SWITCHERGEAR
GEAR TO CONTROL YOUR POWER SWITCHES

Base B12CC1

12 module slot base
DIMM 100-pin host MCU connector

REFERENCE MANUAL

Features

Standard base for SwitcherGear controllers

12 module slots

- *front and rear facing slots*
- *mixture of digital and analogue signals*

Range of modules that provide interfaces for

- *gate drivers*
- *current and voltage measurement*
- *industrial I/O*
- *fieldbus communications*

Direct support for Texas Instruments controlCARD

- *DIMM 100-pin connector with universal pin-out*
- *isolated 14-pin debug probe interface*

On-board temperature sensor

On-board 64 kB non-volatile memory (FRAM)

User LED indicators on front panel

Industrial 24 VDC supply input

- *protected against reverse polarity voltage, over current, under voltage and over current*

Software development using standard C2000 tools

- *TI Code Composer Studio™*
- *TI C2000Ware™ libraries and examples*
- *Denkinetic SwitcherWare Library*
- *graphical coding with Simulink™, etc.*
- *third party code generation tools and libraries*

Can stand alone or be incorporated into user equipment

Applications

Rapid prototyping of power converters

- *AC motor drives*
- *grid converters*
- *DC/DC converters*
- *multi-level converters*
- *novel converter topologies*

Experimental apparatus for power electronics research

Teaching platform for power electronics

- *converter topologies*
- *hardware implementation of power converter systems*
- *control algorithms*
- *source code development tools*

General Description

The SwitcherGear B12CC1 base is a flexible platform for the rapid development of customised controllers for power converter systems. The base accepts a range of host microcontrollers (MCU) and modules that interface to the power stage, sensors and other systems.

SwitcherGear is designed to accept host MCUs in the format of DIMM 100-pin controlCARDs from Texas Instruments (TI). A standard, isolated 14-pin debug probe interface allows the use of all standard development tools and libraries for C2000.

The connections of the module signals to the host MCU can be configured according to each application's requirements. The SwitcherGear hardware is transparent and behaves as a custom PCB design with direct connections would. The possible controllers are limited only by the resources and capabilities of the chosen host MCU.

SwitcherGear operates from a single 24 VDC power supply input. Secondary supplies for external devices such as gate drivers, current and voltage sensors, encoders, etc. are generated on-board by the installed modules.

SwitcherGear is supplied in a sturdy enclosure with cover, rear panel and rubber mounting feet.

Ordering Information

Order Code	***Description***
`B12CC1`	*SwitcherGear Base, 12 module slots and DIMM 100-pin host MCU connector*
`MC28377D1`	*SwitcherGear Micro, dual 200 MHz 32-bit floating-point CPU and CLA, 16-channel high-speed ADC, 16 MB SDRAM*
`CC28335`	*Texas Instruments F28335 controlCARD, 150 MHz 32-bit floating-point CPU, 256k x 16 flash, 16-channel 12-bit ADC*
`PSU001`	*SwitcherGear accessory, power supply 24 VDC at 2.1 A.*
`XDS100v2`	*Texas Instruments XDS100v2 14-pin debug probe.*

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Quick Start

1. **Review the allocation of the module signals.**

   For each module, confirm that the signals of the MCU interface connect to appropriate pins on the host MCU. Refer to the SwitcherGear Configuration Document for your controller.

2. **Set the configurable features of modules.**

   For each module, determine the feature settings that are required for the system under control. If necessary, change the default solder jumper settings. Refer to the Configuration section of each module's reference manual and the Module Configuration section in this manual.

3. **Install the modules.**

   Install each module into the correct module slot of the SwitcherGear Base. Refer to the SwitcherGear Configuration Document for your controller and the Module Configuration section in this manual.

4. **Install the host MCU.**

5. **Connect external wiring to the module system connectors.**

   Refer to the system connector tables of each module's reference manual.

6. **Connect 24 VDC control supply.**

Functional Description

Control Supply

The SwitcherGear base is powered from standard industrial 24 VDC power. Connection of the power is made using a 3-way pluggable terminal strip connector. The pin-out of this connector is shown in Table 1.

Table 1: Pin-out of the power supply connector

Pin	Signal	Description
1 (Left)	GND	Control supply 0 VDC input.
2	VDC	Control supply +24 VDC input.
3 (Right)	CHASSIS	

The SwitcherGear can operate over a wide range of voltage.

Operation from supply voltages outside the normal range is prevented to avoid damage to SwitcherGear by excessive currents or voltages. The power supply will be disconnected if the input voltage crosses the turn-off threshold voltage for under voltage or over voltage lock out. The supply will be reconnected when the input voltage crosses the corresponding turn-on threshold voltage. For stable operation of SwitcherGear, ensure that the control supply remains within operating limits at all times.

The SwitcherGear base is protected against reverse polarity connection of the control supply.

The SwitcherGear base is protected against excessive input currents, such as in-rush currents that charge capacitors in external loads. Initially, the protection circuitry actively limits the input cur-

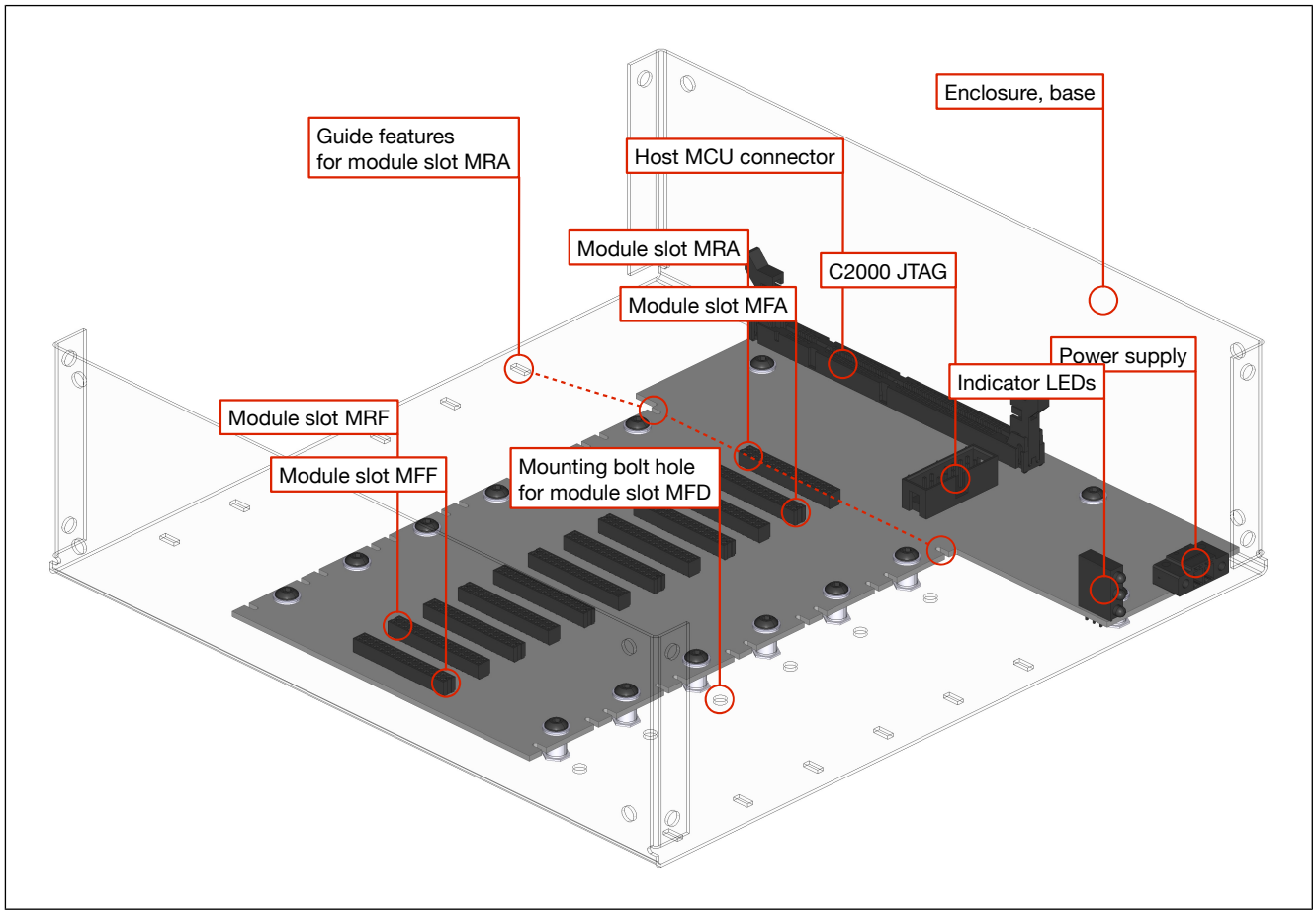

Figure 1: Identification of parts in the SwitcherGear Base. Module slots alternate between front and rear facing. The enclosure is shown in wire-frame for clarity. For clarity, the upper module mounting plate, cover and front and rear panels are not shown.

rent that can be drawn from the control supply. The control supply will be disconnected if the current limit is active for the fault timeout duration. The control supply will be reconnected after the restart duration. If the fault is still present, the fault and restart sequence repeats.

The control supply is used as a supply output on some modules. In this case, the output voltage is not regulated and will not be 24 V unless the control supply input voltage is also 24 V.

Front Panel Indicator LEDs

The SwitcherGear base has three indicator LEDs on the front panel. The top two LEDs are available to the user and can be controlled by the host microcontroller.

The bottom LED indicates the control supply status. The LED is on when the control supply conditions are normal. The LED turns off when any fault condition is present, including reverse polarity input, current limit timeout, under voltage and over voltage.

Table 2: Front panel indicator LEDs

Appearance	Colour	Description
● (Top)	Red	User indicator LED
●	Green	User indicator LED
● (Bottom)	Green	Control supply status LED

Module Slots

The module slots on the SwitcherGear base accept SwitcherGear hardware interface modules. The B12CC1 base has 6 front facing module slots and 6 rear facing module slots. Each electrical connector provides power to the installed module and connects the digital and analogue signals of the module's MCU interface to the host MCU. The mounting brackets and guide features provide mechanical alignment and support for the inserted modules. The module slot connector also provides power to the module and connects digital and analogue signals to the module.

The MCU interface defines the electrical signals between the module and the host MCU – 12 digital signals and 4 analogue signals. It also defines the power provided to the modules from the base. The digital pins can route signals in either direction as required by the installed modules, i.e. from an output on the module to an input on the host MCU, or from an output on the host MCU to an input on the module. Analogue signals in the SwitcherGear system have a pre-defined direction from outputs on the module to the ADC inputs on the host MCU.

Module slots are identified by a three letter code. The signals in the MCU interface are identified by a two part code. Individual signals are identified by the code for the module slot followed by the code for the MCU interface signal, as shown in Table 3.

Table 3: Naming convention for module MCU interface

Module Slot			MCU Interface Signal	
M	**F**	**A**	**D**	**n**
				0 … 11 ID number for digital signals
				0 … 3 ID number for analogue signals
			D	digital signal
			A	analogue signal
		A … F	ID letter for front and rear slots	
	F	front facing slot		
	R	rear facing slot		
M	SwitcherGear Hardware Interface Module Slot			

Not all digital or analogue signals are implemented by every module slot – see Table 4. Also, some analogue signals are shared by two module slots – see section Analogue Signal Connections for more information.

Table 4: Signals implemented in the MCU interfaces of each module slot.

Module Slot	Digital I/O	Analogue Input
MFA	D5 … D0	-
MFB	D5 … D0	-
MFC	D5 … D0	A3 … A0
MFD	D5 … D0	A3 … A0
MFE	D11 … D0	-
MFF	D11 … D0	-
MRA	D11 … D0	A3 … A0
MRB	D11 … D0	A3 … A0
MRC	D5 … D0	A3 … A0
MRD	D5 … D0	A3 … A0
MRE	D11 … D0	-
MRF	D11 … D0	-

According to their functionality, different modules implement different numbers of digital and analogue signals in their MCU interfaces. Some of these signals are optional and may not be used in certain applications. Details of the digital and analogue signals of each module are given in the reference manual for each SwitcherGear module. When designing a SwitcherGear controller, modules should be allocated to module slots based on the compatibility of the signal requirements of the module and the signals implemented by the target module slot.

For example, the AIN004 module (4-channel sensor input module) has 0 digital signals and 4 analogue outputs. It can be allocated to any of the module slots in Table 4 that implement the A3 to A0 signals.

For example, the CON002 module (triple half-bridge interface module) has 10 digital signals for PWM and faults and 0 analogue signals. For a half-bridge application, only D0/1 (top and bottom PWM) and D2 (fault) might be used and the module can be installed in any module slot. A 3-phase converter application might use D0/1/3/4/6/7 (PWM) and D9 (combined fault) and can be installed only in module slots MFE/F or MRA/B/E/F.

The SwitcherGear base is designed so that it can be mounted behind the panel of user equipment. In this case, the front and rear facing slots can be used to segregate I/O interfaces. Front facing slots (MFx) can be populated with modules that require user access, e.g. external process signals, fieldbus, etc. Rear facing slots (MRx), which face to the inside of the user equipment, can be populated with modules that should not be accessible to the user, e.g. converter signals, internal process signals, etc.

Host MCU Connector

The B12CC1 base has one DIMM 100-pin connector into which can be plugged a host MCU. Table 5 shows the signal types allocated to each pin of the host microcontroller slot. The pin-out of the connector is designed to be compatible with Texas Instruments' range of 100-pin controlCARDs.

Table 5: Signal type allocation for DIMM 100-pin host MCU connector

Signal Type	Pin		Signal Type
+3.3V	1	51	+3.3V
RS-232 RX	2	52	RS-232 TX
GPIO	3	53	GPIO
GPIO	4	54	GPIO
GPIO	5	55	GPIO
GND	6	56	GND
ADCIN	7	57	ADCIN
GND	8	58	GND
ADCIN	9	59	ADCIN
GND	10	60	GND
ADCIN	11	61	ADCIN
GND	12	62	GND
ADCIN	13	63	ADCIN
GND	14	64	GND
ADCIN	15	65	ADCIN
GND	16	66	VREFHI
ADCIN	17	67	ADCIN
GPIO	18	68	GPIO
ADCIN	19	69	ADCIN
GPIO	20	70	GPIO
ADCIN	21	71	ADCIN
GPIO	22	72	GPIO
GPIO	23	73	GPIO
GPIO	24	74	GPIO
GPIO	25	75	GPIO
GPIO	26	76	GPIO
GND	27	77	+5V
GPIO	28	78	GPIO
GPIO	29	79	GPIO
GPIO	30	80	GPIO
GPIO	31	81	GPIO
GPIO	32	82	+5V
GPIO	33	83	GPIO
GPIO	34	84	GPIO
GPIO	35	85	GPIO
GPIO	36	86	GPIO
GND	37	87	+5V
GPIO	38	88	GPIO
GPIO	39	89	GPIO
GPIO	40	90	GPIO
GPIO	41	91	GPIO
GPIO	42	92	+5V
GPIO	43	93	GPIO
GPIO	44	94	GPIO
GPIO	45	95	GPIO
GPIO	46	96	+5V
GND	47	97	JTAG
JTAG	48	98	JTAG
JTAG	49	99	JTAG
-	50	100	-

Pins 16 and 66 of the host microcontroller slot are used by some controlCARDs as inputs for the VREFLO and VREFHI reference voltages of the MCU's ADC. On other controlCARDs these pins are not connected. The B12CC1 base connects the pin 16 VREFLO to 0 V and the pin 66 VREFHI to an accurate, stable 3 V reference.

Host MCU modules

Texas Instruments offers a range of controlCARDs featuring MCUs from their C2000 Piccolo and Delfino range. The MCUs are well suited to power converter applications, featuring PWM, ADC, capture counters, SPI, CAN, asynchronous serial, general purpose digital I/O, etc. controlCARDs have different pin-outs depending on the featured microcontroller, but adhere to a scheme that matches the pin-out of the host MCU connector. Consult Texas Instruments documentation for details about controlCARDs.

Denkinetic also offers MCU cards that are compatible with the 100-pin controlCARD format.

Debug Probe Interface

The front panel has a shrouded pin header for the connection of a standard 14-pin Texas Instruments debug probe ("JTAG emulator") to the host MCU. The debug probe interface is galvanically isolated from the internal circuitry.

Any standard 14-pin debug probe can be used, including

- Texas Instruments XDS100
- Texas Instruments XDS510
- Spectrum Digital 14-pin JTAG emulators
- Blackhawk 14-pin JTAG emulators

The standard debug probe interface allows SwitcherGear software to be developed using the standard C2000 tools from Texas Instruments, including Code Composer Studio, libraries and many example projects. Third-party tools offer more libraries and graphical code development that can be targeted to C2000.

Temperature Sensor

The B12CC1 base features a digital temperature sensor. The sensor has a SPI bus interface that is accessible to the host microcontroller.

Consult manufacturer documentation for SPI operation and full specification.

The SwitcherWare library includes an easy-to-use class that enables access to the device.

Non-Volatile Memory

The B12CC1 base features a non-volatile memory for user applications. The memory is a ferroelectric random access memory (FRAM) type that allows latency free writes. The memory has a SPI bus interface that is accessible to the host microcontroller.

Consult manufacturer documentation for SPI operation and full specification.

The SwitcherWare library includes an easy-to-use class that enables access to the device.

Digital Signal Connections

All digital resources of the B12CC1 base are connected to a digital crosspoint switch, including:

- all GPIO signals in the host MCU connector (Table 5)
- all digital I/O signals of the module slots (Table 4)
- SPI bus signals of the temperature sensor
- SPI bus signals of the non-volatile memory
- user indicator LEDs

In this way, the host MCU can be connected in any appropriate way to the other resources. The crosspoint switch is configured at the time of manufacture according to a routing map agreed with the user.

Each SwitcherGear unit is supplied with a SwitcherGear Configuration Document that provides details of the routing map connections. To aid identification, the SwitcherGear Configuration Document contains a three letter configuration code to identify unique routing maps. Every SwitcherGear base is labelled with the code of its routing map configuration.

Analogue Signal Connections

The connection of analogue signals from module slots to the host MCU connector is fixed and shown in Table 6.

Some module slots may share analogue signal connections to the host MCU connector. In this case, modules with analogue outputs can be inserted into either module slot, but not both. For example, an analogue sensor module can be inserted into slot MRC and a digital module can be inserted into slot MFC if the digital module has no analogue outputs. However, analogue sensor modules cannot be inserted into both MRC and MFC. To do so would connect together the respective analogue outputs of both modules, which will corrupt the signal at the host ADC input.

Table 6: Connection of the analogue input signals from the module slots to the host MCU slot.

Host MCU Connector	Front Module Slot	Rear Module Slot
Input Pin	Output Signal	Output Signal
57	MFDA0	MRDA2
7	MFDA1	MRDA3
59	MFDA2	MRDA0
9	MFDA3	MRDA1
61	MFCA0	MRCA2
11	MFCA1	MRCA3
63	MFCA2	MRCA0
13	MFCA3	MRCA1
65	-	MRBA2
15	-	MRBA3
67	-	MRBA0
17	-	MRBA1
69	-	MRAA1
19	-	MRAA0
71	-	MRAA3
21	-	MRAA2

Applications Information

Module Configuration

Many SwitcherGear modules have configurable features that are set using solder jumpers, e.g. analogue signal ranges, etc. The modules may be pre-configured according to your requirements. In other cases, modules may not be pre-configured and are supplied with the solder jumpers in the default, open state.

It is your responsibility to ensure that the module features are configured according to your application. Consult the reference manual of each SwitcherGear module for details.

It is your responsibility to ensure that the modules are installed into the correct module slots, according to the configuration of the SwitcherGear base unit. Refer to your SwitcherGear Configuration Document for details.

If it is necessary to access modules for configuration or to otherwise install or remove modules, the following steps should be followed:

1. Follow standard procedures for the handling of electronic devices that are sensitive to electro-static discharge (ESD).

   If in doubt, seek advice before proceeding.
2. Turn OFF all power to the SwitcherGear controller and the controlled system.
3. Disconnect all cables from the SwitcherGear controller.

To open the SwitcherGear controller

4. Remove the rear panel – remove four countersink screws.
5. Remove the cover of the SwitcherGear base – remove four dome screws on under-side of unit and slide cover to rear.
6. Remove the front panel – four countersink screws and disconnect the debug probe ribbon cable from the Base board.
7. Remove the upper module mounting plate – remove four side dome screws and the upper mounting dome screw of all installed modules.

To remove a module

8. Remove the lower dome mounting screw of the module – accessible from the under-side of the chassis.
9. Remove the module – grip the module above the MCU interface connector, then gently lift module upwards.

To install a module

10. Identify the correct module slot for installation of each module.
11. Install the module – hold the module above the MCU interface connector, ensure correct alignment of the MCU interface connector and lower guides (see Figure 2), then gently press module down.
12. Replace the lower mounting dome screw of the module – fit from the under-side of the chassis, but do not tighten yet.

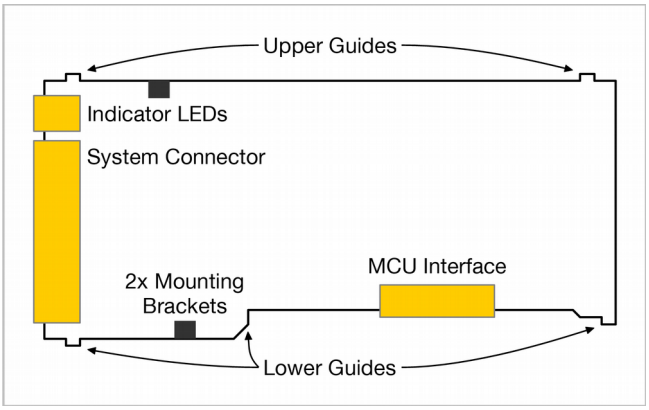

Figure 2: Parts of a SwitcherGear module.

To close the SwitcherGear controller

13. Replace the upper module mounting plate – insert the module upper guides into the mounting plate alignment slots, replace and tighten four side dome screws and the upper mounting dome screw of all installed modules.
14. Tighten the lower mounting dome screws of the installed modules.
15. Replace the front panel – connect the debug probe ribbon cable to the “C2000 JTAG” connector on the Base PCB and replace four countersink screws.
16. Replace the cover of the SwitcherGear base – slide the cover on from the rear and replace four dome screws on under-side of unit.
17. Replace the rear panel – replace four countersink screws.

All dome screws must be fitted with a shake-proof washer and flat washer. The shake-proof washer should be fitted against the head of the screw.

Solder Jumpers

Solder jumpers allow configuration of the SwitcherGear modules. They function like a switch to control the features of the module. Jumpers consist of two adjacent pads on the rear side of the module circuit board. The jumper can be shorted (switch closed) by making a solder bridge across the pads. The jumper can be opened (switch open) by removing the solder bridge.

Modules are supplied with all solder jumpers in the default open state.

The solder jumpers are intended for one-time-only configuration. No warranty is provided for damage to solder jumpers. Only skilled personnel who are trained in correct soldering technique should undertake the configuration of the solder jumpers. Incorrect technique or excessive temperature can result in the pads of the solder jumper detaching from the circuit board, rendering the jumper permanently open-circuit.

Observe the following precautions when configuring solder jumpers:

- Use a fine-tip soldering iron with adjustable temperature.
- Use only lead free solder and compatible tools.
- Use the minimum temperature required to perform the task.
- Do not heat the jumper for more than 5 seconds. Allow to cool before re-applying heat.
- To remove solder from a jumper, use a narrow (e.g. 1.5 mm) fluxed solder wicking braid.

Host MCU Module

To install the host MCU module

1. Ensure the locking arms at both ends of the MCU slot connector are open.
2. Determine correct orientation of host MCU module by matching the feature keys on the MCU slot connector to the notches in the edge connector of the module.
3. Hold the module at both top corners using thumbs and index fingers.
4. Align the module to the connector and press firmly straight down.
5. The locking arms will clasp onto the side edges of the module when it is fully engaged into the connector.

To remove the host MCU module

1. Grip the tops of the locking arms at both ends of the MCU slot connector.
2. Firmly pull the locking arms away from each other until the host MCU module is ejected from the connector.

Non-Volatile Memory

The non-volatile memory has a range of user applications:

- Storage of software configuration parameters, allowing self-configuration after power up.
- Product information, such as part number, serial number, etc.
- Fault logging that persists over power failure.

External Wiring

The pluggable terminal strip of the power supply connector can accept bare conductors with cross sectional area (CSA) in the range 0.2 mm^2 to 2.5 mm^2. The acceptable CSA range for conductors terminated with bootlace ferrules is 0.25 mm^2 to 2.5 mm^2.

Mounting

If you wish to mount the SwitcherGear unit to a custom panel, CAD drawings of the front panel cut-outs are available.

Warnings

The user is responsible to ensure that the cables and connectors used for external wiring have insulation and/or separation distances that provide isolation from live parts and from earth.

The user is responsible to ensure that cables and connectors used for external wiring that carry live voltages have insulation and/or separation distances that provide protection against indirect contact.

The user is responsible to ensure that the installation provides protection against direct contact.

SwitcherGear does not provide galvanic isolation between itself and the power devices in the power system. An appropriate isolated gate driver must be used to drive the power devices.

Do not insert modules with analogue outputs into module slots that share analogue connections to the host processor.

Absolute Maximum Ratings

Stresses above these ratings may cause permanent damage. These are stress ratings only – functional operation is not implied. Exposure to absolute maximum conditions for extended periods may affect reliability.

The following specifications apply for V_{DC} = 24 V, T_A = 25 °C.

Parameter	Conditions	Min	Typ	Max	Unit
POWER INPUT					
Voltage Input Range, V_{DC}		–45		45	V

Electrical Characteristics

The following specifications apply for V_{DC} = 24 V, T_A = 25 °C, unless otherwise noted.

Parameter	Conditions	Min	Typ	Max	Unit
POWER INPUT					
Voltage Input Range, V_{DC}		20	24	28	V
Under Voltage Lock Out					
Turn-off threshold			16.2		V
Turn-on threshold			18.3		V
Over Voltage Lock Out					
Turn-off threshold			29.6		V
Turn-on threshold			27.3		V
Over Current Protection					
Current Limit			4.6		A
Fault timeout duration			22		ms
Restart duration			4.5		s
ANALOGUE					
Reference Voltage, VREFHI		2.997	3.000	3.003	V

SPI Devices

See manufacturer's datasheet for complete specification and applications information.

Parameter	Conditions	Min	Typ	Max	Unit
TEMPERATURE SENSOR – LM71					
Measurement Range		-40		150	°C
Temperature Error	T_A = –40 to 85 °C		±2.0		°C
FRAM – FM25V05					
Memory Size			65536 x 8		bit
SPI Clock Frequency		0		20	MHz

Mechanical

Parameter	Conditions	Min	Typ	Max	Unit
DIMENSIONS					
Width			232		mm
Depth			225		mm
Height			92		mm

Revision History

Revision	Date	Changes From Previous Release
1	16 Apr 2014	▪ Original release.
2	17 Oct 2014	▪ Updated naming and format.
3	20 Sep 2017	▪ Update for new hardware.