

Version

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PLUS+1 Controller Family
Technical Information
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About This Manual

PLUS+1 Controller Family Technical Information

This manual is designed to be a comprehensive PLUS+1™ product family hardware reference tool for vehicle OEM design, engineering, and service personnel. It is one of four sources of PLUS+1 product technical information. Other sources include individual module product data sheets, module specific Application Program Interface (API) specifications and the *PLUS+1 GUIDE Software User Manual*, literature number **10100824**.

What information is in this manual?

This manual describes electrical details that are common to all PLUS+1 modules, including general specifications, input and output parameters, environmental ratings and installation details.

What information is in individual module product data sheets?

Parameters that are unique to an individual PLUS+1 module are contained in the module product data sheet. Data sheets contain the following information:

- Numbers and types of inputs and outputs
- Module connector pin assignments
- Module maximum current capacity
- Module sensor power supply (if present) current capacity
- Module installation drawing
- Module weights
- Product ordering information

What information is in individual module API specifications?

Detailed information about the module BIOS is contained in the module API specification. PLUS+1 BIOS functionality is pin dependent. Pins are defined in module data sheets as *C* (connector number) *p* (pin number). API specifications include:

- Variable name
- Variable data type
- Variable direction (read/write)
- Variable function and scaling

Module API specifications are the definitive source of information regarding PLUS+1 module pin characteristics.

What information is in the PLUS+1 GUIDE Software User Manual?

Detailed information regarding the PLUS+1 GUIDE software tool set that is used to build PLUS+1 machine management solutions is contained in the user manual. This technical information manual covers the following broad topics:

- How to use the GUIDE graphical application development tool to create machine applications
- How to configure module input and output parameters
- How to download GUIDE applications to target PLUS+1 hardware modules
- How to upload and download tuning parameters
- How to use the PLUS+1 service tool

PLUS+1 product literature is available at:
www.sauer-danfoss.com

**PLUS+1 Family of
 Mobile Machine
 Management Products**

12, 24, 38, 50, and 88 Pin Models



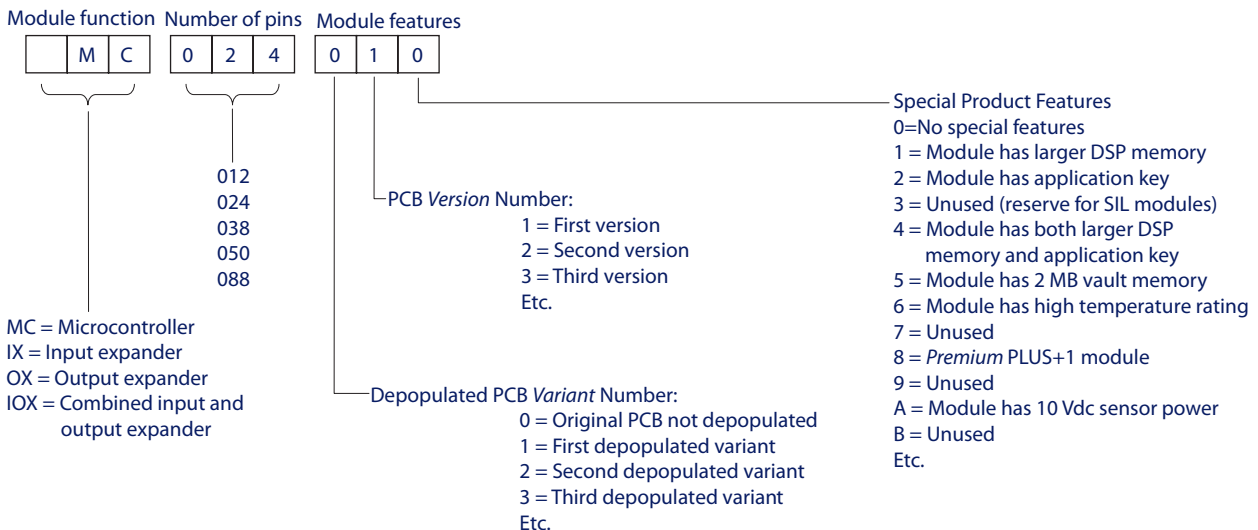
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PLUS+1 controllers and input/output expansion modules are designed to provide flexible, expandable, powerful, and cost effective total machine management systems for off-highway vehicles. These modules communicate with one another and other intelligent systems over a machine Controller Area Network (CAN) data bus. PLUS+1 hardware products are designed to be equally effective in a distributed CAN system, with intelligence in every node, or as stand-alone control for smaller machine systems. PLUS+1 systems are incrementally expandable: additional modules can be easily added to the machine CAN bus to increase system capabilities or computational power.

PLUS+1 control products utilize modular designs wherever possible. This modularity extends to product housings, connectors and control circuitry. Five standard housings, 12, 24, 38, 50, and 88 pin, cover the entire product line.

**PLUS+1 Module
 Naming Convention**

PLUS+1 Master Model Code (Example: MC 024 010)



P108012

**User Liability and
Safety Statements**

OEM Responsibility

The OEM of a machine or vehicle in which PLUS+1 electronic controls are installed has the full responsibility for all consequences that might occur. Sauer-Danfoss has no responsibility for any consequences, direct or indirect, caused by failures or malfunctions.

- Sauer-Danfoss has no responsibility for any accidents caused by incorrectly mounted or maintained equipment.
- Sauer-Danfoss does not assume any responsibility for PLUS+1 products being incorrectly applied or the system being programmed in a manner that jeopardizes safety.
- All safety critical systems shall include an emergency stop to switch off the main supply voltage for the outputs of the electronic control system. All safety critical components shall be installed in such a way that the main supply voltage can be switched off at any time. The emergency stop must be easily accessible to the operator.

Input/Output Types

Each PLUS+1 hardware module has input or output pins that support multiple functions. Pins that support multiple input or output types are user-configurable using PLUS+1 GUIDE software. Refer to product data sheets for the input/output (I/O) content of individual modules.

This section provides technical information and specifications for each I/O type.

The following ratings apply to all PLUS+1 input and output types.

Absolute Rating for All PLUS+1 I/O

Description	Units	Minimum	Maximum	Comment
Input voltage	Vdc	0	36	Modules will survive with full functionality if input voltage does not exceed 36 Vdc

Inputs

Input Types

- Digital (DIN)
- Digital or Analog (DIN/AIN)
- Analog or Temperature or Rheostat (AIN/Temp/Rheo)
- Multifunction: Digital or Analog or Frequency (DIN/AIN/FreqIN)
- Fixed Range Analog or CAN shield (AIN/CAN shield)
- Digital or Analog or Current (DIN/AIN/4-20 mA IN)

Each input pin allows one of the above functional types. For pins with multiple functions, input configurations are user programmable using PLUS+1 GUIDE templates.

Digital (DIN)

Digital inputs connected to PLUS+1 dedicated digital input pins are debounced in software. Digital input debounce is defined as an input being in a given state for three samples before a state change is reported. The sample time is a function of application loop time.

Multifunction pins that are configured to be DIN are subject to the same update rates as the analog input function for that pin. Debounce is not used, as hysteresis is built into the function. The time to recognize a transition is dependent on the timing of the switch activation and the sample rate.

Specifications

Description	Units	Minimum	Max	Comment
Allowed voltage at pin	Vdc	0	36	
Rising voltage threshold	Vdc	2.80	4.15	A digital input is guaranteed to be read as high if the voltage is greater than 4.15 Vdc
Falling voltage threshold	Vdc	1.01	2.77	A digital input is guaranteed to be read as low if the voltage is less than 1.01 Vdc
Time to change state in response to step input	ms		1.5	Input change from maximum to minimum - add to debounce time
Input impedance	kΩ	13.9	15.53	Depends on pin configuration

Inputs (continued)

General

Feature	Comment
Response to input below minimum voltage	Non-damaging, non-latching; reading saturates to the low limit
Response to input above maximum voltage	Non-damaging, non-latching; reading saturates to the high limit
Response to input open	Pin configuration dependent: No pull up/ no pull down = floating Pull up to 5 Vdc = 5 Vdc Pull down = 0 Vdc Pull up/ pull down = 2.5 Vdc
Voltage working ranges	Programmable (see specific data sheets for ranges)

Analog (AIN)

Module analog input offset error can be 80 counts out of 4096 (12 bit A/D resolution). Therefore, the minimum voltage that a module will read at the most common 0 to 5.25 Vdc range is 105 mV.

Specifications

Description	Units	Minimum	Maximum	Comment
Allowed voltage at pin *	Vdc	0	36	
0 to 5 Vdc range Maximum discernable voltage	Vdc	5.21	5.30	5.26 is typical
0 to 36 Vdc range Maximum discernable voltage	Vdc	34.62	35.91	35.26 is typical
Precision	mV		1.28	
Input impedance	kΩ	206	236	Depends on pin configuration

* Maximum allowed voltage on fixed range analog input pins (CAN shield) is 25 Vdc.

A/D Refresh Rate

A/D refresh rates for individual PLUS+1 modules are as follows. A/D channels are sampled at 25KHz and 64 samples are taken to build an average value. This results in a refresh rate of 2.56 ms for channels directly measured. All internal current feedback channels are refreshed at the 2.56 ms rate.

Some PLUS+1 module A/D channels are shared. Each of the shared channels has eight multiplexed analog inputs. Each multiplexed input is serviced every 20.48 ms. Update rates for specific analog input pins are found below. Update rates for input expander modules are dependent on the CAN message frequency selected in the application program.

Inputs (continued)

A/D Refresh Rate (continued)

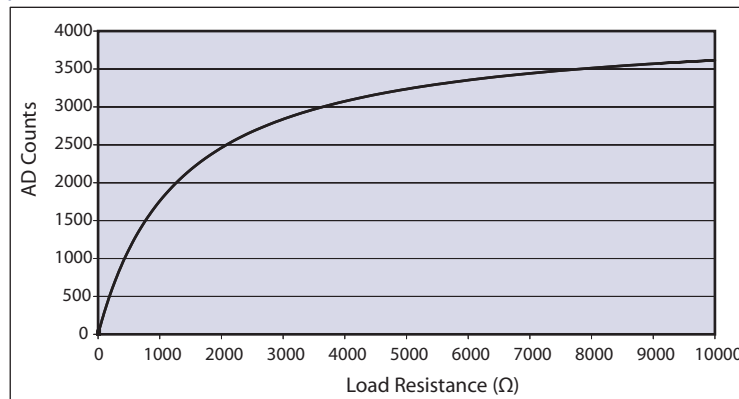
A/D Update Rates for PLUS+1 Modules

PLUS+1 module	A/D refresh rate
MC012-010	All: 2.56 ms
MC024-010	All: 2.56 ms
MC024-020	C1p10 to C1p12: 7.68 ms Remaining pins: 2.56 ms
MC024-500	All: 2.56 ms
MC038-010	C1p08, C1p14, C1p17 to C1p20, C1p24 to C1p27, C1p36 to C1p38: 20.48 ms C1p05, C1p10 to C1p12: 2.56 ms
MC050-010	C1p05, C1p08, C1p14 to C1p19, C1p22 to C1p30, C1p34 to C1p36: 20.48 ms C1p02: 2.56 ms
MC050-020	C1p05, C1p22, C1p25 to C1p32, C1p39, C1p40: 20.48 ms C1p02, C1p08, C1p18, C1p19, C1p23, C1p24: 2.56 ms
MC050-055	C1p05, C1p13 to C1p29, C1p31 to C1p39, C1p41 to C1p45: 20.48 ms C1p46 to C1p49: 2.56 ms
MC088-015, MC088-315	C1p05, C1p08, C1p14 to C1p19, C1p22 to C1p30, C1p34 to C1p36, C1p47 to C1p50, C2p09 to C2p11, C2p35 to C2p38: 20.48 ms
IOX012-010	Refresh rate is a function of CAN message frequency
IX012-010	Refresh rate is a function of CAN message frequency
IX024-010	Refresh rate is a function of CAN message frequency

Analog/Temperature/Rheostat (AIN/Temp/Rheo)

When a PLUS+1 module input pin is configured in the temperature/rheostat mode, the input has a 1.33 kΩ pull up resistor to +5 Vdc. It will source up to 3.75 mA current to an external load (RL) which then can be measured. The equation for relating AD counts to a given load is: $AD\ counts = (4096 * RL) / (RL + 1330)$. This calculation is solved internally and the ohms value is available for the programmer. The following chart shows the relationship between AD counts and load resistance in ohms.

Rheostat Inputs



P108013

Specifications

Description	Units	Minimum	Maximum	Comment
Allowed voltage at pin	Vdc	0	36	

Inputs (continued)

**Digital/Analog/Frequency (DIN/AIN/FreqIN)
 (all modules except IX012-010, IX024-010)**

The characteristics of Digital/Analog/Frequency pins are GUIDE software controlled. The input can be digital, analog or frequency. Inputs can be pulled to 5 Vdc, pulled to ground, pulled to 2.5 Vdc, or no pull-up/pull-down.

General

Feature	Comment
Response to input below minimum voltage	Non-damaging, non-latching; reading saturates to the low limit
Response to input above maximum voltage	Non-damaging, non-latching; reading saturates to the high limit
Expected measurement	Frequency (Hz)
	Period (0.1 μsec)
	Channel to channel phase shift (paired inputs . . .) (0.1 ms)
	PWM duty cycle (0.01%)
	Edge count
	Quadrature count (paired inputs driven from a quadrature encoder)
Pull up/pull down configuration	No pull down/ pull up is standard with pull up or pull down programmable; failure modes are detectable

As with analog input pins, values in the following table assume software compensation for AD converter offset errors.

Specifications

Description	Units	Minimum	Maximum	Comment
Allowed voltage at pin	Vdc	0	36	
Frequency range	Hz	0	10000	In steps of 1 Hz
Maximum discernable voltage (high range)	Vdc	34.62	35.91	35.3 Vdc is typical
Maximum discernable voltage (middle range)	Vdc	5.18	5.33	5.26 Vdc is typical
Maximum discernable voltage (low range)	Vdc	0.360	0.375	0.368 Vdc is typical
Precision (high range)	mV	-	8.62	
Worst case error (high range)	mV	-	614	
Precision (middle range)	mV	-	1.28	
Worst case error (middle range)	mV	-	75	
Precision (low range)	μV	-	89.7	
Worst case error (low range)	mV	-	7.39	
Input impedance (pulled to 5 Vdc or ground, middle and low range)	kΩ	13.9	14.3	
Input impedance (pulled to 2.5 Vdc middle and low range)	kΩ	7.17	7.37	
Input impedance (no pull ups, middle and low range)	kΩ	230	236	
Input impedance (pulled to 5 Vdc or ground, high range)	kΩ	13.0	13.4	
Input impedance (pulled to 2.5 Vdc high range)	kΩ	6.92	7.12	
Input impedance (no pull ups, high range)	kΩ	108	112	

Inputs (continued)

MC050-010
 C1p26
 should not be configured
 as a FreqIN.

**Digital/Analog/Frequency (DIN/AIN/FreqIN)
 (all modules except IX012-010, IX024-010) (continued)**

Specifications (continued)

Description	Units	Minimum	Maximum	Comment
Rising voltage threshold (high range)	Vdc	18.9	27.6	It is inadvisable to use the high range option when configuring the input as a digital or frequency input.
Falling voltage threshold (high range)	Vdc	6.8	18.5	It is inadvisable to use the high range option when configuring the input as a digital or frequency input.
Rising voltage threshold (middle range)	Vdc	2.92	4.12	A digital input is guaranteed to be read as high if the voltage is greater than 3.99 Vdc. These numbers also apply to frequency.
Falling voltage threshold (middle range)	Vdc	1.02	2.75	A digital input is guaranteed to be read as low if the voltage is less than 0.96 Vdc. These numbers also apply to frequency.
Rising voltage threshold (low range)	Vdc	0.197	0.298	A digital input is guaranteed to be read as high if the voltage is greater than 0.28 Vdc.
Falling voltage threshold (low range)	Vdc	0.071	0.192	A digital input is guaranteed to be read as low if the voltage is greater than 0.067 Vdc.

**Digital/Analog/Frequency (DIN/AIN/FreqIN)
 (IX012-010, IX024-010 modules)**

The characteristics of Analog/Digital/Frequency pins are GUIDE software controlled. The input can be digital, analog or frequency. Inputs can be pulled to 5 Vdc, pulled to ground, or pulled to 2.5 Vdc.

As with analog input pins, values in the following table assume software compensation for the errors in the AD converter.

Specifications

Description	Units	Minimum	Maximum	Comment
Allowed voltage at pin	Vdc	0	36	
Frequency range	Hz	0	10000	In steps of 1 Hz
Maximum discernable voltage (high range)	Vdc	35.3	36	36 Vdc is typical
Maximum discernable voltage (middle range)	Vdc	5.67	5.83	5.75 Vdc is typical
Maximum discernable voltage (low range)	Vdc	0.440	0.456	0.448 Vdc is typical
Minimum discernable voltage	Vdc	0	0.08	
Precision (high range)	mV	-	36.5	
Worst case error (high range)	mV	-	614	
Precision (middle range)	mV	-	5.62	
Worst case error (middle range)	mV	-	75	
Precision (low range)	µV	-	438	
Worst case error (low range)	mV	-	7.39	
Input impedance (pulled to 5 Vdc or ground, middle and low range)	kΩ	13.9	14.3	

Inputs (continued)

Digital/Analog/Frequency (DIN/AIN/FreqIN)
 (IX012-010, IX024-010 modules) (continued)

Specifications (continued)

Description	Units	Minimum	Maximum	Comment
Input impedance (pulled to 2.5 Vdc middle and low range)	kΩ	7.17	7.37	
Input impedance (no pull ups, middle and low range)	kΩ	230	236	
Input impedance (pulled to 5 Vdc or ground, high range)	kΩ	10.3	10.7	
Input impedance (pulled to 2.5 Vdc high range)	kΩ	6.07	6.27	
Input impedance (no pull ups, high range)	kΩ	36.4	38.4	

This table shows the rising and falling thresholds when the input is used as a digital or frequency input.

Specifications

Description	Units	Minimum	Maximum	Comment
Rising voltage threshold (high range)	Vdc	-	-	It is inadvisable to use the high range option when configuring the input as a digital or frequency input.
Falling voltage threshold (high range)	Vdc	-	-	It is inadvisable to use the high range option when configuring the input as a digital or frequency input.
Rising voltage threshold (middle range)	Vdc	2.85	4.03	A digital input is guaranteed to be read as high if the voltage is greater than 4.03 Vdc. These numbers also apply to frequency.
Falling voltage threshold (middle range)	Vdc	1.15	2.59	A digital input is guaranteed to be read as low if the voltage is less than 1.15 Vdc. These numbers also apply to frequency.
Rising voltage threshold (low range)	Vdc	0.22	0.31	A digital input is guaranteed to be read as high if the voltage is greater than 0.31 Vdc.
Falling voltage threshold (low range)	Vdc	0.090	0.20	A digital input is guaranteed to be read as low if the voltage is greater than 0.090 Vdc.

Potential for IX modules to not go online. If voltage is applied to an IX module input pin prior to the module being powered on, there is a possibility that the module CPU will not power up. The module is not damaged and will power up and operate normally once power is removed from the input pins. It is recommended that either the IX module's 5 Vdc sensor power be used to power sensors or that power is removed from the input pins until the module is powered up.

Inputs (continued)

Digital/Analog/4-20 mA (DIN/AIN/4-20 mA IN)

Refer to Analog/Digital/Frequency *Specifications* table, page 12, for input properties when pins are configured as digital, analog or frequency. If the pin is configured to read current, the table below applies. When interfacing with sensors that transmit a 4 to 20 mA current signal, the positive lead of the transmitter is connected to battery voltage and the negative lead is connected to the PLUS+1 module pin. The current measuring configuration relies on the application program to provide over current protection.

The current measuring configuration is only available on MC088-XXX modules.

Specifications

Description	Units	Minimum	Maximum	Comment
Allowed voltage at pin	Vdc	0	36	
Minimum input current	mA	3	4	
Maximum input current	mA	20	24	
Precision	μA		5.86	

Outputs

Output Types

PLUS+1 control modules feature user-configurable output circuits. Output parameters are configured using PLUS+1 GUIDE templates. Refer to module data sheets for maximum current ratings of individual modules, and MC038-010 and MC088-015 power planes. The following output types are supported:

- Digital (DOUT, DOUT/PVG Pwr)
- Proportional (PWMOUT/DOUT/PVGOUT)
- High current digital (HDOUT) — MC038-010 and MC088-015 module
- High current proportional (HPWM/DOUT) — MC038-010 module

The controller DSP will be powered if power is supplied to any one of the controller's power planes.

MC038-010, MC088-XXX Output Pin Power Supply

The output pin power supply design of the MC038-010 and MC088-XXX controllers is different from that of other PLUS+1 modules. MC038-010 and MC088-XXX controllers have discrete power supply planes for output pins and a separate dedicated power supply for the DSP. Each output pin is associated with a specific power supply plane. Refer to the controller data sheets for a map of outputs and their associated power plane.

Warning

Potential uncommanded machine movement. If battery voltage is applied to a module output pin when the module is not powered the module will be powered up. If significant current is driven back through an output pin, the module will be damaged, and the warranty voided.

Warning

Potential uncommanded machine movement. DOUT and HDOUT digital outputs do not have an internal feedback to the PLUS+1 module kernel. If the application requires fault detection, an external feedback using an AIN configured pin must be used. External feedback is required if the actual output is to be read by the PLUS+1 Service Tool.

All other output types have internal feedback to the PLUS+1 module kernel that provide pin fault and status information that can be read directly by the application and the PLUS+1 Service Tool.

Outputs (continued)

Digital (DOUT, DOUT/PVE Pwr)

Digital outputs can source up to 3 A (exception: MC038-010 DOUT pins are limited to 2 A). However, the total output current for any PLUS+1 module must not exceed the maximum allowable current specified in the module data sheet. In the case of MCO88-XXX modules, the total output current for an individual power plane and the total output current for the module must not exceed the limits specified on the data sheet.

- Current outputs for MC050-010, MC050-020, MC088-015, and OX024-010 module DOUT and DOUT/PVG Pwr pins are pair limited and a function of temperature. Output per pair is:
 6 A maximum at 25° C [77° F]. Output per pair is 4 A maximum at 70° C [158° F]
- MC050-010 pairs are: C1p31 and C1p32, C1p33 and C1p34, C1p35 and C1p36
- MC050-020 pairs are: C1p33 and C1p34, C1p35 and C1p36, C1p37 and C1p38, C1p39 and C1p40
- MC088-015 pairs are:
 Power plane C2p35: C1p31 and C1p32, C1p33 and C1p34
 Power plane C2p36: C1p35 and C1p36
 Power plane C2p37: C2p1 and C2p7, C2p2 and C2p3, C2p4 and C2p5, C2p30 and C2p33
 Power plane C2p38: C2p6 and C2p12
- OX024-010 pairs are: C1p6 and C1p7, C1p8 and C1p9, C1p10 and C1p11
- Example: at a module temperature of 70° C [158° F], if C1p31 is sourcing 2.5 A, the most current that can be sourced on its paired pin C1p32 is 1.5 A

General

Feature	Comment
Configuration	Sourcing only
Type	Linear switching
Short circuit to ground protection	Non-damage, current/thermal limit with status indication; automatic latch off /resume
Open circuit detection	Fault indication provided. The GUIDE Pin Status requires a load of 500 mA to be connected or an open fault will be declared.
Parallel operation	Digital outputs from the same module are capable of being connected together such that the net current rating is the sum of the individual ratings; timing is resolved by the operating system; diagnostic capability is maintained
Shut off	Processor control with hardware WatchDog override

Specifications

Description	Units	Minimum	Maximum	Comment
Allowed voltage at pin	Vdc	0	36	See caution statement below
Output voltage, energized state	Vdc	Vbatt-1.0	Vbatt	Over all load conditions
Output voltage, off state	Vdc	0	0.1	At Rload=200 Ω
Output current range for a status bit to read OK	A	0.5	3	See pair note, above

Outputs (continued)

High Current Digital Outputs (HDOUT)

High current digital outputs can source up to 6 amps.

General

Feature	Comment
Configuration	Sourcing only
Type	Linear switching
Short circuit to ground protection	Non-damage, current/thermal limit with status indication; automatic latch off/resume
Open circuit detection	Status indication provided. The GUIDE pin status requires a load of 1000 mA to be connected or an open status will be declared
Parallel operation	Digital outputs from the same module are capable of being connected together such that the net current rating is the sum of the individual ratings: timing is resolved by the operating system and diagnostic capability is maintained.
Shut off	Processor control with hardware Watchdog override

Specifications

Description	Units	Minimum	Maximum	Comment
Allowed voltage at pin	Vdc	0	36	See caution statement below
Output voltage, energized state	Vdc	Vbatt-1.0	Vbatt	Over all load conditions
Output voltage, off state	Vdc	0	0.1	At Rload=200 Ω
Output current range for status bit to read OK	A	1	6	See pair comment above

⚠ Warning

Potential uncommanded machine movement. If battery voltage is applied to a module output pin when the module is not powered the module will be powered up. If significant current is driven back through an output pin, the module will be damaged, and the warranty voided.

Outputs (continued)

Proportional (PWMOUT/DOUT/PVGOUT)

All PLUS+1 Module proportional outputs are Pulse Width Modulated (PWM). PWM frequency is software adjustable using GUIDE. A low frequency dither may also be added with software to any of the outputs. There are two modes of PWM operation: open loop and closed loop.

In open loop mode, current can be sourced or sunk (all modules are limited to 8 amps sinking), but the output is a PWM duty cycle. Current feedback may be monitored in open loop mode, but the output is a constant voltage, not a constant current. PVG valves may be driven with open loop PWM.

In closed loop mode, current is sourced and a constant current is maintained by the module's operating system using internal current feedback. Load impedance must not exceed 65 ohms.

The maximum current is limited by measuring the feedback current. There is no thermal protection. If the maximum current is exceeded, the controller kernel will shut down the output and latch it. The kernel also limits how quickly the output can be repowered (250 ms). The output cannot be reset until the command goes to 0 or False (if configured as a digital output).

Proportional outputs that are used as a digital sinking output have a potential for a leakage current of up to 5 mA when off.

Refer to individual module data sheets for the maximum allowable output current for each PLUS+1 module.

General

Feature	Comment
Configuration	Sourcing or sinking
Type (Linear vs. PWM)	PWM
Operating modes	Programmable: closed loop current or open loop voltage (duty cycle)
Dual coil PCPs	Compensated for induced currents in a non-driven coil (closed loop mode)
Short circuit to ground	Output fully protected against damage and fault detected
Mode selection (current or voltage) and full scale current ranges	Programmable

Outputs (continued)

Proportional (PWMOUT/DOUT/PVGOUT) (continued)

Specifications

Description	Units	Minimum	Maximum	Comment
Full scale proportional current output	mA	10	3000	The current may accidentally be exceeded in open loop mode. If the current exceeds the trip point, the output will be latched off.
Output voltage, 100% duty cycle	Vdc	0	Vbatt-1	
Output resolution of 3 A	mA		0.25	
Repeatability of full range	% of full scale		0.5	
Absolute accuracy of full range	% of full scale		0.5	
Output settling time	ms		100	Depends on load characteristics
PWM frequency	Hz	33	4000	Some pins have a fixed frequency, consult module application program interface (API)
Dither frequency	Hz	33	250	Increased in steps, see module API
Dither amplitude	A	0	0.5	Increased in steps, see module API
Over-current trip point	A	5	5.25	There is over-current protection built into each output driver. If the instantaneous current exceeds the trip point, the driver is latched off. GUIDE application software can reset the latch and attempt to drive current again.

High Current Proportional (HPWM/DOUT)

High current proportional outputs are unique to the MCO38-010 controller. These outputs are PWM, with PWM frequency software adjustable using GUIDE.

All high current proportional outputs are operated as open loop. The controller kernel does, however, monitor current for circuit protection, but there is no current feedback to the application. The output is a constant voltage and not a constant current. PWM outputs are hardware protected from short or over current.

The MC038-010 has two types of PWM outputs: paired bi-directional PWMs (10 A) that can be configured as H bridges or independent outputs and sourcing only PWMs (6 A and 10 A). See the product data sheet and API documents for pair assignments.

Specifications

Description	Units	Minimum	Maximum	Comment
Over-current trip point, 6 A	A		12	Temperature dependent.
Over-current trip point, 10 A	A		18	Temperature dependent.
PWM frequency	Hz	33	4000	

CAN (Controller Area Networks) Ports

System Design

All PLUS+1 modules have CAN ports that conform to CAN 2.0B specifications, including CAN shield.

The second (CAN1) port on MC050-010 and MC050-020 controllers may not interface with the PLUS+1 Service Tool, depending on the version of .hwd file used to build the application. MC050-010 .hwd files version 190 and higher allow communication with the PLUS+1 Service Tool. MC050-020 .hwd files version 150 and higher allow communication with the PLUS+1 Service Tool. Regardless of .hwd version, CAN1 port and CAN2 port on MC050-055 controllers cannot be used to download GUIDE application programs.

⚠ Warning

Potential uncommanded machine movement. Machine performance may be impaired if CAN communications are disrupted by electrical fields in excess of 30 V/m between 20 and 30 MHz. To prevent potential uncommanded machine movement and to meet EMC requirements, a shielded CAN bus must be used to achieve 100 V/m immunity.

Terminating Resistor

Each end of the main backbone of the CAN bus must be terminated with an appropriate resistance to provide correct termination of the CAN_H and CAN_L conductors. This termination resistance should be connected between the CAN_H and CAN_L conductors.

Specifications

Description	Units	Minimum	Maximum	Nominal	Comment
Resistance	Ω	110	130	120	Minimum power dissipation 400 mW (assumes a short of 16 Vdc to CAN_H)
Inductance	μH		1		

**Expansion Module
 CAN bus Loading**

System designers incorporating PLUS+1 expansion modules in their applications should be aware of PLUS+1 CAN bus loading and controller memory usage during system design. Each expansion module is associated with a PLUS+1 controller and uses part of the controller’s memory resources for inter-module communications. The table below can be used to estimate system CAN bus loading and the memory impact of I/O modules on their associated controller.

Estimated Usage of Memory and Communication Resources

	IX012-010	IX024-010	OX012-010	OX024-010	IOX012-010	IOX024-20
Estimated module bus load (using default update and 250K bus speed)	4%	10%	11%	27%	11%	27%
Estimated module bus load (using 70 ms updates and 250K bus speed)	2%	5%	3%	8%	4%	8%
RAM usage on MC012-XXX	9%	12%	9%	14%	9%	17%
RAM usage on MC024-010	9%	12%	9%	14%	9%	17%
RAM usage on MC024-011	9%	12%	9%	14%	9%	17%
RAM usage on MC038-010	9%	12%	9%	18%	9%	26%
RAM usage on MC050-010, MC050-020	1%	1%	1%	2%	1%	2%
RAM usage on MC050-055	1%	1%	1%	2%	1%	0%
RAM usage on MC088-010	1%	1%	1%	2%	1%	2%
ROM usage on MC012-XXX	8%	11%	12%	18%	10%	19%
ROM usage on MC024-010	8%	11%	12%	18%	10%	20%
ROM usage on MC024-011	3%	4%	4%	6%	3%	7%
ROM usage on MC038-010	8%	11%	12%	18%	10%	21%
ROM usage on MC050-010, MC050-020	3%	4%	4%	6%	3%	8%
ROM usage on MC050-055	3%	4%	4%	6%	3%	8%
ROM usage on MC088-015	3%	4%	4%	6%	3%	7%

Power

Module Supply Voltage/Maximum Current Ratings

PLUS+1 modules are designed to operate with a nominal 9 to 32 Vdc power supply. The modules will survive with full functionality if the supply voltage remains below 36 Vdc.

Specifications

Description	Units	Minimum	Maximum	Comment
Allowed voltage at pin	Vdc	0	36	
Allowed module current	A	0		Consult module data sheets for maximum allowable current

⚠ Caution

PCB damage may occur. To prevent damage to the module all module power supply + pins must be connected to the vehicle power supply to support advertised module maximum output current capacity. DO NOT use module power supply + pins to supply power to other modules on a machine.

MC038-010 Power Supply

The MC038-010 controller's power supply design recommendations must be followed:

- Power supply to MC038-010 controller's output power planes (C1-p36 to C1-p38) must be wired directly to the vehicle battery and the wiring runs must be kept as short as possible.
- Power supply to the controller's DSP (C1-p2) must be wired separately from the power supply to the controller's output power planes.
- Do not connect any other PLUS+1 controllers to the power supply to MC038-010 controller's output power planes.

MC038-010 Sleep Mode

Sleep mode is unique to the MC038-010 controller. This feature gives OEM designers the ability to implement automotive-like features in their machine control system design. If the sleep mode feature is not implemented, this controller has the same operating characteristics as any other PLUS+1 controller.

When used as a sleep mode controller, supply power to the MC038-010 is connected directly to the battery. Sleep mode initiation is defined by the controller's application software: PLUS+1 GUIDE programmers define the conditions under which the controller is to put to sleep. When in sleep mode, controller outputs are set to zero, sensor power supply is off and the controller consumes a small amount of current.

Controller Sleep Mode Current Consumption

Supply voltage	Sleep mode current consumption
12 Vdc	0.14 mA
24 Vdc	0.28 mA

Power (continued)

Battery power must be supplied to designated wake-up digital inputs, since the controller's 5 Vdc regulated power supply is not available when the controller is in sleep mode.

MC038-010 Sleep Mode (continued)

Either of two conditions will wake up the controller:

- Switching of any of the designated (in the GUIDE application) wake-up digital inputs (DIN) to high.
- Cycling all input power to the controller.

The following input pins may be designated as wake-up digital inputs:

- DIN (C1p06, C1p07)
- DIN/AIN (C1p14, C1p17 to C1p20, C1p24 to C1p27)

Specifications

Description	Units	Minimum	Maximum	Comment
Wake-up pin threshold	Vdc	2	36	To wake up by cycling input power
Wake-up pin threshold	Vdc	4.5	36	To wake up by digital input
Wake-up time delay	mSec	250	500	

Sensor Power Supply Ratings

PLUS+1 modules that support sensor inputs are provided with dedicated regulated sensor power supply and ground pins. Refer to individual product data sheets for sensor power supply current ratings. The sensor power is nominally 5 Vdc, unless otherwise noted on the product data sheet.

General

Feature	Comment
Short circuit to ground	Output is not damaged and fault is detected
Short circuit to battery +	Will not energize an otherwise un-powered controller; output is not damaged and fault is detected

Specifications (all modules except MC050-055)

Description	Units	Minimum	Maximum	Comment
Output short circuit voltage	Vdc		36	
Output voltage	Vdc	4.88	5.12	
Output current	mA			Refer to individual data sheets for sensor power supply ratings
Output Load Capacitance	μF		10	
Hold up time after power loss	ms	5	15	

The MC050-055 controller features two additional levels of regulated power: 1.6 Vdc and 3.3 Vdc. The PLUS+1 GUIDE application developer can detect open and short digital inputs, when these power supplies are used in conjunction with DIN/AIN inputs.

Specifications (MC050-055)

Description	Units	Minimum	Maximum	Comment
Output short circuit voltage	Vdc		36	
Output voltage, sensors	Vdc	4.88	5.12	Sensor power supply drops below minimum if controller power supply is less than 9 Vdc
Output voltage, DIN diagnostics	Vdc	1.54	1.66	Nominal 1.6
Output voltage, DIN diagnostics	Vdc	3.00	3.60	Nominal 3.3

Power (continued)

PVG Valve Power Supply

DOUT/PVG Pwr pins can provide the battery supply voltage required by Sauer-Danfoss PVG valve electronics for those control strategies requiring application software control of the valve power source.

When enabled, the DOUT/PVG Pwr pin passes battery (reference) voltage to the PVG valve electronics. One DOUT/PVG Pwr pin can power up to 3 PVG valves. Refer to individual module API documents for PVG power pin characteristics.

EEPROM Write/Erase

Ratings

Specifications

Description	Minimum	Maximum	Comment
EEPROM write/erase cycles (all modules except IX012-010, IX024-010)	1,000,000		Minimum valid over entire operating temperature range
EEPROM write/erase cycles (IX012-010, IX024-010)	10,000		Minimum valid over entire operating temperature range

To prevent unexpected memory writes, care must be taken to ensure memory with a high number of read/write cycles is either U32 or S32 data types.

EEPROM used in PLUS+1 controllers is rated for 1,000,000 read/write cycles per sector. Sector size is 32 bits. When a value is written to EEPROM, all 32 bits in a particular sector are always written, regardless of the size of the saved value. If the value being saved in a sector is less than 32 bits (e. g. U8, S16, BOLL, etc) adjacent bits in the same EEPROM sector are rewritten with their previous value. The implication of this memory property is that if two values are being written to the same memory sector, the useful life of the sector is determined by the value being written most frequently. If that value exceeds 1 million read/write cycles, all values in the sector may be compromised if the useful life is exceeded.

Vault Memory

Some variants of PLUS+1 modules have 2 MByte of flash vault memory (also referred to as *application logging memory*).

Application developers can use this memory to log machine event data and use the PLUS+1 Service Tool to extract the logged data. As there is no real time clock on PLUS+1 modules, vault memory is not time stamped.

General, Maximum, and Environmental

General Ratings

Description	Comment
Reversed polarity protection	Modules will withstand reversed polarity at supply voltage
Short circuit protection	All inputs and outputs will withstand continuous short circuit to any other leads; when the short circuit is removed, the module will return to normal function
Automotive electrical transients	ISO 7637/2 electrical transient conduction along supply lines ISO 7637/3 electrical transient transmission by capacitive and inductive coupling via lines other than supply lines
EMC	Modules conform to 2004/108/EC directive ISO 14982 agricultural and forestry machinery ISO 13766 earth moving machinery
Electrostatic discharge	EN 61000-4-2 electromagnetic compatibility—electrostatic discharge immunity test: 15 kV air discharge, 8 kV contact SAE J1113-13 8 kV pin direct contact discharge

Absolute Minimum/ Maximum Ratings

Description	Units	Minimum	Maximum	Comment
Operating temperature	°C [°F]	-40 [-40]	70 [158]	
Storage temperature	°C [°F]	-40 [-40]	100 [212]	
Supply voltage	Vdc	9	36	
Sensor voltage	Vdc	4.8	5.2	Sensor voltage drops out if supply voltage < 9 Vdc. Exception for MC050-055, see <i>Sensor Power Supply Ratings</i> , page 22.
Analog input levels	Vdc		36	
Output load current (per pin)				See individual module data sheets.
Module total output current				See individual module data sheets.

All PLUS+1 modules are CE compliant

General Comments

The PLUS+1 module IP 67 rating is only valid when the module mating connector is in place.

Mating connectors must have proper sealing plugs on all unused connector pins.

PLUS+1 Modules Environmental Ratings

Environmental Ratings

Mechanical Environment	Climate Environment
IEC 60068-2-61, Test Fc (Random vibration, 10-250 Hz)	IEC 60068-2-38 (Temperature and humidity)
IEC 60068-2-27, Test Ea (Shock, 11 ms)	IEC 60529 (Degrees of protection)
IEC 60068-2-29B (Bump, 6 ms)	DIN 40050 (High pressure wash)
IEC 60068-2-32 (Free fall, 1000 mm)	IEC 60068-2-11 test Ka (Salt mist)
	IEC 60068-2-1 tests Ab, Ad (Cold test)
	IEC 600-2-2 tests Bb, Bd (Dry heat)
	IEC 60068-2-30 test Db (Cyclic damp heat)
	IEC 60068-2-14 test Nb (Temp change)
	ISO/DIS 16750-5 (Chemical resistance)

Housings

PLUS+1 module housings feature a snap together assembly that is tamper-proof. Once assembled at the factory, the housings cannot be opened for service. If opened the factory warranty will be voided.

**General Comments
 (continued)**

Mating Connectors

PLUS+1 modules use Deutsch® connectors. Sauer-Danfoss has assembled a mating connector kit, referred to as a bag assembly, for the 12, 24, 50, and 88 pin module housings. Mating connector bag assembly ordering information is found in the product data sheet for each module.

Deutsch Mating Connector Part Information

Description	12 pin module	24 pin module	38 pin module	50 pin module	88 pin module
Crimp tool	HDT48-00 (solid contacts) (20 to 24 AWG)	HDT48-00 (solid contacts) (20 to 24 AWG)		HDT48-00 (solid contacts) (20 to 24 AWG)	HDT48-00 (solid contacts) (20 to 24 AWG, 12 to 14 AWG)
	DTT20-00 (stamped contacts) (16 to 20 AWG)	DTT20-00 (stamped contacts) (16 to 20 AWG)	DTT20-00 (stamped contacts) (16 to 20 AWG)	DTT20-00 (stamped contacts) (16 to 20 AWG)	
Contacts	Solid: 0462-201-12031 (20 to 24 AWG)	Solid: 0462-201-12031 (20 to 24 AWG)	Stamped: 0462-203-12141 (10 to 14 AWG) 1062-20-0144 (16 to 20 AWG)	Solid: 0462-201-12031 (20 to 24 AWG)	Solid: 0462-201-12031 (20 to 24 AWG)
	Stamped: 1062-20-0144 (16 to 20 AWG)	Stamped: 1062-20-0144 (16 to 20 AWG)		Stamped: 1062-20-0144 (16 to 20 AWG)	Solid: 0462-201-12141 (12 to 14 AWG)
Connector plug	Gray A-Key DTM 06-12SA	Gray A-Key DTM 06-12SA Black B-Key DTM 06-12SB	DRC26-38S01-P017	DRC26-50S01	DRC26-50S01 DRC26-38S01-P017
Wedge	WM-12S	WM-12S	Not required	Not required	Not required
Strip length	3.96 to 5.54 mm [0.156 to 0.218 in]	3.96 to 5.54 mm [0.156 to 0.218 in]	6.43 to 0.79 mm [0.253 to 0.031 in]	3.96 to 5.54 mm [0.156 to 0.218 in]	20 to 24 AWG: 3.96 to 5.54 mm [0.156 to 0.218 in]
					12 to 14 AWG: 6.43 to 0.79 mm [0.253 to 0.031 in]
Rear seal maximum insulation OD	3.05 mm [0.120 in]	3.05 mm [0.120 in]	4.32 mm [0.17 in]	2.41 mm [0.095 in]	20 to 24 AWG: 2.41 mm [0.095 in]
					12 to 14 AWG: 4.32 mm [0.17 in]
Sealing plugs	0413-204-2005	0413-204-2005	114017	0413-204-2005	0413-204-2005, 114017

Sauer-Danfoss Mating Connector Part Information

Description	12 pin module	24 pin module	38 pin module	50 pin module	88 pin module
Mating connector bag assembly (20 to 24 AWG)	10100944	10100945		10100946	10105649
Mating connector bag assembly (16 to 20 AWG)	10102025	10102023	11027919	10102024	

Sauer-Danfoss Crimp Tool Part Information

Description	Part number
Crimp tool for 20 to 24 AWG	10100745
Crimp tool for 16 to 20 AWG	10102028

PLUS+1 module mating connectors may be mated 10 times.

Recommended torque for the Deutsch® mating connector retaining fastener on 38 and 50 pin connectors is 20 lb•in (2.26 N•m).

Product Installation

Mounting

PLUS+1 12, 24, 38, and 50 pin modules can be mounted in one of three ways:

- End (bulkhead) installation
- Up to 3 units stacked on one another
- Individually side mounted

MC088-XXX modules are designed for bulkhead mounting only.

In each case, care must be taken to insure that the module connector is positioned so that moisture drains away from the module. If the module is side or stack mounted, provide a drip loop in the harness. If the module is mounted vertically, the connector should be on the bottom of the module. Provide strain relief for mating connector wires.

⚠ Caution

Module damage may occur. Use caution when installing MC050-XXX modules. Due to the size of the mating connector wire bundle, it is possible to twist off the end cap of the module if excessive pressure is applied during the installation of harness strain relief.

Suggested Fasteners and Recommended Installation Torque

Mounting method	Recommended OD	Recommended torque
Bulkhead mount; multiple units stacked; single	6.0 mm (.25 in)	9.49 N•m (7 ft•lb)

Machine Diagnostic Connector

It is recommended that a diagnostic connector be installed on machines that are controlled by PLUS+1 modules. The connector should be located in the operator’s cabin or in the area where machine operations are controlled and should be easily accessible.

Communication (software uploads and downloads and service and diagnostic tool interaction) between PLUS+1 modules and personal computers is accomplished over the vehicle CAN network. The diagnostic connector should tee into the vehicle CAN bus and have the following elements:

- CAN +
- CAN -
- CAN shield

Grounding

Proper operation of any electronic control system requires that all control modules including displays, microcontrollers and expansion modules be connected to a common ground. A dedicated ground wire of appropriate size connected to the machine battery is recommended.

Hot Plugging

Machine power should be off when connecting PLUS+1 modules to mating connectors.

**Product Installation
(continued)****Recommended Machine Wiring Guidelines**

1. All wires must be protected from mechanical abuse. Wires should be run in flexible metal or plastic conduits.
2. Use 85° C [185° F] wire with abrasion resistant insulation. 105° C [221° F] wire should be considered near hot surfaces.
3. Use a wire size that is appropriate for the module connector.
4. Separate high current wires such as solenoids, lights, alternators or fuel pumps from sensor and other noise-sensitive input wires.
5. Run wires along the inside of, or close to, metal machine surfaces where possible. This simulates a shield which will minimize the effects of EMI/RFI radiation.
6. Do not run wires near sharp metal corners. Consider running wires through a grommet when rounding a corner.
7. Do not run wires near hot machine members.
8. Provide strain relief for all wires.
9. Avoid running wires near moving or vibrating components.
10. Avoid long, unsupported wire spans.
11. All analog sensors should be powered by the sensor power source from the PLUS+1 controller and ground returned to the sensor ground pin on the PLUS+1 controller.
12. Sensor lines should be twisted about one turn every 10 cm (4 in).
13. It is better to use wire harness anchors that will allow wires to float with respect to the machine rather than rigid anchors.

Recommended Machine Equipped with PLUS+1 Module Welding Procedures

The following procedures are recommended when welding on a machine equipped with PLUS+1 modules:

- The engine should be *off*.
- Disconnect the negative battery cable from the battery.
- Do not use electrical components to ground the welder. Clamp the ground cable for the welder to the component that will be welded as close as possible to the weld.

PLUS+1 USB/CAN Gateway

Communication (software uploads and downloads and service and diagnostic tool interaction) between PLUS+1 modules and a personal computer (PC) is accomplished using the vehicle's PLUS+1 CAN network.

The PLUS+1 CG150 USB/CAN gateway provides the communication interface between a PC USB port and the vehicle CAN bus. When connected to a PC, the gateway acts as a USB slave. In this configuration, all required electrical power is supplied by the upstream PC host. No other power source is required.

Refer to the *PLUS+1 GUIDE Software User Manual 10100824* for gateway set-up information. Refer to the *CG150 USB/CAN Gateway Data Sheet 520L0945* for electrical specifications and connector pin details.



PLUS+1 Controller Family
Technical Information
Notes



PLUS+1 Controller Family
Technical Information
Notes



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