speaker.
When I turn up my throttle to higher values, the locomotive does not speed up but instead, the directional lighting comes on.	Your locomotive is set for 14 speed steps but your base station is set for 28 or 128.
When I turn on my lighting system with the F0 or FL Key, the locomotive speeds up at low throttle settings.	Your locomotive is set for 28 or 128 speed steps but your base station is set for 14.
Sometimes my locomotive slows down when I blow the whistle or horn, particularly at high volume levels.	The Quantum Sound system takes additional power to blow the whistle or horn and this loads your power pack. This can lower the voltage on the track and your locomotive will slow down. Purchase a power pack with good line regulation to prevent this problem.
In Speed Control Mode, there are no speed changes above certain throttle settings.	The top speed of your locomotive is dependent on the gear ratio, load on the locomotive and the available voltage applied to the track. Asking the locomotive to go faster results in no change. (See CV 56.10, BEMF to SMPH Scale Factor to change throttle range).
Under speed control, I do not get 1 scale mile per hour (smph); I get a larger number about 5 to 10 smph.	Check your speed step setting on your base station. To get 1 smph you need to be in 128 speed steps.
In Standard Throttle Control Mode, there are no speed changes above a certain throttle settings.	Try a different speed curve or define your own to provide full range of throttle motion.
My locomotive operates with no problem in DCC, but does not operate at all under Analog control.	Make sure Analog operation is enabled. CV 29 bit 2 must be set to 1.
My Lionel Gas Turbine will not operate over 25 smph under RTC or Speed Control.	This is correct for diesel operation. This is an internal limit on top speed when the locomotive is under diesel operation. The prototype would not travel over 25 mph under diesel power. Switch to turbine operation to gain higher speeds.
F8 key on Digitrax does not mute the locomotive.	The Digitrax DT400 model we examined behaves incorrectly when the F8 key is pressed sending 1010DDDD instead of 1011DDDD. Ask Digitrax for a Software Upgrade.
The F7 Key does not apply brakes.	Make sure your throttle is at speed step zero before applying brakes. Also, earlier Quantum systems only required that the F7 be pressed to trigger the brakes. Later Quantum decoders required F7 to be on (1) before brakes will apply. If F7 was already on when the throttle was turned down it will not automatically apply brakes. Pressing it would turn F7 off (0) so

<p>When I set CV 17 and 18, the Extended Address, I must explicitly set CV29 bit 6 to 1 before the Extended Address is effective. With non-QSI decoders, I don't have to do this. Why isn't it automatic with QSI decoders?</p>	<p>a second pressing was required to turn in on.</p> <p>If CV 62 bit 0 is "1", which enables Programming Verbal Acknowledgement, then your QSI decoder speaks out "C V 1 7 equals x x x x" when you program the extended address. During the time the acknowledgement is being spoken, all incoming DCC packets are discarded. If your controller attempts to program CV29 during this time, the packet for CV29 is discarded by the decoder. Set CV 62 bit 0 to 0, and your QSI decoder will not discard the CV 29 packet.</p>
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## Service Mode Operation using the Program Track

<p>My Quantum equipped locomotive will not program in Service Mode with my command station.</p>	<p>Some command stations do not provide sufficient current to power the Quantum system. If you are using a command station that has selectable track voltage for the different scales try using the O'Scale or G'Gauge alternative. If this does not work, use Ops Mode programming. You can also purchase from Tony's Train Exchange®<sup>142</sup>, a simple, inexpensive power booster (PowerPak™ by DCC Specialties) that will allow you to program on the program track with any DCC command station.</p>
<p>Occasionally, when programming a CV, the reported value is off by one digit.</p>	<p>This is a timing issue with some command stations. Either program in Ops Mode or consider using a PowerPak from DCC Specialties.</p>
<p>When I try to do a complete reset of all CV's using CV 56.128.255 in Program Mode, not all of the CV's reset to factory values.</p>	<p>Resetting all CV's takes considerable time. Some command stations only allow a fixed short amount of time to power the programming track after a command is sent. When you ask for a complete reset, not all of the CV's will be reset if the power shuts down part way through the procedure. We recommend doing a full reset in Ops mode. Or you can do individual reset operations such as "all NMRA CV reset", and "all QSI CV reset", etc. until you have all groups of CV's reset to factory defaults.</p>

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<sup>142</sup> Tony's Train Exchange; 1-800-978-3427; [info@tx-dcc.com](mailto:info@tx-dcc.com) .

# Appendix V

## Using the Quantum Hardware Reset and Volume Controls:

Quantum software can be programmed by the operator to reset the system to factory defaults. As a safety precaution, Quantum decoders also have a backup hardware method to do a system reset. Either method can be used to reset the locomotive to original factory settings. In case your Quantum Sound and Train Control System misbehaves and simply turning the power off from 5 to 15 seconds does not return it to normal operation, you can reset your locomotive using CV 56.128 or you can use the hardware Reset Jumper found on earlier Quantum Systems or the Magnetic Wand to activate a reed switch included on more modern Quantum Systems.

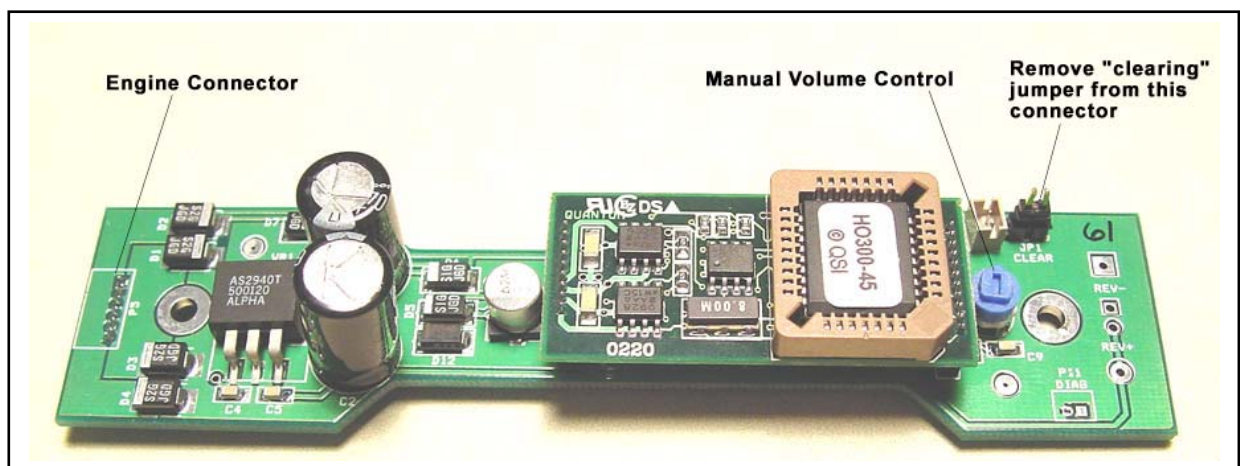
Quantum system volume can also be adjusted using software by programming CV 51.0 or by a hardware volume adjustment. Earlier Quantum systems used a potentiometer volume control and later models use a magnetic wand.

## Reset Jumper Models

Both early Quantum Steam and Diesel locomotives used jumpers and volume potentiometers to control reset and sound volume. The diagram below shows a Quantum circuit board used in some Steam Locomotive tenders. The jumper and volume potentiometer is located on the bottom board as shown in the diagram below.

To Reset the Locomotive:

- Turn off the main track power.
- For Steam Locomotives, remove the tender body or water filler hatch to reveal the circuit board. If it is a plastic tender, there are no screws; it is a press fit to the chassis. Die cast tenders will have retaining screws under the chassis. Most Diesels will have a removable access panel over the Quantum circuit board on the roof. The location of the access panel will be shown in the Steam or Diesel Model Specification sheet that was included with your locomotive instructions.
- To reset the Quantum system to its default values, locate the black "clearing" jumper (see below) and remove by pulling it up.
- Reapply main track power, the horn and/or bell will sound after a few seconds.
- Turn main track power off and reinstall jumper, and tender cab or access panel. The locomotive has now been returned to original factory settings including all Analog and DCC settings.



**Note:** Do not try to perform the jumper reset operation on the Program Track under Service Mode power. Always perform this operation under full power.

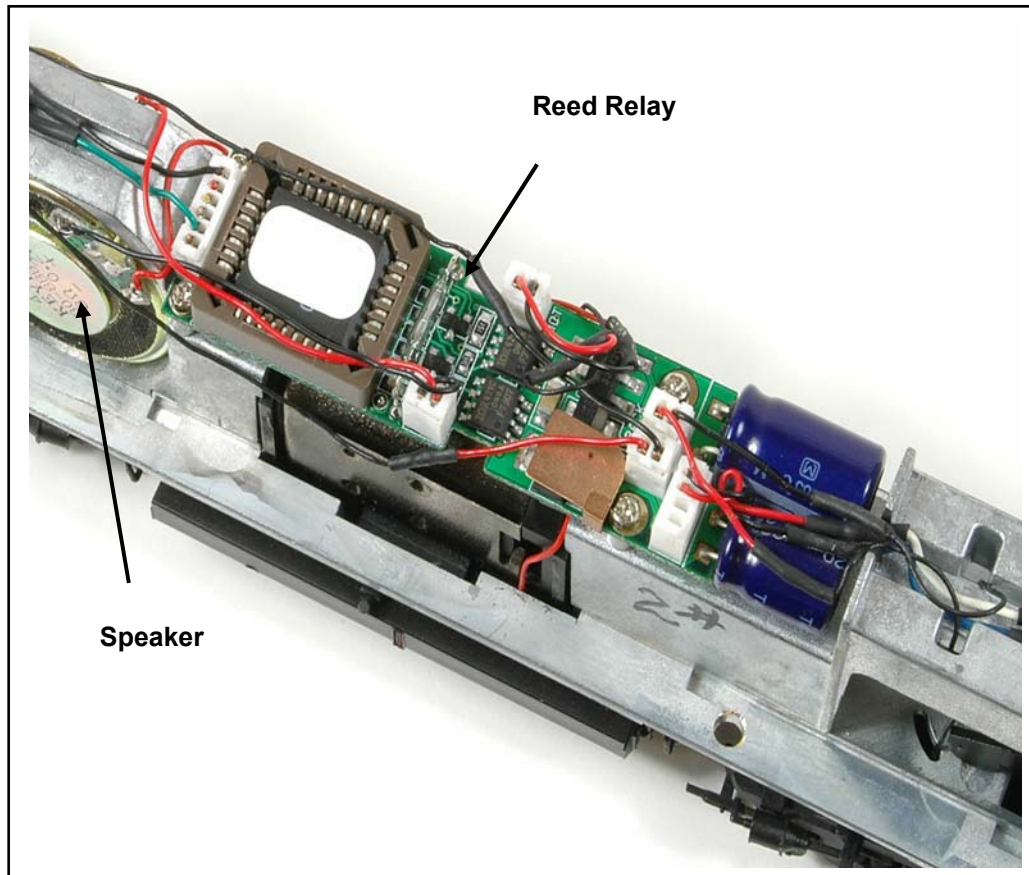
To Adjust the Volume Using the Potentiometer:

- Locate the Manual Volume Control under the access panel on the roof of your Diesel or Electric locomotive or under the water hatch on Steam locomotive tender as shown in the Model Specification sheet that was included with your instructions.
- Turn on main track power. You may want to turn on and leave on some of the significant sound effects such as horn/whistle and bell.
- Use a small screwdriver to turn the volume clockwise to increase volume or turn it counterclockwise to decrease the volume.
- Replace the access panel or water hatch cover.

**Note:** Volume can also be adjusted digitally using the programming methods described in the programming sections of this manual.

## Magnetic Wand Models

Modern Quantum Steam and Diesel models use a glass enclosed reed relay to reset the Quantum System or adjust the volume. The reed relay will close its contacts when the magnet supplied with your locomotive is placed in close proximity. The advantage of this method of adjusting your locomotives volume or resetting it to factory defaults is that you do not need an access panel to gain access to the controls. Also the wand does not need to touch the body; it can be held a reasonable distance from the roof area to prevent possibly marring the painted surface.



Quantum small diesel board with a reed relay mounted in a narrow-body diesel

To Reset the Locomotive:

- Locate the reed relay area as shown in the *Diesel or Steam Model Specifications* sheet that was included with your model.
- Turn off the track power.
- Place the Magnetic Wand over the reed switch area and re-apply track power and leave the wand there until you hear the word "reset". Remove the magnetic wand; your locomotive is now reset.

The locomotive has now been returned to original factory defaults including all DCC and Analog values.

**Note:** Do not try to perform this reset operation on the Program Track under Service Mode power. Always perform this operation under full power.

To Adjust the Volume Using the Magnetic Wand:

- Locate the reed relay area on the locomotive's roof as shown in the *Diesel or Steam Model Specifications* sheet that was included with your model.
- Power up locomotive and leave in Neutral.
- Place the enclosed Magnetic Wand over this reed switch area on the roof of the locomotive perpendicular to the track and wait as you hear the volume increase or decrease in incremental amounts as the Horn hoots about every second. Move the wand away and again place it over the reed area to change the direction (louder or softer) of the volume change. Remove the wand when you reach the desired volume level.



# Appendix VI: Quantum Throttle Control

## QSI Inertial Control™ and Regulated Throttle Control<sup>143</sup>

### The Prototype and the Model

What has been missing in model trains is “Inertia”.

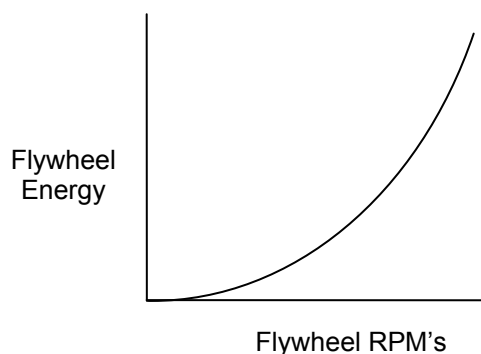
Definition: **Inertia**: A property of matter by which it retains its state of rest or of motion.

Real trains have lots of inertia; model trains have very little. A slow moving prototype train will climb over misaligned track joints, coast over turnout frogs, glide through tight curves and will coast a long distance without power, even up a grade. A slow moving model trains will stop abruptly at a slightly raised track joint, stop on a turnout, stop in a tight curve, will not coast up a grade for any realistic distance and will stop or slow down abruptly when track voltage is reduced.

### Previous Solutions:

There have been a number of attempts to provide some sense of inertia in model trains.

1. **Momentum Control**: In both Analog and DCC, inertia is simulated by not allowing the locomotive to respond quickly to changes in throttle settings. In Analog, this is done at the power pack by activating the momentum switch, which increases or decreases the track voltage over time when the throttle is changed to a new position. In DCC, setting CV 3 and CV 4 to non-zero values can produce the same effect. This however, does not really produce a true inertia affect. Regardless of the values for CV 3 and CV 4, any minor obstacle such as a raised track joint will stop a slow moving locomotive.
2. **Flywheel**: The flywheel was another attempt at providing inertia to a model. Although flywheels do add a true inertia, it is not sufficient to maintain the momentum of a slow moving train. The energy, E, stored in a flywheel is giving by the following formula:  $E = \frac{1}{2} (I \omega^2)$ , where I is the moment of inertia for the flywheel and  $\omega$  is the radian frequency (related to RPM's). As the RPM's or  $\omega$  tends towards zero, the amount of energy available to maintain speed bottoms out as the following graph shows.



In fact, it has been demonstrated that flywheels actually reduces the locomotive's ability to maintain low speed operation as described in an article by Terry Thompson, entitled "The Digital Locomotive" in the August 2003 issue of *Model Railroader* (page 6).

3. **Speed Control**: Although this does keep the locomotive moving at slow speeds, it does not provide Inertia, does not work well in consists, and does not model how prototype locomotives respond to the throttle.

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<sup>143</sup> The following discussion of Quantum Inertial Control and Regulated Throttle Control is based on Clinics that Fred Severson presented at the 2006 NMRA Convention in Philadelphia, PA.

True electronic Speed Control has a fundamental problem. When two or more locomotives with true electronic Speed Control are coupled together in a consist, the consist operation becomes inherently unstable. Imagine two locomotives both responding to a speed command to go 35 smph. If both locomotives were identical, they would travel together at the same speed with no problems. But because of variations in electronic component values, gear ratios, age, etc., both the speed references and the on-board speed measurements will be slightly different. For instance, let's say the trailing locomotive (Locomotive B) has a slightly lower internal speed measurement than the lead locomotive. This is shown in the Figure 3 where Locomotive B believes that is only going 34.9 smph (scale miles per hour) when in reality it is going 35 smph. In this example, the lead locomotive is properly calibrated; it is actually going the speed it thinks it is going, 35 smhp.



Locomotive B thinks 35 smph is actually 34.9 smph

Locomotive A correctly thinks 35 smph is 35 smph

If the two locomotives were both traveling at 35 smph at a particular moment in time, the Locomotive will sense that it is going too slow (34.9 smph) and will apply more power to the motor to speed up the consist to achieve its requested speed of 35 smph. Locomotive A, on the other hand is happy at 35 smph and will react to the increased push exerted by locomotive B by decreasing the motor power to maintain 35 smph. Locomotive B will feel the resistance from Locomotive A and will apply more power to maintain what it believes to be the correct speed value. The trailing locomotive, in turn will decrease the motor power even more. The result will be that Locomotive B will apply full power to the motor while Locomotive A will be shut down completely.

**Locomotive “A” is the “Immovable Object” and Locomotive “B” is the “Irresistible Force”.**

Locomotive “A” is being pushed around the layout and Locomotive “B” is doing all the work. This can result in Locomotive “A” or “B” derailing on curves or turnouts and can damage wheels or spin off rubber tires and can overheat or damage motors.

This instability in True Speed Control will occur even if the speed references or internal speed measurements of the two locomotives is off by an infinitesimal amount (i.e. it is unstable). It is only the finite gain in the motor control circuits that will prevent this from occurring to such an extreme. Indeed some decoders with load compensation purposely limits the loop gain to help this problem. However, no matter what the loop gain, there is this inherent instability that will result in unequal power sharing between locomotives in a consist.

Another way to see this problem is to take a locomotive under True Speed Control at a fixed throttle setting (which will give a fixed speed) and try to pull or push it with your hand at a speed different than what it wants to go. It feels rock solid and resists any attempt to make it go faster or slower. Now imagine another locomotive on the track that wants to travel faster than the first locomotive. If these locomotives are coupled together it will be the “irresistible force” trying to move the “immovable object”.

4. **Low-Gain Speed Control:** This type of speed control has some flexibility in controlling the speed to precisely match the requested speed command. If the locomotive is requested to go 35 smph, the actual speed might slip a bit down to 30 smph if under heavy load or increase to 40 smph if going down grade or being pushed by another locomotive. The disadvantage of Low-Gain Speed Control is that it is difficult to maintain very slow speeds since obstacles will again stop the locomotive. Some companies have a form of true speed control

(high gain) at low speeds and reduce the gain as the locomotive speeds up to higher values. This ensures good low-end speed control and more forgiveness in consists at higher speed. However, at low speeds, there is a problem with power sharing in consists as discussed above. It is not as traumatic or potentially damaging since the speed and overall power demand is low.

## Inertial Control™ and Regulated Throttle Control™

The Quantum System supports two kinds of throttle control, RTC and STC. STC or Standard Throttle Control is the familiar type of non-load compensated throttle control where the locomotive operates at a requested power level set by the speed step value. Under STC, the locomotive reacts quickly to throttle changes, voltage variations and slows down or stops when it encounters even small changes in loading.

**Inertial Control** is a Quantum algorithm that simulates inertia in a model locomotive. When the locomotive is at rest it tends to stay at rest and when moving it tends to maintain constant momentum. When you operate a locomotive under RTC you can feel the inertial control operation. As an experiment, try to resist a moving locomotive using your hand. You will feel the locomotive trying to maintain its momentum and resist your hand attempt to slow it down. If you continue to try and slow down the locomotive, it will eventually lose speed and may even stop. On the other hand, if you push the locomotive with your hand, you will feel it slowly speed up. When you let go, it will gradually slow down to its original speed. In doing these experiments do not restrict the locomotive to the point of allowing the wheels to slip on the rail. It is recommended that you do these experiments on a locomotive that has very good traction or you may not notice any slowing or increase in speed.

**Throttle Control** is a Quantum algorithm that responds to throttle settings as Power Commands, instead of Speed Commands.

These two features are the basis of Regulated Throttle Control (RTC) , which results in a model that acts like the prototype.

RTC allows you to operate your locomotive under normal throttle control and at the same time provide operation as though the locomotive has huge inertia. However, unlike some motor control systems, RTC is not speed control; it is a true throttle control. RTC does not maintain speed at some constant value independent of changing conditions. To understand RTC, we have included the following operation examples:

**Example 1:** Under RTC you will be able to run your locomotives very slowly without concern that it will completely stop from minor impediments such as misaligned track joints, tight curves, rough turnouts, sticky gears, etc. or variations in track voltage. Usually the locomotive will glide through these obstacles without slowing. Even if a locomotive moving a minimum speed is stopped by a large raised track joint, it may stop momentarily but will then climb over the obstacle.

**Example 2:** If your Quantum equipped locomotive under RTC encounters a grade, it will eventually slow down. You will need to provide more throttle, just like the prototype, to accelerate it back to speed. What is different is how it responds to grades or other conditions that would normally stop your train. A standard model locomotive under STC would very quickly slow down or stop when encountering a grade unless you rapidly increase the throttle by the right amount at the right time. Under RTC, the locomotive will still stop or slow down by the same amount but will do so slowly and realistically based on the RTC built-in Inertial Control.

If it encounters a downward grade, a locomotive under RTC will speed up slowly as it descends.

**Example 3:** If track voltage varies in DCC, it does not affect the locomotive's momentum. The Inertial Control algorithm quickly adapts to maintain momentum and power.

**Example 4:** If brakes are applied (F7) the locomotive slows down in proportion to how much braking is applied.

**Example 5:** Because RTC is true throttle control, it is controlled by the same CV that apply to STC. For instance, STC and RTC are both affected by V-Start (C2), Acceleration Rate (C3), Deceleration Rate (C4), V-High (C5), Acceleration Adjustment (C23), Deceleration Adjustment (C24), Speed Table Selection (C25), Forward Trim (CV 66), User Defined Speed Table (CV 67-94), and Reverse Trim (CV 95). There are, however, differences in behavior. At a zero Load setting, the locomotive under RTC will achieve the final motor voltage over time according to the internal Inertial Control algorithm while a locomotive under STC will achieve the final motor voltage immediately. If these two identical locomotives are placed on the same power track section, with the same speed curve settings (CV values above) and inertia CV values set to zero (CV 3, CV 4, CV 23 and CV24), the locomotive programmed to operate under STC will race up to its final speed as quickly as the internal mechanical flywheels will allow, while the locomotive programmed to operate under RTC will accelerate much more slowly. After both

locomotives finally reach “steady state” operation, both locomotives will be seen to have the same requested power and same average speed.

The second difference has to do with how power is delivered to the motor. At a steady throttle setting, the average voltage to the motors will be the same for both locomotives, but the actual voltage variations to the RTC motor will be dithering around trying to maintain the locomotives Inertial Control while the voltage to the STC locomotive will remain relatively constant. The effects on operation are quite noticeable at slow speeds. Since the RTC locomotive is constantly adjusting motor power; it will move much more steadily at slow speeds while the STC locomotive will stop and start and may need a push now and then to keep it going.

**Example 6:** RTC has its own Intrinsic Inertia independent of CV 3, CV 4, CV 23 and CV 24. The Intrinsic Inertia represents the inertia of the locomotive. If the throttle is increased, the locomotive’s momentum increases slowly in proportion to the throttle setting and its Intrinsic Inertia setting. If the throttle is decreased, the locomotive’s momentum decreases slowly in proportion to its Intrinsic Inertia. If any of the Inertia CV’s<sup>144</sup> above is set to non-zero values, they added to the Intrinsic Inertia of the locomotive.

**Example 7:** RTC has a minimum Back EMF value that will maintain minimum momentum. Minimum Back EMF is specified in CV 56.5. Figure 1 shows a linear speed curve of motor power versus speed steps.

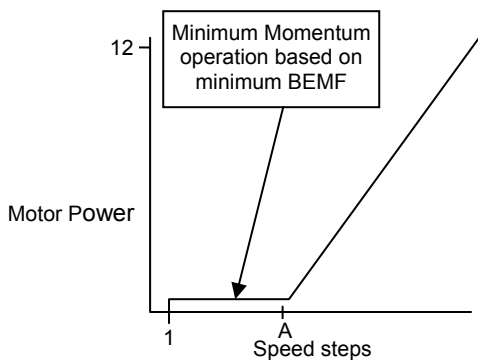


Figure 1

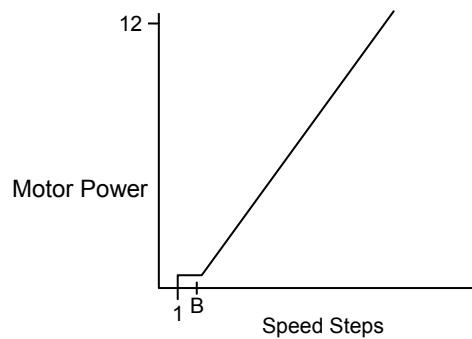


Figure 2

As the speed steps are reduced, the motor power follows this linear power curve and would normally intercept at point “A” where the locomotive would come to a complete stop. The minimum Back EMF maintains a minimum momentum between point “A” and speed step “0” where the locomotive will finally stop. The locomotive minimum speed is bounded by the minimum Back EMF but the speed between speed step “A” and speed Step “0” can be increase if the locomotive is pushed by another locomotive or is moving downhill. This maintains RTC operation and allows the locomotive to operate in concert with others in the same consist.

Point “A” is determined by the track voltage and V-Start, CV 2. If CV 2 is increased, the power curve moves to the left as shown in Figure 2. The linear power curve now intersects at point “B” which is closer to speed step 1. CV2 determines the range of speed steps where the minimum Back EMF is in effect. If CV 2 is too large, minimum speed is not obtained at any speed step. See CV 56.5 for additional information on setting CV 2 for best performance under RTC.

**Note:** Although this example specifies a linear power curve, any power curve can be used from CV 25 or any user defined power curve in CV 67-94.

144 We refer to CV 3, CV 4, CV 23 and CV 24 as Inertia Settings rather than the traditional momentum settings since they do not set the momentum of the locomotive. A locomotive at rest has zero momentum and one in motion has many different momenta depending on its speed. Hence these CV’s do not specify the momentum. Rather they determine acceleration and deceleration, which is better related to simulated inertia.

**Example 8:** Since the RTC algorithm is a throttle control concept, similar locomotives operating together under RTC will attempt to share power equally. Consider the following example of two locomotives both commanded to operate at 50% power.



Locomotive B thinks  
50% power is actually  
51% power

Locomotive A correctly  
thinks 50% power is  
50% power

Locomotive “B” will slow down as it tries to push locomotive “A”. Locomotive “A” will speed up as it feels the push from locomotive “B”. Both locomotives will end up going the same speed at almost the same power setting.

**Example 9:** Two different locomotive manufactures under RTC will tend to equalize power without speed curve correction. If an RTC locomotive is going 40 smph and couples to another RTC locomotive that is going 30 smph, the two locomotives will reach a compromise speed of about 35 smph. RTC allows mismatched locomotives to operate in a consist by internally adjusting their speed to share power equally. If the locomotives are too mismatched, the RTC algorithms may not be able to completely adjust their speeds, which is the same problem that prototype locomotives would have. However, RTC locomotives in a consist would never have the inherent instability where one locomotive would be supplying all the power while the other was completely shut down.

**Example 10:** Mid-Train Helpers and Pushers at the end of the train are possible since each will tend to equalize power.

**Example 11:** Under STC, blowing the horn or activating any sound feature that requires high volume can load the DCC controller, which in turn can lower the track voltage. This can slow or stop a slow moving locomotive. Under RTC, the reduction in track voltage will not affect the speed of the locomotive since the Inertial Control features maintains momentum.

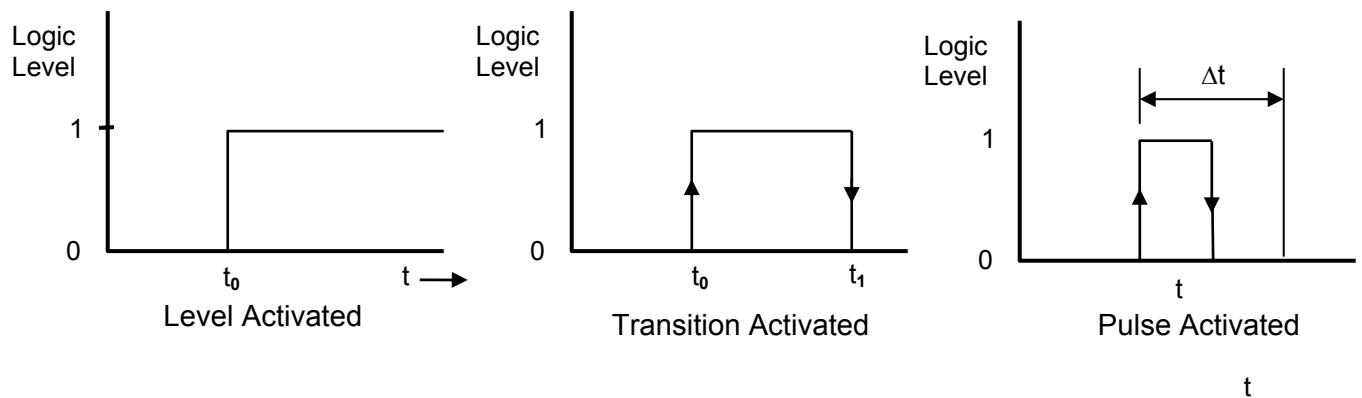
# Appendix VII

## Different types of Feature Operation from Function Commands

QSI will often use the same function to control different effects depending on whether the system is in Neutral or a Motive state (Forward or Reverse). This allows us to increase the number of features commonly available to DCC functions of 14 (FL(f), FL(r), F1-F12). In addition, many QSI features respond to the Function inputs in different ways. It is the purpose of this section to describe how different Quantum features respond to function commands and help you get the most out of operating your locomotives. Also, if you intend to make your own output assignments for features using CV 53, it is important to know the implications of different types of features assigned to Neutral and to Forward/Reverse States for the same output.

### Classification of DCC Signal Types

There is only one kind of function signal for DCC; either a function is “on” and transmits “1’s” every time the command is sent or “off” and transmits “0’s” every time the command is sent. However, Quantum has three different ways to respond to DCC function signals as illustrated below.



**Level Activated:** This is the classic response to a DCC function signal. If the DCC function signal is sent at level 0, the feature is not activated. If the DCC function signal is sent at level 1, the feature will activate. The above figure on the left shows a function signal being sent out at  $t_0$ , where the level changes from “0” to “1” which will cause a Level Activated feature to respond. One possible advantage of Level Activated Signals is that the operator may know the status of a feature<sup>145</sup> by knowing the logic level that has been sent. However, since function signals may not be continuously transmitted, the status of a feature prior to  $t_0$  may not be known unless there had been a recent change to that function or to another function within the same function group.

Another advantage of Level Activated Features is that all locomotives in a Consist receive the same known command. For instance, if the horn feature is turned on, all locomotives blow their horns or if the Mute Feature is activated, all locomotives will mute their sounds or if directional lighting is turned off, all locomotives shut down their directional lighting.

**Transition Activated:** In this case, the feature is activated whenever there is a transition from level 0 to level 1 or from level 1 to level 0. In the above middle figure example, there would be a feature activation at  $t_0$  and a second activation at  $t_1$ . Since the feature is not responding to the logic level of the function signal, the value of the logic level cannot provide any information about the status of the feature.

**Pulse Activated:** Two transitions within a time period,  $\Delta t$ , is required for a Pulse Activated Feature to respond. It makes no difference if the pulse starts at level 0 or at level 1. The figure above shows a transition from level 0 to level 1 followed by a return to level 0, all within the allotted time period,  $\Delta t$ . The advantage of a Pulse Activated feature is that it cannot be accidentally activated since two operations or (presses of the function key) are required within the  $\Delta t$  time period.

<sup>145</sup> This also depends on the type of feature. If it is a triggered feature such as an Air Let-Off, then the logic level provides no information.

## Classification of Feature Types

**Binary Features:** Binary Features have two states; they are either off or on. They can be features that toggle between two states in response to a function commands or they can be set in CV's or respond to different states in the Quantum System. For instance, the Bell sound is binary feature that is toggled by a function key; once it is turned on, it stays on, until it is commanded to turn off. However, the Bell feature also turns off automatically when the power is shut down and reapplied and shuts off at the end of a Doppler sequence, so it responds to other inputs besides the function key.

Binary features are generally Level Activated when operated from function keys. A Level 1 signal will cause the feature to be in one of the two known states, while a level 0 signal will cause it to be in the other known state. This allows the operator to know which state the feature is in by knowing the status of the function signal at his command station or his handheld. For instance, if the feature is a light which can be changed between on (level 1) and off (level 0), then the operator will know the light has been turned on when he sends a level 1 function signal, even if he cannot see the locomotive.

The Horn is also a binary feature, which we assign to F2 as its factory default function key. When the F2 key is activated, then "1's" are sent and the horn sound comes on. The Horn will continue to blow until the F2 key is pressed again to produce "0's" whereupon the horn sound feature will turn off and stay off.

Some command stations have a horn button that can be pressed to operate the horn effect. The Horn sounds when the horn button is pressed and then turns off when the horn button is released. However, the horn button is a custom feature on those DCC controllers and does not act like a normal F2 function key. The horn button is designed to generate "1's" whenever the horn button is pressed and held down and send 0's when the horn button is released. Hence, while the Horn seems like a Momentary Feature when using the horn button, it is actually a Binary Toggled Feature.

Other Binary Features on Quantum include, Bell, Mute, most lighting features, Air-Brakes, Dynamic Brakes, and Blower/Fans.

If function keys are used to active a binary feature, QSI now uses Level Activation as the preferred signaling method for most Binary Features.

Although Binary Features only have two states, there are a number of variations on how these are controlled.

**State Dependent Binary Features:** Features may also change their state depending on other inputs besides function signals. The status of some Binary Features may change when power is turned off and reapplied, or the locomotive changes its motive state or the speed is changed. For instance, the Automatic Headlight switch from bright to Dim when direction is changed; Dynamic Brakes shut off when the speed is reduced below 7smph or whenever the directional state of the locomotive is changed. While state dependent features can be affected by the directional state or other states in the locomotive, binary features are nevertheless either "on" or "off" until changed. In the case of directional lighting and other automatic features, the feature is considered to be the "automatic behavior" and not the behavior of the individual elements. In other words, the Headlight is only part of the automatic Directional Lighting system; it is not considered a separate feature. Directional Lighting is a Binary Feature that has two states; either Directional Lighting is on or it is off. Alternatively, an individual Headlight feature can be assigned to an output and be controlled by function key where the Headlight is the binary feature that is not part of an automatic directional lighting feature.

**Take Control Features:** Some features allow function signals to take priority over automatic behavior. Once the function signal is received, the automatic operation is disabled and the "Take Control" operation is enabled. That feature's on/off state is then under complete control of the Function Key output signal. For instance, in Q1 and Q1a software, Blowers/Fans can be turned on or off by a function key signal, thereby disabling automatic operation. Until automatic operation is restored, the Blower/Fans will only respond to their function key signal.

With "Take Control" features, there needs to be a way to clear the "Take Control" mode to return the feature to automatic operation. Quantum 1 returns the Take Control feature back to automatic operation when power is turned off and reapplied or if the F6 Start Up Key is operated at any time.

Take Control features were eliminated in Q1a DCC software since unintentional Take Control signals could be sent due to the way Function Group packets are sent. If your controller function settings are different than

you locomotive, sending a command to say, “turn on the bell” could result in also changing and taking control of the directional lighting. Function Groups are explained more fully in Appendix VI and in section 1.5.2, *Function Key Operation Explained*.

**Momentary Features:** These are single event features that return to their original status after they are activated. Examples are Air Let-offs, Brake Squeal in Forward and Reverse, Doppler shift and Neutral Events like Pop-off, Blow Down, Cylinder Cocks, etc. All Quantum Momentary Features are Transition Activated. Although it is possible to use Level Activation, it would seem to have limited use. For instance, you could have an Air Let-off respond only when the function signal goes to level 0 from level 1 but not respond when going from level 1 to level 0. This would result in the undesirable and somewhat confusing response of an Air Let-off every other time the function key was pressed.

**Analog Features:** Analog feature respond to a range of inputs. Many QSI CV have Analog values such as Dim headlight intensity that can be change by CV 55.70.10. Analog features are sometimes assigned to Function keys. One example is Air Brakes. Each time the F7 key is pressed, more simulate pressure is released from the brake lines and the greater the braking. If the F7 is released, the braking continues at the last value. In other words, the amount of braking is an analog function of how long the F7 key was pressed.

**Progressive Features:** A Progressive Feature does two things when operated: 1) it activates the currently enabled feature and 2) it enables another feature. The next time it is operated, it may activate a newly enabled feature and enables the next feature, etc. Progressive Features can be Binary or Momentary. Locomotive Shut Down is an example of a Progressive Binary Feature. There are three stages to the shut down operation. Double pressing the F9 Key on a locomotive in Neutral will put it in Disconnect; the next double press operation of the F9 Key will put it in Standby; the next double press operation of the F9 Key will cause it to enter Total Shut Down. At this point, operating F9 key will have no further effect. F6 will start the locomotive and return it to normal operation.

The coupler arm and fire is an example of a Progressive Momentary Feature. The first press of the function key actives the sounds of the coupler lift-bar and coupler pin being raised and enables a second coupler feature the next time the function key is pressed, which is the sound of the coupler knuckle opening and the air-release of the brake-lines parting. Both of the sound effects are momentary.

Progressive features are seldom Level Activated since each feature results in a new feature being enabled. In other words, the individual features cannot toggle on and off. Note that both the Shut Down and Start Up features are Pulse Activated, which requires that the function key be double-pressed within one second to activate each state of Shut Down. Transition Activation would be acceptable for Shut Down but double-pressing ensures that this important feature is not entered accidentally. Coupler sounds are Transition Activated.

#### How Quantum Features Responds to Function Commands

Because Quantum has different features in Forward/Reverse and Neutral, we have implemented software to prevent inadvertent operation of features when the locomotive changes directional state. This applied to both Transition Activated and Level Activated features. For instance, if we had a function setting of “1” for a Binary Feature in Neutral and then changed to Forward, we may not want nor expect that the “1” function setting to affect the feature assigned to that directional state. We require that an actual change in function setting be detected in the Quantum locomotive before a feature can be activated. This sometimes requires two operations of the function before the feature is affected, one operation to match the internal Quantum function level, and one to activate the feature.

For example, imagine we had two State-Dependent Level-Activated features, “A” in Neutral and “B” in Forward that were both controlled by the same function signal, X, where X is continually transmitted. If function X is used to turn on Feature A in Neutral (“X” and Quantum function level set at “1”) and then the locomotive is changed to Forward, the question is what will happen to Feature B. If Feature B was already set to on (Quantum function level set at “1”), there is no conflict since X is still set at “1”; Feature B stays at its current setting. If Feature B was off, we would not want it to automatically respond to the function signal X that continues to transmit “1” when the locomotive changes direction. Requiring that a change in X be detected in Quantum before the feature is activated allows independent operation of Feature B. If B is already off (0), the operator first changes function signal X to 0, which then matches the function setting in Quantum and has no affect on feature B. The operator next changes X to 1, which is detected by Quantum as a change in level to 1 and activates B.



This method of activating features also prevents inadvertent operations of Transition Activated features when changing directional state and allows the user to assigned any type of feature to Neutral and F

## Function Groups

Instead of the Function Commands being sent out as individual commands, they are sent out in groups to the selected locomotive. **Function Group One** sends out the commands for Functions F0 (or FL) and F1 – F4. **Function Group Two** sends out the commands for either Functions F5 – F8 or F9 – F12.

Some decoders do not send out function groups until there is a change to one of the functions within that group. For instance, the controller may have Functions 1, 3 and 4 turned on (set to 1's) while Functions 0 and 2 are off (set to 0's). When the user changes Function 2 to on, then Function Group 1 is transmitted to the locomotive with the entire set of bits for all functions FL, and F1- F4.

This normally does not cause a problem if the locomotive had previously received all of the function settings at the last transmission. However, if the locomotive's function states do not match the controller, the user can expect other functions to respond besides the one that is being changed.

For instance, if the FL command is registered as on (1) in the locomotive while it is shown as off (0) at the DCC controller, then sending a command to turn on the bell, F1, would have the additional effect of turning off the lights.

To complicate the above problem, some controllers do not reset their function settings when a new locomotive is selected. Pressing any function key will send out a set of function commands that were selected for the previous locomotive, which may not be what the operator wants for the newly selected locomotive.

Understanding how function groups operate can explain our Quantum 1 Directional Lighting specification and why we have made changes to Q1a.

### Why Does QSI Now Choose to Have Directional Lights On by Default?

Quantum 1 originally had the Headlight off by default when a locomotive was selected. To understand our reasoning, consider the case where we have the lights on by default. If the lights were on in the controller and any other function key were pressed in Function Group One, then the lights would stay on; this is certainly good. However, if the lights were off in the controller (which is usually the case when starting up), and the user pressed some other function key in Function Group One (like the horn or bell), then the lights would turn off. He would then need to turn the lights back on. This can be distracting, especially with Steam Locomotives that have a very distinctive turn on and turn off Dynamo sound effect. The observer would see and hear the lights come on by default, then turn off when he pressed some other function key like the horn, and then turn on again when he presses the FL Key– very non-prototypical.

However, if the locomotive lights were off by default and the controller had the lights registered as on, then the lights would come on if any other function key were pressed – this would be acceptable. On the other hand, if the controller has the lights registered as off, then the lights would stay off when another key is pressed in Function Group One – this would also be acceptable. The user could then use his Light function command to turn the lights on when he was ready.

While the above makes sense, many customers still prefer the Directional Lighting to come on when a locomotive is selected, particularly diesel locomotives that do not have the problem with a dynamo sound revving up and down. In addition, having the Directional Lighting on by default makes DCC operation consistent with Analog operation. We have therefore changed the default setting for Directional Lighting to “on” when the locomotive is selected.

For those customers that still prefer to have the Directional Lighting off when the locomotive is selected, set CV 55.70.0 to “0”.

## Quantum Features and Signal Types: Table

The following table shows each feature that can be assigned to an output and the type of signal used to operate the feature. These include Level, Transition, or Pulse.

LA = Level Activated

TA = Transition Activated

PA = Pulse Activated

Feature ID	Feature	Signal Type	Allowed States	Function Key Level Assignments
0	Null Output		All	N/A
1	Whistle	LA-Binary	All	1 = Horn On 0 = Horn Off
2	Alternate Horn Selection	LA-Binary	All	1 = Primary Horn 0 = Alternate Horn
3	Bell	LA-Binary	All	1 = Bell On 0 = Bell Off
5	Dynamic Brakes	LA -Binary	FDW/REV, Disconnect in NFF/NFR	1 = Dynamics On 0 = Dynamics Off
6	Arm Cylinder Cocks	TA-Momentary	NFF/NFR	N/A
8	Blower Hiss/Diesel Cooling Fans	LA-Binary "Take Control"	All	1 = Blowers On 0 = Blowers Off
9	Long Air Let-off	TA- Momentary	All	N/A
10	Short Air Let-off	TA- Momentary	All	N/A
12	Pop-off	TA- Momentary	NFF/NFR	N/A
13	Blow Down	TA- Momentary	NFF/NFR	N/A
14	Injector	TA- Momentary	NFF/NFR	N/A
24	Diesel/Turbine Mode Toggle	LA - Binary	NFF/NFR	1 = Turbine 0 = Diesel
64	Mute	LA-Binary	All	1 = Mute On 0 = Mute Off
65	Doppler Shift	TA- Momentary	FWD/REV	N/A
70	Automatic Headlight	LA-Binary	All	1 = Auto On 0 = Auto Off
71	Headlight	LA-Binary	All	1 = Light On 0 = Light Off
72	Dim Headlight	LA-Binary	All	1 = Dim On 0 = Dim Off
73	Automatic Reverse Light	LA-Binary	All	1 = Auto On 0 = Auto Off
75	Dim Reverse Light	LA-Binary	All	1 = Dim On 0 = Dim Off

<b>76</b>	Reverse Light	LA-Binary		1 = Light On 0 = Light Off
<b>77</b>	Mars Light	LA-Binary	All	1 = Light On 0 = Light Off
<b>78</b>	Dim Mars Light	LA-Binary	All	1 = Dim On 0 = Dim Off
<b>79</b>	Strobe Mars Light	LA-Binary	All	1 = Strobe On 0 = Strobe Off
<b>84</b>	Automatic Ditch Lights	LA-Binary	All	1 = Auto On 0 = Auto Off
<b>85</b>	Ditch Lights	LA-Binary	All	1 = Light On 0 = Light Off
<b>86</b>	Dim Ditch Lights	LA-Binary	All	1 = Lights On 0 = Lights Off
<b>87</b>	Strobe Ditch Lights	LA-Binary	All	1 = Strobe On 0 = Strobe Off
<b>100</b>	Automatic Front Number Board Lights	LA-Binary	All	1 = Auto On 0 = Auto Off
<b>101</b>	Front Number Board Lights	LA-Binary	All	1 = Light On 0 = Light Off
<b>102</b>	Automatic Rear Number Board Lights	LA-Binary	All	1 = Auto On 0 = Auto Off
<b>103</b>	Rear Number Board Lights	LA-Binary	All	1 = Lights On 0 = Lights Off
<b>104</b>	Automatic Front Marker Lights	LA-Binary	All	1 = Auto On 0 = Auto Off
<b>105</b>	Front Marker Lights	LA-Binary	All	1 = Lights On 0 = Lights Off
<b>106</b>	Automatic Rear Marker Lights	LA-Binary	All	1 = Auto On 0 = Auto Off
<b>107</b>	Rear Marker Lights	LA-Binary	All	1 = Lights On 0 = Lights Off
<b>116</b>	Automatic Front Cab Lights	LA-Binary	All	1 = Auto On 0 = Auto Off
<b>117</b>	Front Cab Lights	LA-Binary	All	1 = Lights On 0 = Lights Off
<b>118</b>	Automatic Rear Cab Lights	LA-Binary	All	1 = Auto On 0 = Auto Off
<b>119</b>	Rear Cab Lights	LA-Binary	All	1 = Lights On 0 = Lights Off
<b>136</b>	Multiple Automatic Lights #1	LA-Binary	FWD/REV	1 = Auto On 0 = Auto Off
<b>137</b>	Multiple Automatic Lights #2	LA-Binary	All	1 = Auto On 0 = Auto Off
<b>138</b>	Multiple Automatic Lights #3	LA-Binary	All	1 = Auto On 0 = Auto Off
<b>144</b>	Start Up	PA-Binary	NFF/NFR	N/A
<b>145</b>	Disconnect/ Standby/ Total Shut Down	PA-Binary Progressive	NFF/NFR	N/A

<b>176</b>	Air Brakes	LA-Analog Progressive	FWD/REV	1 = Progressive Air Brakes pressure release. 0 = Air Brake pressure reduction stopped.
<b>178</b>	Status Report	TA-Momentary	All	N/A
<b>179</b>	Heavy Load	LA-Binary	FWD/REV	1 = Heavy Load On 0 = Heavy Load Off
<b>211</b>	Coupler	TA-Momentary Progressive	Arm In Neutral Only	N/A
<b>215</b>	Flanges/Air Brakes (Combination of 176 and 215)	TA-Analog Progressive	FWD/REV	N/A
<b>216</b>	Squealing Brakes	TA-Momentary	FWD/REV	N/A
<b>217</b>	Air Pumps	TA- Momentary	NFF/NFR	N/A

## Quantum Default Features and Signal Types

The following table shows our default feature assignments with feature ID shown in bold blue, signal type and feature type shown in blue in blue in parenthesis.

LA = Level Activated

TA = Transition Activated

PA = Pulse Activated

Default F-Key	FWD/REV	NFF/NFR
<b>FL(f)</b>	Multiple Automatic Lights #1 ( <b>136</b> ) (LA Binary)	Multiple Automatic Lights #1 ( <b>136</b> ) (LA Binary)
<b>FL(r)</b>	Multiple Automatic Lights #1 ( <b>136</b> ) (LA Binary)	Multiple Automatic Lights #1 ( <b>136</b> ) (LA Binary)
<b>F1</b>	Bell ( <b>3</b> ) (LA Binary)	Bell ( <b>3</b> ) (LA-Binary)
<b>F2</b>	Horn/Whistle ( <b>1</b> ) (LA Binary)	Horn/Whistle ( <b>1</b> ) (LA-Binary)
<b>F3</b>	Coupler Crash-Coupler Fire ( <b>211</b> ) (TA Momentary)	Coupler Arm (Enable) or Coupler Fire ( <b>211</b> ) (TA-Enabled or TA Momentary)
<b>F4</b>	Steam Blower Hiss/ Diesel Fans and Louvers/ Electric Cooling Fans ( <b>8</b> ) (LA Binary & Take Control)	Steam Blower Hiss (LA-Binary) Diesel Fans and Louvers/ Electric Cooling Fans ( <b>8</b> ) (LA Binary & Take Control)
<b>F5</b>	Dynamic Brakes ( <b>5</b> ) (LA -Binary)	Dynamic Brakes ( <b>5</b> ) (LA-Binary)
<b>F6</b>	Doppler Shift ( <b>65</b> ) (TA Momentary)	Locomotive Start Up ( <b>144</b> ) (PA-Momentary Progressive)
<b>F7</b>	Brake Squeal-Flanges (TA Momentary) Air Brakes ( <b>216</b> ) (LA-Analog)	Steam Cylinder Cocks Arm ( <b>6</b> ) (TA-Momentary) Diesel and Electric Long Air Let-off ( <b>9</b> ) (TA-Momentary) or Gas Turbine Diesel/Turbine Transition ( <b>24</b> ) (LA-Binary)
<b>F8</b>	Sound Mute ( <b>64</b> ) (LA-Binary)	Sound Mute ( <b>64</b> ) (LA-Binary)
<b>F9</b>	Heavy Load ( <b>179</b> ) (TA-Binary)	Shut Down <sup>146</sup> : Disconnect-Low Idle set-Total Shut Down ( <b>145</b> ) (PA-Binary- Progressive)
<b>F10</b>	Status Report ( <b>178</b> ) (TA-Momentary)	Status Report ( <b>178</b> ) (TA-Momentary)
<b>F11</b>	Alternate Horn Selection ( <b>2</b> ) (LA Binary) Multiple Automatic Lights #2 ( <b>137</b> ) (LA Binary)	Alternate Horn Selection ( <b>2</b> ) (LA Binary) Multiple Automatic Lights #2 ( <b>137</b> ) (LA Binary)
<b>F12</b>	Multiple Automatic Lights #3 ( <b>138</b> ) (LA Binary)	Multiple Automatic Lights #3 ( <b>138</b> ) (LA Binary)

By default, in most Q1a and Q2 equipped locomotives, Multiple Automatic Lights #1 controls the automatic Headlight, Reverse Light, Front and Rear Mars Lights, Ditch Lights, and Overhead Blinking Light.

By default, in most Q1a and Q2 equipped locomotives, the Multiple Automatic Lights #2 feature controls the automatic Front and Rear Number Board Lights, Front and Rear Marker Lights, and Front and Rear Step Lights. For most factory models with limited number of lights, Automatic Lights usually only controls Front and Rear Number Board Lights.

By default, in most Q1a and Q2 equipped locomotives, Multiple Automatic Lights #3 controls the automatic Front and Rear Cab Lights.

The features in the above table were designed and assigned to provide the greatest consistency of operation of the different types of locomotives (Steam, Diesel and Electric) as well as maintaining the greatest level of correspondence between the displayed function settings and operating feature status.

Note that FL(f), FL(r), F1, F2, F4, F5, some of F7, F8, F9, F11 and F12 all are Level Activated Binary Features. This means that the displays for these features are likely to indicate the true status of the features in the locomotive.

Most other features are Transition or Pulse Activated Momentary type, which only respond to changes in the function inputs. Status indication on the controller for these features are not required since they return to their

<sup>146</sup> There are three stages to Shut Down. To operate Shut down, you will need to double click the F9 key for each stage.

initial state after a short period or are progressive features where the display would be of no use. This includes F3, F6, F7, F9-Shut Down, and F10.

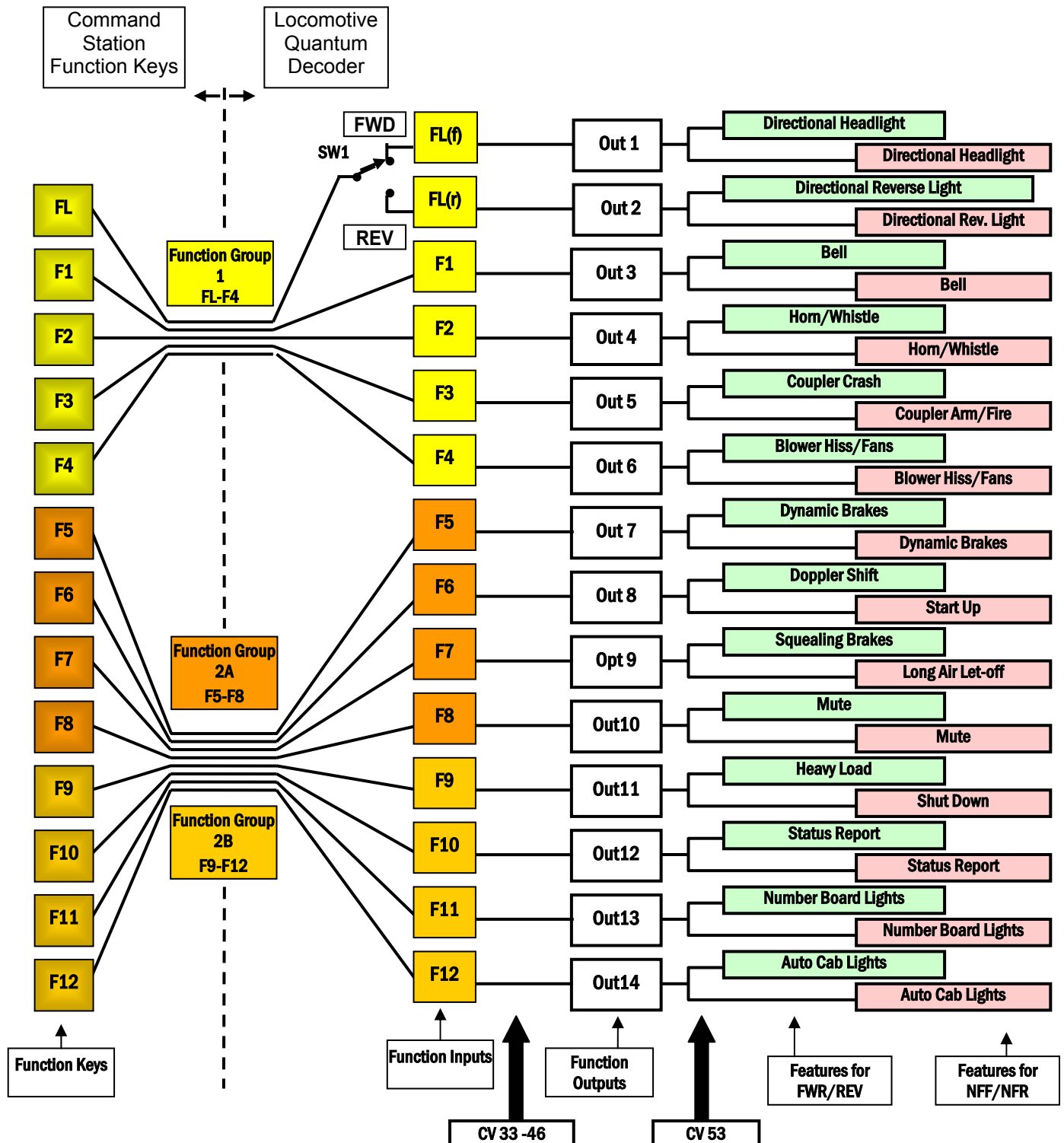
F8, Sound Mute, always comes on in its non-mute state when power is first applied. Since the F-Key status could be displayed as "1" during start up, it may not match the status of the Mute feature in the locomotive. However, the status of this feature is quite evident by the fact the locomotive is making sound. If the Mute Key is operated even once, the status of the Mute key function display will then match the locomotive Mute status for the remainder of the operating session.

Since Dynamic Brakes is a State Dependent feature, its status in the locomotive may not match the F-Key function display of "1". However, since the Dynamic Brakes will shut off whenever entering Neutral or slowing below 7smph, unless you hear the Dynamic Brakes or have recently turned them on with a level 1 setting, it is a fair assumption that they are off. If the display for F5 is "0", then the Dynamic Brakes are known to be off.

# Appendix VIII

## Interaction of Function Keys, Function Groups, Function Inputs and Outputs and Feature Assignments

The diagram below shows graphically how the Function Keys, Function Groups, Function Inputs, and Outputs are configured and how they interact.



**Function Keys and Function Groups:** The thirteen colored squares shown on the left side of the dotted vertical line, designated FL, and F1 through F12 represent push buttons or Function Keys located at the Command Station or on the DCC walk-around throttle.

The Function Keys are shown color-coded depending on which Function Group they use to transmit their bit settings to the locomotive's decoder. Keys FL through F4 (Yellow) use Function Group 1 to send information to the locomotive. Keys F5 through F8 (Orange) and Keys F8 through F12 (Gold) both use Function Group 2 but not at the same time. Bit 5 in Function Group 2 specifies whether this Function Group applies to F5 – F8 or F8 - F12. Each Function Group command contains 4 or 5 bit settings for the Function Inputs.

The locomotive's decoder, shown to the right of the vertical dotted line, receives Function Group commands. Whenever a Function Group Command is sent, the function values are stored in memory as a Function Input, each with a logic level of 1 or 0.

**Function Inputs and Outputs:** Each Function Input is shown connected to a corresponding Function Output designed by the squares Out 1 through Out 14.

The boxed labeled "CV's 33-46" with black arrow pointing up indicates that these CV's determine which Function Input controls which desired Function Output. Function Inputs cannot be connected to any Function Output. For instance, Function Inputs FL through F3 can only be connected to Outputs 1 through 8 (see CV 33-37). The diagram shows the default connections between Function Inputs and Outputs. In the description of each CV 33-42, the default Output is shown with gray background [as an example, see CV 41 on page 72, which shows the Output locations for F7. The default is Output 7 (bit 5) and is shown with gray fill, which corresponds to Output 9].

The FL Function Key is special since it connects to two different Function Inputs depending on the locomotive's direction setting. This is shown schematically in the diagram where the position of the single-pole double-throw switch, SW1, is determined by the locomotive's direction (FWD or REV). In Forward (or Neutral from Forward), the switch, SW1 is in the top position which connects the FL Key to the FL(f) input. When the locomotive is in Reverse (or Neutral from Reverse), the SW1 would be in the bottom position, which connects the FL(f) Key to the FL(r) Input.

The default Outputs for FL(f) and FL(r) are Out 1 and 2 respectively. If the locomotive is in Forward or Neutral from Forward, the FL key will affect the features connected to Out 1. If the locomotive is in Reverse or Neutral from Reverse, the FL key will affect the features connected to Opt 2. Function Outputs 1 and 2 are generally used for directional lighting effects and are usually assigned to the FL(f) and FL(r) Inputs respectively, which are the Quantum default settings.

Although each Function Input is shown connected to only one Output, there is no restriction in connecting an Input to more than one Output. This can be useful if it is desired to control two or more features at the same time. For instance, it might be desired to have the Bell turn on at the same time the Reverse Light is turned on by the FL(r) Key or to have Ditch Lights operate at the same time the Horn is activated.

Since there are only fourteen Inputs and fourteen Outputs, if more than one Output is connected to an Input, there may be unused Inputs.

Of course, the unused Inputs could be connected to other Outputs that are already assigned but this is not recommended. Because there is more than one Input controlling an Output, it is unclear which Input has control. The software is written such that the common Output would be on if any of its Inputs are on. In other words, the Output is off if and only if all connected Inputs are off<sup>147</sup>.

Outputs that are not connected to a Function Input are always off.

---

<sup>147</sup> In other words, the Inputs to a common Output are OR'ed.



**Outputs and Features:** The box labeled “CV 53” with black arrow pointing up indicates that this CV determines which feature is connected to which Output. CV 53 also allows different features or accessories to be assigned to the Neutral States (locomotive stopped) or to a Motive States (Forward/Reverse). Features shown in the green boxes are assigned to the Motive States and features shown in the red boxes are assigned to the Neutral States. The diagram shows the default Quantum features assigned to the different Function Outputs for Motive and Neutral states.

**Effects of Mixing Different Types of Features:** Quantum decoders previously had restrictions on assigning to the same output different types of features with different feature activation methods (Level, Transition or Pulse) for operation in Neutral or Forward/Reverse. The reasons were obvious. If you assigned one feature for operation in Neutral and then another for Forward/Reverse, then the function Input would be changed for both. For instance, if the Bell was assigned to Output 3 in Forward/Reverse and Number Board Lights assigned to Output 3 in Neutral, than there is an issue of what would happen to the Number Board Lights if you turned on the Bell in Forward by sending out a level 1 function and then entered Neutral? The function Input for Output 3 is still at the new value of level 1. Do the Number Board Lights automatically come on, if previously off?

To avoid this problem, we have a simple rule:

**An Output for a particular directional state (Forward/Reverse or Neutral) will change state, if and only if its Function Input changes while in that directional state.**

There would seem to be another way that we could accidentally operate a feature. We could make the change to a feature assigned to an output in one directional state, and after we change to a new directional state, we operate some other function within the same function group. For instance, in the above example, we could turn on the Bell in Forward/Reverse with a level 1 Function Input signal, followed by operating the Horn in Neutral. Now when the common function group, Function Group 1, command packet is sent, it will also change the function input for Output 3 and would turn on the Number Board Lights. However, the above rule still applies since the function input did not change; it remained at level 1, and hence its output did not change. In order for the operator to turn on the Number Board Lights in this case, he would need to send a level 0 function followed by a level 1 function to Output 3 while in Neutral.

The main difficulty with mixing different features in Neutral and Forward/Reverse, is that the status of the function at the command station or handheld, does not match the expected associated behavior of assigned toggled features. This is compounded by state dependent toggled features where other inputs can change the status of a feature independent of the function commands and also by Transition or Pulse Activated toggled features, where the function input level has no bearing on the feature status. While an operator may not know what the status of some features are, he does know that whenever a function input is changed, the function input in the Quantum decoder will match the value indicated at the command station or the handheld during an the entire uninterrupted operating secession<sup>148</sup>. The operator can also infer that for most Level Activated Toggled Features, the state of a feature will match the associated level of the function signal directly after sending a function signal. In other words, the operator will know that he has turned on the Number Board Lights directly after he has sent out the appropriate level 1 function for that feature.

Note that these issues only apply to toggled features. There certainly is no issue for Momentary Features, where they always return to their original status, or any other features that are Transition or Pulse activated.

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<sup>148</sup> Unless he selects a different locomotive whereupon all indicated function key status may very well have no relationship with the function inputs in the newly selected locomotives decoder.

# Appendix IX

## Recommended Reading:

Ames, S., Friberg, R., and Loizeaux, E. *Digital Command Control*. Allt om Hobby 1998

Ireland, Zana (Editor In Chief), *The Digitrax Big Book of DCC*, Digitrax, 1999.

Strang, Lionel, *DCC Made Easy*, Kalmbach Publishing 2003

Polsgrove, Mike, *DCC Projects & Applications*, Kalmbach Publishing, 2006.

# Appendix X

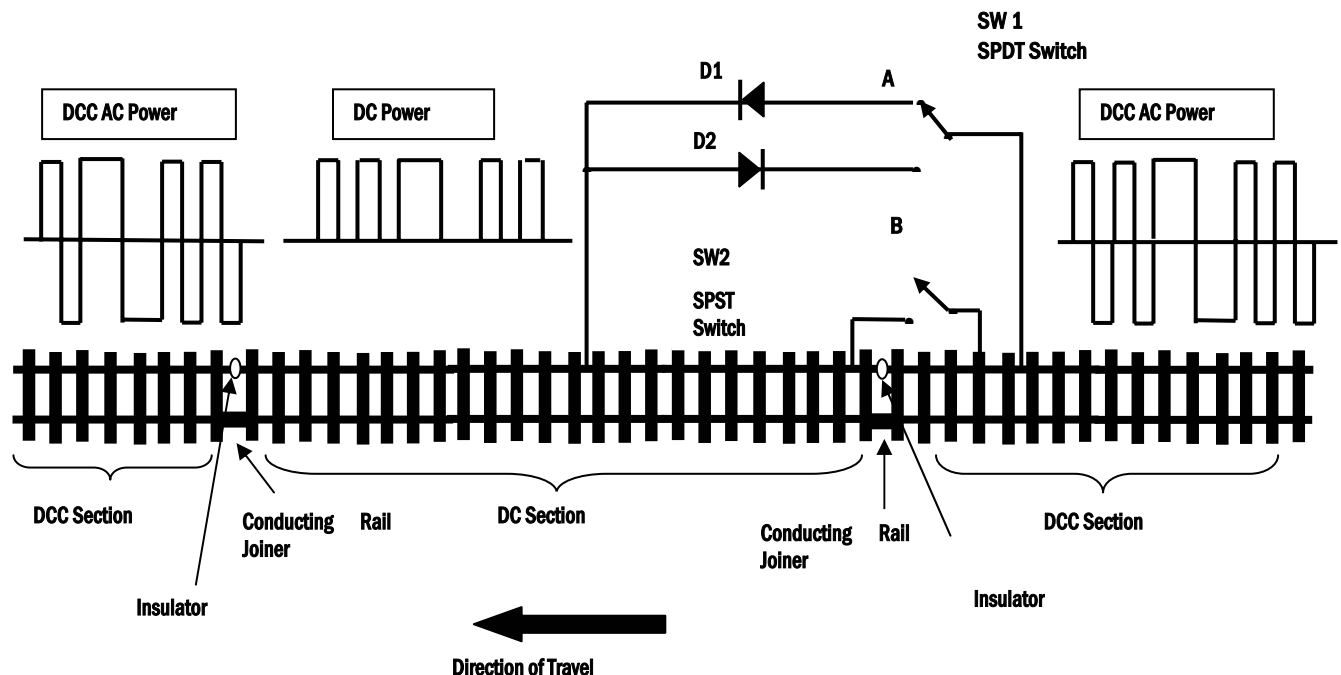
## Application Notes:

### Using DC Power Conversion for Block Signal Control

#### CV 29, Bit 2 =1. Applications for DC Power Conversion: Block Signal Control

DCC Power Conversion as described under CV 29, bit 2, was implemented into Quantum decoders in a way that allows for simple block signal control. Using DC power conversion allows the operator to enable a red signal light to stop a train smoothly, using its internal momentum settings, without having to use the throttle. If Bit 2=1 for CV 29, a DCC controlled locomotive will automatically engage DC Power Conversion when it enters a section of track that is powered with standard DC. If the polarity would normally power the analog locomotive in the direction it is going when it enters the DC section, the locomotive will continue through the DC block at the same speed. If the polarity would normally power the locomotive in the Reverse direction, the locomotive will smoothly come to a stop in the DC section.

The diagram below shows a DCC section connected to a DC section of track. The DC section is powered from the DCC power signal rather than from a separate power supply or battery. For this application, it is only necessary to insulate the one rail as shown by the two insulated rail joiners at either end of the DC section; the other rail is electrically connected to the DCC section by conductive rail joiners.



When switch 2 (SW 2) is open, the DCC signal is half-wave rectified by diodes D1 or D2 to produce a positive DC signal to the DC section when Switch 1 is at position A or a negative DC signal when Switch 1 is at position B. If Switch 2 is closed, the DCC signal is connected directly to the DC section and D1 and D2 have no effect on applying DC power to the DC section.

If DC power conversion is enabled in CV 29 (bit 2 = 1) and SW 2 is open, the polarity on the DC section can be used to stop the Quantum equipped locomotive or let it precede, depending on the position of SW 1. If the locomotive is entering the DC section from the right, and SW 1 is set to A, the locomotive will continue at its current speed setting through the DC section. The locomotive, of course, will not respond to DCC signals until it leaves the DC section and reenters the DCC powered section at the far left. On the other hand, if SW 1 is set to B, the polarity on the DC section is opposite the locomotive's direction and the locomotive will slow to a stop at its DCC momentum setting. If the polarity is reversed again to be consistent with the locomotive's direction, the locomotive will accelerate at its current DCC momentum setting to leave the DC section. Alternately, SW 2 could have been closed to cause DCC signals to be applied to the stopped locomotive, which would also have caused the locomotive to accelerate at its current DCC momentum value to its DCC speed setting.

Since the DC portion is powered from the DCC signal, there are no short circuit problems between the DCC powered section and the DC section as the locomotive wheels pass over the track insulators. In addition, since the Quantum locomotive is equipped with large filter capacitors, the reduced power of half-wave rectification will not affect the power available to operate the locomotive so there is minimal slow down effect. Also, if the train is made up of a series of Quantum locomotives in a Consist, and the polarity is set to stop the train, each locomotive in turn will couple the DCC signal through to the DC section until the last locomotive has passed over the boundary; only then will the entire Consist come to a stop.

The above diagram is simplified to make it easy to describe the basic concept. Switch 1 can be a relay powered by a train detector on the next block to do automatic train control. In addition, Switch 1 could have extra contacts to control red and green signals for the actual block signal. Switch 2 could also be part of a relay network for all DC blocks to disable or enable block signal operation.

D1 and D2 should be rated at 2 amps minimum and have a breakdown voltage of 30 volts or more.

# Appendix XI

## Binary, Hexadecimal, Decimal Conversions

Decimal	Hex	Binary	Decimal	Hex	Binary	Decimal	Hex	Binary	Decimal	Hex	Binary
0	00	00000000	64	40	01000000	128	80	10000000	192	C0	11000000
1	01	00000001	65	41	01000001	129	81	10000001	193	C1	11000001
2	02	00000010	66	42	01000010	130	82	10000010	194	C2	11000010
3	03	00000011	67	43	01000011	131	83	10000011	195	C3	11000011
4	04	00000100	68	44	01000100	132	84	10000100	196	C4	11000100
5	05	00000101	69	45	01000101	133	85	10000101	197	C5	11000101
6	06	00000110	70	46	01000110	134	86	10000110	198	C6	11000110
7	07	00000111	71	47	01000111	135	87	10000111	199	C7	11000111
8	08	00001000	72	48	01001000	136	88	10001000	200	C8	11001000
9	09	00001001	73	49	01001001	137	89	10001001	201	C9	11001001
10	0A	00001010	74	4A	01001010	138	8A	10001010	202	CA	11001010
11	0B	00001011	75	4B	01001011	139	8B	10001011	203	CB	11001011
12	0C	00001100	76	4C	01001100	140	8C	10001100	204	CC	11001100
13	0D	00001101	77	4D	01001101	141	8D	10001101	205	CD	11001101
14	0E	00001110	78	4E	01001110	142	8E	10001110	206	CE	11001110
15	0F	00001111	79	4F	01001111	143	8F	10001111	207	CF	11001111
16	10	00010000	80	50	01010000	144	90	10010000	208	D0	11010000
17	11	00010001	81	51	01010001	145	91	10010001	209	D1	11010001
18	12	00010010	82	52	01010010	146	92	10010010	210	D2	11010010
19	13	00010011	83	53	01010011	147	93	10010011	211	D3	11010011
20	14	00010100	84	54	01010100	148	94	10010100	212	D4	11010100
21	15	00010101	85	55	01010101	149	95	10010101	213	D5	11010101
22	16	00010110	86	56	01010110	150	96	10010110	214	D6	11010110
23	17	00010111	87	57	01010111	151	97	10010111	215	D7	11010111
24	18	00011000	88	58	01011000	152	98	10011000	216	D8	11011000
25	19	00011001	89	59	01011001	153	99	10011001	217	D9	11011001
26	1A	00011010	90	5A	01011010	154	9A	10011010	218	DA	11011010
27	1B	00011011	91	5B	01011011	155	9B	10011011	219	DB	11011011
28	1C	00011100	92	5C	01011100	156	9C	10011100	220	DC	11011100
29	1D	00011101	93	5D	01011101	157	9D	10011101	221	DD	11011101
30	1E	00011110	94	5E	01011110	158	9E	10011110	222	DE	11011110
31	1F	00011111	95	5F	01011111	159	9F	10011111	223	DF	11011111
32	20	00100000	96	60	01100000	160	A0	10100000	224	E0	11100000
33	21	00100001	97	61	01100001	161	A1	10100001	225	E1	11100001
34	22	00100010	98	62	01100010	162	A2	10100010	226	E2	11100010
35	23	00100011	99	63	01100011	163	A3	10100011	227	E3	11100011
36	24	00100100	100	64	01100100	164	A4	10100100	228	E4	11100100
37	25	00100101	101	65	01100101	165	A5	10100101	229	E5	11100101
38	26	00100110	102	66	01100110	166	A6	10100110	230	E6	11100110
39	27	00100111	103	67	01100111	167	A7	10100111	231	E7	11100111
40	28	00101000	104	68	01101000	168	A8	10101000	232	E8	11101000
41	29	00101001	105	69	01101001	169	A9	10101001	233	E9	11101001
42	2A	00101010	106	6A	01101010	170	AA	10101010	234	EA	11101010
43	2B	00101011	107	6B	01101011	171	AB	10101011	235	EB	11101011
44	2C	00101100	108	6C	01101100	172	AC	10101100	236	EC	11101100
45	2D	00101101	109	6D	01101101	173	AD	10101101	237	ED	11101101
46	2E	00101110	110	6E	01101110	174	AE	10101110	238	EE	11101110
47	2F	00101111	111	6F	01101111	175	AF	10101111	239	EF	11101111
48	30	00110000	112	70	01110000	176	B0	10110000	240	F0	11110000
49	31	00110001	113	71	01110001	177	B1	10110001	241	F1	11110001
50	32	00110010	114	72	01110010	178	B2	10110010	242	<b>F2Error!</b>	11110010
51	33	00110011	115	73	01110011	179	B3	10110011	243	F3	11110011
52	34	00110100	116	74	01110100	180	B4	10110100	244	F4	11110100
53	35	00110101	117	75	01110101	181	B5	10110101	245	F5	11110101
54	36	00110110	118	76	01110110	182	B6	10110110	246	F6	11110110
55	37	00110111	119	77	01110111	183	B7	10110111	247	F7	11110111
56	38	00111000	120	78	01111000	184	B8	10111000	248	F8	11111000
57	39	00111001	121	79	01111001	185	B9	10111001	249	F9	11111001
58	3A	00111010	122	7A	01111010	186	BA	10111010	250	FA	11111010
59	3B	00111011	123	7B	01111011	187	BB	10111011	251	FB	11111011
60	3C	00111100	124	7C	01111100	188	BC	10111100	252	FC	11111100
61	3D	00111101	125	7D	01111101	189	BD	10111101	253	FD	11111101
62	3E	00111110	126	7E	01111110	190	BE	10111110	254	FE	11111110
63	3F	00111111	127	7F	01111111	191	BF	10111111	255	FF	11111111

# Appendix XII

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