DoubleTalk RC8650

CMOS, 3.3 Volt / 5 Volt Voice Synthesizer Chipset

FEATURES

- Integrated text-to-speech processor:
  - High voice quality, unlimited vocabulary
  - Converts any ASCII text into speech automatically
  - Add/modify messages by simply editing a text file
  - On-the-fly control of speed, pitch, volume, etc.
- Playback of sound files:
  - Real-time PCM and ADPCM
  - Prerecorded on chip, up to 15 minutes
- Tone generation:
  - Three voice musical
  - Dual sinusoidal
  - DTMF (Touch-Tone) dialer
- On-chip A/D converter:
  - Four channels, 8-bit resolution
  - One-shot, continuous, single sweep, and continuous sweep modes of operation
  - Software and hardware triggering
  - Support for external op amp
- Analog and digital audio outputs
- Serial and bus interfaces
- User programmable greeting and default settings
- Flexible user exception dictionary
- In-circuit, field programmable
- 2 KB input buffer for virtually no-overhead operation
- Available in 3.3 V and 5 V versions
- Low power (typ @ 3.3 V):
  - 11 mA active
  - 0.7 mA idle
  - 2 µA standby

APPLICATIONS

- Robotics
- Talking OCR systems
- Talking pagers and PDAs
- GPS navigation systems
- Vending, ticketing and ATM machines
- Remote diagnostic reporting
- Dial-up information systems
- Handheld barcode readers
- Electronic test and measurement
- Security systems
- Aids for the orally or visually disabled
- Meeting federal ADA requirements

GENERAL DESCRIPTION

The RC8650 integrates a text-to-speech (TTS) processor, real time and prerecorded audio playback, multiple tone generators and telephone dialer into an easy to use chipset. The integrated text-to-speech processor utilizes RC Systems' DoubleTalk™ TTS technology, which is based on a patented voice concatenation technique using real human voice samples. The DoubleTalk TTS processor also gives the user unprecedented real-time control of the speech signal, including pitch, volume, tone, speed, expression, articulation, and so on.

Using a standard serial or bus interface, any ASCII text can be streamed to the RC8650 for automatic conversion into speech. Real time and prerecorded audio playback modes augment the TTS capabilities for applications requiring very high voice quality and a relatively small, fixed vocabulary, or applications requiring special sounds or sound effects. Integrated musical and sinusoidal tone generators, Touch-Tone dialer and four-channel A/D converter further enhance the RC8650's attractiveness by providing these often-needed functions on chip. The audio output is delivered in both analog and digital PCM audio formats, which can be used to drive a speaker or digital audio stream.

The RC8650 includes integrated nonvolatile memory for the storage and on-demand playback of up to 15 minutes of prerecorded speech and sounds. Additional on-chip memory enables the user to store a power-on "greeting" message that is automatically played whenever the chipset is powered up, as well as configure the chip's default settings. A special memory area is also provided for storing a custom pronunciation dictionary, allowing the pronunciation of virtually any character string to be redefined. All of these features can be programmed and updated by the user via the integrated serial port, even in the field after the RC8650 has been integrated into the end-product.

The RC8650 chipset is comprised of two surface-mounted devices. Both operate from a +3.3 V or +5 V supply and consume very little power. Most applications require only the addition of a lowpass filter/audio power amplifier to implement a fully functional system.

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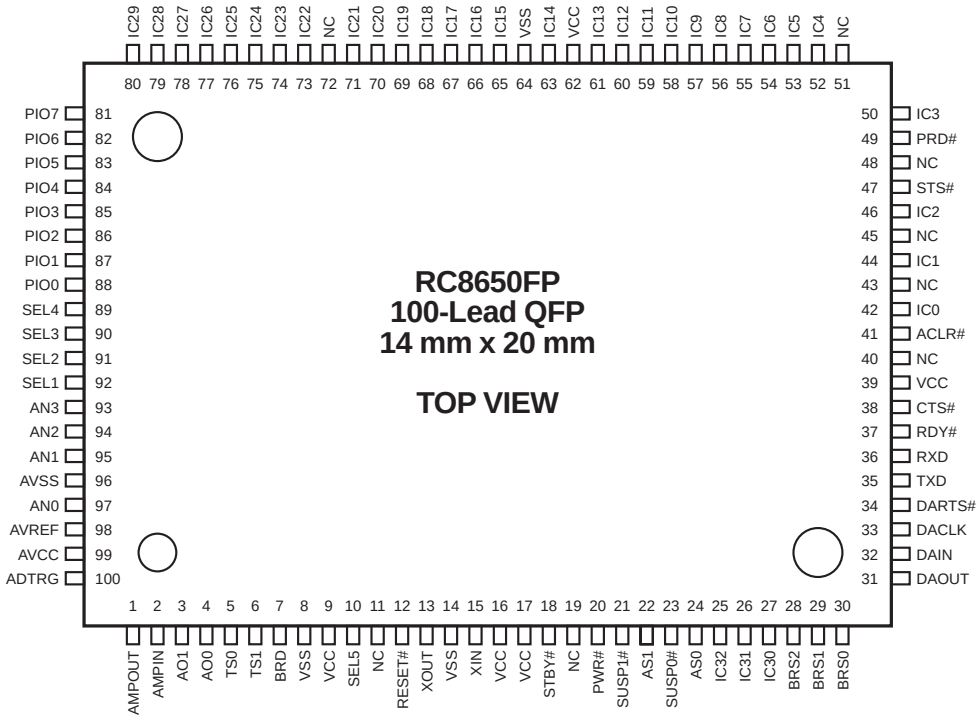
SECTION 1: SPECIFICATIONS

PINOUTS



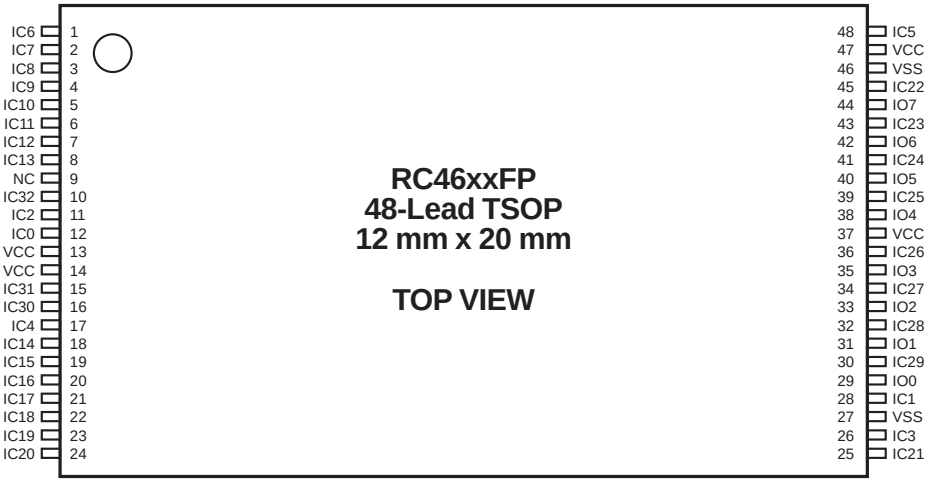


Figure 1.1. Pin Assignments

PIN DESCRIPTIONS

Table 1.1. Pin Descriptions

Pin Name	Type	Name and Function
IC_0–IC_{32}	INPUT/ OUTPUT	**CHIPSET INTERCONNECTS:** Interconnections between the RC8650 and RC46xx chips. IC_0 connects to IC_0, IC_1 to IC_1, etc. IC_{30}–IC_{32} must have a 47 kΩ pullup resistor to VCC. No other connections should be made to these pins.
AO_0 AO_1	OUTPUT	**ANALOG OUTPUT:** Channels 0 and 1 digital to analog (D/A) converter outputs. The output voltage range is from 0 V to AV_{REF}; AV_{REF}/2 V when at rest. Single channel systems must use AO_0.
TS_0 TS_1	OUTPUT	**TALK STATUS:** Indicates whether a voice channel is active. TS_n can be used to enable external devices such as a transmitter, telephone, or audio amplifier. The pins' polarity are programmable, and can be activated automatically or under program control. Single channel systems must use TS_0.
$SUSP_0$# $SUSP_1$#	INPUT	**SUSPEND:** Suspends audio output when Low. These pins affect only the corresponding AO pin; they do not affect the digital audio output DAOUT pin (use DARTS# to control DAOUT). Single channel systems must use $SUSP_0$#. Connect these pins to a High level if not used.
AS_0 AS_1	OUTPUT	**AUDIO SYNC:** Outputs a clock signal in synchronization with the updating of analog outputs AO_0 and AO_1. The pin changes state whenever the corresponding D/A converter is updated. Single channel systems must use AS_0.
DAOUT	OUTPUT	**DIGITAL AUDIO OUTPUT:** Provides the same 8 bit digital audio stream that is fed to the internal D/A converters. This pin can be programmed to be a CMOS or open-drain output. The communication protocol is progammable, and can operate in synchronous or asynchronous mode.
DACLK	INPUT	**DIGITAL AUDIO CLOCK:** This pin is used to clock data out of the DAOUT pin and data into the DAIN pin in the synchronous digital audio output mode. DACLK can be programmed to transfer data on either the rising edge or falling edge of the clock. Connect this pin to a High level if not used.
DAIN	INPUT	**DIGITAL AUDIO CONTROL INPUT:** This pin is used to control the operation of the DAOUT pin in a multi-channel system. Reserved for a future product; connect this pin to a High level.
DARTS#	INPUT	**DIGITAL AUDIO REQUEST TO SEND:** A Low on this pin enables transmission from the DAOUT pin; a High suspends transmission. DARTS# may be used in both the synchronous and asynchronous transfer modes. Connect this pin to a Low level if not used.
PIO_0–PIO_7	INPUT/ OUTPUT	**PERIPHERAL INPUT/OUTPUT BUS:** Eight bit bidirectional peripheral bus. Data is input from a peripheral when PRD# is active. Status information is output when STS# is active. PIO_0–PIO_7 also connect to the RC46xx chip. Text, data and commands can be sent to the RC8650 over this bus.
STS#	OUTPUT	**STATUS:** Controls the transfer of status information from the RC8650 to a peripheral. Status information is driven on the PIO_0–PIO_7 pins when STS# is Low. STS# is active only when there is new status information.
PRD#	OUTPUT	**PERIPHERAL READ:** Controls the transfer of data from a peripheral to the RC8650. Data is read from the PIO_0–PIO_7 pins when PRD# is Low. If a connection is made to PRD#, it must also have a 47 kΩ pullup resistor to V_{CC}.
PWR#	INPUT	**PERIPHERAL WRITE:** Controls the writing of peripheral data to the RC8650. Data on the PIO_0–PIO_7 pins is read by the RC8650 on the rising edge of PWR#. Sufficient time must be given for the RC8650 to process the data before writing additional data—RDY# (or Status Register bit SR.4) should be used for this purpose. Connect this pin to a High level if not used.
RDY#	OUTPUT	**READY:** RDY# High indicates that the RC8650 is busy processing the last byte that was written over the Peripheral I/O Bus. Wait for RDY# to be Low before attempting to write more data. RDY# goes High briefly after each write operation over the PIO_0–PIO_7 bus, acknowledging receipt of each byte. If the RC8650's input buffer becomes full as a result of the last write operation, RDY# will remain High until room becomes available. Note that RDY# can also be read from Status Register bit SR.4.

Table 1.1. Pin Descriptions (Continued)

Pin Name	Type	Name and Function
AN0-AN3	INPUT	**A/D CONVERTER INPUTS:** Analog to digital converter input pins. Leave any unused pins unconnected.
ADTRG	INPUT	**A/D CONVERTER TRIGGER:** Starts A/D conversion when hardware triggering is selected. Minimum Low pulse width is 200 ns. Leave this pin unconnected if not used.
AMPIN AMPOUT	INPUT OUTPUT	**A/D CONVERTER AMPLIFIER:** Connecting an operational amplifier between these pins allows the input voltage to all four A/D converter input pins to be amplified with one operational amplifier. Leave these pins unconnected if not used.
RXD	INPUT	**RECEIVE DATA:** Asynchronous serial data input used to read text, data and commands into the RC8650. Connect this pin to a High level if not used.
TXD	OUTPUT	**TRANSMIT DATA:** Asynchronous serial data output used to read information out of the RC8650.
CTS#	OUTPUT	**CLEAR TO SEND:** The CTS# pin is Low when the RC8650 is able to accept data. CTS# acknowledges each byte received on the RXD pin by going High briefly. If the RC8650's input buffer becomes full as a result of the last byte received, CTS# will remain High until room becomes available.
BRD	INPUT	**BAUD RATE DETECT:** BRD is used by the RC8650 to sample the host's serial data stream in order to determine its baud rate. BRD is normally connected to the RXD pin. The BRS_0–BRS_2 pins affect the operation of BRD. Connect this pin to a High level if not used.
BRS_0– BRS_2	INPUT	**BAUD RATE SELECT:** Programs the asynchronous serial port's baud rate. Both the RXD and TXD pins are programmed to the baud rate set by these pins. Setting BRS_0–BRS_2 to a High level will allow the RC8650 to automatically detect the baud rate with the BRD pin. Connect to a High level if not used.
STBY#	INPUT	**STANDBY/INIT:** Dual function pin which either puts the RC8650 in standby mode or initializes its internal parameter memory. STBY# must be High on the rising edge of RESET#. **Driving STBY# Low for 250 ms or longer causes the RC8650 to enter Standby mode.** All peripheral and serial port handshake lines are driven to their false ("not ready") states, and the input buffer is cleared. During standby, the RC8650 draws the minimum possible current (2 µA typ), but it is not able to respond to any input pin except STBY# and RESET#. Returning STBY# High causes the RC8650 to enter Idle mode (1 mA typ); the handshake lines are re-asserted and the RC8650 will be able to accept input again. If the RC8650 entered standby due to a Sleep Timer event, driving STBY# Low for 250 *ns* or longer then High will return the RC8650 to Idle mode. **Driving STBY# Low for less than 250 ms initializes the RC8650's non-volatile parameter memory.** The greeting message and user dictionary are erased, and all voice parameters are restored to their factory default settings. The prerecorded audio memory is not affected. The RC8650 then announces its version number via the AO_0 pin. Connect this pin to a High level if not used.
SEL_1– SEL_5	INPUT	**SELECT:** Programs the channel pair that the RC8650 is to respond to in a multi-channel system. These pins are reserved for a future product; connect SEL_1–SEL_5 to a Low level to ensure upward compatibility.
RESET#	INPUT	**RESET:** A Low immediately terminates all activity and sets all pins in a known state. RESET# must be held Low a minimum of 3 µs after V_{CC} has stabilized in the proper voltage range. All pins will be valid within 2 ms after reset.
ACLR#	INPUT	**ANALOG CLEAR:** A Low initializes the D/A and A/D converters within the RC8650. Connect ACLR# to RESET#.

Table 1.1. Pin Descriptions (Continued)

Pin Name	Type	Name and Function
XIN XOUT	INPUT OUTPUT	**CLOCK INPUT/OUTPUT:** These pins connect to the internal clock generating circuit. All timing for the RC8650 and RC46xx chips are derived from this circuit. Connect a 7.3728 MHz crystal between XIN and XOUT. Alternatively, an external 7.3728 MHz square wave may be applied to XIN.
V_{CC}		**POWER:** +5 V ±10%, +3.3 V ±0.3 V power supply connection.
V_{SS}		**GROUND:** Connect these pins to system ground.
AV_{CC}		**ANALOG POWER:** Power supply input for the D/A and A/D converters. Connect this pin to V_{CC}.
AV_{SS}		**ANALOG GROUND:** Ground input for the D/A and A/D converters. Connect this pin to V_{SS}.
AV_{REF}		**ANALOG REFERENCE VOLTAGE:** Reference voltage for the D/A and A/D converters. Connect this pin to V_{CC}. *Caution: any noise present on this pin will appear on the AO output pins.*
NC		**NO CONNECT:** NC pins must remain unconnected. Connection of NC pins may result in component failure or incompatibility with future product enhancements.

BLOCK DIAGRAM

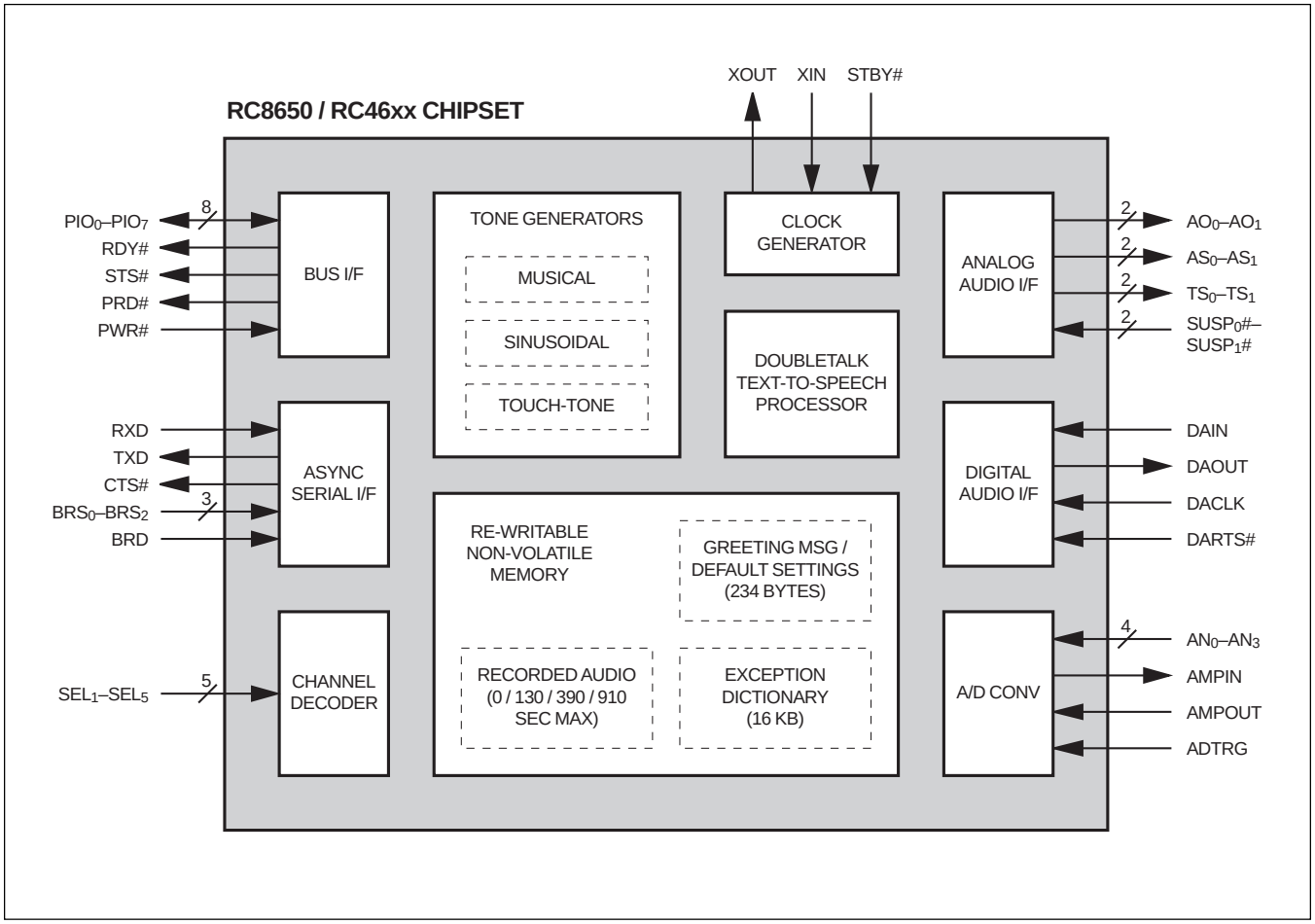


Figure 1.2. Functional Block Diagram

FUNCTIONAL DESCRIPTION

The RC8650 chipset includes a number of features that make it ideally suited for any design requiring voice output. The RC8650's major features are described below.

Text-to-Speech Synthesizer

The RC8650 provides text-to-speech conversion with its integrated DoubleTalk text-to-speech synthesizer. Any English text written to the RC8650 is automatically converted into speech. Commands can be embedded in the input stream to dynamically control the voice, even at the phoneme level (phonemes are the basic sound units of speech).

A greeting message can be stored in the RC8650 which is automatically spoken immediately after the RC8650 is reset. Any of the commands recognized by the RC8650 may be included as part of the greeting message, which can be used to set up custom default settings and/or play back a prerecorded message or tone sequence. An integrated nonvolatile memory area is also provided for storing a custom pronunciation dictionary, allowing the pronunciation of any character string to be redefined.

Musical Tone Generator

An integrated, three-voice musical tone generator is capable of generating up to three tones simultaneously over a four-octave range. Simple tones to attention-getting sounds can be easily created.

Touch-Tone Generator

The RC8650 includes an integrated DTMF (Touch-Tone) generator. This is useful in telephony applications where standard DTMF tones are used to signal a remote receiver, modem, or access the public switched telephone network.

Sinusoidal Tone Generator

A precision, dual sinusoidal tone generator can synthesize the tones often used in signaling applications. The tone frequencies can be independently set, allowing signals such as call-progress tones to be generated.

Recorded Audio Playback

Up to 15 minutes of prerecorded speech and sound effects can be stored in the RC8650 for later playback. Additionally, the RC8650 can play back eight bit PCM and ADPCM audio in real time, such as speech and/or sound effects stored in an external memory or file system.

Versatile I/O

All data is sent to the RC8650 through its built in serial and/or parallel ports. *For maximum flexibility, including infield product upgrade/update capability, use of the serial port is recommended whenever possible.*

The RC8650's audio output is available in both analog and digital formats. The analog output should be used in applications where no further processing of the audio signal is required, such as driving a speaker or headphones (the output still needs to be filtered and amplified, however). The digital output is for applications that require further processing of the audio signal, such as digital mixing or creating sound files for later playback.

RECOMMENDED CONNECTIONS

Power/Ground

Power and ground connections are made to multiple V_{CC} and V_{SS} pins of the RC8650 and RC46xx chips. Every V_{CC} pin must be connected to power, and every V_{SS} pin must be connected to ground. Decoupling capacitors should be placed as close as possible to both chips. In particular, make sure adequate decoupling is placed on the AV_{CC} and AV_{REF} pins, as noise present on these pins will also appear on the AO output pins.

Connect any unused input pins to an appropriate signal level. **Leave any unused output pins and all NC pins unconnected.**

Chip Interconnects

Pins IC_0 through IC_{32} and PIO_0 through PIO_7 must be connected between the RC8650 and RC46xx chips. IC_{30}, IC_{31}, and IC_{32} must have a 47 kΩ pullup resistor to V_{CC}.

Clock Generator

The RC8650 has an internal oscillator and clock generator that can be controlled either by an external 7.3728 MHz crystal or external 7.3728 MHz clock source. Because the serial port baud rate is derived from the clock generator, the use of ceramic resonators is not recommended due to their relatively wide frequency tolerances. If an external clock is used, connect it to the XIN pin and leave XOUT unconnected. See Figure 1.3 for recommended clock connections.

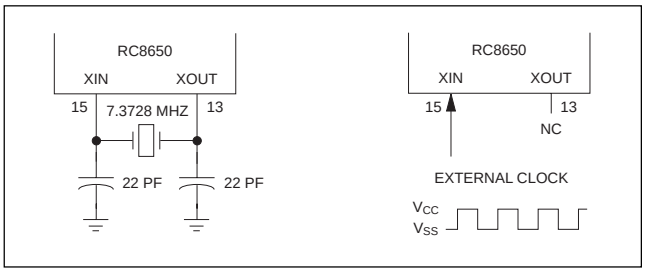


Figure 1.3. Clock Connections

INTERFACING THE RC8650

The RC8650 contains both asynchronous serial and eight bit bus interfaces. All text, commands, tone generator data, real time audio data, etc., are transmitted to the RC8650 via one of these ports. For maximum flexibility, use of the serial port is recommended whenever possible. *Not all RC8650 functions are supported through the bus interface.* In particular, index markers, operating system updates, chipset identification, current operating settings, A/D conversion, and prerecorded audio downloads are only supported through the serial interface.

Serial Interface

The serial port operates with 8 data bits, 1 or more stop bits, no parity, and any standard baud rate between 300 and 115200 bps.

A typical RS-232C interface is shown in Figure 1.4. Note that the MAX232A transceiver is not required if the host system's serial port operates at 0/+5 V logic levels (which most microprocessors and microcontrollers do). The RC8650's serial port may be connected directly to the host system in this case.

The CTS# pin should be used to control the flow of serial data to the RC8650. It is not necessary to check CTS# before transmitting every byte, however. All data is routed through a high speed 16 byte buffer within the RC8650 before being stored in the primary buffer. *CTS# may be checked every eight bytes with no risk of data loss.*

Baud rate selection

The serial port's baud rate can be programmed using any of three methods: pin strapping, auto-detect, and by command. **Pin strapping** sets the baud rate according to the logic levels present on the BRS_0–BRS_2 pins, as shown in Table 1.2. **Auto-detect** enables the serial port to automatically detect the baud rate of the incoming data. The baud rate **command** (described in Section 2) allows the baud rate to be changed at any time, effectively overriding the first two methods. Note that pin strapping cannot be used to program baud rates higher than 19200; to do this, auto-detection or the baud rate command must be used.

Table 1.2. Default Baud Rate Options

BRS_2	BRS_1	BRS_0	Baud Rate
L	L	L	300
L	L	H	600
L	H	L	1200
L	H	H	2400
H	L	L	4800
H	L	H	9600
H	H	L	19200
H	H	H	Auto-detect

The automatic baud rate detection mechanism is enabled when the BRS_0–BRS_2 pins are all at a High logic level and the BRD pin is connected to RXD. The baud rate is determined by the shortest High or Low period detected in the input stream. This period is assumed to be the bit rate of the incoming data.

In order for the RC8650 to determine the incoming baud rate, there must be at least one isolated "1" or "0" in the input character. The CR character, 0Dh, is recommended for locking the baud rate. The character is not otherwise processed by the RC8650; it is discarded.

If the measured bit period is determined to be a valid baud rate, the RC8650 acknowledges lock acquisition by transmitting the ASCII character "l" (6Ch) on the TXD pin.

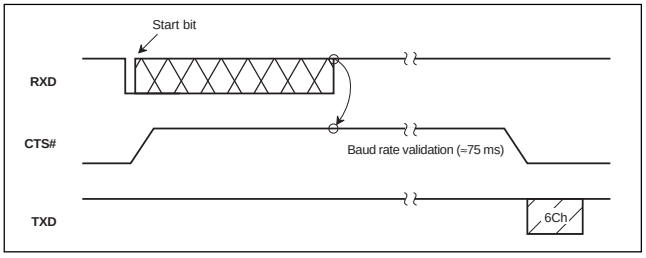


Figure 1.5. Baud Rate Detection Timing

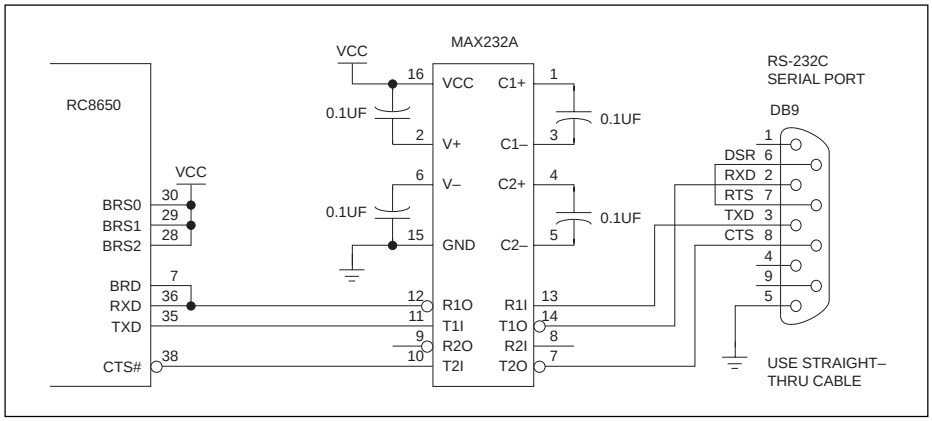


Figure 1.4. RS-232C Interface

Note The measurement cycle ends when there have been no High-to-Low nor Low-to-High transitions on the BRD pin for at least 75 ms. Consequently, the RC8650 will ignore any data sent to it for a period of 75 ms after the "lock-on" character has been received. The CTS# pin is driven High during this time, and the acknowledgment character is not transmitted until the RC8650 is actually ready to accept data. See Figure 1.5.

Status messages

The serial port provides real-time operating status information via the TXD pin. Status are transmitted as one-byte messages, shown in Table 1.3. Each message directly correlates to a status flag in the Status Register (Table 1.4). The specific character used, and whether it will be transmitted, are functions of the VC and STM bits of the Protocol Options Register. (The Protocol Options Register is described in Section 2.) For information about how to obtain reading-progress status, see the Index Marker command description.

Table 1.3. Status Messages

Event	VC = 0 / VC = 1	Requires STM = 1
Output has started	"B" / "s"	Yes
Output has stopped	"E" / "t"	Yes
Buffer almost empty (<100 bytes remaining)	– / "e"	Yes
Buffer almost full (<100 bytes available)	– / "f"	Yes
Sleep/Standby mode confirmation	"S" / "p"	No
Baud rate lock confirmation	"L" / "l"	No

Bus/Printer Interface

The RC8650's bus interface allows it to be connected to a microprocessor or microcontroller in the same manner as a static RAM or I/O device, as shown in Figure 1.7. The microprocessor controls all transactions with the RC8650 over the system data bus using the RD and WR# signals. RD controls the reading of the RC8650's Status Register; WR# controls the transfer of data into the RC8650. The Status Register bits and their definitions are shown in Table 1.4.

A registered bus transceiver is required for communication between the RC8650 and microprocessor; two 74HCT374s placed back to back may be substituted for the 74HCT652 shown in the figure. Prior to each write operation to the RC8650, the host processor should verify that the RC8650 is ready by testing the RDY status flag.

The RC8650 can also be interfaced to a PC's printer port as shown in Figure 1.7. A 74HCT374 can be used in place of the 74HCT652, since bidirectional communication is not necessary. Handshaking is performed automatically via the BUSY pin.

Because the RC8650 can take up to 15 µs to accept data written to it (AC Characteristics, t_{YHWH} parameter), software drivers should wait for RDY to drop to 0 after a byte is written in order to avoid overwriting it with the next data byte. Not doing so could result in the loss of data. Waiting for RDY to drop to 0 ensures that RDY will not falsely show that the RC8650 is ready the next time the driver is called.

If a system interrupt can occur while waiting for RDY to become 0, or if RDY cannot otherwise be checked at least once every 8 µs, a software timeout should be enforced to avoid hanging up in the wait loop. The time RDY stays 0 is relatively short (8 µs min.) and can be missed if interrupted. The timeout should be at least 15 µs, which is the maximum time for RDY to drop to 0 after writing a byte of data. In non time-critical applications, the output routine could simply delay 15 µs or longer before exiting, without checking for RDY = 0 at all.

Figure 1.6 illustrates the recommended method of writing data to the RC8650's bus interface. This method should be used for writing all types of data, including text, commands, tone generator and real time audio data.

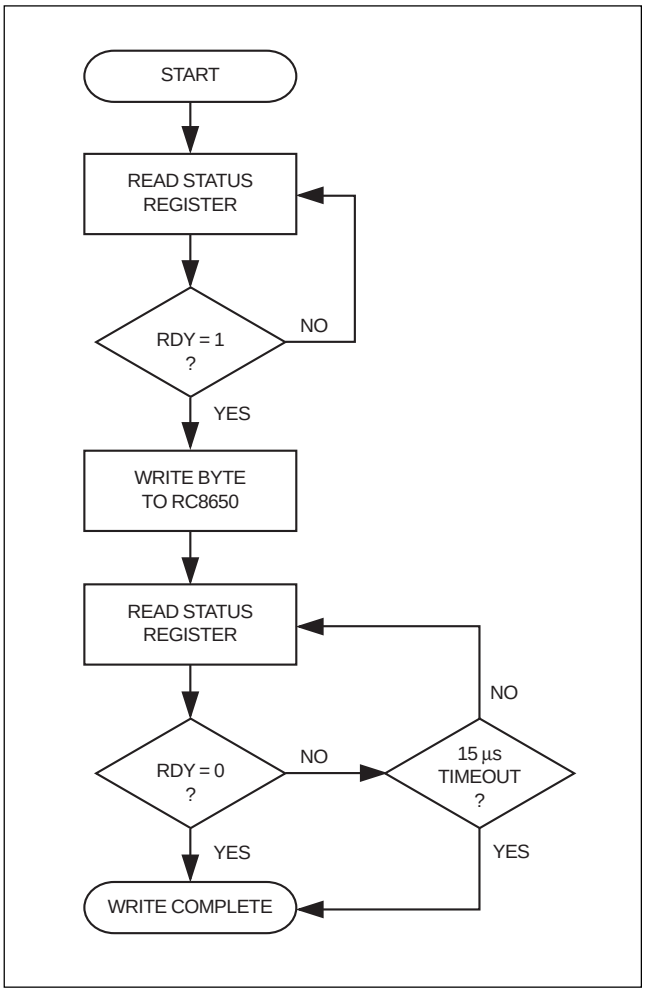


Figure 1.6. Recommended Method of Writing Data Via the Bus Interface

Table 1.4. Bus Interface Status Register Bit Definitions

R	TS	R	RDY	AF	AE	STBY	R
7	6	5	4	3	2	1	0

Status Register Bit	Description
SR.7 = RESERVED (R)	Reserved for future use. Mask out when polling the Status Register.
SR.6 = TALK STATUS (TS) 1 = Talking 0 = Idle	The TS bit has the same meaning as the TS pin. “1” means that the RC8650 is producing output; “0” means output has ceased. The TS bit is not affected by the TS Pin Control command, which affects only the TS pin.
SR.5 = RESERVED (R)	Reserved for future use. Mask out when polling the Status Register.
SR.4 = READY STATUS (RDY) 1 = Ready 0 = Busy	The RDY bit has the same meaning as the RDY# pin. The RC8650 sets RDY to “1” to indicate that it is ready to receive data. RDY drops to “0” momentarily after each write operation over the PIO bus, acknowledging receipt of each character.
SR.3 = ALMOST FULL (AF) 1 = Buffer almost full 0 = Buffer not almost full	This bit is “1” anytime there are less than 100 bytes available in the input buffer. AF is always “0” in the real time audio playback mode and when using the musical tone generator.
SR.2 = ALMOST EMPTY (AE) 1 = Buffer almost empty 0 = Buffer not almost empty	This bit is “1” anytime there are less than 100 bytes remaining in the input buffer. AE is always “1” in the real time audio playback mode and when using the musical tone generator.
SR.1 = STANDBY MODE (STBY) 1 = RC8650 is in Standby mode 0 = RC8650 not in Standby mode	This bit is “1” when the RC8650 has entered Standby mode. Standby mode is entered either by setting the STBY# pin Low or from the Sleep Timer.
SR.0 = RESERVED (R)	Reserved for future use. Mask out when polling the Status Register.

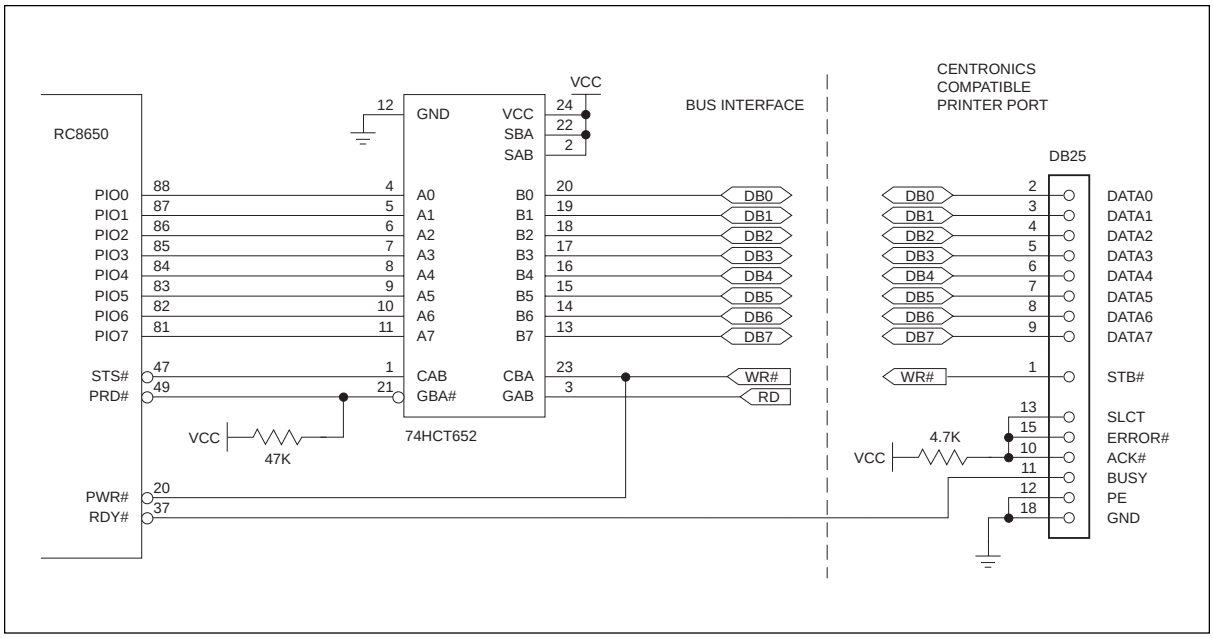


Figure 1.7. Bus/Printer Interface

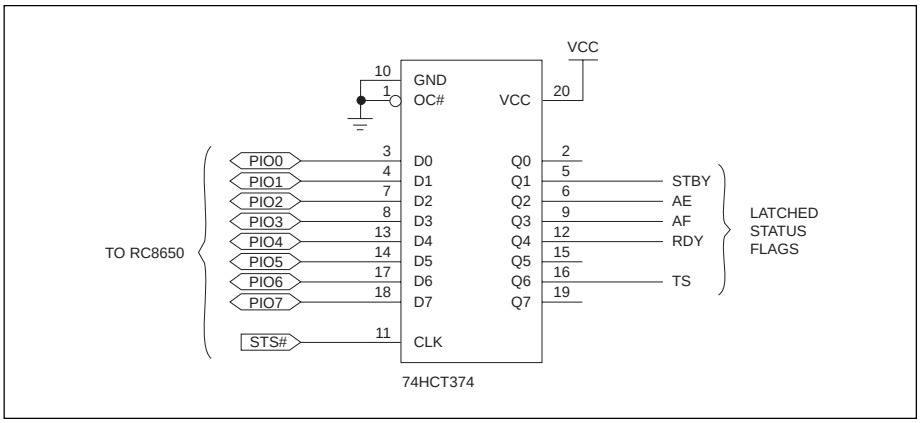


Figure 1.8. Method of Capturing Status Information for Driving External Circuitry

Analog Audio Output

The analog output pins AO_0 and AO_1 are high impedance (10 kΩ typ) outputs from the RC8650's internal D/A converters. When using these outputs, the addition of an external low-pass filter is highly recommended.

The circuit shown in Figure 1.9 is a low-pass filter/power amplifier capable of delivering 675 mW into an 8 Ω load. The circuit is representative of one channel (use AO_0 in single-channel systems). The amplifier's shutdown pin can be controlled by the corresponding channel's TS pin to minimize current drain when the channel is inactive.

Digital Audio Output

The digital audio pin DAOUT outputs the RC8650's audio signal as a digital audio stream consisting of 8 data bits per sample. The normalized sampling rate for all text to speech modes and the DTMF generator is 84 kbs (10,500 bytes/sec). The sinusoidal generator, prerecorded and real time audio playback mode rates are user programmable, so their normalized rates will vary. See the Pin Descriptions and Audio Control Register command description for further details.

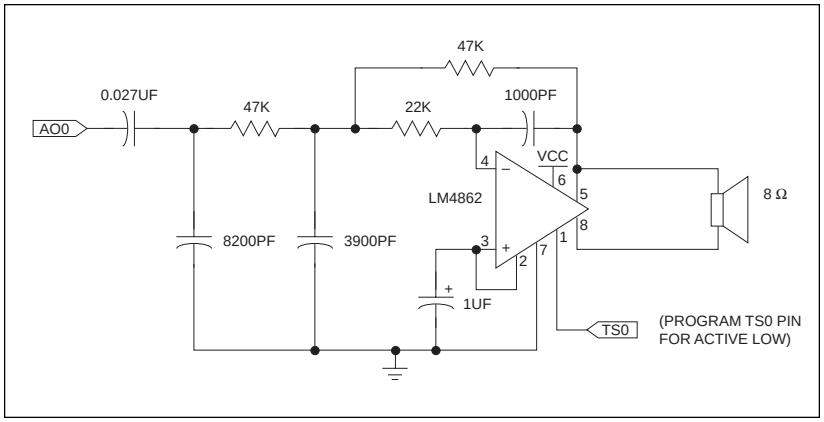


Figure 1.9. 3 kHz Low-Pass Filter/Power Amplifier

ELECTRICAL SPECIFICATIONS

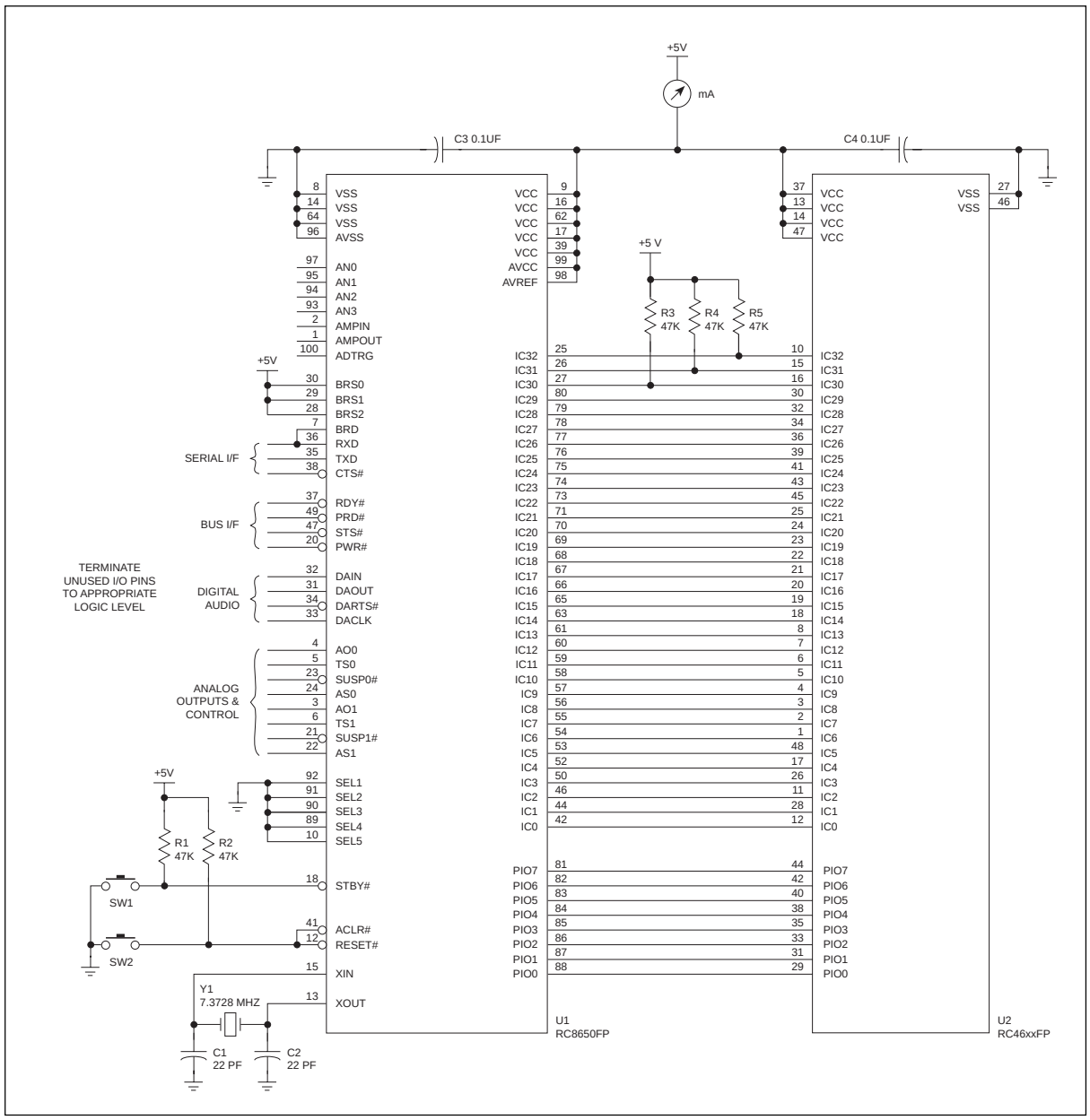


Figure 1.10. Typical Operating Circuit/Test Circuit

ABSOLUTE MAXIMUM RATINGS*

Supply voltage, V_{CC} and AV_{CC} . . . . . –0.3 V to +6.5 V

DC input voltage, V_I . . . . . –0.3 V to V_{CC} +0.3 V

Operating temperature, T_A . . . . . 0 °C to +70 °C

Storage temperature, T_S . . . . . –55 °C to +125 °C

** WARNING: Stresses greater than those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. This is a stress rating only; operation of the device at any condition above those indicated in the operational sections of these specifications is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.*

DC CHARACTERISTICS

T_A = 0 °C to +70 °C, V_{CC} = AV_{CC} = AV_{REF} = 3.3 V / 5 V, V_{SS} = AV_{SS} = 0 V, X_{IN} = 7.3728 MHz

Symbol	Parameter	3.3 ± 0.3 V			5 V ± 10%			Unit	Test Conditions
		Min	Typ	Max	Min	Typ	Max		
V_{IL}	Input voltage, Low	0		$0.2V_{CC}$	0		$0.2V_{CC}$	V	
V_{IH}	Input voltage, High	$0.8V_{CC}$		V_{CC}	$0.8V_{CC}$		V_{CC}	V	
V_{IA}	Analog input voltage (AN_{0-3})	0		AV_{REF}	0		AV_{REF}	V	
V_{HYR}	Input hysterisis, RESET#	0.2		1.8	0.2		1.8	V	
V_{OL}	Output voltage, Low			0.5			0.5	V	I_{OL} = 1 mA
V_{OH}	Output voltage, High	V_{CC} – 0.5			V_{CC} – 0.5			V	I_{OH} = –1 mA
I_{IL}	Input load current			± 4			± 5	µA	V_{IN} = V_{SS} to V_{CC}
R_O	Analog output resistance (AO_{0-1})	4	10	20	4	10	20	kΩ	
I_{CC}	Supply current								All outputs open; all inputs = V_{CC} or V_{SS}; AV_{CC} and AV_{REF} currents included
	Active		11	20		17	35	mA	
	Idle		0.7	1.5		1	2	mA	
	Standby		2	15		2	25	µA	
	Program (Note 1)			50			70	mA	

[1] Applies during internal programming operations: greeting message, dictionary and prerecorded sound file downloads, and microcode updates.

AC CHARACTERISTICS

T_A = 0 °C to +70 °C, V_{CC} = AV_{CC} = AV_{REF} = 3.3 V / 5 V, V_{SS} = AV_{SS} = 0 V

External Clock Input Timing

Symbol	Parameter	3.3 ± 0.3 V			5 V ± 10%			Unit
		Min	Nom	Max	Min	Nom	Max	
f_C	External clock input frequency	7.3359	7.3728	7.4097	7.3359	7.3728	7.4097	MHz
t_{WCL}	External clock input Low pulse width	60	67.8		40	67.8		ns
t_{WCH}	External clock input High pulse width	60	67.8		40	67.8		ns
t_{CR}	External clock rise time			18			15	ns
t_{CF}	External clock fall time			18			15	ns

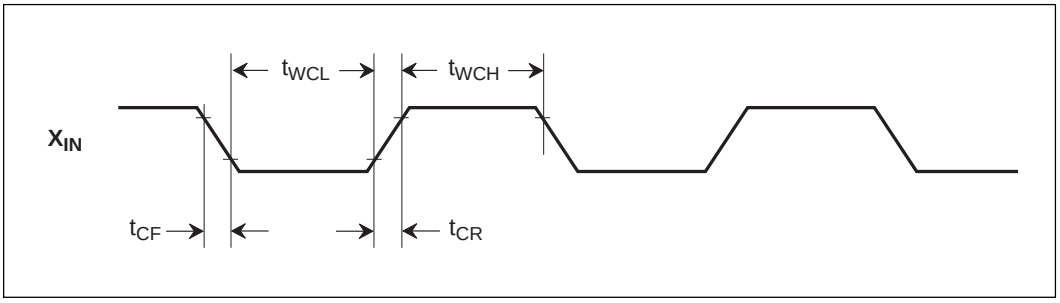
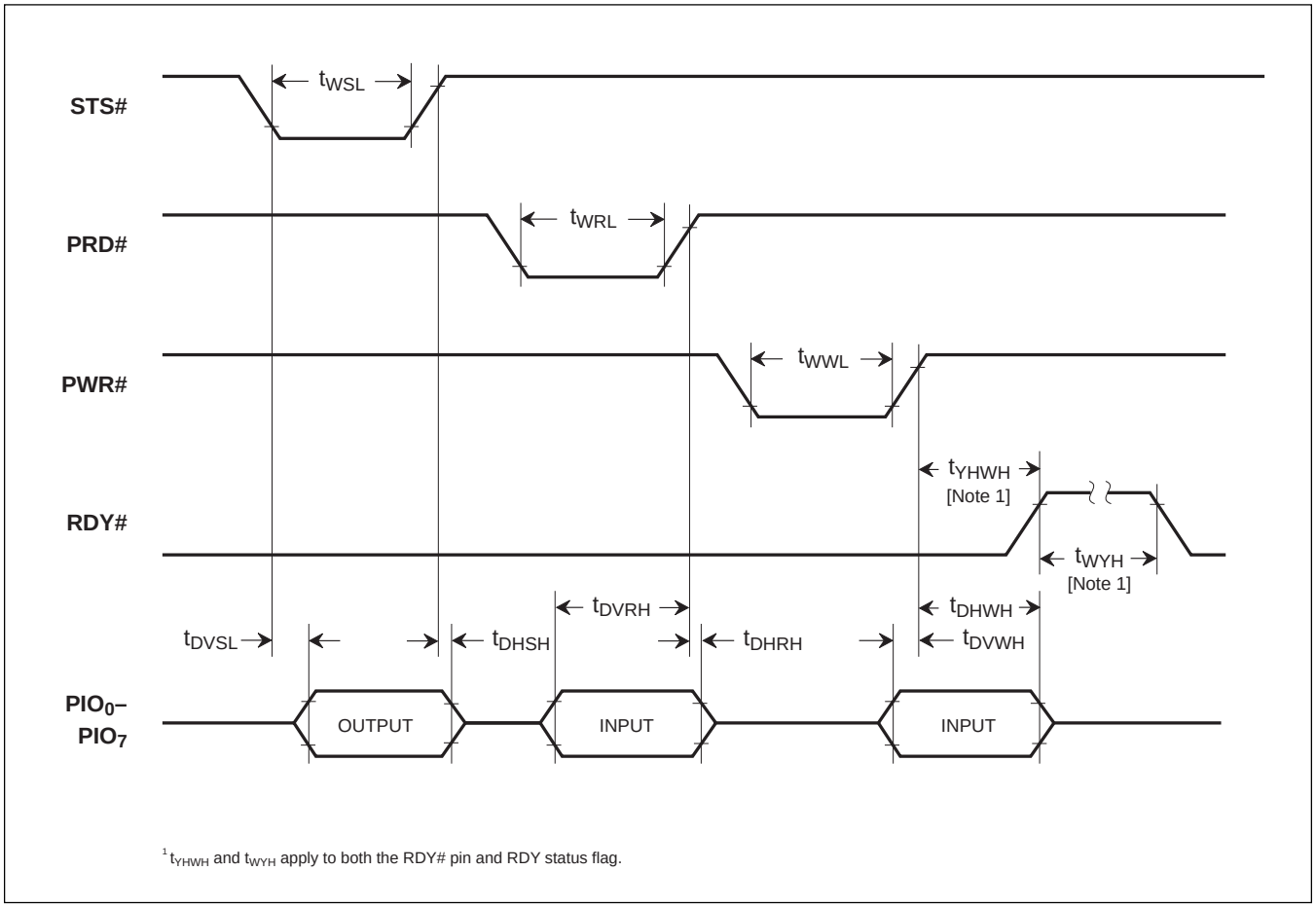


Figure 1.11. External Clock Waveform

Bus Interface Timing

Symbol	Parameter	3.3 ± 0.3 V		5 V ± 10%		Unit
		Min	Max	Min	Max	
t_{WSL}	STS# pulse width Low	215		250		ns
t_{DVSL}	STS# Low to data valid		155		150	ns
t_{DHSH}	Data hold from STS# going High	5		5		ns
t_{WRL}	PRD# pulse width Low	215		250		ns
t_{DVRH}	Data setup to PRD# going High	85		40		ns
t_{DHRH}	Data hold from PRD# going High	0		0		ns
t_{WWL}	PWR# pulse width Low	380		250		ns
t_{DVWH}	Data setup to PWR# going High	–2		–2		µs
t_{DHWH}	Data hold from PWR# going High	15		15		µs
t_{YHWH}	RDY# High from PWR# going High (Note 1)		15		15	µs
t_{WYH}	RDY# pulse width High (Note 1)	8		8		µs

[1] Applies to the RDY# pin and RDY status flag.



[1] t_{YHWH} and t_{WYH} apply to both the RDY# pin and RDY status flag.

Figure 1.12. Bus Interface Waveforms

Analog Audio Timing

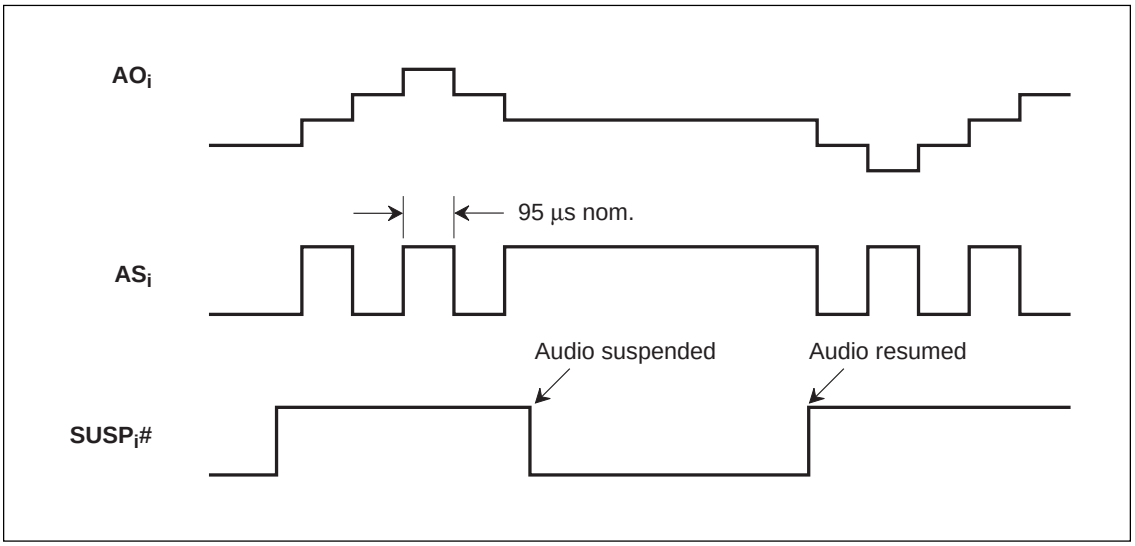


Figure 1.13. Analog Audio Waveforms

Digital Audio Timing

Symbol	Parameter	Min	Max	Unit	Notes
t_{CYC}	DACLK cycle time	200		ns	
t_{WCL}	DACLK pulse width Low	100		ns	
t_{WCH}	DACLK pulse width High	100		ns	
t_{DVCL}	DACLK Low to data valid		80	ns	
t_{DHCL}	Data hold from DACLK going Low	0		ns	
f_S	TTS and DTMF generator internal sampling rate	10.5	10.5	kHz	Nominal

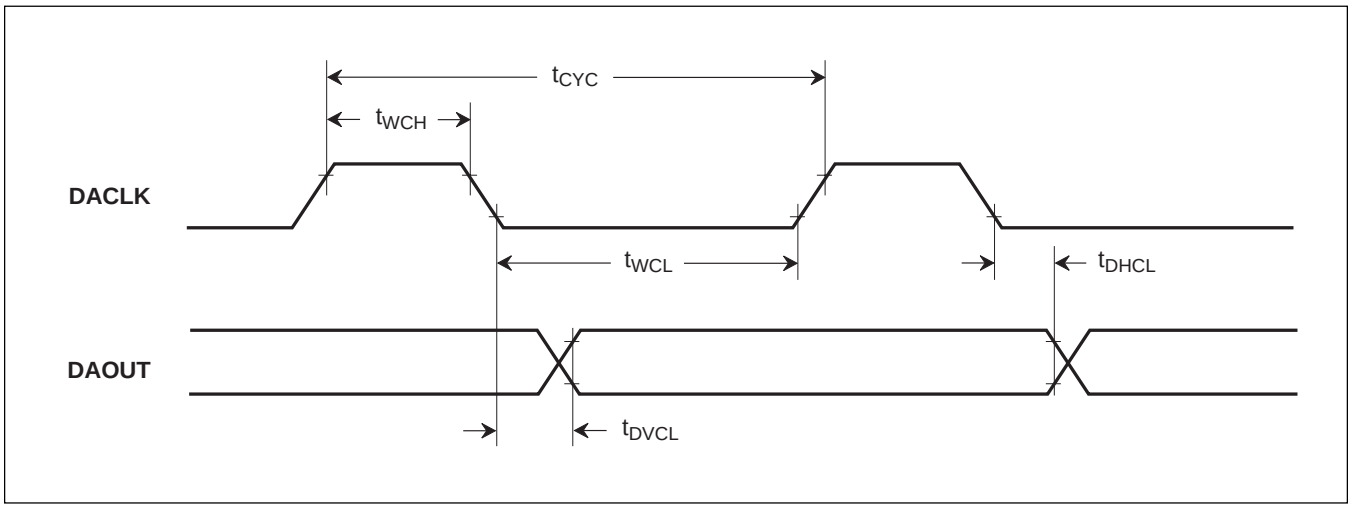


Figure 1.14. Digital Audio Waveforms

Standby Timing

Symbol	Parameter	3.3 ± 0.3 V		5 V ± 10%		Unit
		Min	Max	Min	Max	
t_{WSBL}	STBY# pulse width Low					
	To enter Standby mode	250		250		ms
	To reinitialize parameter memory		250		250	ms
	To exit Sleep mode	380		250		ns

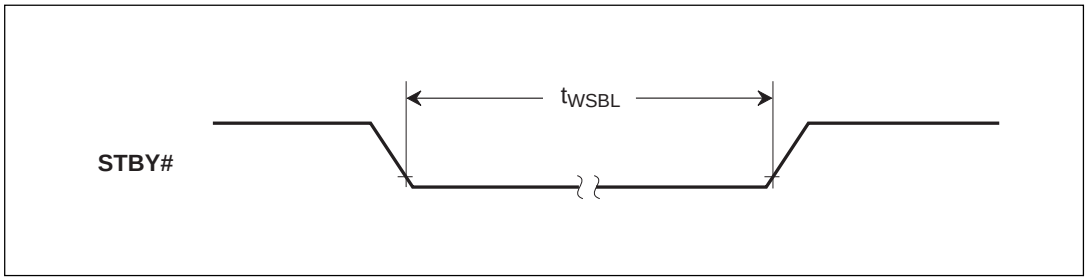
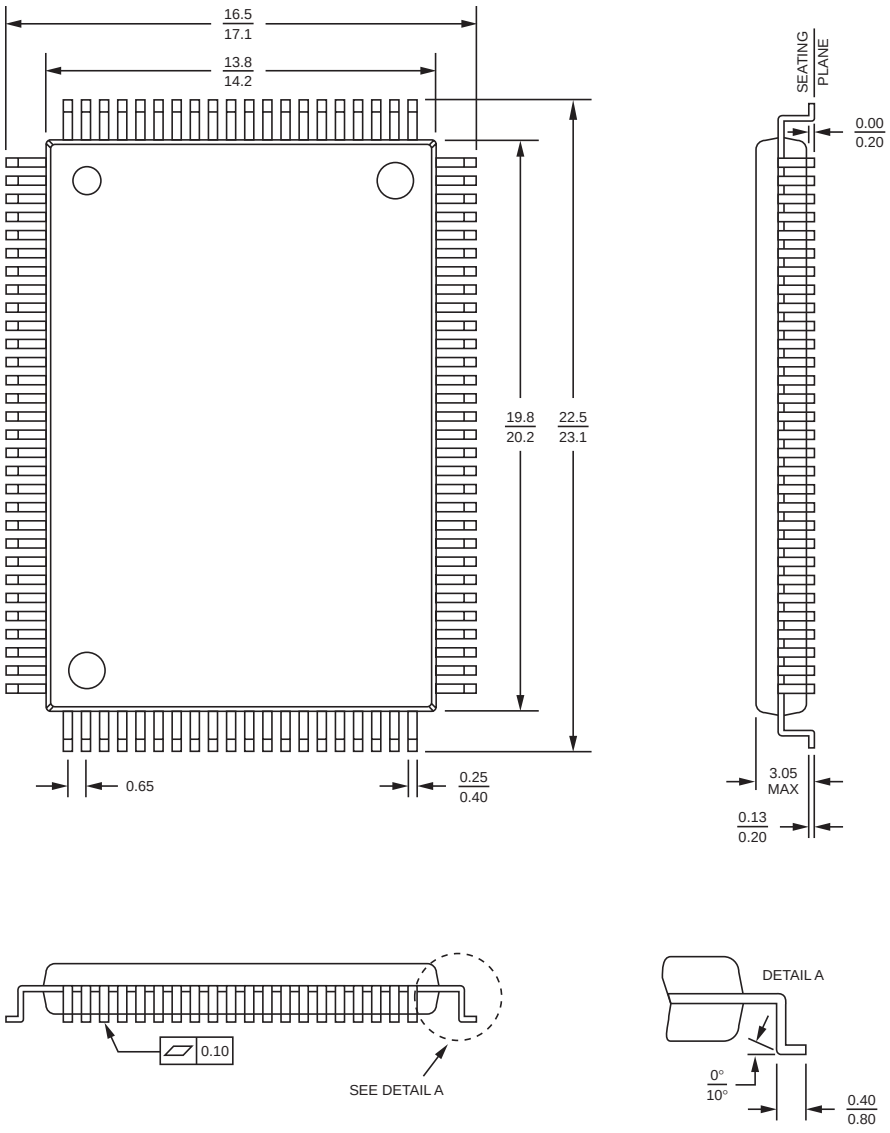


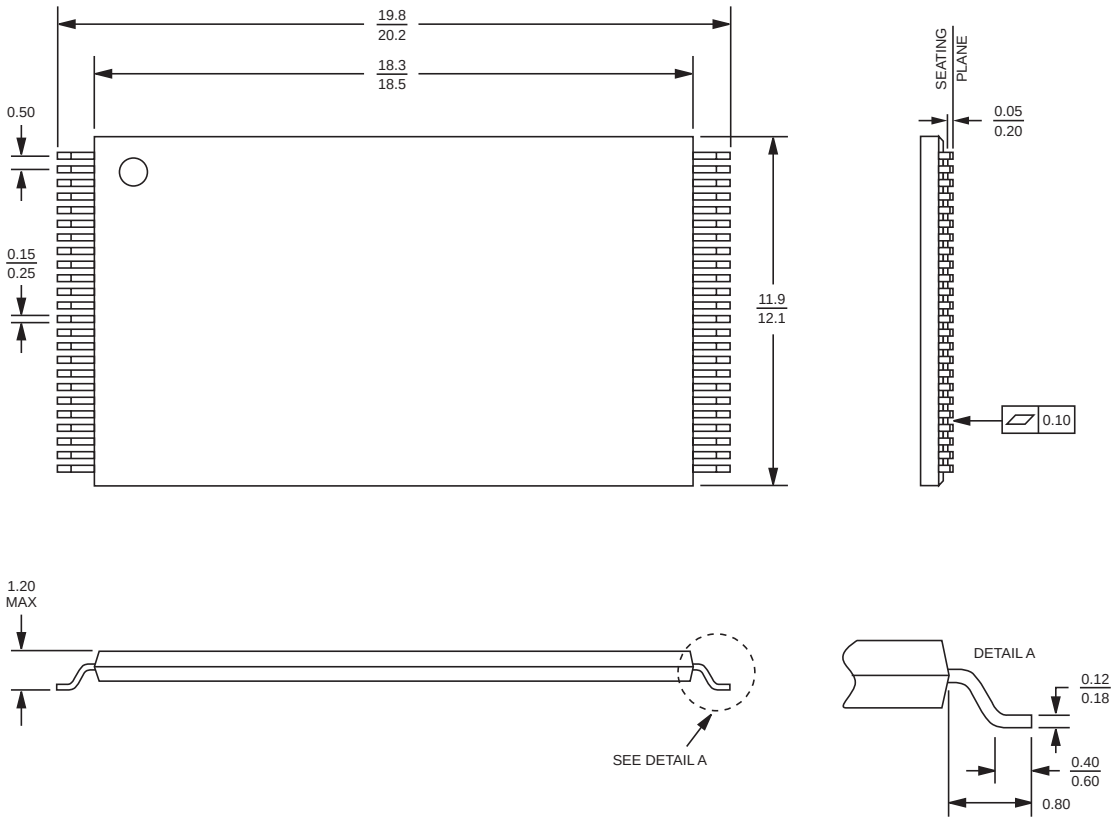
Figure 1.15. Standby Waveform

PACKAGE INFORMATION

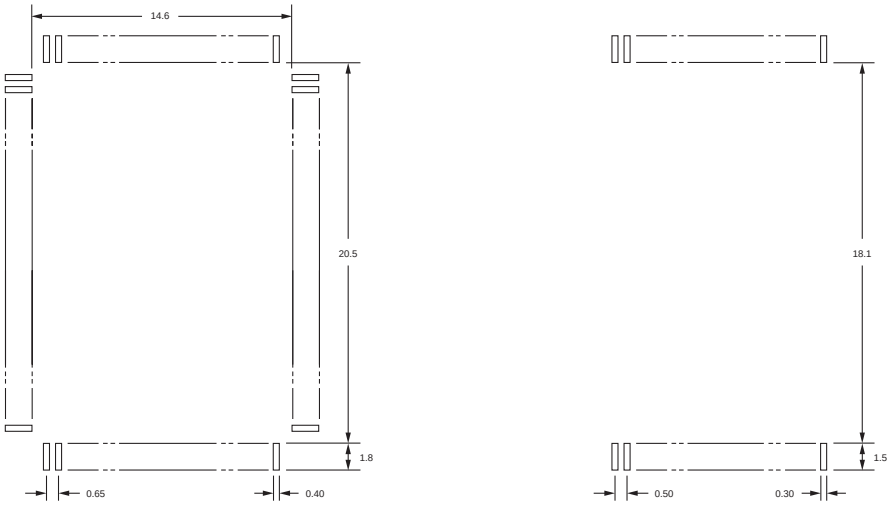
100 Pin Plastic 14 x 20 mm QFP (measured in millimeters)



48 Pin Plastic 12 x 20 mm TSOP (measured in millimeters)



Recommended PCB Layouts (measured in millimeters)



ORDERING INFORMATION

R	C	8	6	L	5	0	–	0

V_{CC} RANGE
BLANK = 5 V ± 10%
L = 3.3 ± 0.3 V

RECORDED AUDIO CAPACITY
0 = 0 sec
1 = 130 sec
2 = 390 sec
3 = 910 sec

VALID COMBINATIONS:[†]

RC8650-0	(RC4641FP)
RC86L50-0	(RC46L41FP)
RC8650-1 *	(RC4651FP)
RC86L50-1	(RC46L51FP)
RC86L50-2	(RC46L61FP)
RC86L50-3	(RC46L71FP)

[†] All chipset versions come with RC8650FP.
Companion chip is shown in parentheses.
* Denotes standard product.

SECTION 2: PRINCIPLES OF OPERATION

This section describes the operating characteristics of the DoubleTalk RC8650 chipset.

OPERATING MODES

The RC8650 has six primary operating modes and two low-power modes designed to achieve maximum functionality and flexibility. The operating mode can be changed anytime, even on the fly.

Note The RC8650 will not begin speaking until it receives a CR (ASCII 13) or Null (ASCII 00) character—this ensures that a complete contextual analysis can be performed on the input text. If it is not possible for the application to send a CR or Null at the end of each text message, use the Timeout Delay command (*n*Y).

The RC8650 does not make any distinction between uppercase and lowercase characters. Text and commands may be sent as all uppercase, all lowercase, or any combination thereof.

Text mode. In this mode, all text sent to the RC8650 is spoken normally. Punctuation is also taken into consideration by the intonation generation algorithms. This is the default operating mode.

Character mode. This mode causes the RC8650 to translate input text on a character-by-character basis; i.e., text will be spelled instead of spoken as words.

Phoneme mode. This mode disables the RC8650's text-to-phonetics translator, allowing the RC8650's phonemes to be directly accessed.

Real Time Audio Playback mode. In this mode, data sent to the RC8650 is written directly to its audio buffer. This results in a high data rate, but provides the capability of producing the highest quality speech, as well as sound effects. PCM and ADPCM data types are supported.

Prerecorded Audio Playback mode. This mode allows recorded speech and sound effects to be stored on-chip and played back at a later time. PCM and ADPCM data types are supported.

Tone Generator modes. These modes activate the RC8650's musical tone generator, sinusoidal generator, or DTMF generator. They can be used to generate audible prompts, music, signaling tones, dial a telephone, etc.

Idle mode. To help conserve power in battery-powered systems, the RC8650 automatically enters a reduced-power state whenever it is inactive. Data can still be read and written to the RC8650 while in this mode. Current draw is typically 1 mA.

Standby mode. This mode powers down the RC8650, where current draw is typically only 2 µA. Standby mode can be invoked from either the STBY# pin or with the Sleep command. Data cannot be read from or written to the RC8650 in this mode.

TRANSLATION ACCURACY

Because the RC8650 must handle the highly irregular spelling system of English, as well as proper names, acronyms, technical terms, and borrowed foreign words, there inevitably will be words that it will mispronounce. If a word is mispronounced, there are three techniques for correcting it:

1. Spell the word phonetically for the desired pronunciation.
2. Redefine the way the word should be pronounced by creating an exception for it in the RC8650's exception dictionary. This method allows words to be corrected without having to modify the original text, and it automatically corrects all instances of the word. Exception dictionaries are covered in detail in Section 4.
3. Use the RC8650's Phoneme mode.

The first technique is the easiest way to fine tune word pronunciations—by tricking the RC8650 into the desired pronunciation. Among the more commonly mispronounced words are compound words (*baseball*), proper names (*Sean*), and foreign loan words (*chauffeur*). Compound words can usually be corrected by separating the two words with a space, so that "baseball" becomes "base ball." Proper names and foreign words may require a bit more creativity, so that "Sean" becomes "Shon," and "chauffeur" becomes "show fur." Heteronyms (words with identical spelling but different meanings and pronunciations) can also be modified using this technique. For example, if the word *read* is to be pronounced "reed" instead of "red," it can simply be respelled as "reed."

COMMANDS

The commands described in the following pages provide a simple yet flexible means of controlling the RC8650 under software control. They can be used to vary voice attributes, such as the volume or pitch, to suit the requirements of a particular application or listener's preferences. Commands are also used to change operating modes.

Commands can be freely intermixed with the text that is to be spoken, allowing the voice to be dynamically controlled. Commands affect only the data that follows them in the data stream.

Command Syntax

All RC8650 commands are composed of the command character, a parameter *n* comprised of a one to four-digit number string, and a single string literal that uniquely identifies the command. Some commands simply enable or disable a feature of the RC8650 and do not require a parameter. The general command format is:

<command character>[<number string>]<string literal>

If two or more commands are to be used together, each must be prefaced with the command character. This is the only way the RC8650 knows to treat the remaining characters as a command, rather than text that should be spoken. For example, the following commands program pitch level 40 and volume level 7 (Control-A is the default command character):

```
Control-A "40P" Control-A "7V"
```

The command character

The default RC8650 command character is Control-A (ASCII 01). The command character itself can be spoken by the RC8650 by sending it twice in a row: `Control-A Control-A`. This special command allows the command character to be spoken without affecting the operation of the RC8650, and without having to change to another command character and then back again.

Changing the command character

The command character can be changed to another control character (ASCII 01-26) by sending the current command character, followed by the new character. To change the command character to Control-D, for example, issue the command `Control-A Control-D`. To change it back, issue the command `Control-D Control-A`. It's generally a good idea to change the command character if the forthcoming text contains characters which may otherwise be interpreted as command characters (and hence commands).

The command character can be unconditionally reset to Control-A by sending Control-^ (ASCII 30) to the RC8650 while operating in the Text, Character, or Phoneme modes.

Command parameters

Command parameters are composed of one to four digit number strings. The RC8650 supports two types of parameters: absolute and relative. **Absolute** parameters explicitly specify the parameter's new value, such as 9S or 3B. **Relative** parameters specify a *displacement* from a parameter's current value, not the actual new value itself.

Relative parameters can specify either a positive or negative displacement from a parameter's current value. For example, the Volume command +2V increases the volume level by two (V+2→V). If the current volume is 4, the volume will increase to 6 after the command has executed. The command –2V will have a similar effect, except the volume will be *decreased* by two.

If the value of a parameter falls outside the command's range, the value will either wrap around or saturate, depending on the setting of the SAT bit of the Protocol Options Register. For example, if parameters are programmed to wrap, the current volume is 7 and the command +4V is issued, the resultant volume will be (7+4)–10 = 1, since the volume range is 0-9. If parameters are programmed to saturate, the resultant volume would be 9 instead.

When writing application programs for the RC8650, it is recommended that relative parameters be used for temporarily changing voice attributes (such as raising the pitch of a word), using absolute-parameter commands only once in the program's initialization routine. This way, if the base value of an attribute needs to be changed, it only needs to be changed in the initialization routine.

TTS COMMANDS

This section describes the software commands that affect the text-to-speech synthesizer.

Text Mode/Delay (T/nT)

This command places the RC8650 in the Text operating mode. The optional delay parameter *n* is used to create a variable pause between words. The shortest, and default delay of 0, is used for normal speech. For users not accustomed to synthetic speech, the synthesizer's intelligibility may be improved by introducing a delay. The longest delay that can be specified is 15. If the delay parameter is omitted, the current (last set) value will be used and *the exception dictionary will be disabled*. This feature is useful for returning from another operating mode or disabling the exception dictionary (see Enable Exceptions command).

Character Mode/Delay (C/nC)

This command puts the RC8650 in the Character operating mode. The optional delay parameter *n* is used to create a variable pause between characters. Values between 0 (the default) and 15 provide pauses from shortest to longest, respectively. Values between 16 and 31 provide the same range of pauses, but control characters will not be spoken. If the delay parameter is omitted, the current value will be used and *the exception dictionary will be disabled*.

Phoneme Mode (D)

This command disables the text-to-phonetics translator, allowing the RC8650's phonemes to be accessed directly. Table 2.1 lists the phonemes that can be produced by the RC8650.

When concatenating two or more phonemes, each phoneme must be delimited by a space. For example, the word "computer" would be represented phonetically as

```
K AX M P YY UW DX ER
```

Phoneme attribute tokens

The RC8650 supports a number of phoneme attribute tokens that can be used in addition to the standard commands. These tokens do not require the command character or any parameters, but can only be used in Phoneme mode.

As indicated in Table 2.2, the / and \ tokens temporarily increase and decrease the pitch by *m* steps. Besides being temporary, the difference between using the pitch tokens and the Pitch command is that the effective pitch range is extended beyond the normal 0-99 range by approximately ±20 steps, and if the pitch should fall out of range, it will always saturate, regardless of the Protocol Options Register SAT setting.

All other phoneme attribute token commands remain in effect until explicitly changed.

Applications of Phoneme mode

Phoneme mode is useful for creating customized speech, when the normal text-to-speech modes are inappropriate for producing the desired voice effect. For example, Phoneme mode should be used to change the stress or emphasis of specific words in a

Table 2.1. DoubleTalk Phoneme Symbols

Phoneme Symbol	Example Word	Phoneme Symbol	Example Word
A	das (Spanish)	M	me
AA	cot	N	new
AE	cat	NG	rung
AH	cut	NY	niño (Spanish)
AW	cow	O	no (Spanish)
AX	bottom	OW	boat
AY	bite	OY	boy
B	bib	P	pop
CH	church	PX	spot
D	did	R	ring
DH	either	RR	tres (Spanish)
DX	city	S	sell
E	ser (Spanish)	SH	shell
EH	bet	T	tin
EI	mesa (Spanish)	TH	thin
ER	bird	TX	stick
EW	acteur (French)	U	uno (Spanish)
EY	bake	UH	book
F	fee	UW	boot
G	gag	V	valve
H	he	W	we
I	libro (Spanish)	WH	when
IH	bit	Y	mayo (Spanish)
IX	rabbit	YY	you
IY	beet	Z	zoo
J	age	ZH	vision
K	cute	space	variable pause *
KX	ski	,	medium pause
L	long	.	long pause

** Normally used between words; duration determined by nT command*

Table 2.2. Phoneme Attribute Tokens

Symbol	Function
nn	Set pitch to 'nn' (0-99)
/	Increase pitch m steps *
\	Decrease pitch m steps *
+	Increase speed 1 step
–	Decrease speed 1 step
>	Increase volume 1 step
<	Decrease volume 1 step

** Step size determined by nE command; m ≈ 2n*

phrase. This is because Phoneme mode allows voice attributes to be modified on phoneme boundaries within each word, whereas Text mode allows changes only at word boundaries. This is illustrated in the following Basic program examples.

```
100 A$ = CHR$(1)
105 LPRINT A$;"D";A$;"M"
110 LPRINT "//H AW  -/D>/EH R  +<\\YY UW
    S P \IY K  T UW  \M IY   DH AE T  -\W
    EY .+/"
```

Note in line 105 that expression is disabled, since the pitch variations due to the internal intonation algorithms would otherwise interfere with the pitch tokens. Compare this with the same phrase produced in Text mode with expression enabled:

```
100 A$ = CHR$(1)
105 LPRINT A$;"T";A$;"E"
110 LPRINT "How dare you speak to me that
    way!"
```

Phoneme mode is also useful in applications that provide their own text-to-phoneme translation, such as the front end of a custom text-to-speech system.

Speed (nS)

The synthesizer's speech rate can be adjusted with this command, from 0S (slowest) through 9S (fastest). The default rate is 1S (5S if the VC bit of the Protocol Options Register is set to 0).

Voice (nO)

The text-to-speech synthesizer has eight standard voices and a number of individual voice controls that can be used to independently vary the voice characteristics. Voices are selected with the commands 0O through 7O, shown in Table 2.3. Because this command alters numerous internal voice parameters (pitch, expression, tone, etc.), it should precede any individual voice control commands.

Table 2.3. Voice Presets

n	Voice Name
0	Perfect Paul (default)
1	Vader
2	Big Bob
3	Precise Pete
4	Ricochet Randy
5	Biff
6	Skip
7	Robo Robert

Articulation (nA)

This command adjusts the articulation level, from 0A through 9A. Excessively low articulation values tend to make the voice sound slurred; very high values, on the other hand, can make the voice sound choppy. The default articulation is 5A.

Expression (E/nE)

Expression, or intonation, is the variation of pitch within a sentence or phrase. When expression is enabled (*n* > 0), the RC8650 attempts to mimic the pitch patterns of human speech. For example, when a sentence ends with a period, the pitch drops at the end of the sentence; a question mark will cause the pitch to rise.

The optional parameter *n* determines the degree of intonation. 0E provides no intonation (monotone), whereas 9E is very animated sounding. 5E is the default setting. If the parameter is omitted, the current (last set) value will be used. This is useful for re-enabling intonation after a Monotone command.

Monotone (M)

This command disables all intonation (expression), causing the RC8650 to speak in a monotonic voice. Intonation should be disabled whenever manual intonation is applied using the Pitch command or phoneme attribute tokens. Note that this command is equivalent to the 0E command.

Formant Frequency (nF)

This command adjusts the synthesizer's overall frequency response (vocal tract formant frequencies), over the range 0F through 9F. By varying the frequency, voice quality can be fine-tuned or voice type changed. The default frequency is 5F.

Pitch (nP)

This command varies the synthesizer's pitch over a wide range, which can be used to change the average pitch during speech production, produce manual intonation, or create sound effects (including singing). Pitch values can range from 0P through 99P; the default is 50P.

Tone (nX)

The synthesizer supports three tone settings, bass (0X), normal (1X) and treble (2X), which work much like the bass and treble controls on a stereo. The best setting to use depends on the speaker being used and personal preference. Normal (1X) is the default setting.

Reverb (nR)

This command is used to add reverberation to the voice. 0R (the default) introduces no reverb; increasing values of *n* correspondingly increase the reverb delay and effect. 9R is the maximum setting.

Punctuation Filter (nB)

Depending on the application, it may be desirable to limit the reading of certain punctuation characters. For example, if the RC8650 is used to proofread documents, the application may call for only unusual punctuation to be read. On the other hand, an application that orally echoes keyboard entries for a blind user may require that all punctuation be spoken.

The RC8650 supports four primary levels of punctuation filtering as shown in Table 2.4. These levels determine which punctuation characters will be spoken and which will not. In addition to the four base levels, the command can be expanded to control how number strings will be read. This is done by ORing the values 04h and/or 08h to the base parameter range, as described below.

Table 2.4. Punctuation Filter

n	Punctuation Spoken
0	All
1	Most (all but CR, LF, Space)
2	Some ($%&#@=+*^|\<>)
3	None

Effect on number strings

The values of *n* listed in Table 2.4 cause number strings to be read one digit at a time (e.g., 0123 = "zero one two three"). ORing 04h to the values listed in the table (*n* = 4-7) forces number strings to be read as numbers (0123 = "one hundred twenty three"). *N* = 6 and *n* = 7 also force currency strings to be read as they are normally spoken—for example, $11.95 is read as "eleven dollars and ninety five cents." Finally, ORing 08h to these values (*n* = 8-15) disables leading zero suppression; number strings beginning with zero will always be read one digit at a time.

The default filter setting is 6B (Some punctuation, Numbers mode, leading zero suppression enabled).

CONTROL COMMANDS

Volume (nV)

This is a global command that controls the RC8650's output volume level, from 0V through 9V. 0V yields the lowest possible volume; maximum volume is attained at 9V. The default volume is 5V. The Volume command can be used to set a new listening level, create emphasis in speech, or change the output level of the tone generators.

Timeout Delay (nY)

The RC8650 defers translating the contents of its input buffer until a CR or Null is received. This ensures that text is spoken smoothly from word to word and that the proper intonation is given to the beginnings and endings of sentences. If text is sent to the RC8650 without a CR or Null, it will remain untranslated in the input buffer indefinitely.

The RC8650 contains a programmable timer that is able to force the RC8650 to translate its buffer contents after a preset time interval. The timer is enabled only if the Timeout Delay parameter *n* is non-zero, the RC8650 is not active (not talking), and the input buffer contains no CR or Null characters. Any characters sent to the RC8650 before timeout will automatically restart the timer.

The Timeout parameter *n* specifies the number of 200 millisecond periods in the delay time, which can range from 200 milliseconds to 3 seconds. The default value is 0Y, which disables the timer.

Table 2.5. Timeout Delays

n	Delay
0	Indefinite (wait for CR/Null)
1	200 milliseconds
2	400 milliseconds
.	.
.	.
15	3000 milliseconds (3 sec.)

Sleep Timer (nQ)

This command activates the RC8650's sleep timer. If the user forgets to turn off the system's power at the end of the day, for example, the sleep timer can be used to force the RC8650 into Standby mode automatically. An audible "reminder" tone can even be programmed to sound every ten minutes to remind the user that the power was left on, before shutdown occurs.

The sleep timer is reset anytime the RC8650 is active, or more precisely, whenever the TS pin is asserted. The timer begins running on the falling edge of TS. In this way, the RC8650 will not shut itself down during normal use, as long as the programmed timer interval is longer than the maximum time the RC8650 is inactive.

The command parameter *n* determines when Standby mode will be entered. You can place the RC8650 in Standby mode immediately, program the sleep timer to any of 15 ten-minute intervals (10 to 150 minutes), or disable the sleep timer altogether.

Note that the delay interval is simply *n* x 10 minutes for $0 < n < 16$. ORing 10h to these values ($16 < n < 32$) also enables the reminder tone, which sounds at the end of each ten minute interval. Programming $n = 0$ disables the sleep timer, which is the default setting. Setting $n = 16$ forces the RC8650 to enter Standby mode as soon as all output has ceased.

If the sleep timer is allowed to expire, the RC8650 will emit the ASCII character "p" from the TXD pin and the STBY status flag will be set to 1, just before entering Standby mode. This enables the host to detect that the RC8650 has entered Standby mode.

Table 2.6. Sleep Timer

n	Delay
0	Sleep timer disabled
1	10 min
.	.
.	.
15	150 min
16	0 (immediate)
17	10 min w/reminder
.	.
.	.
31	150 min w/reminder

Once the RC8650 has entered Standby mode, it can be re-awakened only by a hardware reset or by driving the STBY# pin low for 250 ns or longer, then High again. All of the RC8650 handshake signals (BUSY, DTR#, and RDY#) are forced to their "not ready" states when the RC8650 is in Standby.

Index Marker (nI)

Index markers are nonspeaking "bookmarks" that can be used to keep track of where the RC8650 is reading within a passage of text. The parameter *n* is any number between 0 and 99; thus, up to 100 unique markers may be active at any given time.

When the RC8650 has spoken the text up to a marker, it transmits the marker number to the host via the TXD pin. Note that this value is a *binary* number between 0 and 99, not a literal number string as was used in the command to place the marker. This allows the marker to be transmitted as a one-byte value.

Baud Rate (nH)

The serial port's baud rate may be programmed to any of the rates listed in Table 2.7. If included as part of the greeting message, the command will effectively override the default baud rate set by the BRS pins.

Table 2.7. Programmable Baud Rates

n	Baud Rate
0	300
1	600
2	1200
3	2400
4	4800
5	9600
6	19200
7	Auto-detect
8	38400
9	57600
10	115200

TS Pin Control (nK)

The TS pins provide talk status information for each audio channel, which can be used to activate a transmitter, take a telephone off hook, enable an audio power amplifier, etc., at the desired time. Each pin's state and polarity can be independently configured, as shown in Table 2.8. The programming of the TS pins do not affect the Status Register TS flag in any way. The default setting is 1K.

If a TS pin is programmed High or Low, it will remain so until changed otherwise. This feature can be used to activate a transmitter, for example, before speech output has begun. In the automatic mode, the TS pin is asserted as soon as output begins; it will return to its false state when all output has ceased. Note that because RC8650 commands work synchronously, the TS pin will not change state until all text and commands, up to the TS Pin Control command, have been spoken and/or executed.

Table 2.8. TS Pin Control

n	TS Mode/Polarity
0	Automatic/Active Low
1	Automatic/Active High
2	Forced Low
3	Forced High

Protocol Options Register (nG)

This command controls various internal RC8650 operating parameters. The command parameter n is calculated by ORing together the individual control bits shown in Table 2.9. For example, 193G (193 = 128 + 64 + 1) disables V8600 emulation, enables all status messages and specifies that parameters should saturate. 128G is the default setting.

Bit POR.7 (VC) programs the RC8650 to emulate RC Systems' original V8600 voice synthesizer module. When this bit is set to 0 (which V8600 application programs do, as this bit was undefined in the V8600), the overall voice speed range is reduced and the default speed is changed from 1S to 5S, matching the characteristics of the V8600. The serial port status messages are also affected by the setting of this bit.

Note Relative parameters work differently than usual with this command. Instead of specifying a displacement from the register's current value, relative parameters allow you to set ("+") and clear ("–") individual register bits. For example, +65G sets bits POR.0 and POR.6; –65G clears POR.0 and POR.6.

Table 2.9. Protocol Options Register Bit Definitions

VC	SAT	DDUR	R	R	R	R	STM
7	6	5	4	3	2	1	0

Protocol Options Register Bit	Description
POR.7 = V8600 COMPATIBILITY (VC) 1 = Compatibility disabled 0 = Compatibility enabled	Emulates RC Systems' V8600 voice synthesizer module when set to "0." Overall voice speed range and serial port status responses are adjusted to that of the V8600. Default: "1" (in the V8600A module, this bit defaults to "0").
POR.6 = SATURATE (SAT) 1 = Parameters saturate 0 = Parameters wrap	Determines whether command parameters wrap or saturate when their range has been exceeded. Default: "0."
POR.5 = DTMF DURATION (DDUR) 1 = 500 ms 0 = 100 ms	Determines DTMF (Touch-Tone) generator burst duration. When set to "1," tone bursts are 500 ms long; when "0," 100 ms. Default: "0."
POR.4 = RESERVED (R)	Reserved for future use. Write "0" to ensure future compatibility.
POR.3 = RESERVED (R)	Reserved for future use. Write "0" to ensure future compatibility.
POR.2 = RESERVED (R)	Reserved for future use. Write "0" to ensure future compatibility.
POR.1 = RESERVED (R)	Reserved for future use. Write "0" to ensure future compatibility.
POR.0 = STATUS MESSAGES (STM) 1 = Enabled 0 = Disabled	Enables and disables the transmission of certain status messages from the TXD pin. Default: "0."

ADC Control Register (n$)

The ADC Control Register controls the operation of the integrated analog-to-digital converter. All ADC results are transferred via the TXD pin.

The following is an overview of the ADC:

- Four channels, 8-bit resolution (±2 LSB precision)
- One-shot, continuous, single sweep, and continuous sweep modes of operation
- Selectable software or hardware triggering
- Support for external amplification/signal conditioning of all four ADC channels

Figure 2.1 is a functional block diagram of the ADC input stage; Figure 2.2 illustrates the ADC in operation. Table 2.10 lists the definitions of each bit of the ADC Control Register. The default register setting is 0$.

Operation of the ADC is not mutually exclusive of other RC8650 functions. The ADC can operate concurrently with text-to-speech, tone generation, audio playback, etc. The effective sampling rate is one-tenth the serial port baud rate (115200 baud = 11.5 ksps).

Note Relative parameters work differently than usual with this command. Instead of specifying a displacement from the register's current value, relative parameters allow you to set ("+") and clear ("–") individual register bits. For example, +34$ sets bits ADR.1 and ADR.5; –16$ clears ADR.4.

Table 2.10. ADC Control Register Definitions

R	AMP	TRG	CONT	SWP	R	CH	CH
7	6	5	4	3	2	1	0

ADC Control Register Bit	Description
ADR.7 = RESERVED (R)	Reserved for future use. Write "0" to ensure future compatibility.
ADR.6 = EXTERNAL AMPLIFIER (AMP) 1 = Amp connected 0 = Amp not connected	Set this bit to "1" to use an operational amplifier connected between the AMPIN and AMPOUT pins. Connecting an op amp and enabling this function allows the voltage input to each ADC input pin to be amplified with one op amp. Default: "0."
ADR.5 = TRIGGER SOURCE (TRG) 1 = Hardware trigger (ADTRG pin) 0 = Software trigger	Setting this bit to "1" enables hardware triggering of the ADC. The ADC will not begin operating until the ADTRG pin changes from a High to a Low level. When TRG is "0" the ADC will begin operating whenever the ADR register is written to. Default: "0."
ADR.4 = CONTINUOUS MODE (CONT) 1 = Continuous mode 0 = One-shot mode	Setting this bit to "1" causes the ADC to operate continuously. If a single channel is selected for measurement (ADR.3 = 0), that channel will be read repeatedly. If sweep mode is selected (ADR.3 = 1), the active input channels will be continuously read in a cyclic fashion. Clearing this bit while the ADC is operating will stop the ADC. Default: "0."
ADR.3 = SWEEP MODE (SWP) 1 = Sweep mode 0 = Single-channel mode	This bit determines whether a single channel or multiple input channels will be read. When Sweep mode is selected, ADR.1–0 determine which input channels will be scanned. Default: "0."
ADR.2 = RESERVED (R)	Reserved for future use. Write "0" to ensure future compatibility.
ADR.1–0 = CHANNEL SELECT (CH) When ADR.3 = 0: 00 = AN_0 01 = AN_1 10 = AN_2 11 = AN_3 When ADR.3 = 1: 00 = undefined 01 = AN_0–AN_1 sweep 10 = undefined 11 = AN_0–AN_3 sweep	These bits determine which input channel(s) will be read by the ADC. Default: "00."

NOTES:

1. The AMPOUT pin can be used as a fifth ADC input if an external op amp is not used. Set ADR.6 = 1 to select the AMPOUT pin for conversion.

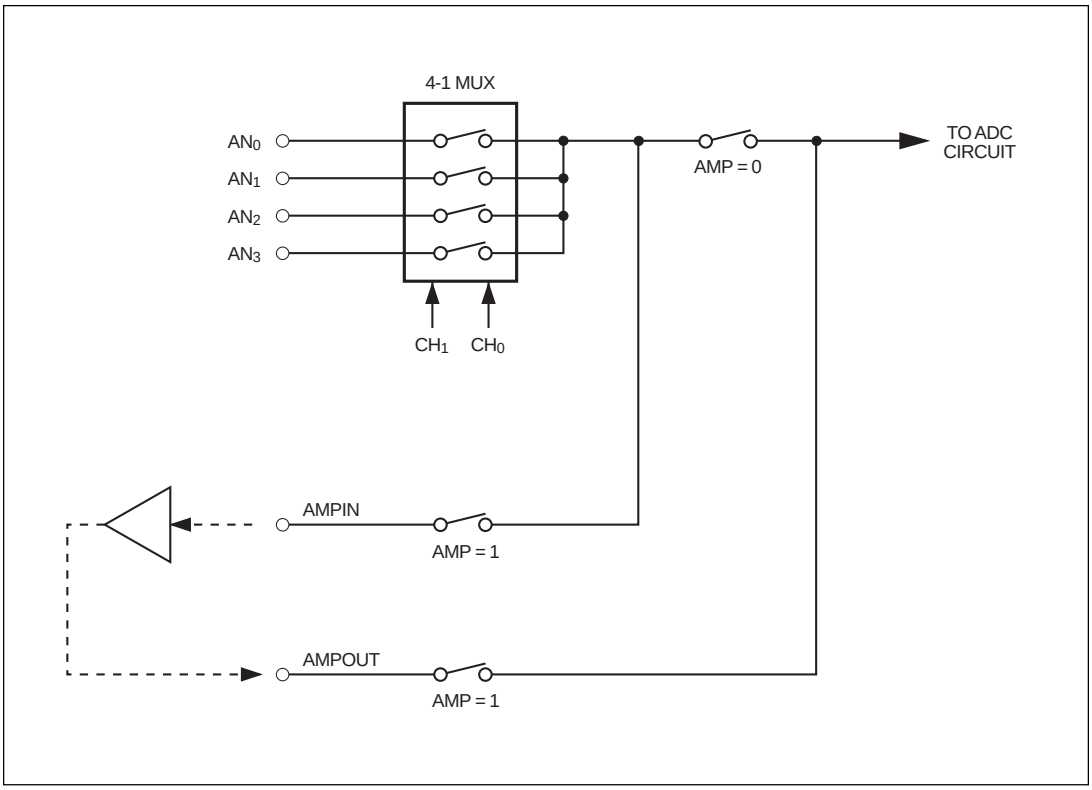


Figure 2.1. ADC Input Block Diagram

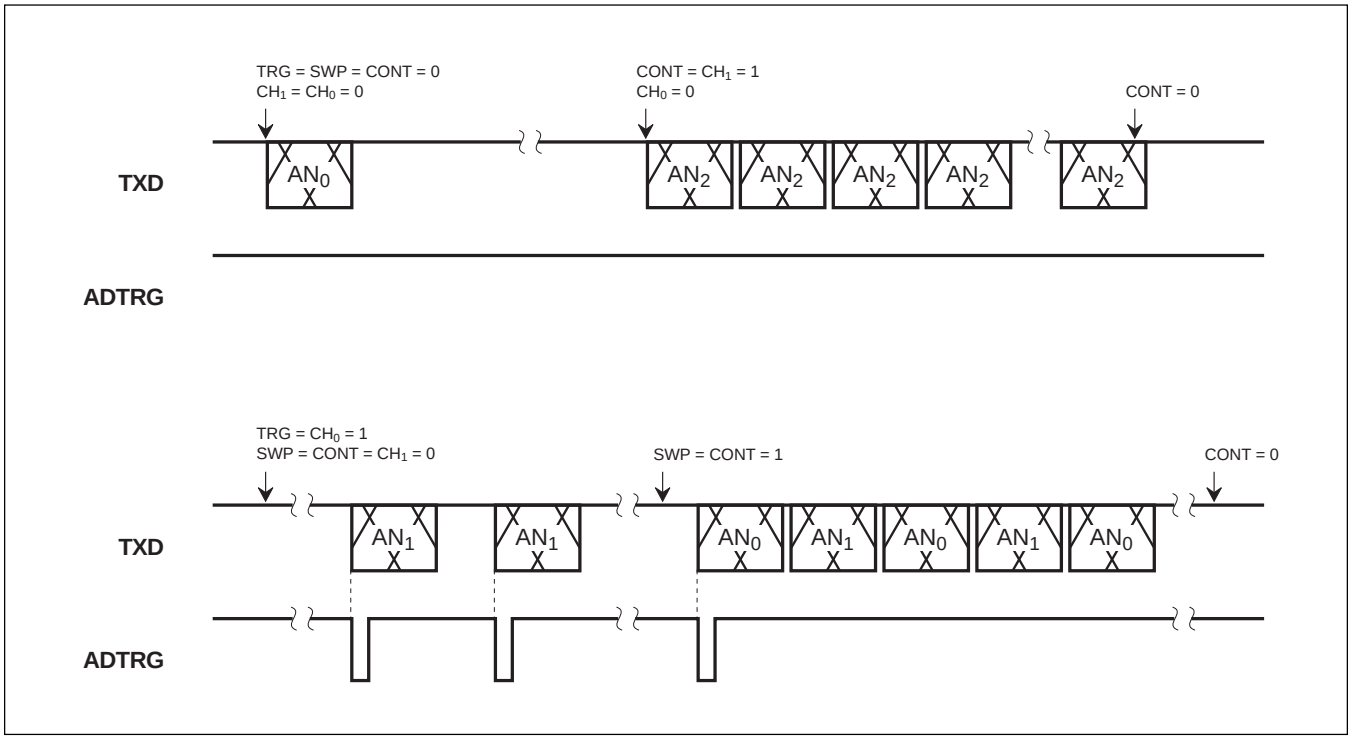


Figure 2.2. ADC Transfer Timing

Audio Control Register (nN)

The Audio Control Register determines whether the audio stream will be output as an analog signal on the AO pins or as serial digital data on the DAOUT pin. See Table 2.11 for the definition of each register bit. The default register setting is 0N.

In the digital audio modes, data is transferred from the DAOUT pin in 8 bit linear, offset binary format (midscale = 80h). The DARTS# pin can be used to regulate the flow of data—it must be Low for transfers to begin. In the synchronous mode, do not attempt to read the data at an average rate faster than 10 kbytes/sec. At clock rates above 80 kHz the host must pause between reading each byte in order to keep the average transfer rate from exceeding 10 kbytes/sec.

Figure 2.3 illustrates the synchronous data transfer mode. Note how either DARTS# or DACLK can be used to regulate the flow of data from the RC8650.

Note Relative parameters work differently than usual with this command. Instead of specifying a displacement from the register's current value, relative parameters allow you to set ("+") and clear ("–") individual register bits. For example, +40N sets bits ACR.3 and ACR.5; –5N clears ACR.0 and ACR.2.

Table 2.11. Audio Control Register Definitions

AM	TM	DPC	TF	TCP	BR	BR	BR
7	6	5	4	3	2	1	0

Audio Control Register Bit	Description
ACR.7 = AUDIO MODE (AM) 1 = Digital 0 = Analog	Set this bit to "0" to direct the audio stream to the AO pin (analog). Set the bit to "1" to direct output to the DAOUT pin (digital). Default: "0."
ACR.6 = TRANSFER MODE (TM) 1 = Synchronous 0 = Asynchronous	**In the asynchronous transfer mode** the data rate and timing are controlled by the internal bit rate generator (ACR.2–0). Data is output on the DAOUT pin and formatted as 1 start bit, 8 data bits (LSB first), and 1 stop bit. **In the synchronous transfer mode** the data rate and timing are controlled by the host with the DACLK pin. Data is output from the DAOUT pin as 8 bit data frames. Default: "0."
ACR.5 = DAOUT PIN CONTROL (DPC) 1 = Open-drain 0 = CMOS	Set this bit to "1" to configure the DAOUT pin as an open-drain output, or to "0" for a CMOS output. The open-drain configuration should be used when wire-or'ing two or more DAOUT pins together. Default: "0."
ACR.4 = TRANSFER FORMAT (TF) 1 = MSB first 0 = LSB first	Set this bit to "1" to have the 8 bit data frames transmitted most-significant bit first, or to "0" for least-significant bit first. Valid only in the synchronous transfer mode. Default: "0."
ACR.3 = TRANSFER CLOCK POLARITY (TCP) 1 = Rising edge 0 = Falling edge	Set this bit to "1" to clock data out of the DAOUT pin on the rising edge of the DACLK pin, or to "0" to clock data on the falling edge. Valid only in the synchronous transfer mode. Default: "0."
ACR.2–0 = BIT RATE (BR) 000 = 2400 001 = 4800 010 = 9600 011 = 14400 100 = 19200 101 = 28800 110 = 57600 111 = 115200	These bits determine the bit rate used in the asynchronous transfer mode. Valid only in the asynchronous transfer mode. Default: "000."

NOTES:

1. ACR.6–ACR.0 are valid only when ACR.7 = 1.
2. ACR.4–ACR.3 are valid only when ACR.7 and ACR.6 = 1.
3. ACR.2–ACR.0 are valid only when ACR.7 =1 and ACR.6 = 0.

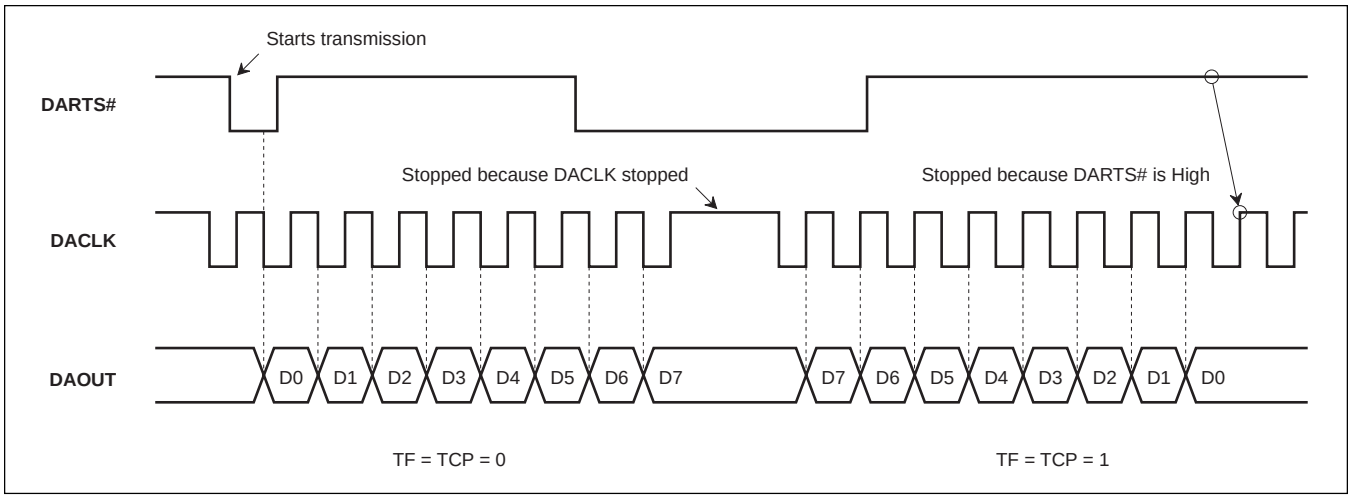


Figure 2.3. Synchronous Digital Audio Transfer Timing

Load Exception Dictionary (L)

This command purges the RC8650's exception dictionary and stores subsequent output from the host in the RC8650's dictionary memory. The maximum dictionary size is 16 KB.

Exception dictionaries must be compiled into the format used by the RC8650 before they can be used. The *RC8650 Studio* software, available from RC Systems, includes a dictionary editor and compiler for performing this task.

The creation of exception dictionaries is covered in detail in Section 4.

Enable Exceptions (U)

The exception dictionary is enabled with this command. If the RC8650 is in Phoneme mode, or if an exception dictionary has not been loaded, the command will have no effect. The exception dictionary can be disabled by issuing one of the mode commands D, T, or C.

Clear (Control-X), Skip (Control-Y)

The Clear command stops the RC8650 and flushes its input buffer of all text and commands. The Skip command skips to the next sentence in the buffer. Neither command affects the RC8650's settings.

Note that the format of these commands is unique in that the command character (Control-A) is not used with them. The Control-X (ASCII 24) and Control-Y (ASCII 25) characters are *written directly* to the RC8650, which enables it to react immediately, even if its input buffer is full. To be most effective, the states of the RC8650 handshaking signals should be ignored.

Reinitialize (@)

This command reinitializes the RC8650 by clearing the input buffer and restoring the voice parameters to their factory default settings. The exception dictionary, prerecorded audio, nor greeting message are affected.

Zap Commands (Z)

This command prevents the RC8650 from honoring subsequent commands, causing it to read commands as they are encountered (useful in debugging). Any pending commands in the input buffer will still be honored. The only way to restore command recognition after the Zap command has been issued is to write Control-^ (ASCII 30) to the RC8650 or perform a hardware reset.

TONE GENERATION COMMANDS

Musical/Sinusoidal Tone Generators (J/nJ)

The musical and sinusoidal tone generators are activated with these commands. Refer to Section 3 for detailed information.

DTMF Generator (n*)

The DTMF (Touch-Tone) generator generates the 16 standard tone pairs commonly used in telephone systems. Each tone is 100 ms in duration, followed by a 100 ms inter-digit pause (both durations can be extended to 500 ms by setting the DDUR bit of the Protocol Options Register)—more than satisfying telephone signaling requirements. The mapping of the command parameter *n* to the buttons on a telephone is shown in Table 2.12.

The "pause" tone can be used to generate longer inter-digit delays in phone number strings, or to create silent periods in the RC8650's output. The generator's output level can be adjusted with the Volume command (*n*V). DTMF commands may be intermixed with text and other commands without restriction.

Table 2.12. DTMF Dialer Button Map

n	Button
0	0
.	.
.	.
9	9
10	*
11	#
12	A
13	B
14	C
15	D
16	pause

AUDIO PLAYBACK COMMANDS

Prerecorded Audio Playback Mode (n&)

A virtually unlimited number of sound files can be stored in the RC8650, limited only by the amount of available on-chip audio memory. *RC8650 Studio*, a Windows-based application available from RC Systems, makes it easy to arrange and manage standard Windows wave files that can be downloaded into the RC8650.

Each sound file (word, phrase, or sound effect) is automatically assigned a record number, beginning with zero. The first file is record 0, the second is record 1, and so on. The playback command plays records in any random order, using *n* to specify the desired record.

The playback level can be adjusted with the Volume (*n*V) command. A volume setting of 5 will cause the files to be played back at their original volume level.

Text and/or commands may be freely intermixed with the playback command. For example,

```
^A "11*" "Hello" ^A "-3V" ^A "3&" ^A "+3V" ^A "9&"
```

plays the Touch-Tone "#" key and says "hello" at the current volume setting, followed by the fourth sound file at a reduced volume level, and finally the tenth sound file at the original volume level.

Real Time Audio Playback Mode (n#/n%)

This mode allows audio samples to be written directly to the RC8650's digital-to-analog converter (DAC) via the RC8650's serial and parallel ports. All data sent to the RC8650 is routed directly to the RC8650's internal audio buffer; the RC8650 then outputs samples from the buffer to the DAC at the rate programmed by *n*. Because the audio data is buffered within the RC8650, the output sampling rate is independent of the data rate into the RC8650, as long as the input rate is equal to or greater than the programmed sampling rate.

The RC8650 supports PCM and ADPCM audio data formats. ADPCM data is audio data that has been compressed using utility software available from RC Systems (this software can also convert Wave files to PCM and ADPCM formats for the RC8650). ADPCM compression yields data files that are half the size of PCM files, thereby reducing the required data bandwidth and storage requirements.

The output sampling rate can be programmed to any rate between 4 and 11 kHz (32,000-88,000 bps) by choosing the appropriate parameter value. The relationship between the command parameter *n* and the sampling rate f_S is

$$n = 155 - 617/f_S$$
$$f_S = 617/(155 - n)$$

where f_S is measured in kHz. For example, to program an 8 kHz sampling rate, choose *n*=78. The range of *n* is 0–99, hence f_S can range from 4 to 11 kHz.

The following procedure should be used for sending PCM or ADPCM audio data to the RC8650 in real time:

1) Program the desired volume level with the Volume (*n*V) command. A volume setting of 5 will cause the data to be played back at its original volume level. This step is optional.

2) Issue the Real Time Audio Playback Mode command *n*# if PCM data is being sent, or *n*% for ADPCM data. The TS pin and TS flag will be asserted at this time.

3) If the RC8650's serial port is being used for transferring the audio data, change the host system's baud rate to 115,200 baud at this time.

4) Begin transferring the audio data to the RC8650. The same methods employed for sending ASCII data to the text-to-speech synthesizer should be used. PCM data must be sent to the RC8650 as linear, eight bit signed data (–127 to +127, 0 = midscale).

5) After the last byte of audio data has been sent to the RC8650, send the value 80h (–128). This signals the RC8650 to terminate Real Time Audio Playback mode and return to the text-to-speech mode of operation. Note that up to 1024 bytes of data may still be in the audio buffer, so the RC8650 may continue producing sound for as long as 0.25 second (at 4 kHz sampling rate) after the last byte of data has been sent. The TS pin/flag will not be cleared until all of the audio data has been output to the DAC, at which time the RC8650 will again be able to accept data from the host.

   If the host's serial port baud rate was changed in step 3, it should now be changed back to its original rate.

MISCELLANEOUS COMMANDS

Write Greeting Message (255W)

Anytime the RC8650 is reset, an optional user-defined greeting message is automatically played. The message may consist of any text/command sequence up to 234 characters in length. Modal commands can be included, such as tone generator and audio playback commands.

Note The exception dictionary is erased whenever a new greeting message is written to the RC8650.

To create a new greeting message, perform the following steps:

1) Write the command `Control-A “255W”`.

2) Write the exact text/command sequence you want to store, up to 234 characters. For example, the string

   `Control-A “3S” Control-A “20” “ready”`

   will program the RC8650 to use voice speed 3, Big Bob’s voice, and say “ready” whenever it is reset.

3) Write a Null (ASCII 00) to terminate the command and store the greeting in the RC8650’s nonvolatile memory.

Chipset Identification (6?)

This command returns RC8650 system information that is used during factory testing. Eight bytes are transmitted via the TXD pin. The only information that may be of relevance to an application is the internal microcode revision number, which is conveyed in the last two bytes in packed-BCD format. For example, 13h 01h would be returned if the version number was 1.13.

Interrogate (12?)

This command retrieves the current operating settings of the RC8650. Table 2.13 lists the parameters in the order they are transmitted from the TXD pin, the command(s) that control each parameter, and each parameter’s range. The parameters are organized as a byte array of one byte per parameter.

Table 2.13. Parameters Returned by Interrogate Command

Parameter	Cmd	Range
Mode	C/D/T	0=Char; 1=Phon; 2=Text
Punc filter	nB	0-15
Formant freq	nF	0-9
Pitch	nP	0-99
Speed	nS	0-9
Volume	nV	0-9
Tone	nX	0-2
Expression	nE	0-9
Dict loaded	L	1=loaded; 0=not loaded
Dict status	U	1=enabled; 0=disabled
Input buffer size	–	x100 bytes
Articulation	nA	0-9
Reverb	nR	0-9
TS pin control	nK	0-3
POR register	nG	0-255
ACR register	nN	0-255
Rec audio capacity	–	x16K bytes
Sleep delay	nQ	0-31
Timeout delay	nY	0-15
Char mode delay	nC	0-31
Text mode delay	nT	0-15
Voice	nO	0-7
ADR register	n$	0-255

COMMAND SUMMARY

Table 2.14. RC8650 Command Summary

Command	Function	*n* Range	Default
*n*A	Articulation	0-9	5
*n*B	Punctuation filter	0-15	6
C/*n*C	Character mode/delay	0-31	0
D	Phoneme mode	–	–
E/*n*E	Expression	0-9	5
*n*F	Formant frequency	0-9	5
*n*G	Protocol Options Register	0-255	128
*n*H	Baud rate	0-10	–
*n*I	Index marker	0-99	–
J/*n*J	Musical/sinusoidal tone generators	0-99	–
*n*K	TS pin control	0-3	1
L	Load exception dictionary	–	–
M	Monotone	–	–
*n*N	Audio Control Register	0-255	0
*n*O	Voice	0-7	0
*n*P	Pitch	0-99	50
*n*Q	Sleep timer	0-31	0
*n*R	Reverb	0-9	0
*n*S	Speed	0-9	2
T/*n*T	Text mode/delay	0-15	0
U	Enable exception dictionary	–	–
*n*V	Volume	0-9	5
W	Write greeting message	255	–
*n*X	Tone	0-2	1
*n*Y	Timeout delay	0-15	0
Z	Zap commands	–	–
@	Reinitialize	–	–
*n**	DTMF generator	0-16	–
n#/*n*%	Real time audio playback	0-99	–
n&	Prerecorded audio playback	0-9999	–
n$	ADC Control Register	0-255	–
n?	Chipset ID/Interrogate	6/12	–

SECTION 3: MUSICAL & SINUSOIDAL TONE GENERATORS

MUSICAL TONE GENERATOR

The RC8650 contains a three-voice tone generator that can be used for creating music and sound effects. This section explains how to program the generator.

Note The musical tone generator output is available only from the AO pins. Digital audio output is not possible.

The musical tone generator is activated with the J command (no parameter). Once activated, all data output to the RC8650 is directed to the tone generator.

Note The RC8650 assumes that tone generator data will immediately follow the J command; therefore, be sure not to terminate the command with a CR or Null.

The tone generator is controlled with four, four-byte data and command frames, called **Initialize**, **Voice**, **Play**, and **Quit**. With these, the programmer can control the volume, duration, and frequencies of the three voices.

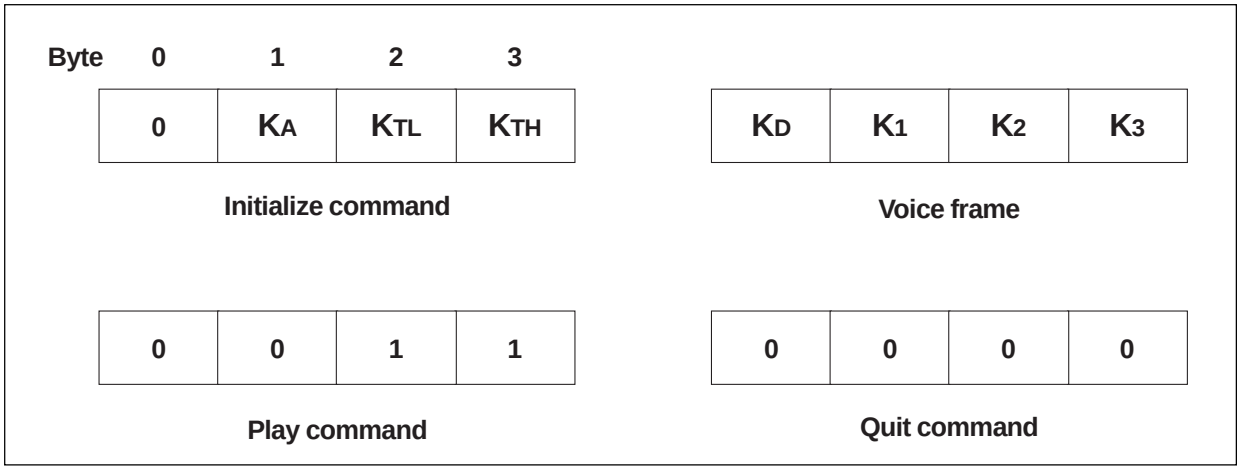


Figure 3.1. Musical Tone Generator Command Formats

Initialize Command

The Initialize command sets up the tone generator's relative amplitude and tempo (speed). The host must issue this command to initialize the tone generator before sending any Voice frames. The Initialize command may, however, be issued anytime afterward to change the volume or tempo on the fly.

Initialize command format

The Initialize command consists of a byte of zero and three parameters. The parameters are defined as follows:

K_A	Voice amplitude (1-255)
K_{TL}	Tempo, low byte (0-255)
K_{TH}	Tempo, high byte (0-255)

The range of the tempo K_T (K_{TL} and K_{TH}) is 1-65,535 (1–FFFFh); the larger the value, the slower the overall speed of play. The amplitude and tempo affect all three voices, and stay in effect until another Initialize command is issued. If the command is issued between Voice frames to change the volume or tempo on the fly, only the Voice frames following the command will be affected.

Voice Frame

Voice frames contain the duration and frequency (pitch) information for each voice. All Voice frames are stored in a 2K buffer within the RC8650, but are not played until the Play command is issued. If the number of Voice frames exceeds 2K bytes in length, the RC8650 will automatically begin playing the data.

Voice frame format

Voice frames are composed of three frequency time constants (K_1-K_3) and a duration byte (K_D), which specifies how long the three voices are to be played.

The relationship between the time constant K_i and the output frequency f_i is:

$$f_i = 16{,}768/K_i$$

where f_i is in Hertz and K_i = 4-255. Setting K_i to zero will silence voice *i* during the frame.

K_D may be programmed to any value between 1 and 255; the larger it is made, the longer the voices will play during the frame.

Table 3.1. Musical Note Pitch/K_i Values

Note	K_i	Note	K_i
C	255 (FFh)	D	57 (39h)
C#	241 (F1h)	D#	54 (36h)
D	228 (E4h)	E	51 (33h)
D#	215 (D7h)	F	48 (30h)
E	203 (CBh)	F#	45 (2Dh)
F	192 (C0h)	G	43 (2Bh)
F#	181 (B5h)	G#	40 (28h)
G	171 (ABh)	A	38 (26h)
G#	161 (A1h)	A#	36 (24h)
A	152 (98h)	B	34 (22h)
A#	144 (90h)	C	32 (20h)
B	136 (88h)	C#	30 (1Eh)
C	128 (80h)	D	28 (1Ch)
C#	121 (79h)	D#	27 (1Bh)
D	114 (72h)	E	25 (19h)
D#	107 (6Bh)	F	24 (18h)
E	101 (65h)	F#	23 (17h)
F	96 (60h)	G	21 (15h)
F#	90 (5Ah)	G#	20 (14h)
G	85 (55h)	A	19 (13h)
G#	81 (51h)	A#	18 (12h)
A	76 (4Ch)	B	17 (11h)
A#	72 (48h)	C	16 (10h)
B	68 (44h)	C#	15 (0Fh)
C-Mid	64 (40h)	D	14 (0Eh)
C#	60 (3Ch)		

The task of finding K_i for a particular musical note is greatly simplified by using Table 3.1. The tone generator can cover a four-octave range, from C two octaves below Middle C (K_i = 255), to D two octaves above Middle C (K_i = 14). K_i values less than 14 are not recommended.

For example, the Voice frame

```
DATA 24,64,0,0
```

will play Middle C using voice 1 (K_1 = 64). Since K_2 and K_3 are zero, voices 2 and 3 will be silent during the frame. The duration of the note is a function of both the tempo K_T and duration K_D, which in this case is 24.

As another example,

```
DATA 48,64,51,43
```

plays a C-E-G chord, for a duration twice as long as the previous example.

Choosing note durations and tempo

Table 3.2 lists suggested K_D values for each of the standard musical note durations. This convention permits shorter ($^1/_{64}$th note) and intermediate note values to be played, while maintaining the same degree of accuracy. This is important when, for example, a thirty-second note is to be played staccato, or a note is dotted (multiplying its length by 1.5).

Table 3.2. Musical Note Duration/K_D Values

Note Duration	K_D
Whole	192 (C0h)
Half	96 (60h)
Quarter	48 (30h)
Eighth	24 (18h)
Sixteenth	12 (0Ch)
Thirty-second	6 (06h)

Using the suggested values, it turns out that most musical scores sound best when played at a tempo of 255 or faster (i.e., K_{TH} = 0). Of course, the "right" tempo is the one that sounds the best.

Play Command

The Play command causes the voice data in the input buffer to begin playing. Additional Initialize commands and Voice frames may be sent to the RC8650 while the tone generator is operating. The TS pin and TS flag are asserted at this time, enabling the host to synchronize to the playing of the tone data. TS becomes inactive after all of the data has been played.

Quit Command

The Quit command marks the end of the tone data in the input buffer. The RC8650 will play the contents of the buffer up to the Quit command, then return to the text-to-speech mode that was in effect when the tone generator was activated. Once the Quit command has been issued, the RC8650 will not accept any more data until the entire buffer has been played.

Example Tune

The Basic program shown in Figure 3.2 reads tone generator data from a list of DATA statements and LPRINTs each value to the RC8650. The program assumes that the RC8650 is connected to a PC's printer port, although output could be redirected to a COM port with the DOS MODE command.

The astute reader may have noticed some "non-standard" note durations in the DATA statements, such as the first two Voice frames in line 240. According to the original music, some voices were not to be played as long as the others during the beat. The F-C-F notes in the first frame are held for 46 counts, while the low F and C in the second frame are held for two additional counts. Adding the duration (first and fifth) bytes together, the low F and C do indeed add up to 48 counts (46 + 2), which is the standard duration of a quarter note.

```
100 LPRINT               ' ensure serial port baud rate is locked
110 LPRINT CHR$(1);"J";  ' activate tone generator
120 READ B0,B1,B2,B3     ' read a frame (4 bytes)
130 LPRINT CHR$(B0); CHR$(B1); CHR$(B2); CHR$(B3);
140 IF B0 + B1 + B2 + B3 > 0 THEN 120  ' loop until Quit
150 END
160 '
170 '
180 ' Data Tables:
190 '
200 ' Init (volume = 255, tempo = 86)
210 DATA  0,255,86,0
220 '
230 ' Voice data
240 DATA  46,48,64,192, 2,0,64,192, 48,48,0,0, 48,40,0,0, 48,36,0,0
250 DATA  94,24,34,0, 2,24,0,0, 24,0,36,0, 24,0,40,0, 48,0,48,0
260 DATA  48,40,0,192, 46,36,0,0, 2,0,0,0, 48,36,0,0, 48,24,34,0
270 DATA  46,24,34,0, 2,0,34,0, 46,24,34,0, 2,24,0,0, 24,0,36,0
280 DATA  24,0,40,0, 48,0,48,0
290 '
300 ' Play, Quit
310 DATA  0,0,1,1, 0,0,0,0
```

Figure 3.2. Example Musical Tone Generator Program

SINUSOIDAL TONE GENERATOR

The musical tone generator is capable of producing three tones simultaneously, and works well in applications which require neither precise frequencies nor a "pure" (clean) output. The output is a pulse train rich in harmonic energy, which tends to sound more interesting than pure sinusoids in music applications.

The sinusoidal tone generator enables the simultaneous generation of two sinusoidal waveforms. Applications for this generator range from generating simple tones to telephone call-progress tones (such as a dial tone or busy signal). The frequency range is 0 to 2746 Hz, with a resolution of 4 to 11 Hz.

The sinusoidal tone generator is activated with the command *n*J, where *n* is an ASCII number between 0 and 99. Note the similarity to the musical tone generator command, J, which uses no parameter. The parameter *n* programs the internal sampling rate, much like the Real Time Audio Playback command does; in fact, the sampling rate f_s has the same relationship to *n* as the Real Time Audio Playback command:

$$f_s = 617 / (155 - n)$$

Immediately following the *n*J command are three *binary* parameter bytes:

*n*J K_d K_1 K_2

where K_d determines the tone duration, and K_1 and K_2 set the output frequencies of generators 1 and 2, respectively.

The tone duration and frequencies are not only functions of these parameters, but of *n* as well. The output amplitude is a function of the Volume command (*n*V). The command and parameter values are buffered within the RC8650, and can be intermixed with text and other commands without restriction.

The tone duration T_d is calculated as follows:

$$T_d = K_d \times 256 / f_s \text{ (sec)}$$

where $0 \le K_d \le 255$. Substituting the relationship $f_s = 617 / (155 - n)$ into the above equation,

$$T_d = K_d \times (155 - n) / 2410 \text{ (sec)}$$

Setting $K_d = 1$ yields the shortest duration; $K_d = 0$ (treated as 256) the longest. Depending on the value of *n*, T_d can range from 23 ms to 16.5 sec.

The tone frequencies F_1 and F_2 are computed as follows:

$$F_i = K_i \times f_s / 1024 \text{ (Hz)}$$

where $0 \le K_i \le 255$. Substituting the relationship $f_s = 617 / (155 - n)$ into this equation,

$$F_i = K_i \times 603 / (155 - n) \text{ (Hz)}$$

Depending on the value of *n*, F_i can range from 0 Hz to 2746 Hz. If only one tone is to be generated, the other tone frequency may be set to 0 ($K_i = 0$), or equal in frequency. Note, however, that due to the additive nature of the tone generators, the output amplitude from both generators running at the same frequency will be twice that of just one generator running. Both K_1 and K_2 may be set to 0 to generate silence.

Note that the frequency step size and frequency range are strictly functions of *n*. In general, the larger *n* is, the larger the step size and range will be. The parameter K_i can be thought of as a multiplier, which when multiplied by the step size, yields the output frequency. For example, setting *n* = 95 (corresponding to an internal sampling rate of 10.28 kHz) results in a frequency step size of 603 / (155 - 95) Hz, or 10 Hz. Thus, the output frequency range spans 0 Hz to 255 x 10 Hz, or 2550 Hz, in 10 Hz steps.

As an example, suppose your application needed to generate the tone pair 440/350 Hz (a dial tone) for say, 2.5 seconds. We will choose *n* = 95, because it yields a convenient step size of 10 Hz. The tone duration parameter K_d is calculated as follows:

$$K_d = 2410 \times T_d / (155 - n)$$

substituting $T_d = 2.5$ (sec) and *n* = 95,

$$K_d = 2410 \times 2.5 / (155 - 95) = 100$$

K_1 (440 Hz) is computed as follows:

$$K_1 = F_1 \times (155 - n) / 603$$

$$= 440 \times (155 - 95) / 603 = 44$$

In like manner, K_2 (350 Hz) is computed to be 35.

In order to embed the command in a text file, the computed values must be converted into their ASCII equivalents: 100 = "d", 44 = "," and 35 = "#". The complete command becomes

```
^A95Jd,#
```

which can be embedded within normal text for the synthesizer.

SECTION 4: EXCEPTION DICTIONARIES

Exception dictionaries make it possible to alter the way the RC8650 interprets character strings it receives. This is useful for correcting mispronounced words, triggering the generation of tones and/or the playback of prerecorded sounds, or even speaking in a foreign language. In some cases, an exception dictionary may even negate the need of a text pre-processor in applications that cannot provide standard text strings. This section describes how to create exception dictionaries for the RC8650.

The text-to-speech modes of the RC8650 utilize an English lexicon and letter-to-sound rules to convert text the RC8650 receives into speech. The pronunciation rules determine which sounds, or phonemes, each character will receive based on its relative position within each word. The integrated DoubleTalk text-to-speech engine analyzes text by applying these rules to each word or character, depending on the operating mode in use. Exception dictionaries augment this process by defining exceptions for (or even replacing) these built in rules.

Exception dictionaries can be created and edited with a word processor or text editor that stores documents as standard text (ASCII) files. However, the dictionary must be compiled into the internal format used by the RC8650 before it can be used. The *RC8650 Studio* software, available from RC Systems, includes a dictionary editor and compiler.

EXCEPTION SYNTAX

Exceptions have the general form

L(F)R=P

which means "the **text fragment** F, occurring with **left context** L and **right context** R, gets the **pronunciation** P." All three parts of the exception to the left of the equality sign must be satisfied before the text fragment will receive the pronunciation given by the right side of the exception.

The text fragment defines the input characters that are to be translated by the exception, and may consist of any combination of letters, numbers, and symbols. Empty (null) text fragments may be used to generate sound based on a particular input pattern, without actually translating any of the input text. The text fragment (if any) must always be contained within parentheses.

Characters to the left of the text fragment specify the left context (what must come before the text fragment in the input string), and characters to the right define the right context. Both contexts are optional, so an exception may contain neither, either, or both contexts. There are also 15 special symbols, or **context tokens**, that can be used in an exception's context definitions (Table 4.1).

Note that although context tokens are, by definition, valid only within the left and right context definitions, the wildcard token may also be used within text fragments. Any other context token appearing within a text fragment will be treated as a literal character.

Table 4.1. Context Tokens

Symbol	Definition
#	A vowel: a, e, i, o, u, y
+	A front vowel: e, i, y
^	A consonant: b, c, d, f, g, h, j, k, l, m, n, p, q, r, s, t, v, w, x, z
*	One or more consonants
:	Zero or more consonants
?	A voiced consonant: b, d, g, j, l, m, n, r, v, w, z
@	One of: d, j, l, n, r, s, t, z, ch, sh, th
!	One of: b, c, d, f, g, p, t
%	A suffix: able(s), ably, e(s), ed(ly), er(s), ely, eless, ement(s), eness, ing(s), ingly (must also be followed by a non- alphabetic character)
&	A sibilant: c, g, j, s, x, z, ch, sh
$	A nonalphabetic character (number, space, etc.)
~	One or more non-printing characters (spaces, controls, line breaks, etc.)
\	A digit (0-9)
|	One or more digits
`	Wildcard (matches any character)

The right side of an exception (P) specifies the pronunciation that the text fragment is to receive, which may consist of any combination of phonemes (Table 2.1), phoneme attribute tokens (Table 2.2), and commands (Table 2.14). Using the tone generator and prerecorded audio playback commands, virtually limitless combinations of speech, tones, and sound effects can be triggered from any input text pattern. If no pronunciation is given, no sound will be given to the text fragment; the text fragment will be silent.

A dictionary file may also contain comments, but they must be on lines by themselves (i.e., they cannot be on the same line as an exception). Comment lines begin with a semicolon character (;), so that the compiler will know to skip over it.

An example of an exception is

```
C(O)N=AA
```

which states that o after c and before n gets the pronunciation AA, the o-sound in cot. For example, the o in conference, economy, and icon would be pronounced according to this exception.

Another example is

```
$R(H)=
```

which states that h after initial r is silent, as in the word rhyme (the $ context token represents any non-alphabetic character, such as a space between words; see Table 4.1).

Punctuation, numbers, and most other characters can be redefined with exceptions as well:

```
(5)=S I NG K O                (Spanish five)
(CHR$)=K EH R IX K T ER       (Basic function)
```

THE TRANSLATION ALGORITHM

In order to better understand how an exception dictionary works, it is helpful to understand how the DoubleTalk text-to-speech engine processes text.

Algorithms within the DoubleTalk engine analyze input text a character at a time, from left to right. A list of pronunciation rules is searched sequentially for each character until a rule is found that matches the character in the correct position and context. The algorithm then passes over the input character(s) bracketed in the rule (the text fragment), and assigns the pronunciation given by the right side of the rule to them. This process continues until all of the input text has been converted to phonetic sounds.

The following example illustrates how the algorithm works by translating the word *receive*.

The algorithm begins with the letter r and searches the R pronunciation rules for a match. The first rule that matches is `$(RE)^#=R IX`, because the r in receive is an initial r and is followed by an e, a consonant (c), and a vowel (e). Consequently, the text fragment *re* receives the pronunciation `R IH`, and the scan moves past *re* to the next character: receive. (E is not the next scan character because it occurred inside the parentheses with the r; the text fragment *re* as a whole receives the pronunciation `R IX`)

The first match among the C rules is `(C)+=S`, because c is followed by an e, i, or y. *C* thus receives the pronunciation `S`, and processing continues with the second e: receive.

`(EI)=IY` is the first rule to match the second e, so *ei* receives the sound `IY`. Processing resumes at the character receive, which matches the default V rule, `(V)=V`.

The final e matches the rule `#:(E)$=`, which applies when e is final and follows zero or more consonants and a vowel. Consequently, *e* receives no sound and processing continues with the following word or punctuation, if any. Thus, the entire phoneme string for the word receive is `R IX S IY V`.

RULE PRECEDENCE

Since DoubleTalk uses its translation rules in a sequential manner, the position of each exception relative to the others must be carefully considered. For example, consider the following pair of exceptions:

```
(O)+=OW
(O)=UW
```

The first exception states that o followed by e, i, or y is to be pronounced `OW`, the o-sound in boat. The second exception does not place any restriction on what must come before or after o, so o in any context will receive the `UW` pronunciation. If the exceptions were reversed, the `(O)+` exception would never be reached because the `(O)` exception will always match o in any context. In general, tightly-defined exceptions (those containing many context restrictions) should precede loosely-defined exceptions (those with little or no context definitions).

```
(RAT)=R AE T
(RATING)=R EY T IH NG
(R)=R
```

This is an example of how *not* to organize exceptions. The exception `(RATING)` will never be used because `(RAT)` will always match first. According to these exceptions, the word *rating* would be pronounced “rat-ing.”

It can be beneficial to group exceptions by the first character of the text fragments, that is, all of the A exceptions in one group, all the B exceptions in a second group, and so on. This gives an overall cleaner appearance, and can prove to be helpful if the need arises to troubleshoot any problems in your dictionary.

TEXT NOT MATCHED BY THE DICTIONARY

It is possible that some input text may not match anything in a dictionary, depending on the nature of the dictionary. For example, if a dictionary was written to handle unusual words, only those words would be included in the dictionary. On the other hand, if a dictionary defined the pronunciation for another language, it would be comprehensive enough to handle all types of input. In any case, *if an exception is not found for a particular character, the English pronunciation will be given to that character according to the built in pronunciation rules.*

Generally, the automatic switchover to the built in rules is desirable if the dictionary is used to correct mispronounced words, since by definition the dictionary is defining exceptions to the built in rules. If the automatic switchover is not desired, however, there are two ways to prevent it from occurring. One way is to end each group of exceptions with an unconditional exception that matches any context. For example, to ensure that the letter “a” will always be matched, end the A exception group with the exception `(A)`=pronunciation. This technique works well to ensure matches for specific characters, such as certain letters or numbers.

If the exception dictionary is to replace the built in rules entirely, end the dictionary with the following exception:

```
()=
```

This special exception causes unmatched characters to be ignored (receive no sound), rather than receive the pronunciation defined by the built in rules.

EFFECT ON PUNCTUATION

Punctuation defined in the exception dictionary has priority over the Punctuation Filter command. Any punctuation defined in the dictionary will be used, regardless of the Punctuation Filter setting. However, if the dollar sign character ($) is defined within the text fragment of any exception, currency strings will not be read as dollars and cents.

CHARACTER MODE EXCEPTIONS

Exceptions are defined independently for the Character and Text modes of operation. The beginning of the Character mode exceptions is defined by inserting the letter `C` just before the first Character mode exception. No exceptions prior to this marker will be used when the RC8650 is in Character mode, nor will any exceptions past the marker be used in Text mode. For example:

```
.          (Text mode exceptions)
.
()=        (optional; used if built in rules are not to be
           used in no-match situations)

C          (Character mode exceptions marker)
.
.          (Character mode exceptions)
.
()=        (optional; used if built in rules are not to be
           used in no-match situations)
```

APPLICATIONS

The following examples illustrate some ways in which the exception dictionary can be used.

Correcting Mispronounced Words

The most obvious of all applications—correcting mispronounced words.

```
S(EAR)CH=ER
$(OK)$=OW K EY
```

The first exception corrects the pronunciation of all words containing *search* (search, searched, research, etc.). As this exception illustrates, it is only necessary to define the problem word in its root form, and only the part of the word that is mispronounced (*ear*, in this case). The second exception corrects the word *ok*, but because of the left and right contexts, will not cause other words (joke, look, etc.) to be incorrectly translated.

No Cussing, Please

The reading of specific characters or words can be suppressed by writing exceptions in which no pronunciation is given.

```
(????)=        (YOU fill in the blanks!)
```

When Zero Isn't Really Zero

When reading addresses or lists of numbers, we humans often substitute the word "oh" for the digit 0. For example, we might say 1020 North Eastlake as "one oh two oh North Eastlake." The digit 0 can be redefined in this manner with the following exception:

```
(0)=OW
```

Arithmetic Operators

Some characters may have more than one name; for example, the character "/" may be read as "slash" or "divided by," depending on the context. Such characters can be redefined if their default names don't fit the application. For example, the arithmetic operators (/, *, ^, etc.) can be defined for mathematical applications with the following exceptions:

```
\(/)\=D IX V AY D IX D   B AY
\(*)\=M AH L T AX P L AY D   B AY
\(^)\=R EY Z D   T UW
  .
  .
 etc.
```

Acronyms and Abbreviations

Acronyms and abbreviations can be defined so the words they represent will be spoken.

```
$(KW)$=K IH L AH W AA T
$(DR)$=D AA K T ER
$(TV)$=T EH L AX V IH ZH IX N
```

String Parsing & Decryption

Sometimes the data that we would like to have read is not available in a "ready-to-read" format. For example, the output of a GPS receiver may look something like this:

```
$GPGGA,123456,2015.2607,N,...
```

The first 14 characters of the string contain fixed header and variable time data, which we don't care about. The following exception will ensure that the first 14 characters are not read:

```
($GPGGA,``````,)=
```

In addition, the following exceptions handle the "degrees" and "minutes" components of the latitudinal coordinate:

```
,\\()\\.=D IX G R IY Z , ,
(.)=M IH N IH T S , ,
(,N,)=N OW R TH   L AE T IH T UW D
```

The four exceptions taken together will translate the example string as "20 degrees, 15 minutes, north latitude." (Additional exceptions for handling the seconds component, and digits themselves, are not shown for clarity).

Heteronyms

Heteronyms are words that have similar spellings but are pronounced differently, depending on the context, such as read ("reed" and "red") and wind ("the wind blew" and "wind the clock"). Exceptions can be used to fix up these ambiguities, by including non-printing (Control) characters in the text fragment of the exception.

Suppose a line of text required the word "close" to be pronounced as it is in "a close call," instead of as in "close the window." The following exception changes the way the *s* will sound:

```
(^DCLOSE)=K L OW S
```

Note the Control-D character (^D) in the text fragment. Although a non-printing character, the translation algorithms treat it as they would any printing character. Thus, the string "^D close" will be pronounced with the s receiving the "s" sound, wherever it appears in the text stream. Plain "close" (without the Control-D) will be unaffected—the s will still receive the "z" sound. It does not matter where you place the Control character in the word, as long as you use it the same way in your application's text. You may use any non-printing character (except LF and CR) in this manner.

Foreign Languages

Dictionaries can be created that enable the RC8650 to speak in foreign languages. It's not as difficult as it may seem—all that is required in most cases is a pronunciation guide and a bit of patience. If you don't have a pronunciation guide for the language you're interested in, check your local library. Most libraries have foreign language dictionaries that include pronunciation guides, which make it easy to transcribe the pronunciation rules into exception form.

Language Translation

Exception dictionaries even allow the RC8650 to read foreign language text in English! The following exceptions demonstrate how this can be done with three example Spanish/English words.

```
(GRANDE)=L AA R J
(BIEN)=F AY N
(USTED)=YY UW
```

The sense of translation can also be reversed:

```
(LARGE)=G RR A N D EI
(FINE)=B I EI N
(YOU)=U S T EI DH
```

Message Macros

Certain applications may not be able to send text strings to the RC8650. An example of such an application is one that is only able to output a four bit control word and strobe. Sixteen unique output combinations are possible, but this is scarcely enough to represent the entire ASCII character set.

You can, however, assign an entire spoken phrase to a single ASCII character with the exception dictionary. By driving four of the data bus lines of the bus interface (see Figure 1.7) and hardwiring the remaining four to the appropriate logic levels, virtually any set of 16 ASCII characters can be generated, which in turn can be interpreted by the exception dictionary.

For example, by connecting the four control bits to DB_0 through DB_3, DB_4 and DB_5 to V_{CC}, DB_6 and DB_7 to ground and the strobe to PWR#, ASCII codes 30h through 3Fh (corresponding to the digits "0" through "9" and the six ASCII characters following them) can be generated by the four control bits. Message strings would then be assigned to each of these ASCII characters. For example, you could make the character "0" (corresponding to all four control bits = 0) say, "please insert quarter," with the following dictionary entry:

```
(0)=P L IY Z   IH N S ER T   K W OW R T ER
```

The Timeout timer should also be activated (1Y, for example) in order for the "message" to be executed. Otherwise, the RC8650 will wait indefinitely for a CR/Null character that will never come. The timer command could be included in the greeting message.

TIPS

Make sure that your exceptions aren't so broad in nature that they do more harm than good. Exceptions intended to fix broad classes of words, such as word endings, are particularly notorious for ruining otherwise correctly pronounced words.

Take care in how your exceptions are organized. Remember, an exception's position relative to others is just as important as the content of the exception itself.

Exception Anomalies

On rare occasions, an exception may not work as expected. This occurs when the built in pronunciation rules get control before the exception does. The following example illustrates how this can happen.

Suppose an exception redefined the o in the word "process" to have the long "oh" sound, the way it is pronounced in many parts of Canada. Since the word is otherwise pronounced correctly, the exception redefines only the "o:"

```
PR(O)CESS=OW
```

But much to our horror, the RC8650 simply refuses to take on the new Canadian accent.

It so happens the RC8650 has a built in rule which looks something like this:

```
$(PRO)=P R AA
```

This rule translates a group of three characters, instead of only one as most of the built in rules do. Because the text fragment `PRO` is translated as a group, the o is processed along with the initial "pr," and consequently the exception never gets a shot at the o.

If you suspect this may be happening with one of your exceptions, include more of the left-hand side of the word in the text fragment (in the example above, `(PRO)=P R OW` would work).

SECTION 5: RC8650 EVALUATION KIT

The RC8650 Evaluation Kit comes with everything required to evaluate and develop applications for the RC8650 chipset using a Windows-based PC. The included *RC8650 Studio™* software provides an integrated development environment with the following features:

- Read any text, either typed or from a file
- Easy access to the various RC8650 voice controls
- Manage collections of sound files and store them in the RC8650
- Exception dictionary editor/compiler, and much more...

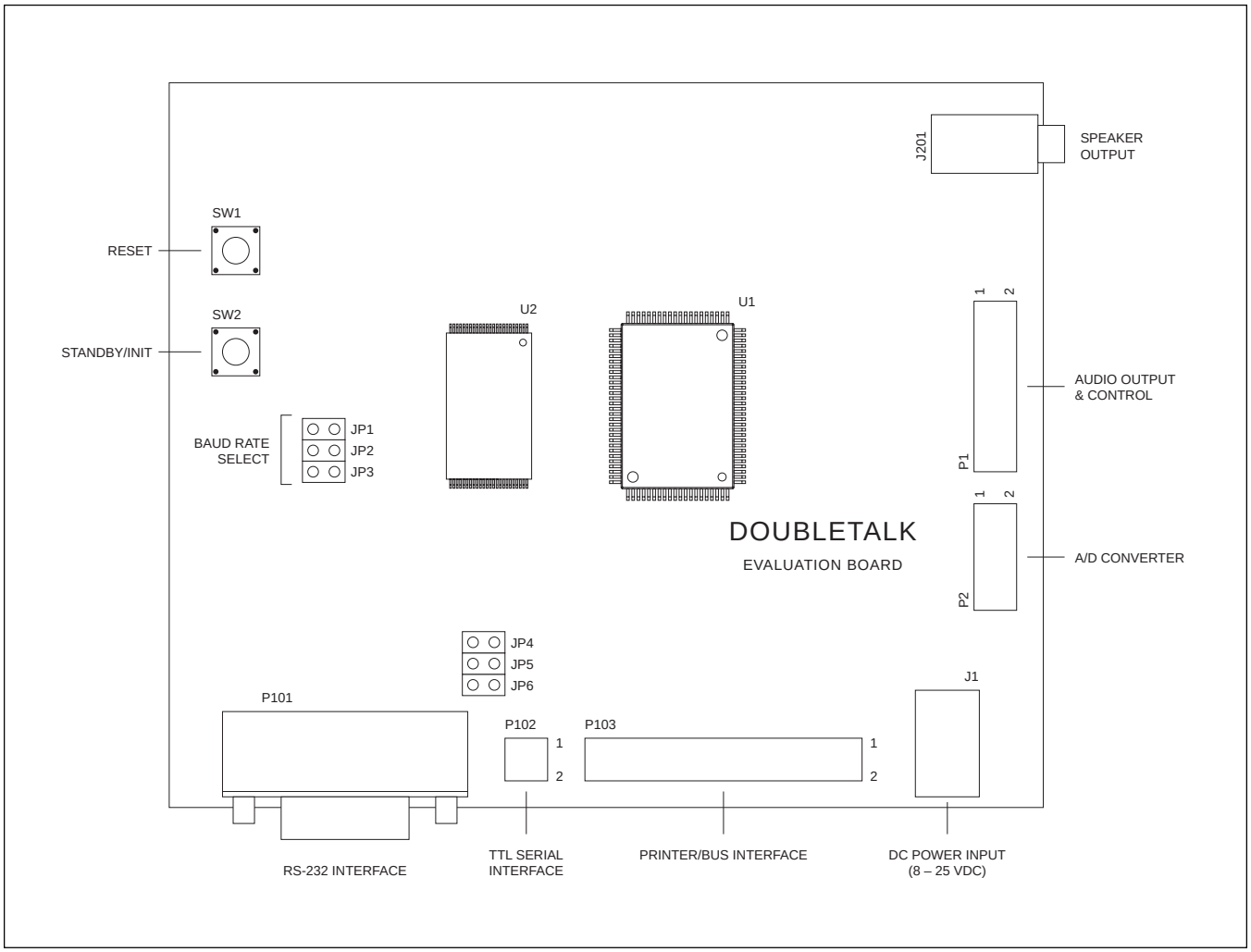
The evaluation board can also be used in stand-alone environments by simply printing the desired text and commands to it via the onboard RS-232 serial or parallel ports.

EVALUATION KIT CONTENTS

The following components are included in the DoubleTalk RC8650 Evaluation Kit:

- Printed circuit board containing the RC8650-1 chipset
- AC power supply
- Speaker
- Serial cable
- *RC8650 Studio™* development software CD

EVAL BOARD OUTLINE



CONNECTOR PIN ASSIGNMENTS & SCHEMATICS

Table 5.1. P1 Pin Assignments (Audio Output & Control)

Pin No.	Pin Name	Pin No.	Pin Name
1	AO_0	9	AS_0
2	AO_1	10	AS_1
3	$SP+_0$	11	$SUSP_0$
4	$SP+_1$	12	$SUSP_1$
5	$SP-_0$	13	DAOUT
6	$SP-_1$	14	DARTS#
7	TS_0	15	DACLK
8	TS_1	16	GND

Table 5.2. P2 Pin Assignments (A/D Converter)

Pin No.	Pin Name	Pin No.	Pin Name
1	AN_0	6	GND
2	GND	7	AN_3
3	AN_1	8	GND
4	GND	9	ADTRG
5	AN_2	10	GND

Table 5.3. JP1-JP3 Pin Assignments (Baud Rate)

JP3	JP2	JP1	Baud Rate
X	X	X	300
X	X		600
X		X	1200
X			2400
	X	X	4800
	X		9600
		X	19200
			Auto-detect (default)

"X" denotes jumper installed

Table 5.4. P101 Pin Assignments (RS-232 Serial Interface)

Pin No.	Pin Name	Pin No.	Pin Name
1	NC	6	DSR
2	RXD	7	RTS
3	TXD	8	CTS
4	NC	9	NC
5	GND	—	—

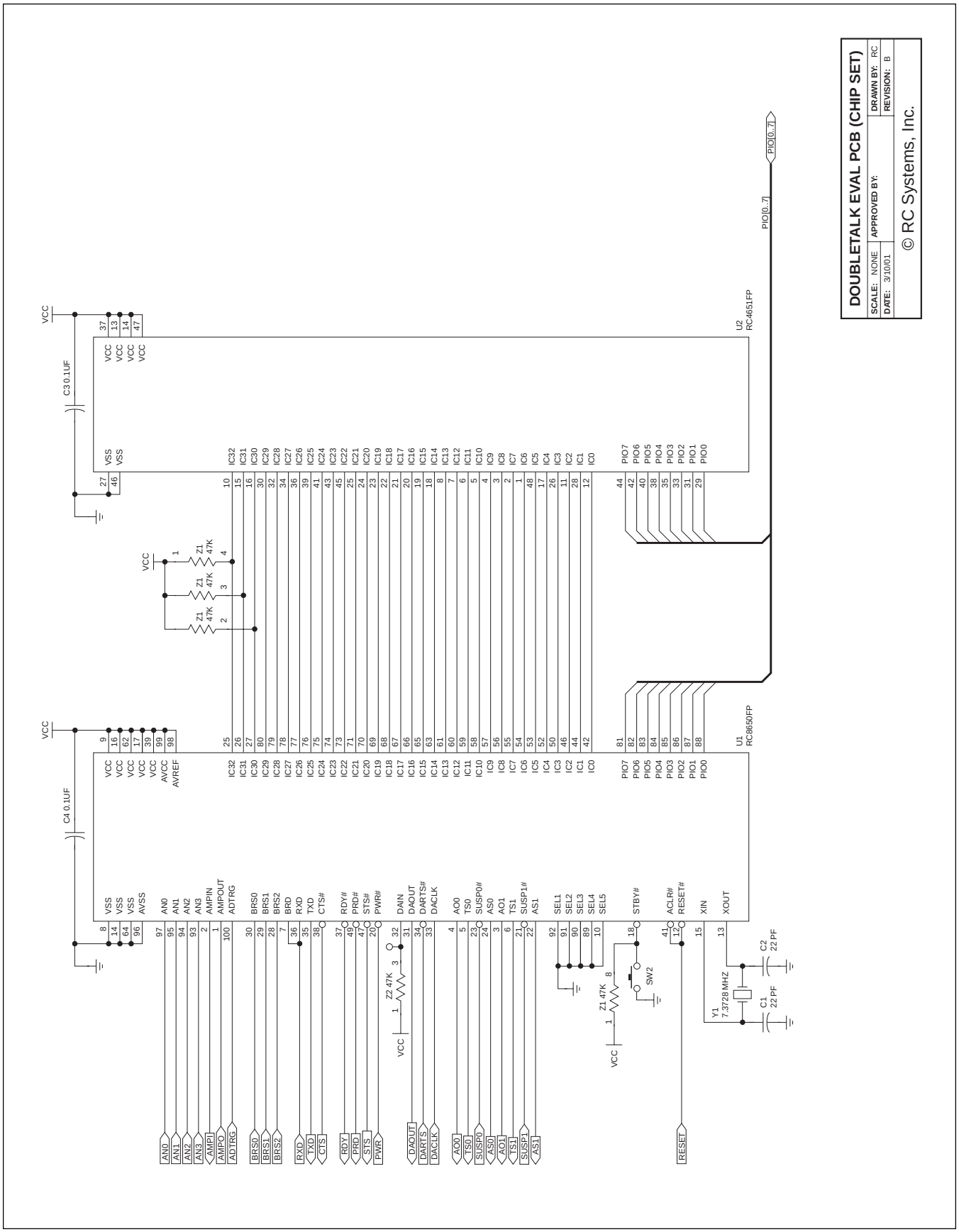
Table 5.5. P102 Pin Assignments (TTL Serial Interface)

Pin No.	Pin Name	Pin No.	Pin Name
1	GND	3	TXD
2	CTS	4	RXD

JP4-JP6 must be open in order to use the TTL interface

Table 5.6. P103 Pin Assignments (Printer/Bus Interface)

Pin No.	Pin Name	Pin No.	Pin Name
1	STB#	14	GND
2	AFD#	15	$DATA_6$
3	$DATA_0$	16	GND
4	ERROR#	17	$DATA_7$
5	$DATA_1$	18	GND
6	INIT#	19	ACK#
7	$DATA_2$	20	GND
8	SLCTIN#	21	BUSY
9	$DATA_3$	22	GND
10	GND	23	PE
11	$DATA_4$	24	GND
12	GND	25	SLCT
13	$DATA_5$	26	RD#


DOUBLETALK EVAL PCB (CHIP SET)
SCALE: NONE
APPROVED BY:
DRAWN BY: RC
DATE: 3/10/01
REVISION: B
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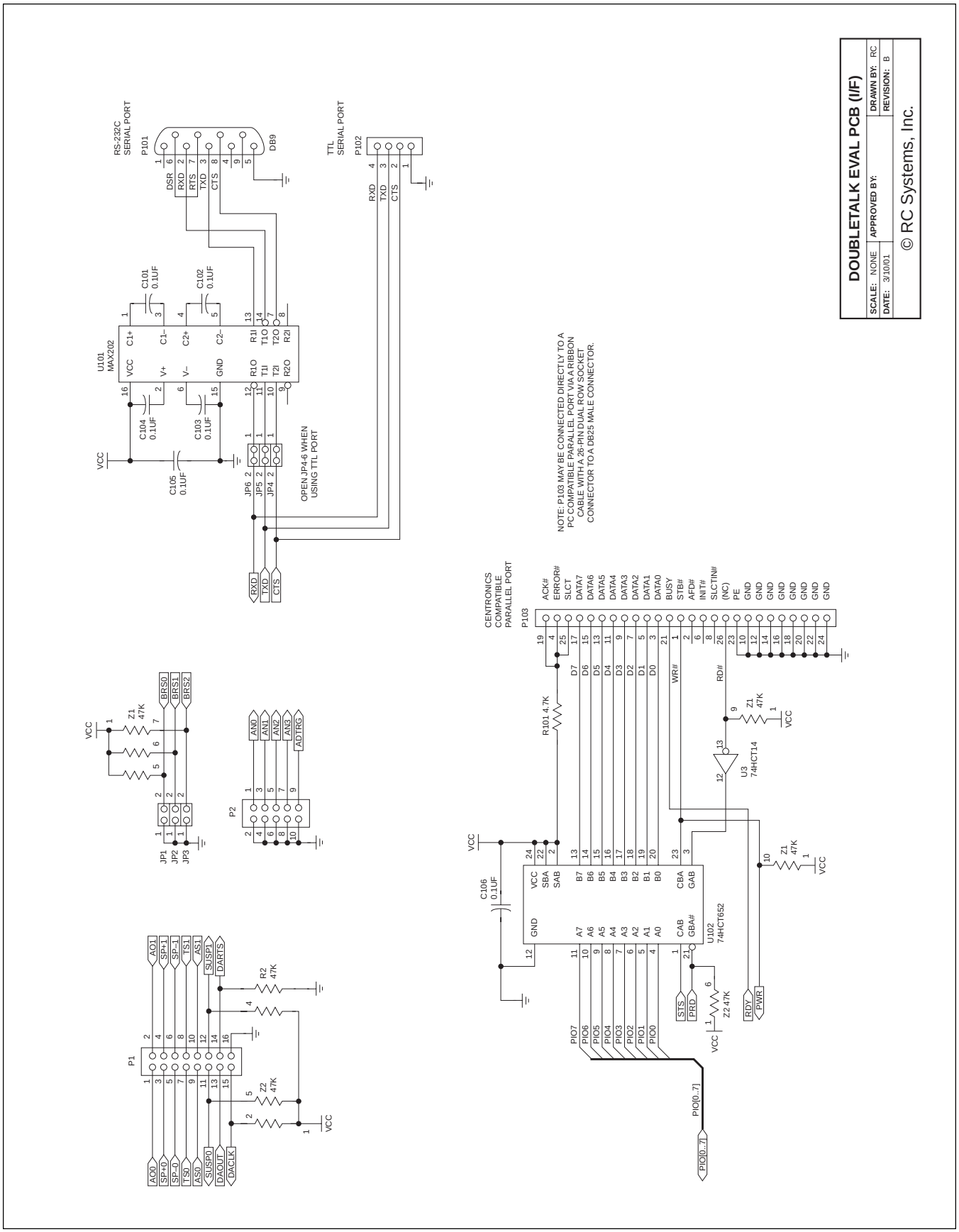
U1 RC8650FP
U2 RC4651FP
C4 0.1UF
C3 0.1UF
C1 22 PF
C2 22 PF
Y1 7.3728 MHZ
Z1 47K
22 47K
SW2
PIO[0..7]
AN0
AN1
AN2
AN3
AMPI
AMPO
ADTRG
BRS0
BRS1
BRS2
RXD
TXD
CTS
RDY
PRD
STS
PWR
DAOUT
DARTS
DACLK
AO0
TS0
SUSP0
AS0
AO1
TS1
SUSP1
AS1
RESET


DOUBLETALK EVAL PCB (I/F)
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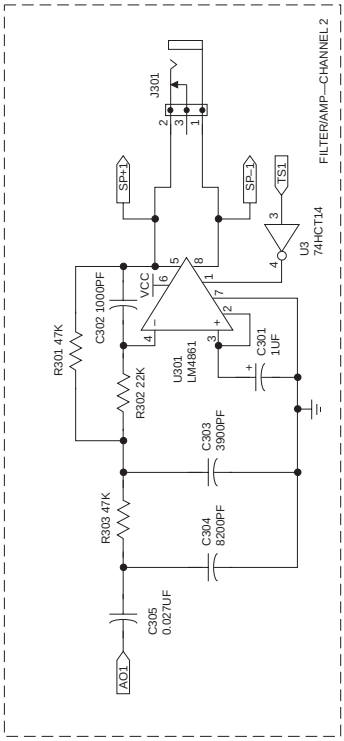
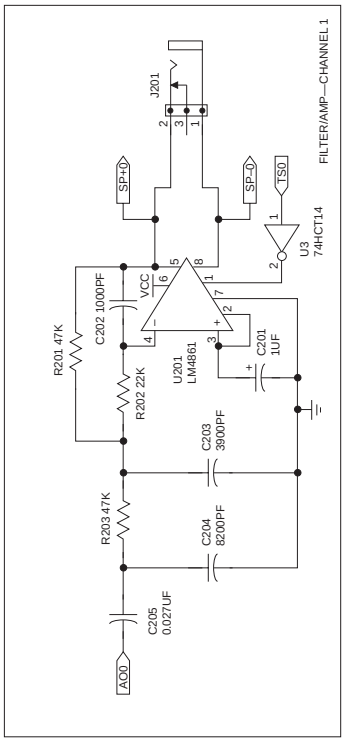
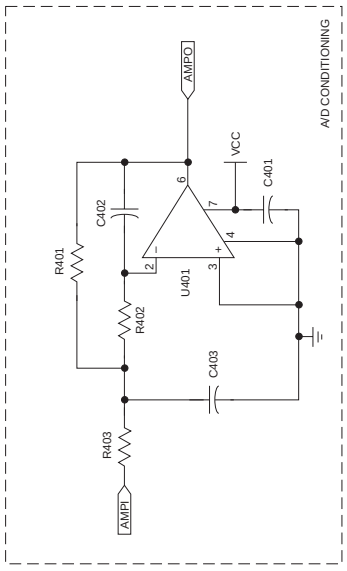
RS-232C SERIAL PORT
TTL SERIAL PORT
U101 MAX202
OPEN JP4-6 WHEN USING TTL PORT
NOTE: P103 MAY BE CONNECTED DIRECTLY TO A PC COMPATIBLE PARALLEL PORT VIA A RIBBON CABLE WITH A 26-PIN DUAL ROW SOCKET CONNECTOR TO A DB25 MALE CONNECTOR.
CENTRONICS COMPATIBLE PARALLEL PORT
U102 74HCT652
U3 74HCT14







– – – = COMPONENTS NOT INSTALLED ON EVAL BOARD

DOUBLETALK EVAL PCB (AUDIO)		
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DOUBLETALK EVAL PCB (P/S)		
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DATE: 3/10/01		REVISION: B

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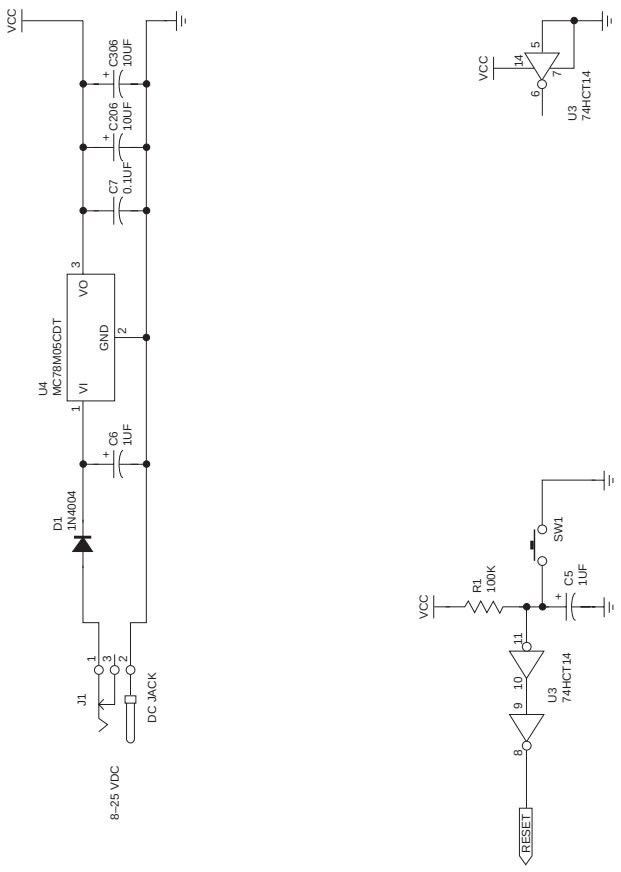

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