DESIGNERS MANUAL

EXCELSYS COOLX®3000 Series

High Efficiency, Intelligent and Reliable 3000W Modular Power Supply

Advanced Energy's Excelsys CoolX3000 Power Supply Designers Manual has been prepared by Advanced Energy experts to assist qualified engineers and technicians in understanding the correct system design practices necessary to achieve maximum versatility and performance from any of the CoolX3000 range of Intelligent Modular Configurable power supplies.

AT A GLANCE

	C3S	C3M
Total Power	3000 W	3000 W
Slots	12	12

Cooling

Variable fan speed control

Dimensions

325 x 131 x 120 mm
12.8 x 5.2 x 4.7 inch

Certifications

Medical (C3M)

- IEC60601-1 3rd edition
- IEC60601-1-2 4th edition (EMC)
- 2 MOPP
- Dual fused

Industrial (C3S)

- IEC62368-1

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SECTION 1 PRODUCT DESCRIPTIONS

1.1 Overview of CoolX3000

The CoolX3000 Series is the latest modular power supply from Advanced Energy. It provides an incredible 3000W in a compact 4.70" x 12.8" x 3U package. Delivering best in class performance in efficiency and unrivalled reliability, the CoolX3000 offers system designers the most comprehensive feature set and specifications.

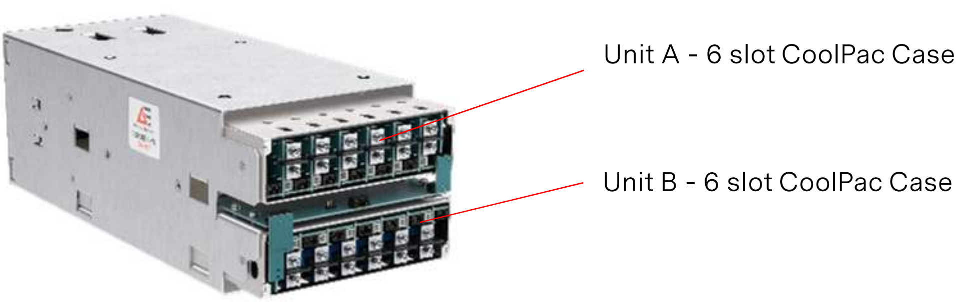
The series comprises two base models. The C3S is certified to IEC63268-1 for ITE and audio-visual applications. The C3M carries IEC60601-1 3rd edition & IEC60601-1-2 4th edition (EMC) for medical applications. The CoolX3000 can be populated with up to 12 CoolMods output modules, providing up to 25 isolated DC outputs ranging from 1.0V to 200.0V. Continuing the Advanced Energy tradition of flexibility, the CoolX3000 is completely user and field configurable. Outputs can be adjusted to the required set point voltages and can be configured in parallel or series for higher current and/or higher voltages.

Stand-out features for medical applications include dual input fusing, 2 x MOPP isolation and <300uA leakage current. Other features include 4KV input surge immunity, SEMI F47 compliance, and the ability to withstand input voltages of up to 300Vac making it ideal for use in remote locations and those subject to input voltage disturbances. With analog and digital communications (PMBus™), the CoolX3000 provides the most flexible, highest specification modular power supply in the market, all backed up by the Advanced Energy 5 Years Warranty ensuring quality and the lowest total cost of ownership.

A complete power supply is configured by selecting and inserting up to 12 DC output modules called CoolMods into two 6-slots CoolPac cases (Unit A and Unit B) to build a user defined power supply. This offers the advantages of a custom supply but is assembled from standard and modular building blocks. If output requirements change, i.e., more power or a different output voltage is needed, upgrading is easy, by replacing the CoolMod with the preferred alternative. Allowing additional flexibility, CoolMods can be connected in parallel to increase output power, or in series for higher voltages (subject to staying within isolation ratings and giving due consideration to any SELV requirements).

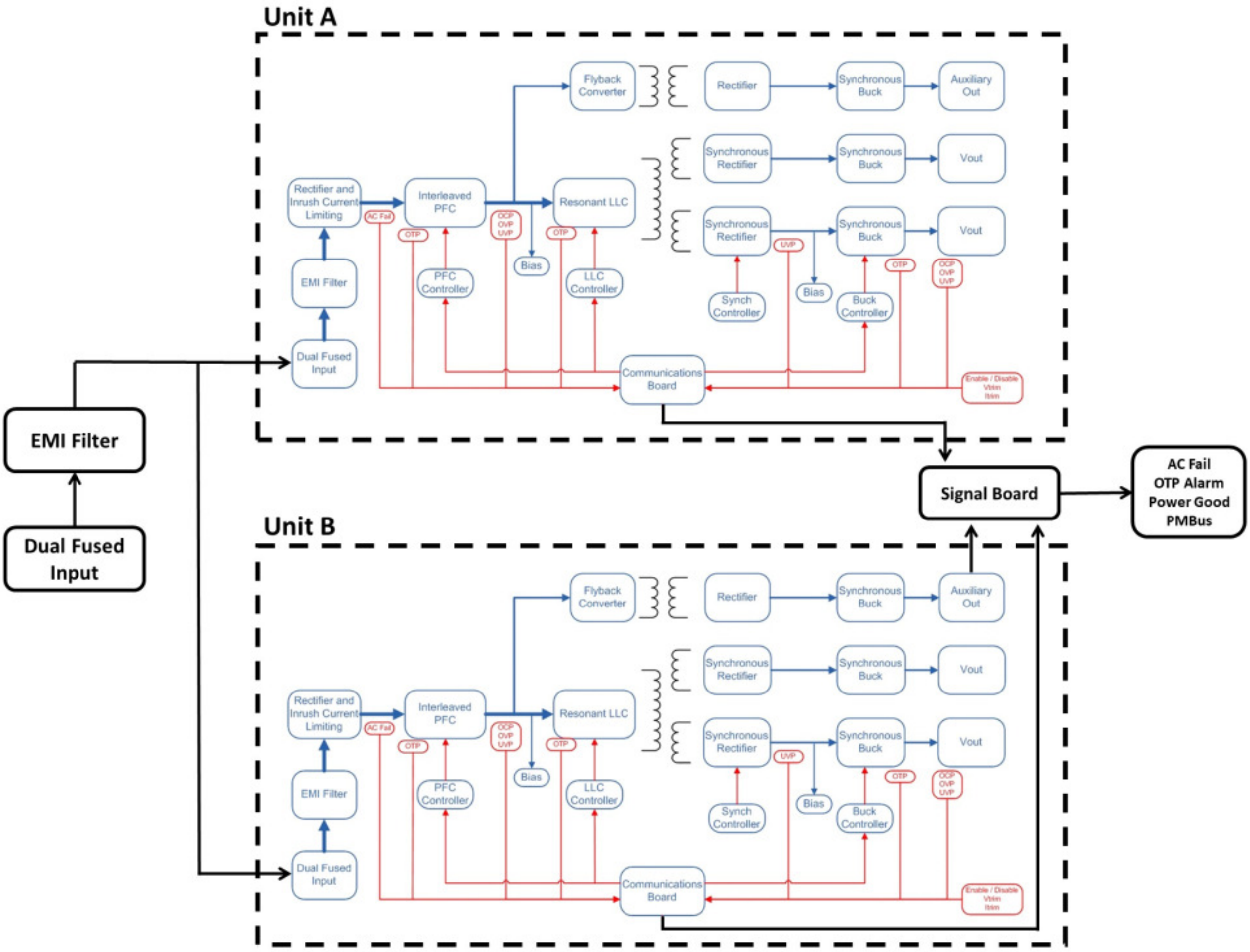
A user-friendly interface on each CoolMod provides control and output sequencing capability, in addition to useful status indicators. Alternatively, digital control and monitoring is accessible through the PMBus™ interface.

CoolX3000 Power Supply



SECTION 1 PRODUCT DESCRIPTIONS CON'T

1.2 Theory of Operation



The CoolX3000 unit is comprised of an outer mechanical chassis, a power-entry unit, two units power supplies and a C3S/M System Signal Board. An operational block diagram is shown above.

The unit power supplies are comprised of a CoolPac case and a selection of CoolMod DC output modules selected to deliver the exact volts and amps requirements of the system designer. The CoolPac is made up of an off-line single-phase AC front end, EMI filter, and customer interface and associated housekeeping circuits.

The CoolX3000 can not be used to deliver continuous output power greater than 3000 W. Maximum output power from any row of outputs (6 slots on top row or 6 slots on bottom row) must not exceed 1500 W. For example, if bottom row of outputs are configured to deliver 1200 W, the top row is still limited to a max of 1500 W output power.

The power-entry module provides the dual fused input and EMI filtering external to each units. Input AC mains voltage (L, N and GND) is applied to a screw terminal input block and then through an EMI filter designed to meet EN55022 Class B. Some applications may require an external ferrite on cabling to meet Class B Radiated EMI. Please contact Technical Support for recommendations.

SECTION 1 PRODUCT DESCRIPTIONS CON'T

For medical applications, the EMI filter also ensures the power supply meets the low earth leakage current requirements of EN60601-1 3rd Edition. All output modules provide medical isolation of 4000Vac (2 x MOPP) from input to output and extended isolation of 1850Vac from output to earth (Note: 1 x MOPP requirement is 1500Vac). A 24W auxiliary "always-on" isolated bias supply of 12Vdc or 5Vdc (optional) is provided from the unit A CoolPac case only, for peripheral use. This bias supply also has medical isolation of 4000Vac (2 MOPP).

The CX30 System Signal Board communicates with the communication board of each unit power supply, to provide a single customer accessible system signal connector. A full suite of monitor and controls including AC Fail, Global Inhibit/Enable, Over-Temperature Alarm and a PMBus™ interface are provided.

CoolMods DC output modules provide isolated DC outputs. These can be set to the required voltage setpoints by the user or factory set as required. Each CoolMod has its own discrete Enable/Inhibit control, Voltage Adjust (Vtrim), Current limit adjust (ITRIM), and Remote Sense.

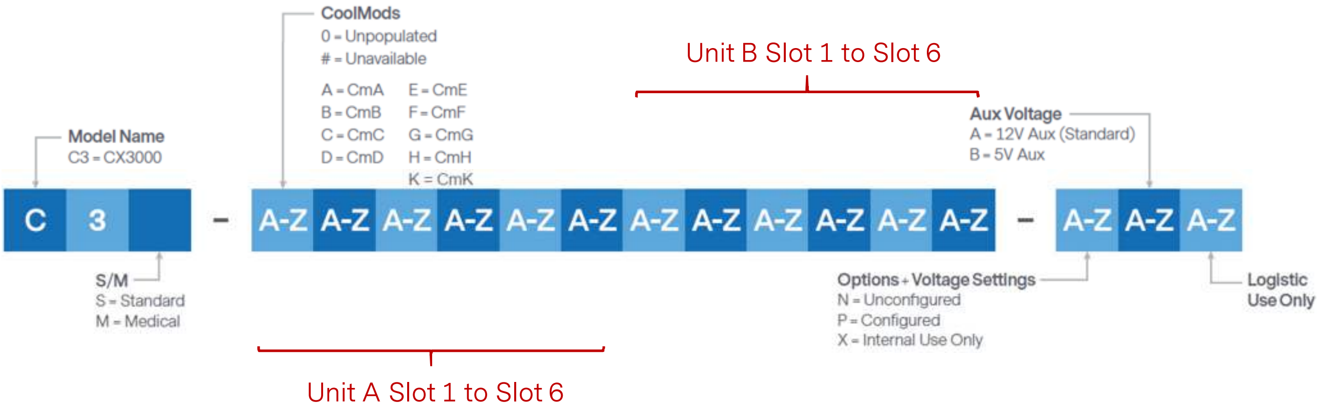
A configured CoolX3000 has the following galvanic isolation barriers.

Isolation Barrier	Type	Withstand Voltage
Input to Output	Reinforced (2 x MOPP)	4000Vac
Input to Case (GND)	Basic (1 x MOPP)	1850Vac
Output to Case (GND)	Basic (1 x MOPP)	1850Vac
Output to Output	Basic (1 x MOPP)	1850Vac
Output (V1) to Output (V2) - Dual	Functional	500Vac

SECTION 2 MODEL / ORDERING INFORMATION

2.1 CoolX Nomenclature

The CoolX3000 user configurable power supply part-numbering system is described below.



Model Name

C3 = CX3000

S/M (Standard of Medical CoolPac)

S = Standard IEC62368-1
M = Medical IEC60601-1 3rd Edition

CoolMods - Output Modules (see section 2.2 for module details)

A = CmA - 5V/30A, 1 slot
B = CmB - 12V/23.3A, 1 slot
C = CmC - 24V/12.5A, 1 slot
D = CmD - 48V/6.25A, 1 slot
E = CmE - 24V/37.5A, 3 slots
F = CmF - 48V/18.75A, 3 slots
K = CmK - 200V/1A, 1 slot
0 = Unpopulated
# = Unavailable (two slots preceding E and F module - ie: ##E)

G = CmG - 24V/4A + 24V/4A, 1 slot
H = CmH - 5V/10A + 24V/4A, 1 slot
A[1] = CmA-W01 - 5V/30A, 1 slot
B[1] = CmB-W01 - 12V/23.3A, 1 slot
C[1] = CmC-W01 - 24V/12.5A, 1 slot
D[1] = CmD-W01 - 48V/6.25A, 1 slot

Options + Voltage Settings

N = Standard. No additional configuration. Nominal output voltages
P = Configured. Preset. Voltage Adjustments, Series, Parallel Outputs
X = When Wide Trim Module is used or other special configuration (Internal use only)

Auxiliary Voltage

A = 12V/1.96A isolated Bias Supply Voltage
B = 5V/4.7A isolated Bias Supply Voltage

Note 1: The wide trim modules CmA-W01 to CmD-W01 are variants of the standard modules CmA to CmD and will have the same module code in the part number nomenclature system, change "Option + Voltage Settings" code to "X" when a wide trim module is used.

SECTION 2 MODEL / ORDERING INFORMATION CON'T

2.2 Output Modules

Table 1 CoolX CoolMods Table

		Output Voltage	Output Adjust Range	Maximum Current	Maximum Power
Single Output Modules (1 Slot)					
CmA		5V	2.5-6.0V	30.0A	150W
CmB[1]		12V	6.0-15.0V[2]	23.3A	280W
CmC		24V	15.0-28.0V	12.5A	300W
CmD		48V	28.0-58.0V[3]	6.25A	300W
High Power Modules (3 Slots)					
CmE[4]		24V	24-25.2V	37.5A	900W
CmF[4]		48V	48-50.4V	18.75A	900W
Dual Output Modules (1 Slot)					
CmG[5]	V1	24V	3.0-30.0V	4.0A	120W
	V2	24V	3.0-30.0V	4.0A	120W
CmH[6]	V1	5V	3.0-6.0V	10.0A	60W
	V2	24V	3.0-30.0V	4.0A	120W
Wide Trim Modules (1 Slot)					
CmA-W01		5V	1.0-6.0V	30.0A	150W
CmB-W01		12V	1.0-15.0V	23.3A	280W
CmC-W01		24V	2.0-28.0V	12.5A	300W
CmD-W01		48V	3.0-58.0V	6.25A	300W
High Voltage Module (1 Slot)					
CmK[7]		200V	175.0-205.0V	1.0A	200W

Note 1 - Full dynamic specifications may not be met at full load when output voltage is trimmed above 13 V.
Note 2 - Max Trim 14 V when used with High Power Module in CoolPac case.
Note 3 - Max Trim 56 V when used with High Power Module in CoolPac case.
Note 4 - a) Only one High Power module (CmE or CmF) can be used per CoolPac.
b) During load transients starting from 0% load on the High Power modules, other modules in the CoolPac may experience an output voltage dynamic during the load change. Contact applications support for details or support.
Note 5 - For the CmG module the max combined power of both outputs is 200 W.
Note 6 - For the CmH module the max combined power of both outputs is 180 W.
Note 7 - When a CmK module is used in Unit A along with a CmE or CmF module, one module slot of Unit A must remain unpopulated. When a CmK module is used in Unit B along with a CmE or CmF module, one module slot of Unit B must remain unpopulated.

SECTION 2 MODEL / ORDERING INFORMATION CON'T

2.3 Selecting & Ordering Configured CoolX

Configured CoolX3000 power supplies may be specified and ordered using the part numbering system shown. At our configuration centre, we will assemble the CoolX3000 as specified by you accounting for slot preferences and also for preferred settings (Voltage/Series/Parallel etc.), and also incorporating any options required.

Configuration Example 1

Required power supply:	200-240Vac input, IEC62368-1 approved
Outputs:	5V/10A, 24V/30A, 48V/4A, 24V/2A, 24V/2A, 48 V/6A, 5V/20A, 24V/4A, 24V/12A
Auxiliary Bias Supply:	12V/1A

Solution: CoolX part number C3S0HG##E00ADCDNA specifies the following product.

- C3S 3000W IEC62368 approved
- Unit A Slot 1: Empty Slot
- Unit A Slot 2: CmH: 5V/10A, 24 V/2A
- Unit A Slot 3: CmG: 24V/2A, 24V,4A
- Unit A Slot 4: Not Available (CmE is three slot CoolMod module)
- Unit A Slot 5: Not Available (CmE is three slot CoolMod module)
- Unit A Slot 6: CmE: 24V/30A
- Unit B Slot 1: Empty Slot
- Unit B Slot 2: Empty Slot
- Unit B Slot 3: CmA: 5V/20A
- Unit B Slot 4: CmD: 48V/4A
- Unit B Slot 5: CmC: 24V/12A
- Unit B Slot 6: CmD: 48V/6A
- Option N: Nominal Output voltage settings
- Option A: 12V/1.96A Bias Supply Voltage

Configuration Example 2

Required power supply:	100-240Vac input, IEC60601-1 3rd edition approved
Outputs:	5V/10A, 24V/10A, 45V/4A, 12V/25A, 19V/50A, 50V/10A
Auxiliary Bias Supply:	5V/2A

Solution: CoolX part number C3MAAADCCCCCCCCPB specifies the following product;

- C3M 3000W IEC60601-1 approved
- Unit A Slot 1: CmA: 5V/10A
- Unit A Slots 2-3: 2 CmA in Series: 12V/25A
- Unit A Slot 4: CmD: 45V/4A
- Unit A Slots 5-6: 2 CmC in Series: 50V/10A
- Unit B Slots 1-5: 5 CmC in Parallel: 19V/50A
- Unit B Slot 6: CmC: 24 V/10A
- Option P: Parallel / Series Links added or Custom Voltages set by Factory
- Option B: 5V/4.7A Bias Supply Voltage

SECTION 3 ELECTRICAL SPECIFICATIONS

3.1 Input Specifications

Table 2 Input Specifications

Parameter	Condition	Symbol	Min	Typ	Max	Unit
Nominal Input Voltage, AC[1]	47 to 63Hz	$V_{IN,AC}$	200	-	240	Vac
Operating Input Voltage, AC[2]	47 to 440Hz	$V_{IN,AC}$	180	-	264	Vac
Extended AC Operating Range	Maximum for 5 seconds	$V_{IN,AC}$	-	-	300	Vac
Operating Input Voltage, DC[3]		$V_{IN,DC}$	283	-	340	Vdc
Maximum Input AC current	See Power Derating Curve	$I_{IN,max}$			16	A
Harmonic Line Currents	All	THD	EN 61000-3-2, Class A			
Power Factor	$V_{IN,AC}$ = 230Vac $P_O = P_{O,max}$		0.98	-	-	
Undervoltage Lockout	Shutdown		65	-	74	Vac
Inrush Current	$V_{IN,AC}$ = 230Vac	$I_{IN,inrush}$	-	-	50	A
Leakage Current to Earth Ground	Normal Condition (High Line) $V_{IN,AC}$ = 264Vac/60Hz	$I_{leakage}$	-	244	-	uA
	Single Fault Condition (High Line) $V_{IN,AC}$ = 264Vac/60Hz	$I_{leakage}$	-	435	-	uA
Touch Current to Earth Ground	Normal Condition (High Line) $V_{IN,AC}$ = 264Vac/60Hz	I_{touch}	-	14.2	-	uA
	Single Fault Condition (High Line) $V_{IN,AC}$ = 264Vac	I_{touch}	-	246	-	uA
Input Fuses Rating	Dual Fused (Line and Neutral) 500Vac		-	30	-	A
Operating Efficiency @ 25 ^{O}C	$V_{IN,AC}$ = 230Vac, P_O = 3000W with 12 x CmC CoolMods	η	-	91	-	%

Note 1 - Safety Approval
Note 2 - Extended Frequency Range not Safety Certified
Note 3 - DC Operation not Safety Certified

SECTION 3 ELECTRICAL SPECIFICATIONS CON'T

3.2 General Output Specifications

Table 3 Output Specifications

Parameter	Condition	Symbol	Min	Typ	Max	Unit
Maximum Output Power[1]	Derate from 215Vac	$P_{O,max}$	-	-	3000	W
Minimum Load		$I_{O,min}$	0	-	-	A
Remote Sense	Max line drop compensation (N/A in CmG, CmH and CmK)	V_O	-	-	0.5	Vdc
Turn On Overshoot	All	V_O	-	-	±1	%
Turn-On Delay	From AC Input From Deep Sleep[2] From Global EN From CoolMod EN	$T_{turn\ on}$	- - -	- - -	1000 700 10 10	mS
Hold Up Time	See Note 2	$T_{hold\ up}$	16	-	-	mS
Overtemperature Protection			Yes, Auto-Recovery			

Note 1 - The CoolX3000 can not be used to deliver continuous output power greater than 3000 W. Maximum output power from any row of outputs (6 slots on top row or 6 slots on bottom row) must not exceed 1500 W. For example, if bottom row of outputs are configured to deliver 1200 W, the top row is still limited to a max of 1500 W output power.

Note 2 - The CoolX3000 will enter a power saving Deep Sleep mode if all modules have been disabled for more than 5 seconds.

Note 3 - In configurations that have a CmE and CmF on both output rails, 16mS hold up is achieved when the total power draw is less than 2600 W (1300 W from each output rail) all other configuration have 16mS over the total power range.

SECTION 3 ELECTRICAL SPECIFICATIONS CON'T

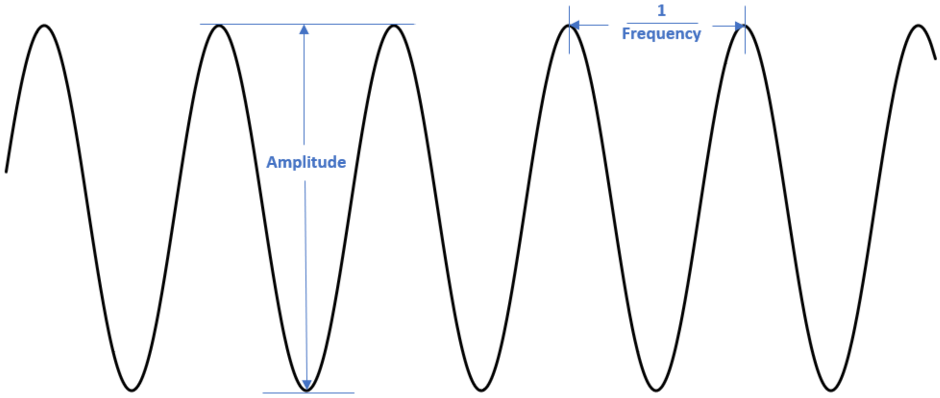
3.3 Standard Modules (CmA-CmD) Output Specifications

Parameter	Module	Symbol	Min	Typ	Max	Unit
Output Voltage	CmA CmB CmC CmD	V_O	2.5 6 15 28	5 12 24 48	6 15[1] 28 58	Vdc
Factory Setting Accuracy	CmA CmB CmC CmD	$V_{O,factory}$	- - - -	- - - -	10 10 20 40	mV
Output Current[2]	CmA CmB CmC CmD	$I_{O,max}$	- - - -	- - - -	30 23.3 12.5 6.25	A
Output Power[3]	CmA CmB CmC CmD	$P_{O,max}$	- - - -	- - - -	150 280 300 300	W
Capacitive Loading[4]	CmA CmB CmC CmD	$C_{O,max}$	- - - -	- - - -	20000 10000 8000 4700	uF

Note 1 - Full Dynamic Specifications of the CmB module may not be met at full load when the CmB module is trimmed above 13 V in the CoolX3000.
Note 2 - Maximum output current to be derated by 10% when used in parallel.
Note 3 - Maximum output power to be derated when CoolX is used in ambient temperatures greater than 40°C - see page 48 - Thermal Derating for further details.
Note 4 - Maximum capacitive load of the module to ensure monotonic startup (with no additional load applied). Higher capacitive loading is possible if non-monotonic startup is acceptable. Contact technical support for further details.

SECTION 3 ELECTRICAL SPECIFICATIONS CON'T

Ripple and Noise - CmA, CmB, CmC, CmD



Parameter	Module	Symbol	Min	Typ	Max	Unit
Output Ripple[1]	CmA CmB CmC CmD	$V_{O,ripple}$	- - - -	- - - -	100 120 240 480	mV
Output Ripple Frequency[2]	All Modules	f	220	240	260	KHz

Note 1 - Amplitude of ripple measured at nominal voltage and at 20 MHz Bandwidth

Regulation- CmA, CmB, CmC, CmD

Parameter	Module	Symbol	Min	Typ	Max	Unit
Load Regulation 0-100% Load	CmA CmB CmC CmD	V_O	- - - -	- - - -	20 24 48 96	mV
Load Regulation - Paralleled[1] 0-100% Load	CmA CmB CmC CmD	V_O	- - - -	- - - -	135 293 840 1380	mV
Line Regulation 85 - 264 Vac	CmA CmB CmC CmD	V_O	- - - -	- - - -	10 12 24 48	mV
Temperature Regulation[2]	All Modules		-	-	0.02	%/^{O}C

Note 1 - Load Regulation is softened in parallel mode to improve current share
Note 2 - Over ambient temperature change

SECTION 3 ELECTRICAL SPECIFICATIONS CON'T

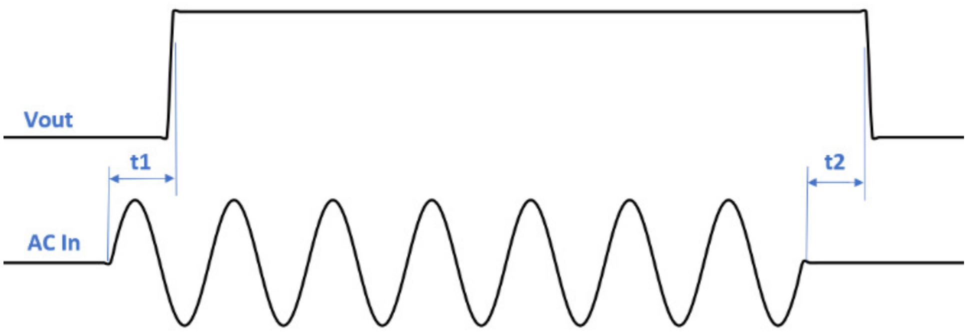
Protective Limits - CmA, CmB, CmC, CmD

Parameter	Module	Symbol	Min	Typ	Max	Unit
Current Limit[1]	CmA CmB CmC CmD	$I_{O,limit}$	31.5 24.4 13.1 6.56	- - - -	39.0 30.4 16.3 8.13	A
Short-Circuit Current Limit[2]	CmA CmB CmC CmD	$I_{O,short}$	- - - -	- - - -	15.0 11.7 6.25 3.125	A
Power Limit[3]	CmA CmB CmC CmD	$P_{O,limit}$	158 294 315 315	- - - -	195 364 390 390	W
Overvoltage Protection[4]	CmA CmB CmC CmD	V_O	7.5 17 32 62	- - - -	9.6 21.0 37.0 69.6	V
Sense Lead Protection[5]	All Modules		-	-	3.1	V

Note 1 - Constant Current Limit into Hiccup. Auto-Recovery
Note 2 - Auto-Recovery, Measured over 5 hiccup cycles
Note 3 - Voltage Foldback into Hiccup, Auto-Recovery
Note 4 - Shutdown (All outputs), Auto-Recovery
Note 5 - Shutdown, Auto-Recovery

SECTION 3 ELECTRICAL SPECIFICATIONS CON'T

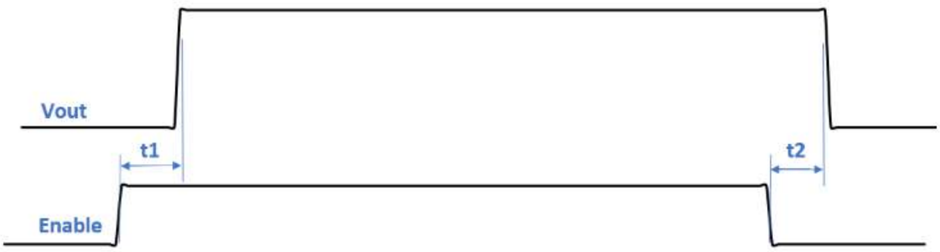
Start-Up / Shut-Down - CmA, CmB, CmC, CmD



Parameter	Module	Symbol	Min	Typ	Max	Unit
Turn-On Delay[1]	All Modules	t1	-	-	1000	mS
Turn-Off Delay[2]	All Modules	t2	16	-	-	mS

Note 1 - Time from application of Input AC to Output Voltage Regulation (t1)
Note 2 - From Loss of AC to Loss of Output Voltage Regulation - Nominal Voltage (t2)

Enable / Disable - CmA, CmB, CmC, CmD

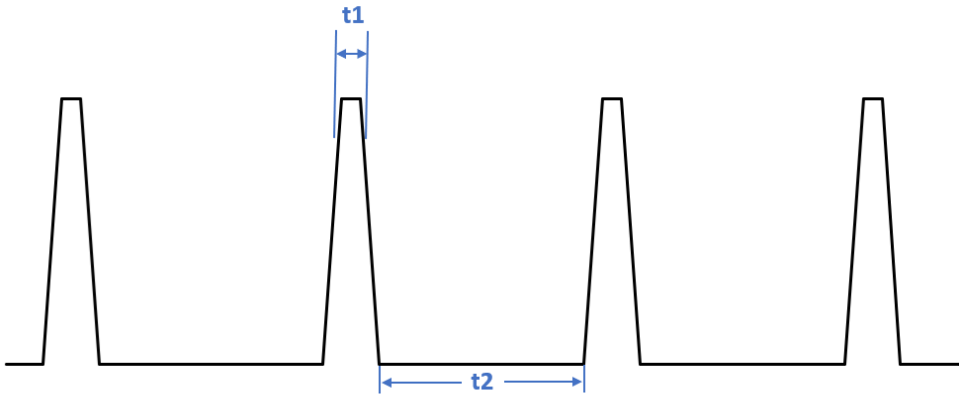


Parameter	Module	Symbol	Min	Typ	Max	Unit
Enable Delay[1]	All Modules	t1	-	-	12	mS
Enable Delay (From Deep Sleep)[2]	All Modules	t1	-	-	700	mS
Rise Time[3]	All Modules		1	-	5	mS
Disable Delay[4]	All Modules	t2	-	-	8	mS
Fall Time[5]	All Modules		0.01	-	3	mS

Note 1 - Time from application of Enable signal to Output Voltage Regulation (t1)
Note 2 - The CoolX3000 will enter a power saving Deep Sleep mode if all modules have been disabled for more than 5 seconds.
Note 3 - Measured from 10 - 90% of Vout
Note 4 - Time from application of Disable signal to loss of Output Voltage Regulation (t2)
Note 5 - Fully Loaded measured from 90% - 10% of Vout

SECTION 3 ELECTRICAL SPECIFICATIONS CON'T

Hiccup Characteristics - CmA, CmB, CmC, CmD

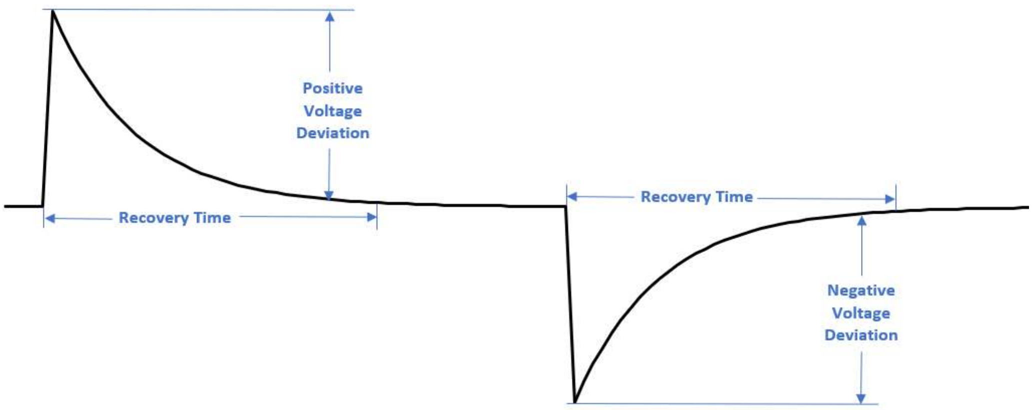


Parameter	Module	Symbol	Min	Typ	Max	Unit
Hiccup On-Time[1]	All Modules	t1	1	-	100	mS
Hiccup Off-Time[2]	All Modules	t2	900	-	1200	mS
Short Circuit Hiccup Level[3]	CmA CmB CmC CmD	$V_{O,short}$	1.0 3.5 7.2 14.3	- - - -	2.0 5.7 9.6 18	V

Note 1 - Length of time output is on during hiccup (t1)
Note 2 - Length of time output is off during hiccup (t2)
Note 3 - Output voltage at which module enters hiccup protection

SECTION 3 ELECTRICAL SPECIFICATIONS CON'T

Transient Response - CmA, CmB, CmC, CmD



Parameter	Module	Symbol	Min	Typ	Max	Unit
Transient Response, Voltage Deviation[1]	CmA CmB CmC CmD	V_O	- - - -	- - - -	0.3 0.6 0.96 1.2	V
Transient Response, Recovery Time[1]	All Modules		-	-	500	uS
Transient Response, Voltage Deviation[2]	CmA CmB CmC CmD	V_O	- - - -	- - - -	0.6 1.2 1.8 2.4	V
Transient Response, Recovery Time[2]	All Modules		-	-	1000	uS

Note 1 - Measured during 25 - 75% and 75 - 25% Step Load Changes
Note 2 - Measured during 10 - 100% and 100 - 10% Step Load Changes

Galvanic Isolation - CmA, CmB, CmC, CmD

Parameter	Module	Symbol	Min	Typ	Max	Unit
Input to Output 2 x MOPP	All Modules		4000	-	-	Vac
Output to Output 1 x MOPP	All Modules		1850	-	-	Vac

SECTION 3 ELECTRICAL SPECIFICATIONS CON'T

PMBus™ Communications - CmA, CmB, CmC, CmD

Standard modules can be monitored and controlled with the following PMBus Commands (for further details see the PMBus™ Manual available for download from the Advanced Energy website.

<table>
<tr><th>Command</th><th>Description</th><th colspan="3"></th></tr>
<tr><td rowspan="5">READ_VOUT (0x8B)</td><td rowspan="5">The READ_VOUT command is used to return the output voltage measurement of the selected (or paged) module</td><td>Module</td><td>Accuracy[1]</td><td>Resolution</td></tr>
<tr><td>CmA</td><td>+/- 4%</td><td>6.6 mV</td></tr>
<tr><td>CmB</td><td>+/- 4%</td><td>16.5 mV</td></tr>
<tr><td>CmC</td><td>+/- 4%</td><td>44.3 mV</td></tr>
<tr><td>CmD</td><td>+/- 4%</td><td>82.4 mV</td></tr>
<tr><td rowspan="5">READ_IOUT (0x8C)</td><td rowspan="5">The READ_IOUT command is used to return the output current measurement of the selected (or paged) module</td><td>Module</td><td>Accuracy[2]</td><td>Resolution</td></tr>
<tr><td>CmA</td><td>+/- 4%</td><td>40 mA</td></tr>
<tr><td>CmB</td><td>+/- 4%</td><td>29 mA</td></tr>
<tr><td>CmC</td><td>+/- 4%</td><td>16 mA</td></tr>
<tr><td>CmD</td><td>+/- 4%</td><td>8 mA</td></tr>
<tr><td>READ_TEMPERATURE_1 (0x8D)</td><td colspan="4">The READ_TEMPERATURE_1 command is used to return the temperature measurement of the selected (or paged) module in Degrees Celsius. The accuracy of the READ_TEMPERATURE_1 command is +/- 10 °C, while its resolution is 1 °C.</td></tr>
<tr><td>STATUS_WORD (0x79)</td><td colspan="4">The STATUS_WORD command is used to check for the presence of fault conditions such as OTP (Overtemperature Protection) and PG (Power Good) fail.</td></tr>
<tr><td>PAGE (0x00)</td><td colspan="4">The PAGE command is used to select which of the modules subsequent commands are to be applied to. When read, this command shall return the currently selected page number.</td></tr>
<tr><td>VOUT_COMMAND (0x21)</td><td colspan="4">The VOUT_COMMAND command is used to explicitly set the output voltage of the selected (or paged) module to the commanded value.</td></tr>
<tr><td>ILIIMIT_TRIM (0xD1)</td><td colspan="4">The ILIMIT_TRIM command is used to explicitly set the current limit of the selected (or paged) module to the commanded value.</td></tr>
<tr><td rowspan="5">MODULE_ID (0xD0)</td><td colspan="2" rowspan="5">The MODULE_ID command is used to return a code representing the model type of the selected (or paged) CoolMod.</td><td>Module</td><td>ID Code</td></tr>
<tr><td>CmA</td><td>0x20</td></tr>
<tr><td>CmB</td><td>0x40</td></tr>
<tr><td>CmC</td><td>0x60</td></tr>
<tr><td>CmD</td><td>0x80</td></tr>
</table>

Note 1 - With Respect to Nominal
Note 2 - With Respect to Maximum

SECTION 3 ELECTRICAL SPECIFICATIONS CON'T

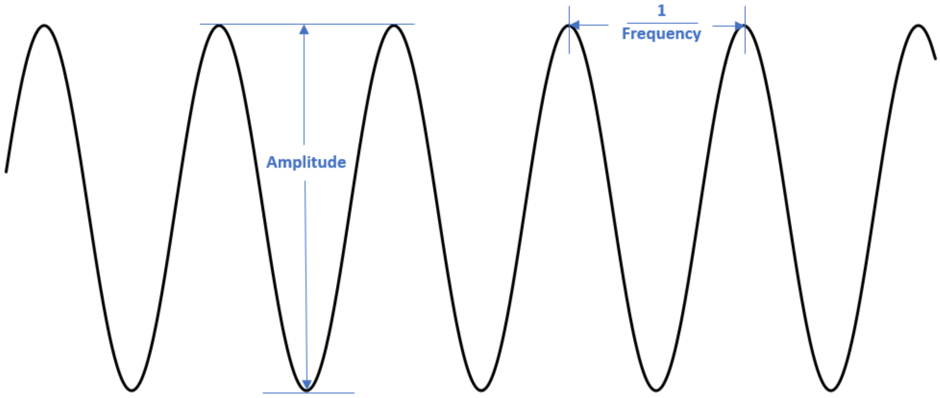
3.4 High Power Modules (CmE-CmF) Output Specifications

Parameter	Module	Symbol	Min	Typ	Max	Unit
Output Voltage	CmE CmF	V_O	24 48	24 48	25.2 50.4	Vdc
Factory Setting Accuracy	CmE CmF	$V_{O,factory}$	- -	- -	40 40	mV
Output Current	CmE CmF	$I_{O,max}$	- -	- -	37.50 18.75	A
Output Power[1]	CmE CmF	$P_{O,max}$	- -	- -	900 900	W
Capacitive Loading[2]	CmE CmF	$C_{O,max}$	- -	- -	10000 2500	uF

Note 1 - Maximum output power to be derated when CoolX is used in ambient temperatures greater than 40°C - see page 48 - Thermal Derating for further details.
Note 2 - Maximum capacitive load of the module to ensure monotonic startup (with no additional load applied).

SECTION 3 ELECTRICAL SPECIFICATIONS CON'T

Ripple and Noise - CmE, CmF



Parameter	Module	Symbol	Min	Typ	Max	Unit
Output Ripple[1]	CmE CmF	$V_{O,ripple}$	- -	- -	360 1680	mV
Output Ripple Frequency[2]	All Modules	f	200	-	350	KHz

Note 1 - Amplitude of ripple measured at nominal voltage and at 20 MHz Bandwidth

Regulation - CmE, CmF

Parameter	Module	Symbol	Min	Typ	Max	Unit
Load Regulation 25-75% Load	CmE CmF	V_O	- -	- -	180 1680	mV
Line Regulation 85-264 Vac	CmE CmF	V_O	- -	- -	120 240	mV
Temperature Regulation[1]	All Modules		-	-	0.02	%/°C

Note 1 - Over ambient temperature change

SECTION 3 ELECTRICAL SPECIFICATIONS CON'T

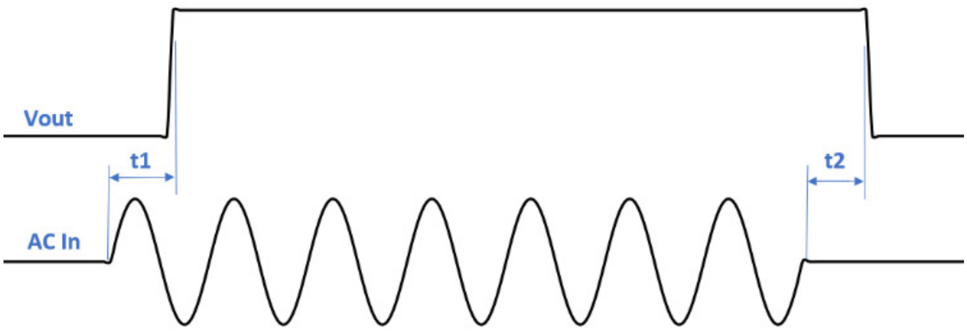
Protective Limits - CmE, CmF

Parameter	Module	Symbol	Min	Typ	Max	Unit
Current Limit[1]	CmE CmF	$I_{O,limit}$	39.3 19.6	- -	48.8 24.4	A
Short-Circuit Current Limit[2]	CmE CmF	$I_{O,short}$	- -	- -	5.0 2.5	A
Power Limit[3]	CmE CmF	$P_{O,limit}$	945 945	- -	1170 1170	W
Overvoltage Protection[4]	CmE CmF	V_O	27 55	- -	32.5 62.0	V
Sense Lead Protection[5]	All Modules		-	-	7	V

Note 1 - Hiccup. Auto-Recovery
Note 2 - Measured over 5 hiccup cycles
Note 3 - Hiccup, Auto-Recovery
Note 4 - Shutdown (All outputs), Auto-Recovery
Note 5 - Shutdown, Auto-Recovery

SECTION 3 ELECTRICAL SPECIFICATIONS CON'T

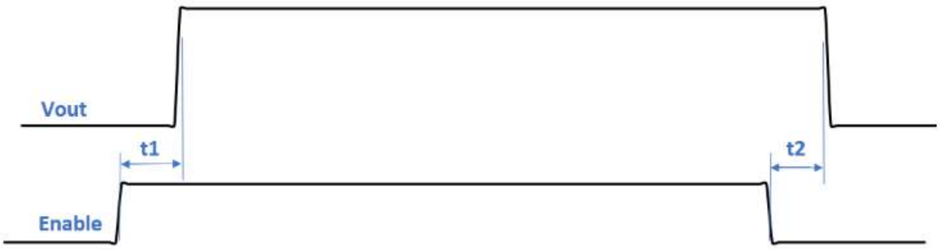
Start-Up / Shut-Down - CmE, CmF



Parameter	Module	Symbol	Min	Typ	Max	Unit
Turn-On Delay[1]	All Modules	t1	-	-	1000	mS
Turn-Off Delay[2]	All Modules	t2	16	-	-	mS

Note 1 - Time from Application of Input AC to Output Voltage Regulation (t1)
Note 2 - From Loss of AC to Loss of Output Voltage Regulation - Nominal Voltage (t2)

Enable / Disable - CmE, CmF

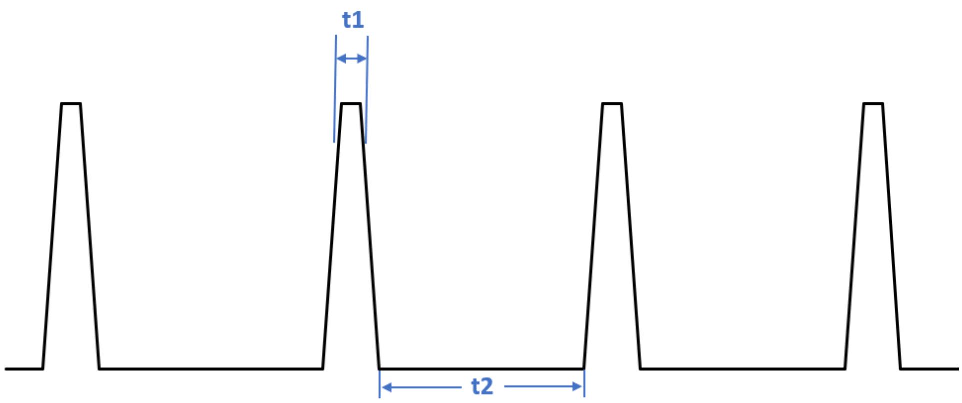


Parameter	Module	Symbol	Min	Typ	Max	Unit
Enable Delay[1]	All Modules	t1	-	-	20	mS
Enable Delay (From Deep Sleep)[2]	All Modules	t1	-	-	700	mS
Rise Time[3]	All Modules		1	-	5	mS
Disable Delay[4]	All Modules	t2	-	-	8	mS
Fall Time[5]	All Modules		0.01	-	3	mS

Note 1 - Time from application of Enable signal to Output Voltage Regulation (t1)
Note 2 - The CoolX3000 will enter a power saving Deep Sleep mode if all modules have been disabled for more than 5 seconds.
Note 3 - Measured from 10 - 90% of Vout
Note 4 - Time from application of Disable signal to loss of Output Voltage Regulation (t2)
Note 5 - Fully Loaded measured from 90% - 10% of Vout

SECTION 3 ELECTRICAL SPECIFICATIONS CON'T

Hiccup Characteristics - CmE, CmF

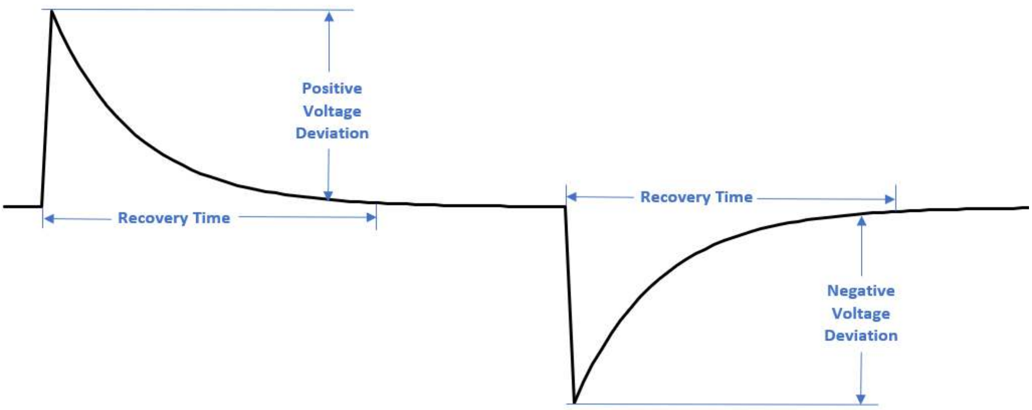


Parameter	Module	Symbol	Min	Typ	Max	Unit
Hiccup On-Time[1]	All Modules	t1	0.5	-	50	mS
Hiccup Off-Time[2]	All Modules	t2	950	-	7000	mS
Short Circuit Hiccup Level[3]	CmE CmF	I_O	39.3 19.6	- -	48.8 24.4	A

Note 1 - Length of time output is on during hiccup (t1)
Note 2 - Length of time output is off during hiccup (t2)
Note 3 - Output current at which module enters hiccup protection

SECTION 3 ELECTRICAL SPECIFICATIONS CON'T

Transient Response - CmE, CmF



Parameter	Module	Symbol	Min	Typ	Max	Unit
Transient Response, Voltage Deviation[1]	CmE CmF	V_O	- -	- -	0.96 1.92	V
Transient Response, Recovery Time[1]	All Modules		-	-	1000	uS

Note 1 - Measured during 25 - 75% and 75 - 25% Step Load Changes

Galvanic Isolation - CmE, CmF

Parameter	Module	Symbol	Min	Typ	Max	Unit
Input to Output 2 x MOPP	All Modules		4000	-	-	Vac
Output to Output 1 x MOPP	All Modules		1850	-	-	Vac

SECTION 3 ELECTRICAL SPECIFICATIONS CON'T

PMBus™ Communications - CmE, CmF

High Power modules can be monitored and controlled with the following PMBus Commands (for further details see the PMBus™ Manual available for download from the Advanced Energy website.

<table>
<tr><th>Command</th><th>Description</th><th colspan="3"></th></tr>
<tr><td rowspan="3">READ_VOUT (0x8B)</td><td rowspan="3">The READ_VOUT command is used to return the output voltage measurement of the selected (or paged) module</td><td>Module</td><td>Accuracy[1]</td><td>Resolution</td></tr>
<tr><td>CmE</td><td>+/- 4%</td><td>31 mV</td></tr>
<tr><td>CmF</td><td>+/- 4%</td><td>60 mV</td></tr>
<tr><td rowspan="3">READ_IOUT (0x8C)</td><td rowspan="3">The READ_IOUT command is used to return the output current measurement of the selected (or paged) module</td><td>Module</td><td>Accuracy[2]</td><td>Resolution</td></tr>
<tr><td>CmE</td><td>+/- 4%</td><td>45 mA</td></tr>
<tr><td>CmF</td><td>+/- 4%</td><td>22 mA</td></tr>
<tr><td>READ_TEMPERATURE_1 (0x8D)</td><td colspan="4">The READ_TEMPERATURE_1 command is used to return the temperature measurement of the selected (or paged) module in Degrees Celsius. The accuracy of the READ_TEMPERATURE_1 command is +/- 10 °C, while its resolution is 1 °C.</td></tr>
<tr><td>STATUS_WORD (0x79)</td><td colspan="4">The STATUS_WORD command is used to check for the presence of fault conditions such as OTP (Overtemperature Protection) and PG (Power Good) fail.</td></tr>
<tr><td>PAGE (0x00)</td><td colspan="4">The PAGE command is used to select which of the modules subsequent commands are to be applied to. When read, this command shall return the currently selected page number.</td></tr>
<tr><td>VOUT_COMMAND (0x21)</td><td colspan="4">The VOUT_COMMAND command is used to explicitly set the output voltage of the selected (or paged) module to the commanded value.</td></tr>
<tr><td>ILIMIT_TRIM (0xD1)</td><td colspan="4">The ILIMIT_TRIM command is used to explicitly set the current limit of the selected (or paged) module to the commanded value.</td></tr>
<tr><td rowspan="3">MODULE_ID (0xD0)</td><td colspan="2" rowspan="3">The MODULE_ID command is used to return a code representing the model type of the selected (or paged) CoolMod.</td><td>Module</td><td>ID Code</td></tr>
<tr><td>CmE</td><td>0xBC</td></tr>
<tr><td>CmF</td><td>0xBD</td></tr>
</table>

Note 1 - With Respect to Nominal
Note 2 - With Respect to Maximum

SECTION 3 ELECTRICAL SPECIFICATIONS CON'T

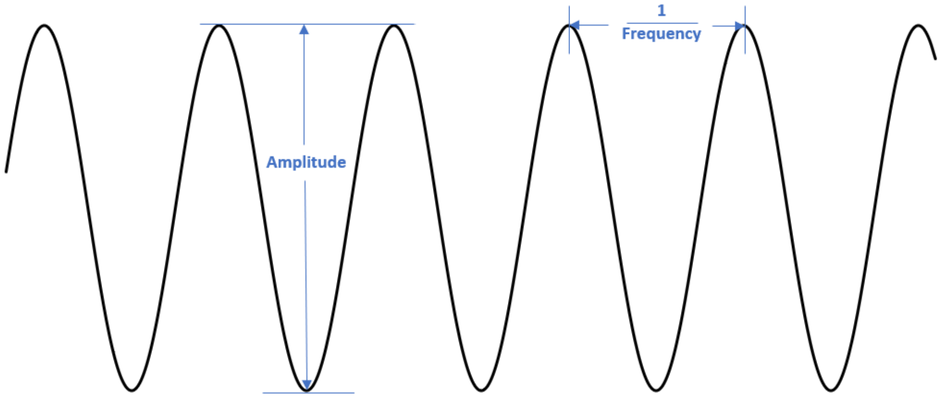
3.5 Dual Modules (CmG-CmH) Output Specifications

Parameter	Module	Symbol	Min	Typ	Max	Unit
Output Voltage	CmG (V1,V2) CmH (V1) CmH (V2)	V_O	3 3 3	24 5 24	30 6 30	Vdc
Factory Setting Accuracy	All Modules	$V_{O,factory}$	-	-	40	mV
Output Current	CmG (V1,V2) CmH (V1) CmH (V2)	$I_{O,max}$	- - -	- - -	4 10 4	A
Output Power per Channel[1]	CmG (V1,V2) CmH (V1) CmH (V2)	$P_{O,max}$	- - -	- - -	120 60 120	W
Total Output Power[1]	CmG CmH	$P_{O,max}$	- -	- -	200 180	W
Capacitive Loading[2]	CmG (V1,V2) CmH (V1) CmH (V2)	$C_{O,max}$	- - -	- - -	6600 13200 6600	uF

Note 1 - Maximum output power to be derated when CoolX is used in ambient temperatures greater than 40°C - see page 48 - Thermal Derating for further details.
Note 2 - Maximum capacitive load of the module to ensure monotonic startup (with no additional load applied).

SECTION 3 ELECTRICAL SPECIFICATIONS CON'T

Ripple and Noise - CmG, CmH



Parameter	Module	Symbol	Min	Typ	Max	Unit
Output Ripple[1]	CmG (V1,V2) CmH (V1) CmH (V2)	$V_{O,ripple}$	- - -	- - -	240 100 240	mV
Output Ripple Frequency	All Modules	f	175	-	220	KHz

Note 1 - Amplitude of ripple measured at nominal voltage and at 20 MHz Bandwidth

Regulation - CmG, CmH

Parameter	Module	Symbol	Min	Typ	Max	Unit
Load Regulation 0-100% Load	CmG (V1,V2) CmH (V1) CmH (V2)	V_O	- - -	- - -	480 100 480	mV
Line Regulation 85 - 264 Vac	CmG (V1,V2) CmH (V1) CmH (V2)	V_O	- - -	- - -	120 25 120	mV
Temperature Regulation[1]	All Modules		-	-	0.2	%/^{O}C

Note 1 - Over ambient temperature change

SECTION 3 ELECTRICAL SPECIFICATIONS CON'T

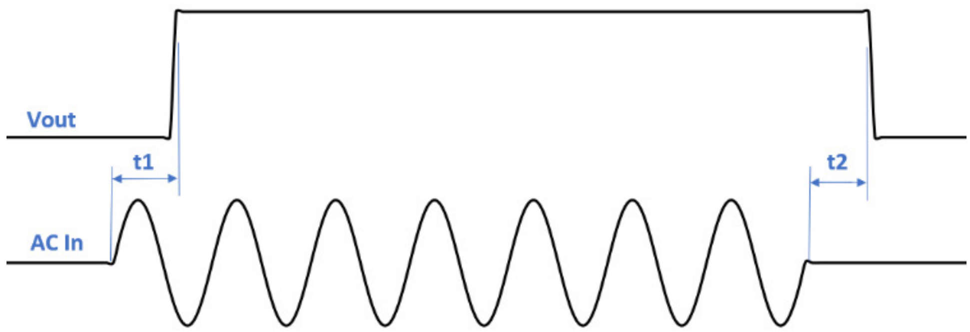
Protective Limits - CmG, CmH

Parameter	Module	Symbol	Min	Typ	Max	Unit
Current Limit[1]	CmG (V1,V2) CmH (V1) CmH (V2)	$I_{O,limit}$	5.5 10 5.5	- - -	10 15 10	A
Short-Circuit Current Limit[2]	CmG (V1,V2) CmH (V1) CmH (V2)	$I_{O,short}$	- - -	- - -	2.5 5.0 3.5	A
Overvoltage Protection[3]	CmG (V1,V2) CmH (V1) CmH (V2)	V_O	33 6.9 33	- - -	39 7.5 39	V

Note 1 - Hiccup, Auto-Recovery
Note 2 - Measured over 5 hiccup cycles
Note 3 - Shutdown, Auto-Recovery

SECTION 3 ELECTRICAL SPECIFICATIONS CON'T

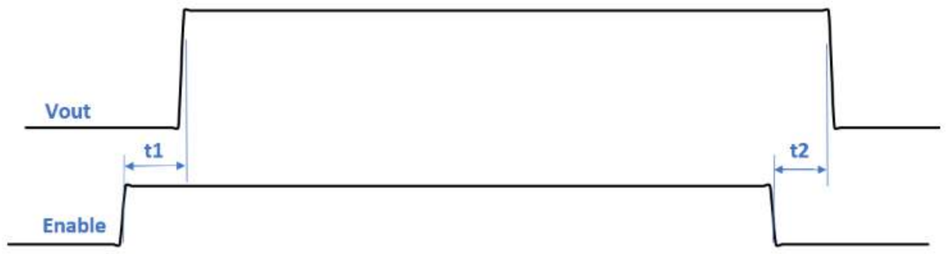
Start-Up / Shut-Down - CmG, CmH



Parameter	Module	Symbol	Min	Typ	Max	Unit
Turn-On Delay[1]	All Modules	t1	-	-	1000	mS
Turn-Off Delay[2]	All Modules	t2	16	-	-	mS

Note 1 - Time from Application of Input AC to Output Voltage Regulation (t1)
Note 2 - From Loss of AC to Loss of Output Voltage Regulation - Nominal Voltage (t2)

Enable / Disable - CmG, CmH

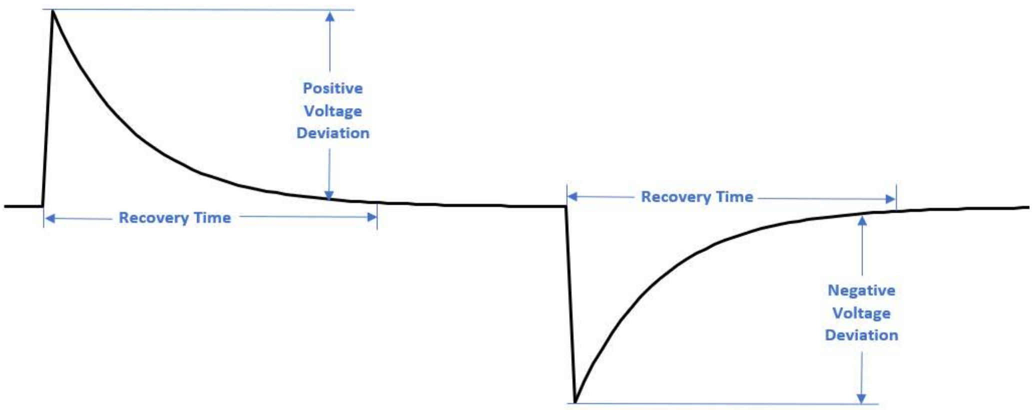


Parameter	Module	Symbol	Min	Typ	Max	Unit
Enable Delay[1]	All Modules	t1	-	-	100	mS
Enable Delay (From Deep Sleep)[2]	All Modules	t1	-	-	700	mS
Rise Time[3]	All Modules		-	-	20	mS
Disable Delay[4]	All Modules	t2	-	-	8	mS
Fall Time[5]	All Modules		0.01	-	1.3	mS

Note 1 - Time from application of Enable signal to Output Voltage Regulation (t1)
Note 2 - The CoolX3000 will enter a power saving Deep Sleep mode if all modules have been disabled for more than 5 seconds.
Note 3 - Measured from 10 - 90% of Vout
Note 4 - Time from application of Disable signal to loss of Output Voltage Regulation (t2)
Note 5 - Fully Loaded measured from 90% - 10% of Vout

SECTION 3 ELECTRICAL SPECIFICATIONS CON'T

Transient Response - CmG, CmH



Parameter	Module	Symbol	Min	Typ	Max	Unit
Transient Response, Voltage Deviation[1]	CmG (V1,V2) CmH (V1) CmH (V2)	V_O	- - -	- - -	960 500 960	mV
Transient Response, Recovery Time[1]	All Modules		-	-	1000	uS

Note 1 - Measured during 25% - 75% and 75% - 25% Step Load Changes

Galvanic Isolation - CmG, CmH

Parameter	Module	Symbol	Min	Typ	Max	Unit
Input to Output 2 x MOPP	All Modules		4000	-	-	Vac
Output to Output of Another Module 1 x MOPP	All Modules		1850	-	-	Vac
Output to Output of the Same Module	All Modules		500	-	-	Vac

SECTION 3 ELECTRICAL SPECIFICATIONS CON'T

PMBus™ Communications - CmG, CmH

Dual modules can be monitored and controlled with the following PMBus Commands (for further details see the PMBUS Manual available for download from the Advanced Energy website.

Command	Description
PAGE (0x00)	The PAGE command is used to select which of the modules subsequent commands are to be applied to. When read, this command shall return the currently selected page number.
OPERATION (0x01)	The OPERATION command is used to enable or disable the both outputs of the Dual module.
MODULE_ID (0xD0)	The MODULE_ID command is used to return a code representing the model type of the selected (paged) CoolMod. The ID code of a Dual CoolMod is 0xDD. (Please note that this is the same for all modules that do not come with the full suite of PMBus™ communications)

SECTION 3 ELECTRICAL SPECIFICATIONS CON'T

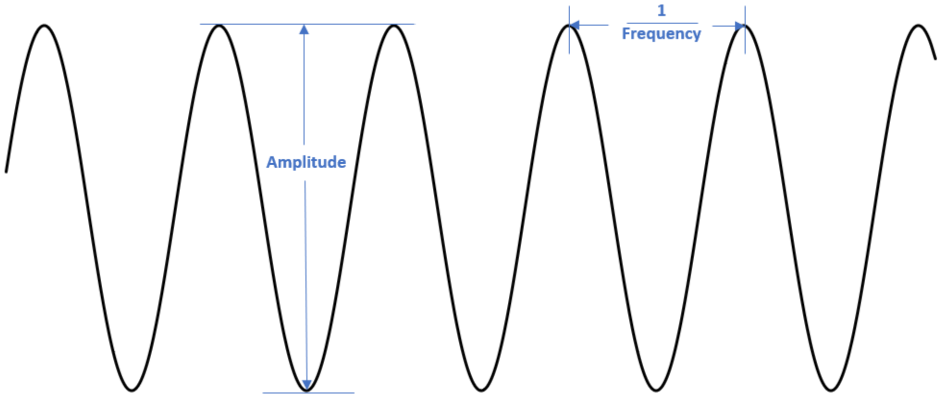
3.6 Wide Trim Modules (CmA-W01 to CmD-W01) Output Specifications

Parameter	Module	Symbol	Min	Typ	Max	Unit
Output Voltage	CmA - W01 CmB - W01 CmC - W01 CmD - W01	V_O	1 1 2 3	5 12 24 48	6 15[1] 28 58	Vdc
Factory Setting Accuracy	CmA - W01 CmB - W01 CmC - W01 CmD - W01	$V_{O,factory}$	- - - -	- - - -	20 20 40 100	mV
Output Current[2]	CmA - W01 CmB - W01 CmC - W01 CmD - W01	$I_{O,max}$	- - - -	- - - -	30 23.3 12.5 6.25	A
Output Power[3]	CmA - W01 CmB - W01 CmC - W01 CmD - W01	$P_{O,max}$	- - - -	- - - -	150 280 300 300	W
Capacitive Loading[4]	CmA - W01 CmB - W01 CmC - W01 CmD - W01	$C_{O,max}$	- - - -	- - - -	20000 10000 8000 4700	uF

Note 1 - Full Dynamic Specifications of the CmB-W01 module may not be met at full load when the CmB-W01 module is trimmed above 13V in the CoolX3000.
Note 2 - Maximum output current to be derated by 10% when used in parallel.
Note 3 - Maximum output power to be derated when CoolX is used in ambient temperatures greater 40°C - see page 48 - Thermal Derating for further details.
Note 4 - Maximum capacitive load of the module to ensure monotonic startup (with no additional load applied). Higher capacitive loading is possible if non-monotonic startup is acceptable. Contact technical support for further details.

SECTION 3 ELECTRICAL SPECIFICATIONS CON'T

Ripple and Noise - CmA-W01, CmB-W01, CmC-W01, CmD-W01



Parameter	Module	Symbol	Min	Typ	Max	Unit
Output Ripple[1]	CmA - W01 CmB - W01 CmC - W01 CmD - W01	$V_{O,ripple}$	- - - -	- - - -	100 120 240 480	mV
Output Ripple Frequency[2]	All Modules	f	220	-	260	KHz

Note 1 - Amplitude of ripple measured at nominal voltage and at 20 MHz Bandwidth

Regulation - CmA-W01, CmB-W01, CmC-W01, CmD-W01

Parameter	Module	Symbol	Min	Typ	Max	Unit
Load Regulation 0-100% Load	CmA - W01 CmB - W01 CmC - W01 CmD - W01	V_O	- - - -	- - - -	20 48 96 192	mV
Load Regulation - Paralleled 0-100% Load	CmA - W01 CmB - W01 CmC - W01 CmD - W01	V_O	- - - -	- - - -	135 293 840 1380	mV
Line Regulation 85-264 Vac	CmA - W01 CmB - W01 CmC - W01 CmD - W01	V_O	- - - -	- - - -	12.5 30 60 120	mV
Temperature Regulation[1]	All Modules		-	-	0.02	%/^{O}C

Note 1 - Over ambient temperature change

SECTION 3 ELECTRICAL SPECIFICATIONS CON'T

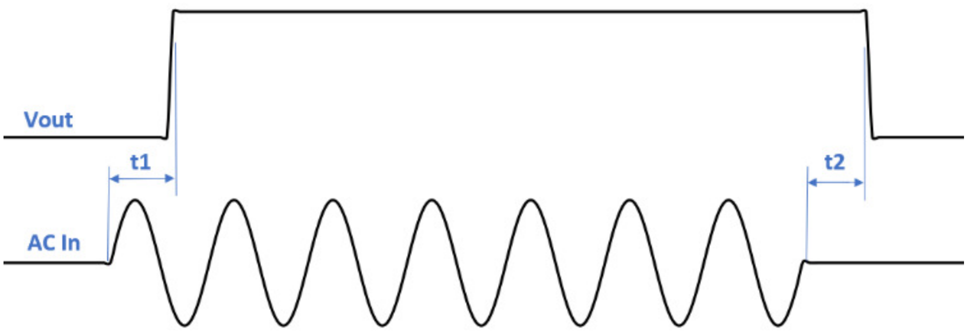
Protective Limits- CmA-W01, CmB-W01, CmC-W01, CmD-W01

Parameter	Module	Symbol	Min	Typ	Max	Unit
Current Limit[1]	CmA - W01 CmB - W01 CmC - W01 CmD - W01	$I_{O,limit}$	31.5 24.4 13.1 6.56	- - - -	39.0 30.3 16.3 8.13	A
Short-Circuit Current Limit[2]	CmA - W01 CmB - W01 CmC - W01 CmD - W01	$I_{O,short}$	- - - -	- - - -	22.5 17.5 9.4 4.7	A
Power Limit[3]	CmA - W01 CmB - W01 CmC - W01 CmD - W01	P_O	158 294 315 315	- - - -	195 364 390 390	W
Overvoltage Protection[4]	CmA - W01 CmB - W01 CmC - W01 CmD - W01	V_O	7.5 17 32 62	- - - -	9.6 21 37 69.6	V
Sense Lead Protection[5]	All Modules		-	-	3.1	V

Note 1 - Constant Limit into Hiccup, Auto-Recovery
Note 2 - Measured over 5 hiccup cycles
Note 3 - Voltage Foldback into Hiccup, Auto-Recovery
Note 4 - Shutdown (All Outputs), Auto-Recovery
Note 5 - Shutdown, Auto-Recovery

SECTION 3 ELECTRICAL SPECIFICATIONS CON'T

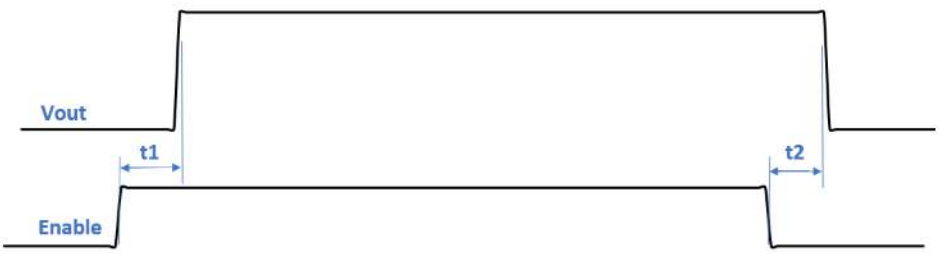
Start-Up / Shut-Down- CmA-W01, CmB-W01, CmC-W01, CmD-W01



Parameter	Module	Symbol	Min	Typ	Max	Unit
Turn-On Delay[1]	All Modules	t1	-	-	1000	mS
Turn-Off Delay[2]	All Modules	t2	16	-	-	mS

Note 1 - Time from Application of Input AC to Output Voltage Regulation (t1)
Note 2 - From Loss of AC to Loss of Output Voltage Regulation - Nominal Voltage (t2)

Enable / Disable- CmA-W01, CmB-W01, CmC-W01, CmD-W01

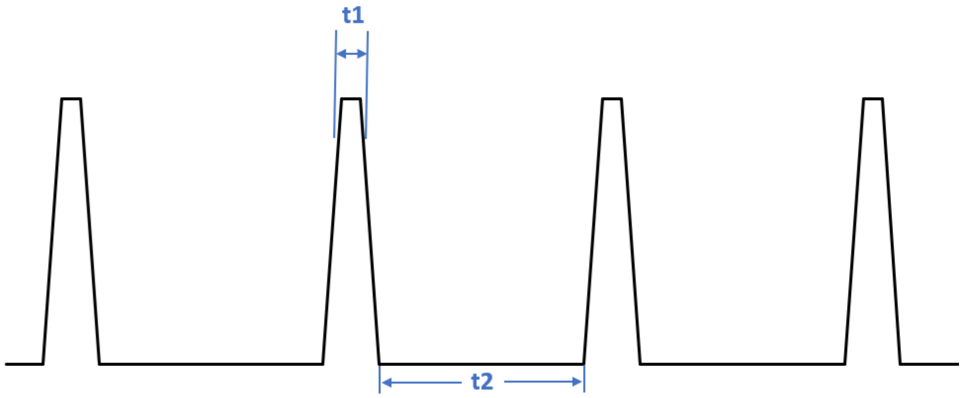


Parameter	Module	Symbol	Min	Typ	Max	Unit
Enable Delay[1]	All Modules	t1	-	-	12	mS
Enable Delay (From Deep Sleep)[2]	All Modules	t1	-	-	700	mS
Rise Time[3]	All Modules		1	-	5	mS
Disable Delay[4]	All Modules	t2	-	-	8	mS
Fall Time[5]	All Modules		0.01	-	3	mS

Note 1 - Time from application of Enable signal to Output Voltage Regulation (t1)
Note 2 - The CoolX3000 will enter a power saving Deep Sleep mode if all modules have been disabled for more than 5 seconds.
Note 3 - Measured from 10 - 90% of Vout
Note 4 - Time from application of Disable signal to loss of Output Voltage Regulation (t2)
Note 5 - Fully Loaded measured from 90% - 10% of Vout

SECTION 3 ELECTRICAL SPECIFICATIONS CON'T

Hiccup Characteristics - CmA-W01, CmB-W01, CmC-W01, CmD-W01

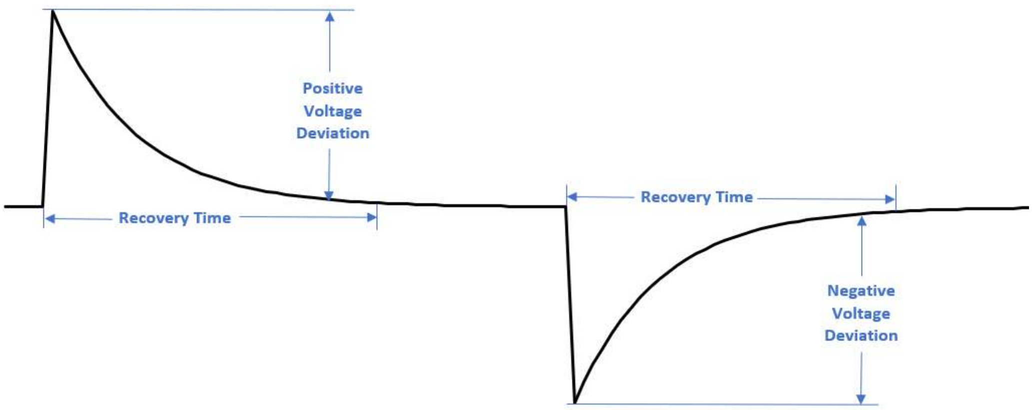


Parameter	Module	Symbol	Min	Typ	Max	Unit
Hiccup On-Time[1]	All Modules	t1	1	-	200	mS
Hiccup Off-Time[2]	All Modules	t2	900	-	1200	mS
Short Circuit Hiccup Level[3]	CmA - W01 CmB - W01 CmC - W01 CmD - W01	V_O	0.4 0.4 0.5 1.1	- - - -	0.85 0.85 1.8 2.5	V

Note 1 - Length of time output is on during hiccup (t1)
Note 2 - Length of time output is off during hiccup (t2)
Note 3 - Output voltage at which module enters hiccup protection

SECTION 3 ELECTRICAL SPECIFICATIONS CON'T

Transient Response - CmA-W01, CmB-W01, CmC-W01, CmD-W01



Parameter	Module	Symbol	Min	Typ	Max	Unit
Transient Response, Voltage Deviation[1]	CmA - W01 CmB - W01 CmC - W01 CmD - W01	V_O	- - - -	- - - -	0.3 0.6 0.96 1.2	V
Transient Response, Recovery Time[1]	All Modules		-	-	500	uS
Transient Response, Voltage Deviation[2]	CmA - W01 CmB - W01 CmC - W01 CmD - W01	V_O	- - - -	- - - -	0.6 1.2 1.8 2.4	V
Transient Response, Recovery Time[2]	All Modules				1000	uS

Note 1 - Measured during 25% - 75% and 75% - 25% Step Load Changes
Note 2 - Measured during 10% - 100% and 100 - 10% Step Load Changes

Galvanic Isolation - CmA-W01, CmB-W01, CmC-W01, CmD-W01

Parameter	Module	Symbol	Min	Typ	Max	Unit
Input to Output 2 x MOPP	All Modules		4000	-	-	Vac
Output to Output 1 x MOPP	All Modules		1850	-	-	Vac

SECTION 3 ELECTRICAL SPECIFICATIONS CON'T

PMBus™ Communications - CmA-W01, CmB-W01, CmC-W01, CmD-W01

Wide Trim modules can be monitored and controlled with the following PMBus Commands (for further details see the PMBUS Manual available for download from the Advanced Energy website.

<table>
<tr><th>Command</th><th>Description</th><th colspan="3"></th></tr>
<tr><td rowspan="5">READ_VOUT (0x8B)</td><td rowspan="5">The READ_VOUT command is used to return the output voltage measurement of the selected (or paged) module</td><td>Module</td><td>Accuracy[1]</td><td>Resolution</td></tr>
<tr><td>CmA-W01</td><td>+/- 4%</td><td>6.6 mV</td></tr>
<tr><td>CmB-W01</td><td>+/- 4%</td><td>16.5 mV</td></tr>
<tr><td>CmC-W01</td><td>+/- 4%</td><td>44.3 mV</td></tr>
<tr><td>CmD-W01</td><td>+/- 4%</td><td>82.4 mV</td></tr>
<tr><td rowspan="5">READ_IOUT (0x8C)</td><td rowspan="5">The READ_IOUT command is used to return the output current measurement of the selected (or paged) module</td><td>Module</td><td>Accuracy[2]</td><td>Resolution</td></tr>
<tr><td>CmA-W01</td><td>+/- 4%</td><td>40 mA</td></tr>
<tr><td>CmB-W01</td><td>+/- 4%</td><td>29 mA</td></tr>
<tr><td>CmC-W01</td><td>+/- 4%</td><td>16 mA</td></tr>
<tr><td>CmD-W01</td><td>+/- 4%</td><td>8 mA</td></tr>
<tr><td>READ_TEMPERATURE_1 (0x8D)</td><td colspan="4">The READ_TEMPERATURE_1 command is used to return the temperature measurement of the selected (or paged) module in Degrees Celsius. The accuracy of the READ_TEMPERATURE_1 command is +/- 10 °C, while its resolution is 1 °C.</td></tr>
<tr><td>STATUS_WORD (0x79)</td><td colspan="4">The STATUS_WORD command is used to check for the presence of fault conditions such as OTP (Overtemperature Protection) and PG (Power Good) fail.</td></tr>
<tr><td>PAGE (0x00)</td><td colspan="4">The PAGE command is used to select which of the modules subsequent commands are to be applied to. When read, this command shall return the currently selected page number.</td></tr>
<tr><td>VOUT_COMMAND (0x21)</td><td colspan="4">The VOUT_COMMAND command is used to explicitly set the output voltage of the selected (or paged) module to the commanded value.</td></tr>
<tr><td>ILIIMIT_TRIM (0xD1)</td><td colspan="4">The ILIMIT_TRIM command is used to explicitly set the current limit of the selected (or paged) module to the commanded value.</td></tr>
<tr><td rowspan="5">MODULE_ID (0xD0)</td><td rowspan="5" colspan="2">The MODULE_ID command is used to return a code representing the model type of the selected (or paged) CoolMod.</td><td>Module</td><td>ID Code</td></tr>
<tr><td>CmA-W01</td><td>0x22</td></tr>
<tr><td>CmB-W01</td><td>0x42</td></tr>
<tr><td>CmC-W01</td><td>0x62</td></tr>
<tr><td>CmD-W01</td><td>0x82</td></tr>
</table>

Note 1 - With Respect to Nominal
Note 2 - With Respect to Maximum

SECTION 3 ELECTRICAL SPECIFICATIONS CON'T

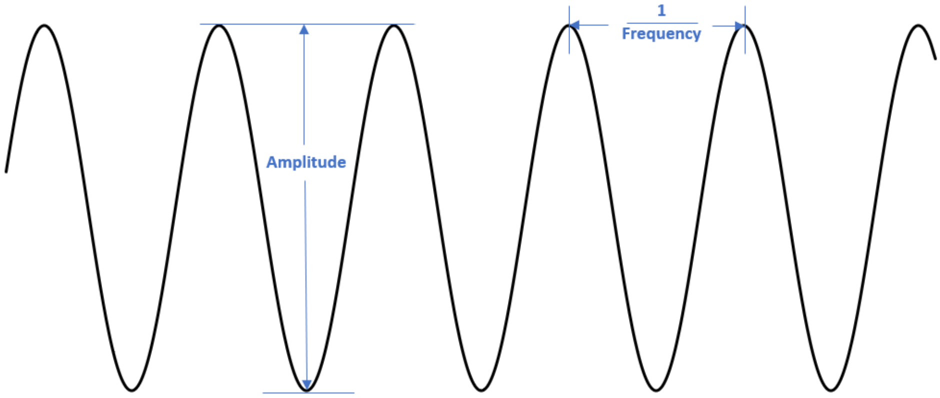
3.7 High Voltage Modules (CmK) Output Specifications

Parameter	Module	Symbol	Min	Typ	Max	Unit
Output Voltage	CmK	V_O	175	200	205	Vdc
Factory Setting Accuracy	CmK	$V_{O,factory}$	-	-	40	mV
Output Current	CmK	$I_{O,max}$	-	-	1	A
Output Power[1]	CmK	$P_{O,max}$	-	-	200	W
Capacitive Loading[2]	CmK	$C_{O,max}$	-	-	100	uF

Note 1 - Maximum output current to be derated by 10% when used in parallel.
Note 2 - Maximum output power to be derated when CoolX is used in ambient temperatures greater than 40°C - see page 48 - Thermal Derating for further details.
Note 3 - Maximum capacitive load of the module to ensure monotonic startup (with no additional load applied). Higher capacitive loading is possible if non-monotonic startup is acceptable. Contact technical support for further detail.

SECTION 3 ELECTRICAL SPECIFICATIONS CON'T

Ripple and Noise - CmK



Parameter	Module	Symbol	Min	Typ	Max	Unit
Output Ripple[1]	CmK	$V_{O,ripple}$	-	-	2000	mV
Output Ripple Frequency[2]	CmK	f	220	-	260	KHz

Note 1 - Amplitude of ripple measured at nominal voltage and at 20 MHz Bandwidth

Regulation - CmK

Parameter	Module	Symbol	Min	Typ	Max	Unit
Load Regulation	CmK	V_O	-	-	2000	mV
Load Regulation Paralleled[1]	CmK	V_O	-	-	4000	mV
Line Regulation	CmK	V_O	-	-	1000	mV
Temperature Regulation[2]	CmK	V_O	-	-	0.02	%/^{O}C

Note 1 - Load Regulation is softened in parallel mode to improve current share
Note 2 - Over ambient temperature change

SECTION 3 ELECTRICAL SPECIFICATIONS CON'T

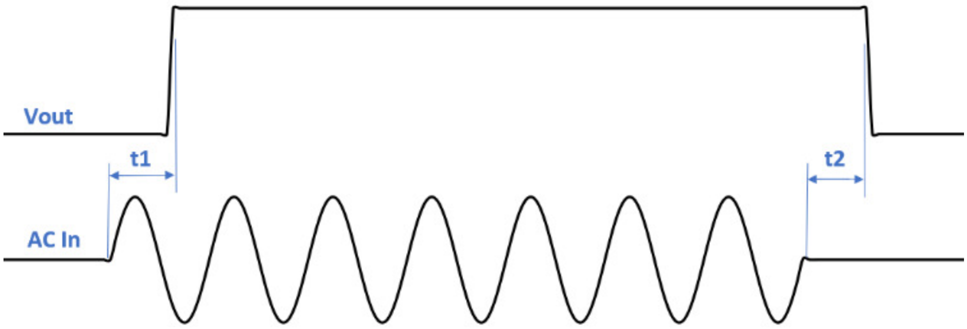
Protective Limits - CmK

Parameter	Module	Symbol	Min	Typ	Max	Unit
Current Limit[1]	CmK	$I_{O,limit}$	1.05	-	1.3	A
Short-Circuit Current Limit[2]	CmK	$I_{O,short}$	-	-	1	A
Power Limit[3]	CmK	$P_{O,limit}$	210	-	270	W
Overvoltage Protection[4]	CmK	V_O	230	-	250	V

Note 1 - Constant Current Limit into Hiccup. Auto-Recovery
Note 2 - Auto-Recovery, Measured over 5 hiccup cycles
Note 3 - Voltage Foldback into Hiccup, Auto-Recovery
Note 4 - Shutdown (All outputs), Auto-Recovery

SECTION 3 ELECTRICAL SPECIFICATIONS CON'T

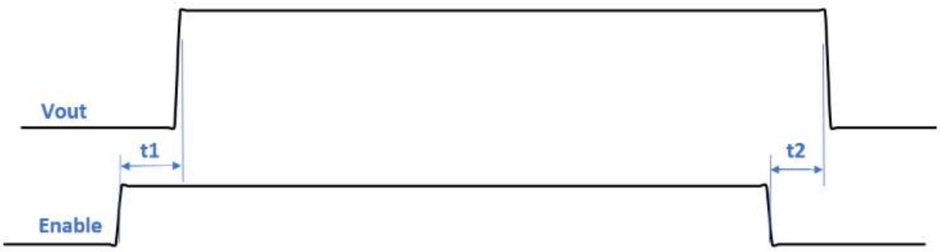
Start-Up / Shut-Down - CmK



Parameter	Module	Symbol	Min	Typ	Max	Unit
Turn-On Delay[1]	CmK	t1	-	-	1000	mS
Turn-Off Delay[2]	CmK	t2	16	-	-	mS

Note 1 - Time from Application of Input AC to Output Voltage Regulation (t1)
Note 2 - From Loss of AC to Loss of Output Voltage Regulation - Nominal Voltage (t2)

Enable / Disable - CmK

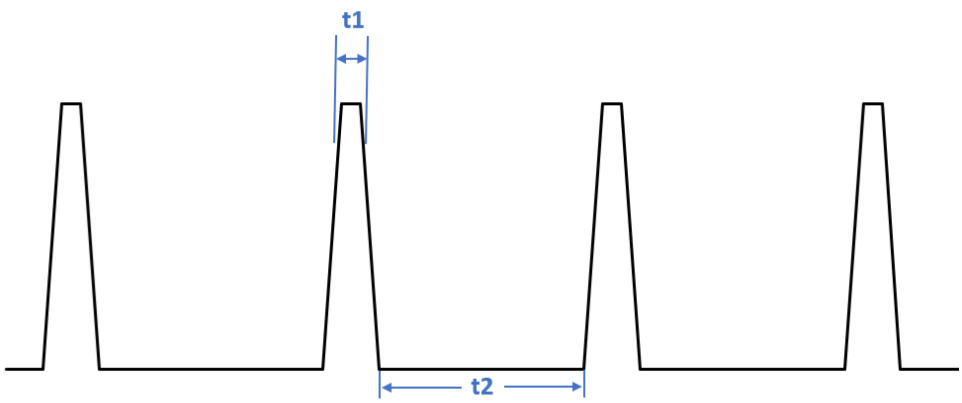


Parameter	Module	Symbol	Min	Typ	Max	Unit
Enable Delay[1]	CmK	t1	-	-	30	mS
Enable Delay (From Deep Sleep)[2]	CmK	t1	-	-	700	mS
Rise Time[3]	CmK		4	-	20	mS
Disable Delay[4]	CmK	t2		-	30	mS
Fall Time[5]	CmK		0.01	-	3	mS

Note 1 - Time from application of Enable signal to Output Voltage Regulation (t1)
Note 2 - The CoolX3000 will enter a power saving Deep Sleep mode if all modules have been disabled for more than 5 seconds.
Note 3 - Measured from 10 - 90% of Vout
Note 4 - Time from application of Disable signal to loss of Output Voltage Regulation (t2)
Note 5 - Fully Loaded measured from 90% - 10% of Vout

SECTION 3 ELECTRICAL SPECIFICATIONS CON'T

Hiccup Characteristics - CmK

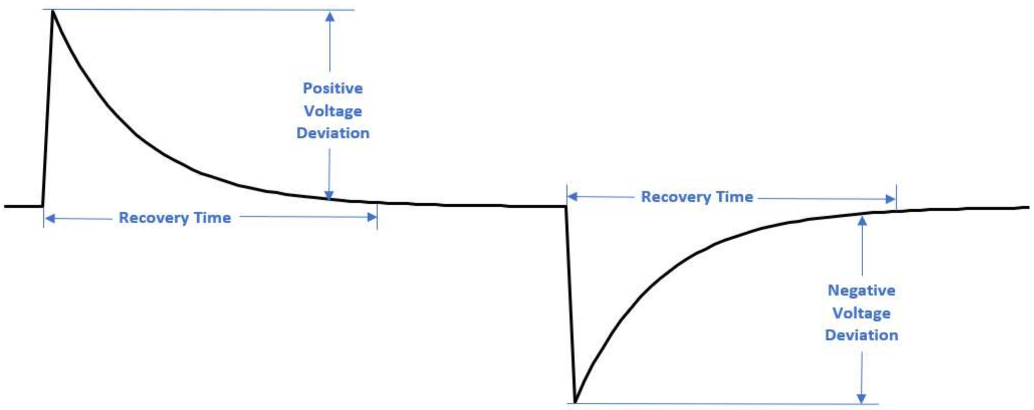


Parameter	Module	Symbol	Min	Typ	Max	Unit
Hiccup On-Time[1]	CmK	t1	1	-	100	mS
Hiccup Off-Time[2]	CmK	t2	900	-	1200	mS
Short Circuit Hiccup Level[3]	CmK	$V_{O,Short}$	37	-	53	V

Note 1 - Length of time output is on during hiccup (t1)
Note 2 - Length of time output is off during hiccup (t2)
Note 3 - Output voltage at which module enters hiccup protection

SECTION 3 ELECTRICAL SPECIFICATIONS CON'T

Transient Response - CmK



Parameter	Module	Symbol	Min	Typ	Max	Unit
Transient Response, Voltage Deviation[1]	CmK	V_O	-	-	7.5	V
Transient Response, Recovery Time[1]	Cmk		-	-	1000	uS
Transient Response, Voltage Deviation[2]	CmK	V_O	-	-	7.5	V
Transient Response, Recovery Time[2]	Cmk		-	-	500	uS

Note 1 - Measured during 25% - 75% and 75% - 25% Step Load Changes
Note 2 - Measured during 10% - 100% and 100% - 10% Step Load Changes

Galvanic Isolation - CmK

Parameter	Module	Symbol	Min	Typ	Max	Unit
Input to Output 2 x MOPP	CmK		4000	-	-	Vac
Output to Output 1 x MOPP	Cmk		1850	-	-	Vac

SECTION 3 ELECTRICAL SPECIFICATIONS CON'T

PMBus™ Communications - CmK

High Voltage modules can be monitored and controlled with the following PMBus Commands (for further details see the PMBus™ Manual available for download from the Advanced Energy website.

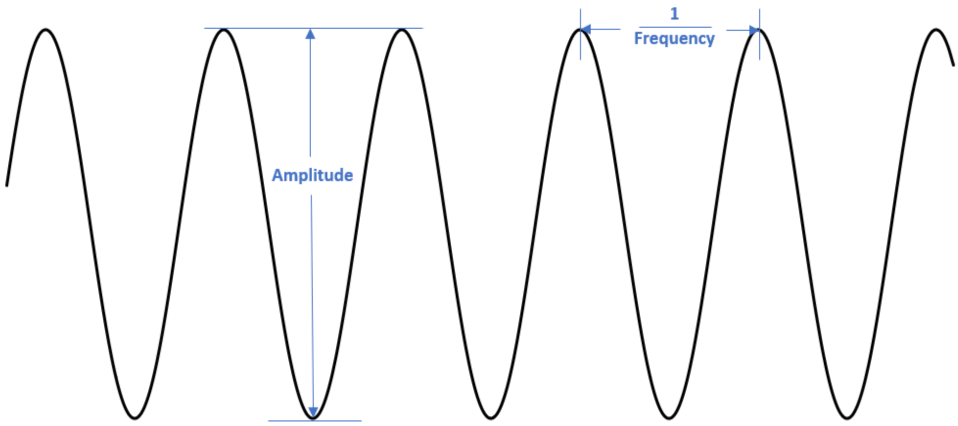
Command	Description			
READ_VOUT (0x8B)	The READ_VOUT command is used to return the output voltage measurement of the selected (or paged) module.	Module	Accuracy[1]	Resolution
		CmK	+/- 4%	280 mV
READ_IOUT (0x8C)	The READ_IOUT command is used to return the output current measurement of the selected (or paged) module.	Module	Accuracy[2]	Resolution
		CmK	+/- 4%	2 mA
READ_TEMPERATURE_1 (0x8D)	The READ_TEMPERATURE_1 command is used to return the temperature measurement of the selected (or paged) module in Degrees Celsius. The accuracy of the READ_TEMPERATURE_1 command is +/- 10 °C, while its resolution is 1 °C.			
STATUS_WORD (0x79)	The STATUS_WORD command is used to check for the presence of fault conditions such as OTP (Overtemperature Protection) and PG (Power Good) fail.			
PAGE (0x00)	The PAGE command is used to select which of the modules subsequent commands are to be applied to. When read, this command shall return the currently selected page number.			
VOUT_COMMAND (0x21)	The VOUT_COMMAND command is used to explicitly set the output voltage of the selected (or paged) module to the commanded value.			
ILIMIT_TRIM (0xD1)	The ILIMIT_TRIM command is used to explicitly set the current limit of the selected (or paged) module to the commanded value.			
MODULE_ID (0xD0)	The MODULE_ID command is used to return a code representing the model type of the selected (or paged) CoolMod.		Module	ID Code
			CmK	0xA0
Note 1 - With Respect to Nominal Note 2 - With Respect to Maximum				

SECTION 3 ELECTRICAL SPECIFICATIONS CON'T

3.8 Auxiliary Output Specifications

Parameter	Option	Symbol	Min	Typ	Max	Unit
Output Voltage	12V (Option A) 5V (Option B)	V_{AUX}	11.60 4.80	12.00 5.00	12.40 5.20	Vdc
Output Current	12V (Option A) 5V (Option B)	$I_{AUX,max}$	- -	- -	1.96 4.7	A
Output Power	12V (Option A) 5V (Option B)	$P_{AUX,max}$	- -	- -	23.5 23.5	W

Ripple and Noise - Auxiliary Output



Parameter	Module	Symbol	Min	Typ	Max	Unit
Output Ripple[1]	12V (Option A) 5V (Option B)	$V_{AUX,ripple}$	- -	- -	480 200	mV mV
Output Ripple Frequency	Both Options	f	180	-	220	KHz

Note 1 - Amplitude of ripple measured at nominal voltage and at 20 MHz Bandwidth

SECTION 3 ELECTRICAL SPECIFICATIONS CON'T

Regulation - Auxiliary Output

Parameter	Option	Symbol	Min	Typ	Max	Unit
Load Regulation 0-100% Load	12V (Option A) 5V (Option B)	V_{AUX}	- -	- -	96 40	mV
Line Regulation 85-264 Vac	12V (Option A) 5V (Option B)	V_{AUX}	- -	- -	36 15	mV

Protective Limits - Auxiliary Output

Parameter	Option	Symbol	Min	Typ	Max	Unit
Current Limit[1]	12V (Option A) 5V (Option B)	$I_{AUX,limit}$	2.0 5.0	- -	2.8 6.8	A
Short-Circuit Current Limit[2]	12V (Option A) 5V (Option B)	$I_{AUX,short}$	- -	- -	1.0 2.4	A
Power Limit[3]	12V (Option A) 5V (Option B)	P_{AUX}	24.6 24.1	- -	33.6 33.6	W

Note 1 - Hiccup, Auto-Recovery
Note 2 - Measured over 5 hiccup cycles
Note 3 - Hiccup, Auto-Recovery

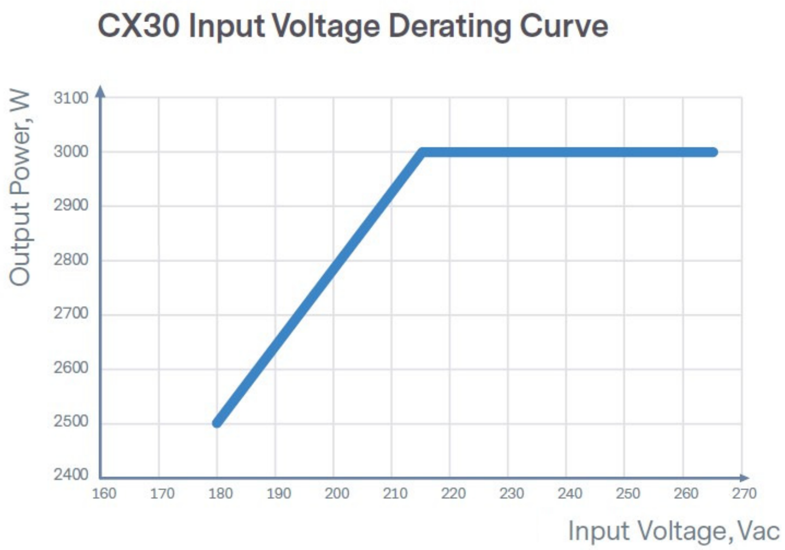
Galvanic Isolation - Auxiliary Output

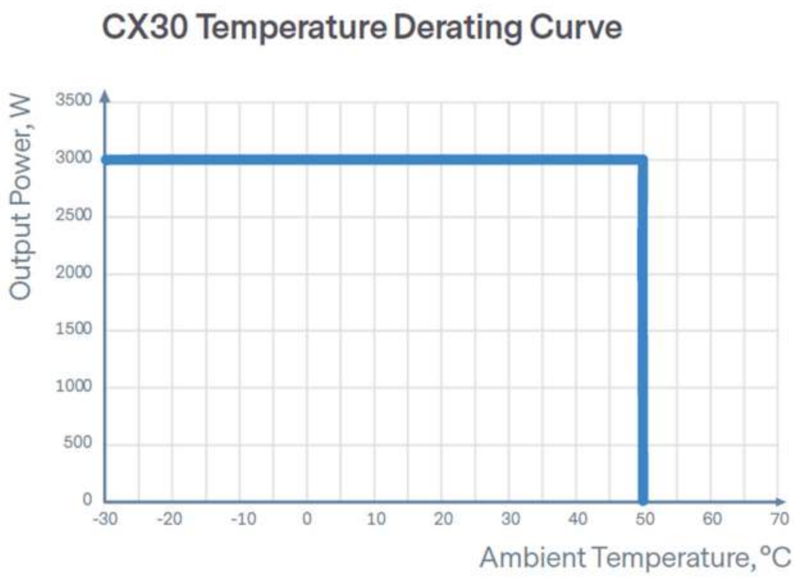
Parameter	Module	Symbol	Min	Typ	Max	Unit
Input to Output 2 x MOPP	Both Options		4000	-	-	Vac
Output to Output 1 x MOPP	Both Options		1850	-	-	Vac

SECTION 3 ELECTRICAL SPECIFICATIONS CON'T

3.9 Power Ratings

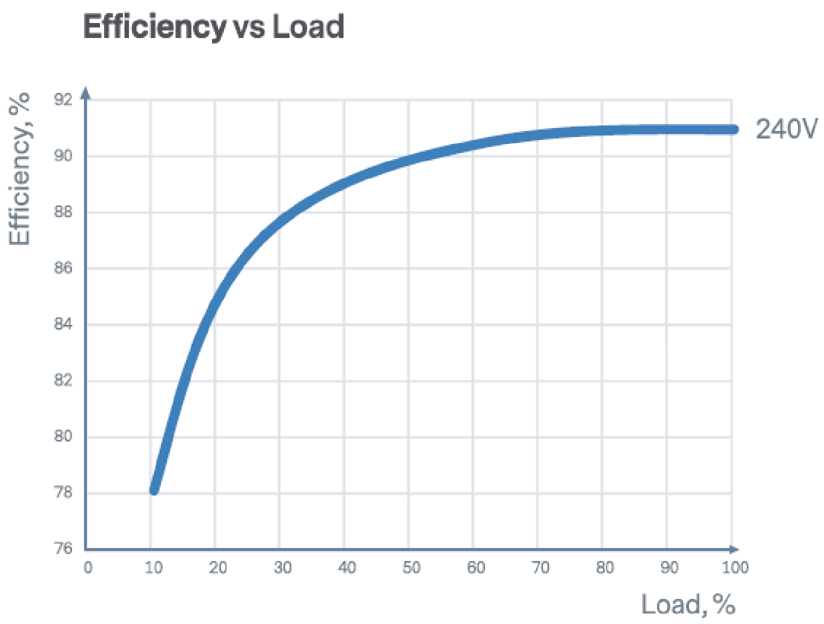
When selecting a power supply for an application it is necessary to ensure it operates within its power capabilities by taking into account both Temperature Derating and Input Voltage Derating. Input Voltage Derating and Temperature Derating curves are shown below. Line Derating applies to the CoolPac only while Temperature Derating applies to both the CoolPac and the CoolMods.





SECTION 3 ELECTRICAL SPECIFICATIONS CON'T

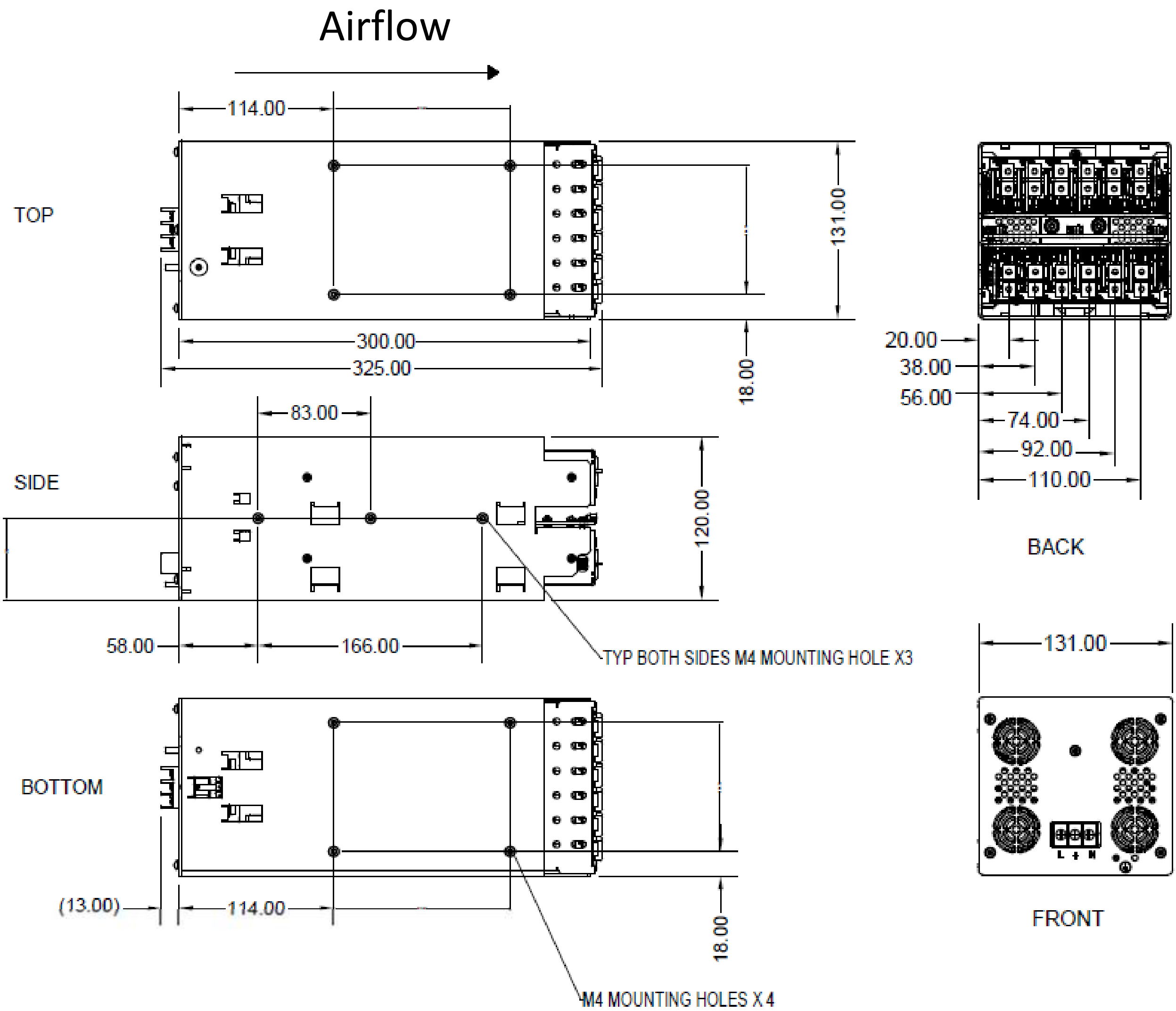
3.10 Efficiency Curve at 240V input



SECTION 4 MECHANICAL SPECIFICATIONS

4.1 Mechanical Information

The CoolX3000 mechanical outline is shown below. Full 3D and STEP files can be downloaded from www.advancedenergy.com or alternatively contact productsupport.ep@aei.com for details.



ISOMETRIC VIEW

BACK VIEW

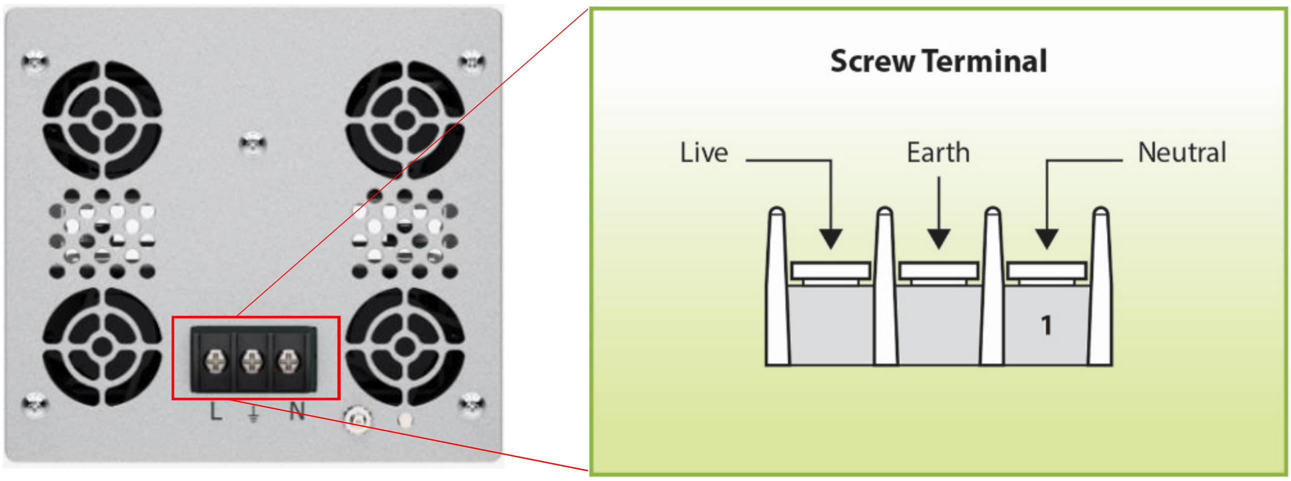
FRONT VIEW

SECTION 4 MECHANICAL SPECIFICATIONS CON'T

4.2 Connectors Definition and Mating Connector

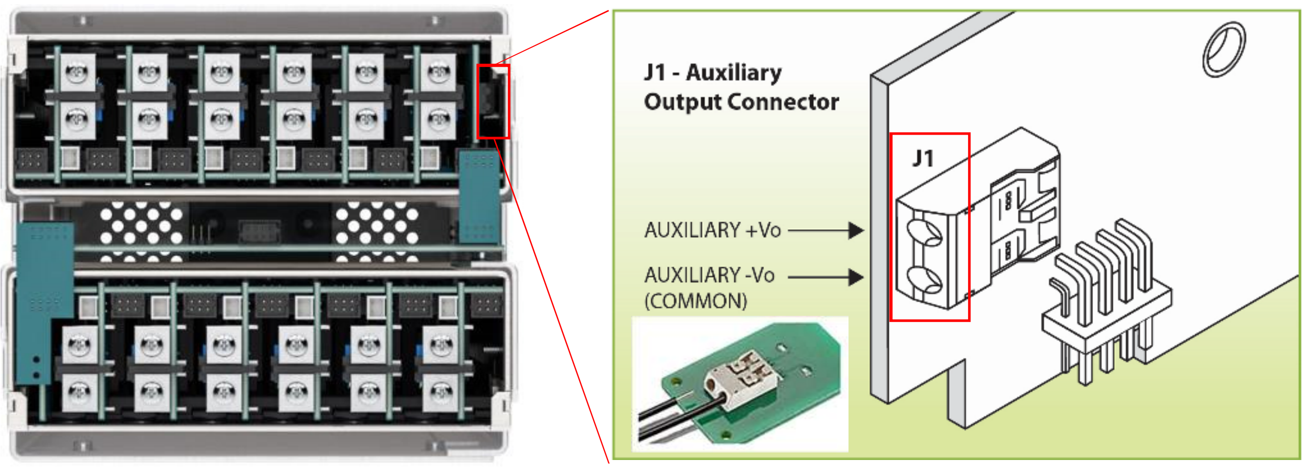
Input Connectors (CoolPac)

AC mains is applied to the CoolX via the 3 Screw Terminal.



Auxiliary Bias Supply Voltage

The Auxiliary Bias supply (always ON) of 12V/1.96A or 5V/4.7A (optional) is provided on J1 connector of the unit A only.

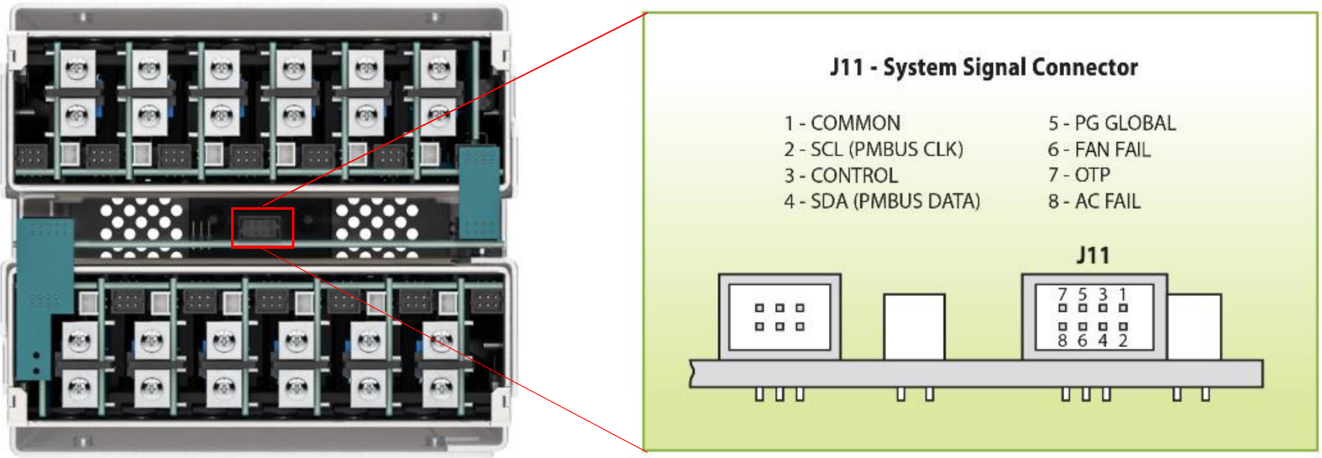


Reference	On Power Supply	Mating Connector or Equivalent
J1 Auxiliary Output Connector	Molex 104188-0210	Stripped Wire

SECTION 4 MECHANICAL SPECIFICATIONS CON'T

Global System Signal Connector

The System Signal Connector contains all the Global signals including AC Fail, Power Good, and Over-Temperature Alarm.

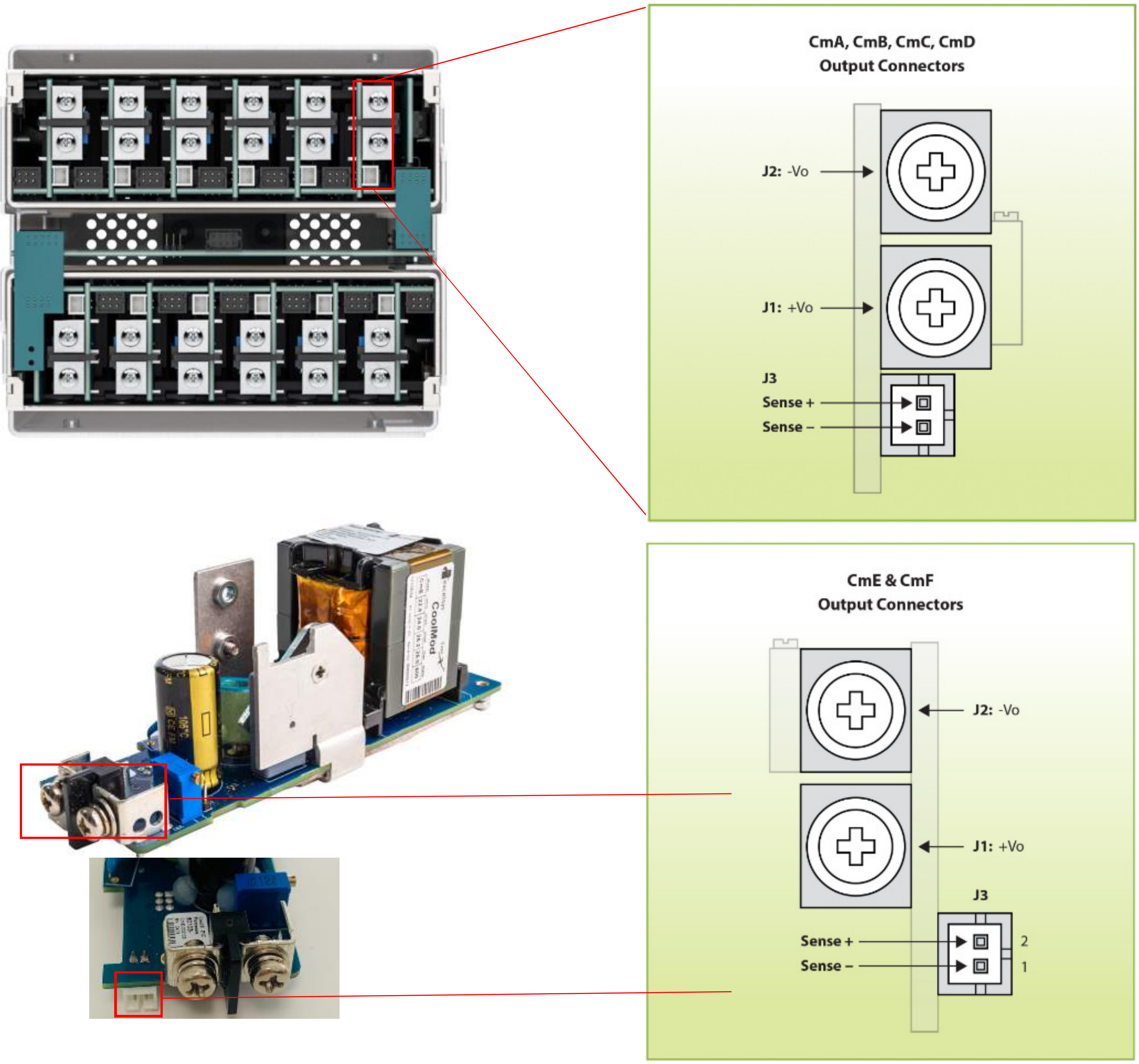


Reference	On Power Supply	Mating Connector or Equivalent
J11 System Signal Connector	8-way Molex: 87833-0831	Locking Molex: 51110-0860, Non-Locking Molex: 51110-0850; Locking and Polarizing: 51110-856 Crimp Terminal: Molex p/n 50394

SECTION 4 MECHANICAL SPECIFICATIONS CON'T

Output Power and Sense Connectors (Standard, Wide-Trim and High Power Modules)

Each CoolMod (CmA-D and CmE-F) has Power Terminals (J1 and J2) and a Remote Sense Connector (J3).

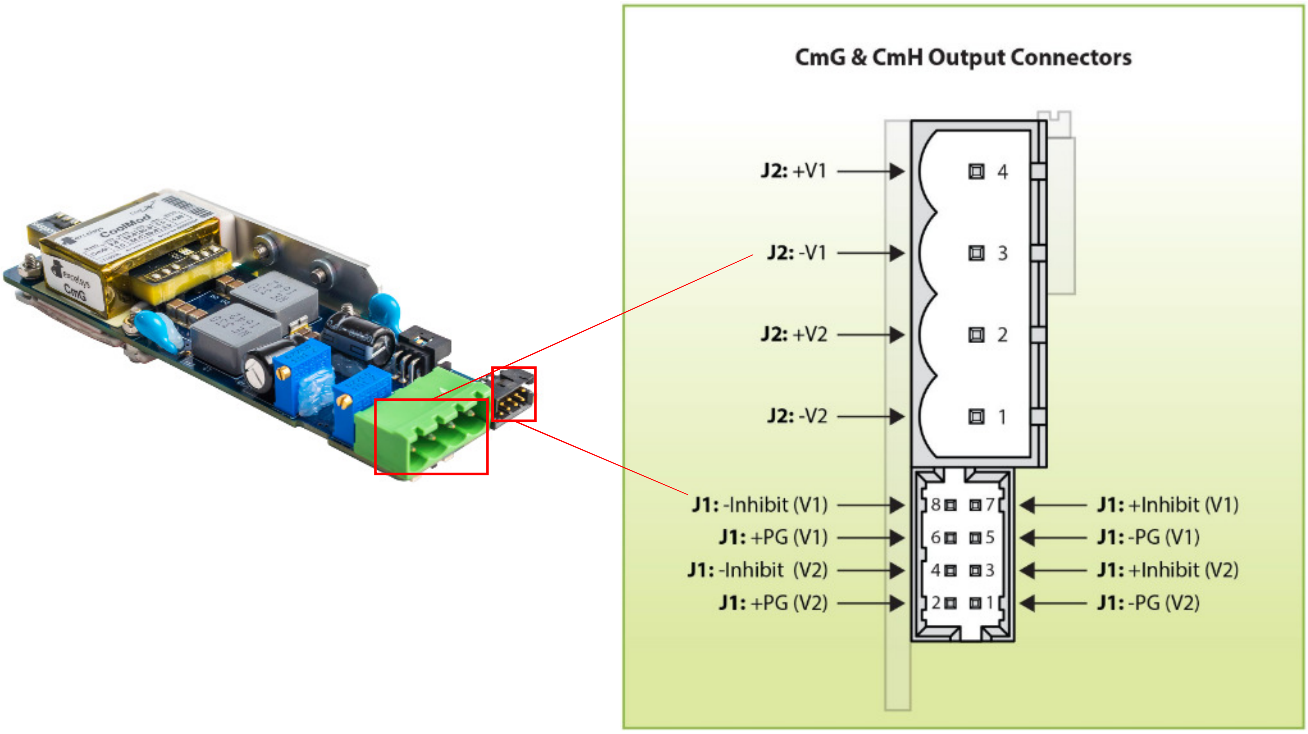


Reference	On Power Supply	Mating Connector or Equivalent
J1 & J2 Output Connectors	Terminals	M4 Screws
J3 Sense Connector	JST - S2BPH-K-S (LF) (SN)	JST PHR-2, Crimp: JST BPH-002T-P0.5S or SPH-002T-P0.5S

SECTION 4 MECHANICAL SPECIFICATIONS CON'T

Output Power and Signal Connectors (CmG-H)

The CmG and CmH modules have a Dual Power Terminal J2 and a Signal Connector J1.

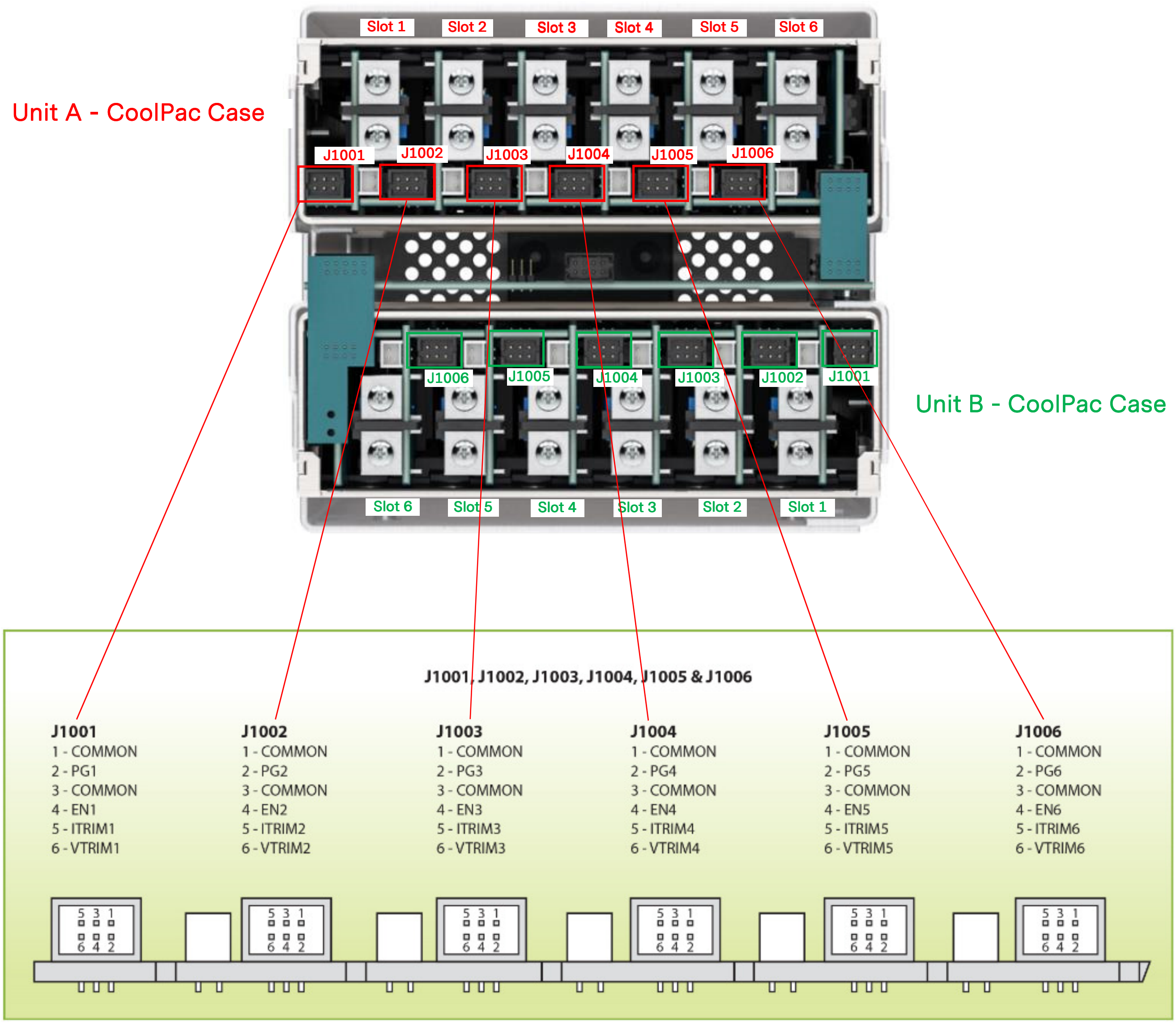


Reference	On Power Supply	Mating Connector or Equivalent
J1 CmG/CmH Signal Connector	8-way Molex: 87833-0831	Locking Molex: 51110-0860, Non-Locking Molex: 51110-0850; Locking and Polarizing: 51110-856 Crimp Terminal: Molex p/n 50394
J2 Power Terminal	Camden: CTB9350/4A Wurth Elektronik: 691 313 710 004	Camden: CTB9200/4A Wurth Elektronik: 691 352 710 004

SECTION 4 MECHANICAL SPECIFICATIONS CON'T

DC Output Signals and Control Connectors

The DC Output Signals Connectors contain the individual Output Signals and Control Signals, including, PG, EN, VTRIM, ITRIM.



Reference	On Power Supply	Mating Connector or Equivalent
J1001-J1006	6-way Molex: 87833-0631	Locking Molex: 51110-0660; Non-Locking Molex: 51110-0650 Locking and Polarizing Molex: 51110-0656 Crimp Terminal: Molex p/n 50394

SECTION 4 MECHANICAL SPECIFICATIONS CON'T

Mounting Options

Base Plate Mounting

The CoolX3000 can be mounted in the system via the 4 mounting holes on the base of the power supply. See mechanical drawings for mounting hole positions. Use M4 mounting screws and ensure that maximum screw penetration from base does not exceed 9mm.

Side Mounting

The CoolX3000 can be mounted in the system via the 3 mounting holes on each side of the case. See mechanical drawings for mounting hole positions. Use M4 mounting screws and ensure that maximum screw penetration from base does not exceed 9mm.

SECTION 5 ENVIRONMENTAL SPECIFICATIONS

5.1 Environmental Parameters

The CoolX3000 series are designed for the following parameters

- Material Group IIIb, Pollution Degree 2
- Installation Category 2
- Class I
- Indoor use (installed, accessible to Service Engineers only).
- Altitude: -155 meters to +5000 meters from sea level.
- Humidity: 5 to 95% non-condensing.
- Operating temperature -20 °C to 60

In addition, CoolX3000 is compliant with the following directives:

RoHS 3.0	EU Directive 2015/863 RoHS compliancy
REACH	Compliant

Additional Information

Additional information such as Application Note, White Papers, Safety Certificates etc. are available at www.advancedenergy.com . Alternatively, please do not hesitate to contact productsupport.ep@aei.com if you have any further questions or need additional information.

SECTION 5 ENVIRONMENTAL SPECIFICATIONS CON'T

5.2 EMC Characteristics

EMC Directive 2004/108/EC

Component Power Supplies such as the CoolX series are not covered by the EMC directive. It is not possible for any power supply manufacturer to guarantee conformity of the final product to the EMC directive, since performance is critically dependent on the final system configuration. System compliance with the EMC directive is facilitated by AE products compliance with several of the requirements as outlined in the following paragraphs. Although the CoolX meets these requirements, the CE mark does not cover this area.

The table below outlines the EMC characteristics of the CoolX3000 power supply under load conditions.

A full EN60601-1-2 4th edition test report is available on request. Contact Advanced Energy for details.

Parameter	Conditions/Descriptions	Criteria
Radiated Emissions	EN55011, EN55022 and FCC, Class B	-
Conducted Emissions	EN55011, EN55022 and FCC, Class B	-
Power Line Harmonics	EN61000-3-2, Class A	-
Voltage Flicker	EN61000-3-3	-
ESD	EN61000-4-2, Level 4, 8kV Contact, 15kV air	A
Radiated Immunity	EN61000-4-3, Level 3, 10V/m	A
Electrical Fast Transient	EN61000-4-4, Level 4, ±4kV	A
Surge Immunity	EN61000-4-5, Level 4, 2kV DM, 4kV CM	A
Conducted RF Immunity	EN61000-4-6, Level 3, 10Vrms	A
Power Frequency Magnetic Field	EN61000-4-8, Level 4, 30A/m	A

Radiated EMI should be tested in a system environment, Radiated EMI performance in a system will vary significantly from a stand-alone power supply due to the system enclosure which will provide additional shielding.

Criteria A: The apparatus shall continue to operate as intended. No degradation of performance or loss of function is observed during or after the test.

Criteria B: The apparatus shall continue to operate as intended after the test. No degradation of performance or loss of function is allowed below a performance level specified by the manufacturer when the apparatus is used as intended. During the test, temporary degradation of performance is allowed if is self-recoverable.

Criteria C: Temporary loss of function is allowed during and after the test that require operator intervention to restore the product/apparatus to normal operation.

Criteria D: During the test, Loss of function which is not recoverable.

SECTION 5 ENVIRONMENTAL SPECIFICATIONS CON'T

Additional EMI Characterization

CoolX3000 is compliant with SEMI F47 for voltage dips and interruptions. Input voltage must be >180Vac

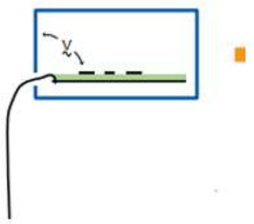
Guidelines for Optimal EMC Performance

CoolX3000 series products are designed to comply with European Normative limits (EN) for conducted and radiated emissions and immunity when correctly installed in a system. See performance levels attained in previous page. However, power supply compliance with these limits is not a guarantee of system compliance. System EMC performance can be impacted by a number and combination items. Design consideration such as PCB layout and tracking, cabling arrangements and orientation of the power supply amongst others all directly contribute to the EMC performance of a system.

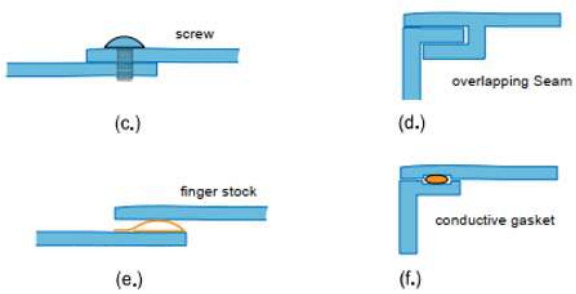
Cabling arrangements and PCB tracking layouts are the greatest contributing factors to system EMC performance. It is important that PCB tracks and power cables are arranged to minimise current carrying loops that can radiate, and to minimise loops that could have noise currents induced into them. All cables and PCB tracks should be treated as radiation sources and antenna and every effort should be made to minimise their interaction

- Route all cables as close as possible to a well earthed sheet of metal.
- Keep all cable lengths as short as possible
- Minimise the area of power carrying loops to minimise radiation, by using twisted pairs of power cables with the maximum twist possible.
- Run PCB power tracks back to back.
- Minimise noise current induced in signal carrying lines, by twisted pairs for sense cables with the maximum twist possible.
- Do not combine power and sense cables in the same harness.
- Ensure good system grounding. System Earth should be a "starpoint". Input earth of the equipment should be directed to the "starpoint" as soon as possible. The power supply earth should be connected directly to the "starpoint". All other earths should go to the 'starpoint".

If the power supply is enclosed in a larger system enclosure, it is preferable to use a conductive metal enclosure and that all seams have a good conductive bond using one of these methods.



System enclosure

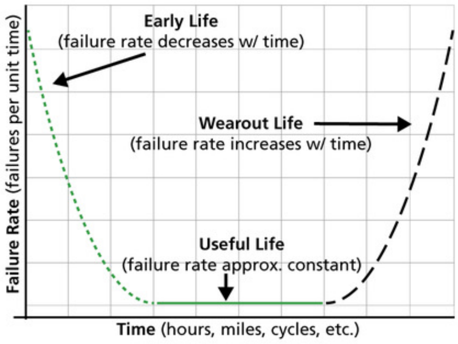


Treatment of Seams

SECTION 5 ENVIRONMENTAL SPECIFICATIONS CON'T

5.3 Reliability

The 'bath-tub' curve shows how the failure rate of a power supply develops over time. It is made up of three separate stages. Immediately after production, some units fail due to defective components or production errors. To ensure that these early failures do not happen while in the possession of the user, carries out a full burn-in on each unit, designed to ensure that all these early failures are detected at Advanced Energy. After this period, the power supplies fail very rarely, and the failure rate during this period is fairly constant. The reciprocal of this failure rate is the MTBF (Mean Time Between Failures).



At some time, as the unit approaches its end of life, the first signs of wear appear and failures become more frequent. Generally 'lifetime' is defined as that time where the failure rate increases to five times the statistical rate from the flat portion of the curve. In summary, the MTBF is a measurement of how many devices fail in a period of time (i.e. a measure of reliability), before signs of wear set in. On the other hand, the lifetime is the time after which the units fail due to wear appearing. The MTBF may be calculated mathematically as follows:

MTBF = Total x t / Failure, where

Total is the total number of power supplies operated simultaneously.
Failure is the number of failures.
t is the observation period.

MTBF may be established in two ways, by actual statistics on the hours of operation of a large population of units, or by calculation from a known standard such as latest Telecordia SR-332.

Determining MTBF by Calculation

MTBF, when calculated in accordance with Telecordia, and other reliability tables involves the summation of the failure rates of each individual component at its operating temperature. The failure rate of each component is determined by multiplying a base failure rate for that component by its operating stress level. The result is FPMH, the failure rate per million operating hours for that component. Then FPMH for an assembly is simply the sum of the individual component FPMH.

Total FPMH = FPMH1 + FPMH2 + ………... +FPMHn
MTBF (hours) = 1,000,000 ÷ FPMH
In this manner, MTBF can be calculated at any temperature.
CoolMod (CmA-D): 0.11 failures per million hours
CoolPac: 1.1 failures per million hours
Example: What is the MTBF of C3SBCCD00BCCD00NA?
C3S FPMH = 1.1
CmA, B, C, D FPMH = 0.11 each
Total FPMH = 1.1 + (8 x 0.11) = 1.98 FPMH.
MTBF = 505050 hours at 40 °C

SECTION 5 ENVIRONMENTAL SPECIFICATIONS CON'T

MTBF and Temperature

Reliability and MTBF are highly dependent on operating temperature. The figures above are given at 40 ^{O}C. For each 10 ^{O}C decrease, the MTBF increases by a factor of approximately 2.

Conversely, however, for each 10 ^{O}C increase, the MTBF reduces by a similar factor. Therefore, when comparing manufacturer's quoted MTBF figures, look at the temperature information provided.

Shelf Life of Power Supplies

If electrolytic capacitors are stored without voltage for an extended period of time, the oxide film on the anode foil can deteriorate which will result in higher than specified leakage current when voltage is applied. This has a negative impact on the ripple current on the capacitor, which results in additional heating of the component and has a direct impact on reliability.

According to published research, the commencement of this chemical reaction can occur after a two year period of an unpowered unit, and as such Advanced Energy recommends that the maximum shelf life for our platform designs is two years.

SECTION 6 SAFETY APPROVALS / CERTIFICATION

6.1 Safety Approvals

C3M is certified to IEC60601-1 3rd Edition and IEC60601-1-2 4th Edition for medical applications.

C3S is certified to IEC62368-1.

Galvanic isolation levels are shown below

Input to Output	Reinforced (2 x MOPP)	4000Vac
Input to Case (GND)	Basic (1 x MOPP)	1850Vac
Output to Case (GND)	Basic (1 x MOPP)	1850Vac
Output to Output	Basic (1 x MOPP)	1850Vac

Low Voltage Directive (LVD) 2006/95/EC.

The LVD applies to equipment with an AC input voltage of between 50V and 1000V or a DC input voltage between 75V and 1500V. The CoolX series is CE marked to show compliance with the LVD. The relevant European standard for CoolX is EN60950 2nd Edition (Information technology). The relevant European standard for CoolX is EN60601-1 3rd Edition (Medical Devices Directive).

The full table of Safety certifications are listed below

Module	Standard	Certification/Description
C3S	IEC 62368-1 Edition 2	IEC 62368-1 (2014) Edition 2 5000m (16,400ft) altitude, 100 - 240Vac ±10%
C3M	IEC/EN 60601-1 Edition 3 and all national deviations	IEC 60601-1(2005), EN 60601-1(2006) ANSI/AAMI ES 60601-1(2005) CAN/CSA C22.2 No. 60601-1 (2008) 5000m (16,400ft) altitude, 100-240Vac ±10%

SECTION 7 OPERATION - POWER, CONTROL AND COMMUNICATION

7.1 CoolX3000 Operation

The CoolX3000 provides the front end input power to the CoolMod. The CoolPac operates of 180-264Vac, 47-440Hz and can withstand 300Vac input voltage for up to 5 secs.

The CoolPac can also operate off DC inputs of 283-340Vdc.

There are two CoolPac versions.

- C3S for Industrial and Hi Rel Applications
- C3M for Medical Applications

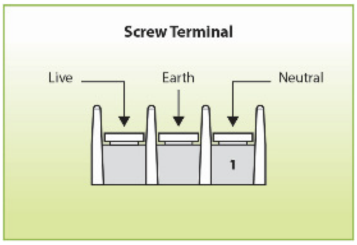
7.2 Input Power

AC Input Connector

L - Live

⏚ - Earth

N - Neutral



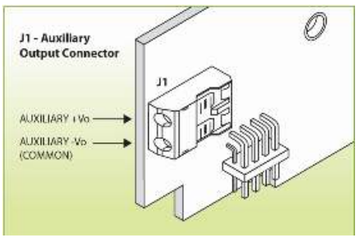
7.3 System/Global Output/ Signal

J1 - AUX Output Connector

CoolX3000 has a SELV isolated 24W auxiliary (always on) voltage of 12V/1.97A or 5V/4.7A (optional). This is available through the J1 connector on the upper CoolX3000. This Bias supply output has 4000Vac isolation from the primary and is ideal for powering displays, system housekeeping, control circuits or may be used as an additional output voltage. Please note that the negative of the auxiliary (-Vo) is connected to the Common of the System Signal Connector.

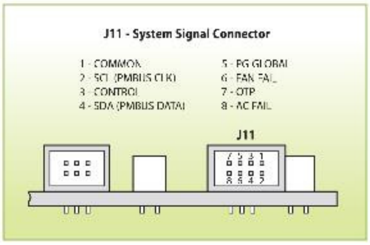
AUXILIARY +Vo - +AUXILIARY Output (V_{AUX})

AUXILIARY -Vo - AUXILIARY Output Return



SECTION 7 OPERATION - POWER, CONTROL AND COMMUNICATION

J11 - System Signal Connector



COMMON - (Pin 1 of J11)

Ground reference of the system signal, this is connected to V- of the auxiliary output.

SCL, SDA (PMBUS CKL and PMBUS DATA) - (Pins 2, 4 of J11)

PMBus serial clock and data bus - These pins will be pulled-up by the user to a 3.3V or 5V bus. A resistor value of 2k - 10k is recommended.

CONTROL (Global Enable/Inhibit) - (Pin 3 of J11)

All outputs will be enabled/inhibited simultaneously by means of an appropriate signal applied to the Control input on J11, between Pin 3 (Control) and Pin 1 (Common). Under normal conditions Pin 3 is pulled to 5V internally (logic high) and all modules are enabled. To disable all modules simply pull Pin 3 to Common (logic low). There is a max 15ms delay from change in signal logic to change in output voltage.

If all modules have been disabled for more than 5 seconds, the CoolX will enter a low power consumption Deep Sleep mode of operation. There is a max 700ms delay when enabling modules from Deep Sleep. When not in Deep Sleep, there is a max 30ms delay from change in signal logic to change in output voltage.

The Control pin has a 1K ohm series resistor and a 100nF filtering capacitor to filter noise on this signal. The maximum allowable voltage on Pin 3 is 5V.

PG GLOBAL (Global Power Good) - (Pin 5 of J11)

A PG GLOBAL signal is controlled with an NPN transistor providing an unbiased open collector signal that is available on the J11 System Signal Connector via the collector on Pin 5 and the emitter on Pin 1 (Common). This is activated when all enabled CoolMods report individual Power Good for their outputs. There is a 390 ohm resistor in series with the collector for current limiting. When the output of all CoolMods are within 10% of Vset, the transistor is turned on. When the output of any enabled CoolMod is >10% outside of Vset, the transistor is turned off.

Note: The status of dual modules are not included in PG GLOBAL

The maximum collector voltage is 5V, and the maximum collector current is 12mA.

Refer to the implementation circuit and table of logics at page 66 for recommendations for driving logic level circuits with open collector signal outputs.

SECTION 7 OPERATION - POWER, CONTROL AND COMMUNICATION CON'T

FAN FAIL - (Pin 6 of J11)

The FAN FAIL Signal indicates that the four fans of the CoolX3000 are operating correctly. The Fan Fail signal is controlled with an NPN transistor providing an unbiased open collector that is available on the J11 System Signal Connector via the collector on Pin 6 and the emitter on Pin 1 (Common). There is a 390 ohm resistor in series with the collector for current limiting. During normal operation the transistor is ON. When any fan stalls or stops turning, the transistor is turned OFF, and approximately three seconds later, the CoolX3000 will shut down. The maximum collector voltage is 5V, and the maximum collector current is 12mA.

Refer to the implementation circuit and table of logics at page 66 for recommendations for driving logic level circuits with open collector signal outputs.

OTP - Over Temperature Protection - (Pin 7 of J11)

The CoolX3000 monitors internal temperatures on the power supply to ensure that component temperatures do not exceed their ratings. The OTP warning signal an unbiased open collector signal that is available on the J11 System Signal Connector via the collector on Pin 7 and the emitter on Pin 1 (Common). There is a 390 ohm resistor in series with the collector for current limiting. During normal operation the transistor is turned off. If an Over Temperature condition is detected, the OTP signal will be pulled low via a 390 ohm resistor as a pre-warning of a possible shutdown of the power supply. If the OTP condition persists for a further 2 seconds, the CoolX3000 will shut down. The CoolX3000 will auto recover when temperatures reach normal operating level.

Shut down from over temperature signal is dependent on environment, and this signal can be used to turn on an external fan or to shed loads both of which would reduce the temperature rise in the power supply.

The maximum collector voltage is 5V, and the maximum collector current is 12mA.

Refer to the implementation circuit and table of logics at page 66 for recommendations for driving logic level circuits with open collector signal outputs.

AC FAIL - (Pin 8 of J11)

The AC FAIL signal indicates that the input voltage has failed or has dropped below 70Vac. The AC Mains Fail signal is controlled with an NPN transistor providing an unbiased open collector that is available on the J11 System Signal Connector via the collector on Pin 8 and the emitter on Pin 1 (Common). There is a 390ohm resistor in series with the collector for current limiting. During normal operation the transistor is ON, when the input voltage is lost or goes below 70Vac, the transistor is turned OFF at least 1mS before loss of output voltage regulation.

The maximum collector voltage is 5V, and the maximum collector current is 12 mA.

Refer to the implementation circuit and table of logics at page 66 for recommendations for driving logic level circuits with open collector signal outputs.

SECTION 7 OPERATION - POWER, CONTROL AND COMMUNICATION CON'T

Open Collector Driving Common Logic Levels for System Signals

Each System Signals (Global Power Good, FAN FAIL, AC FAIL and OTP) is an Open Collector driver to Common with a 390 ohm resistor in series with the collector for current limiting. These outputs can safely sink up to 12mA and have a breakdown voltage of greater than 25V. Pull up resistors should be chosen to keep the sink current under 12mA. The table below shows some resistor combinations translating the Open Collector output into a voltage level suitable for various logic types with using either the 12V or 5V Auxiliary voltage. Other voltages can be used to bias these circuits with adjustments taking into account the 12mA max sink current and the 390 ohm resistance in series with the collector.

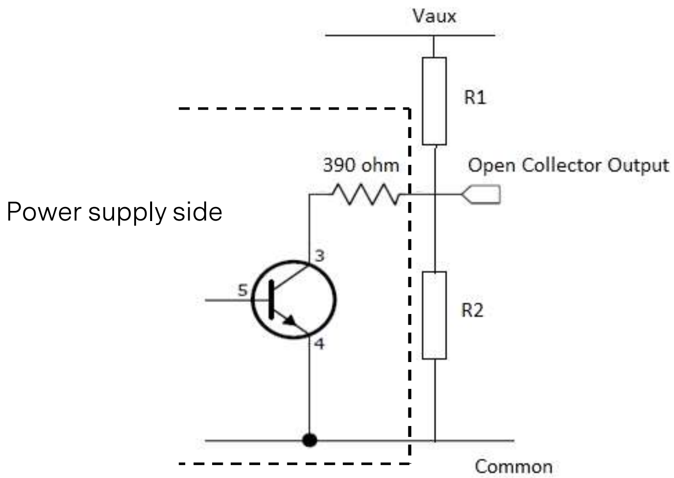


Table of Logics

Auxiliary Voltage	Logic Voltage	R1	R2	V_{high}	V_{low}	$I_{sink\ max}$
12V	12 Volt Logic	12K ohm	Open	12V	0.4V	12mA
12V	5 Volt Logic	10K ohm	7K ohm	4.9V	0.45V	12mA
12V	3.3 Volt Logic	10K ohm	3.9K ohm	3.2V	0.4V	12mA
5V	5 Volt Logic	5K ohm	Open	5V	0.36V	12mA
5V	3.3 Volt Logic	5K ohm	10K ohm	3.3V	0.36V	12mA

SECTION 7 OPERATION - POWER, CONTROL AND COMMUNICATION CON'T

J13/J1011 - Global Enable Reverse - Polarity Header

Inhibit/Enable Reverse Logic Header - (Pin 1,2,3 of J13)

Short pin 1 & 2 of J13 - Reverse Polarity - see table at page 68

Short pin 2 & 3 of J13 - Normal Polarity - see table at page 68

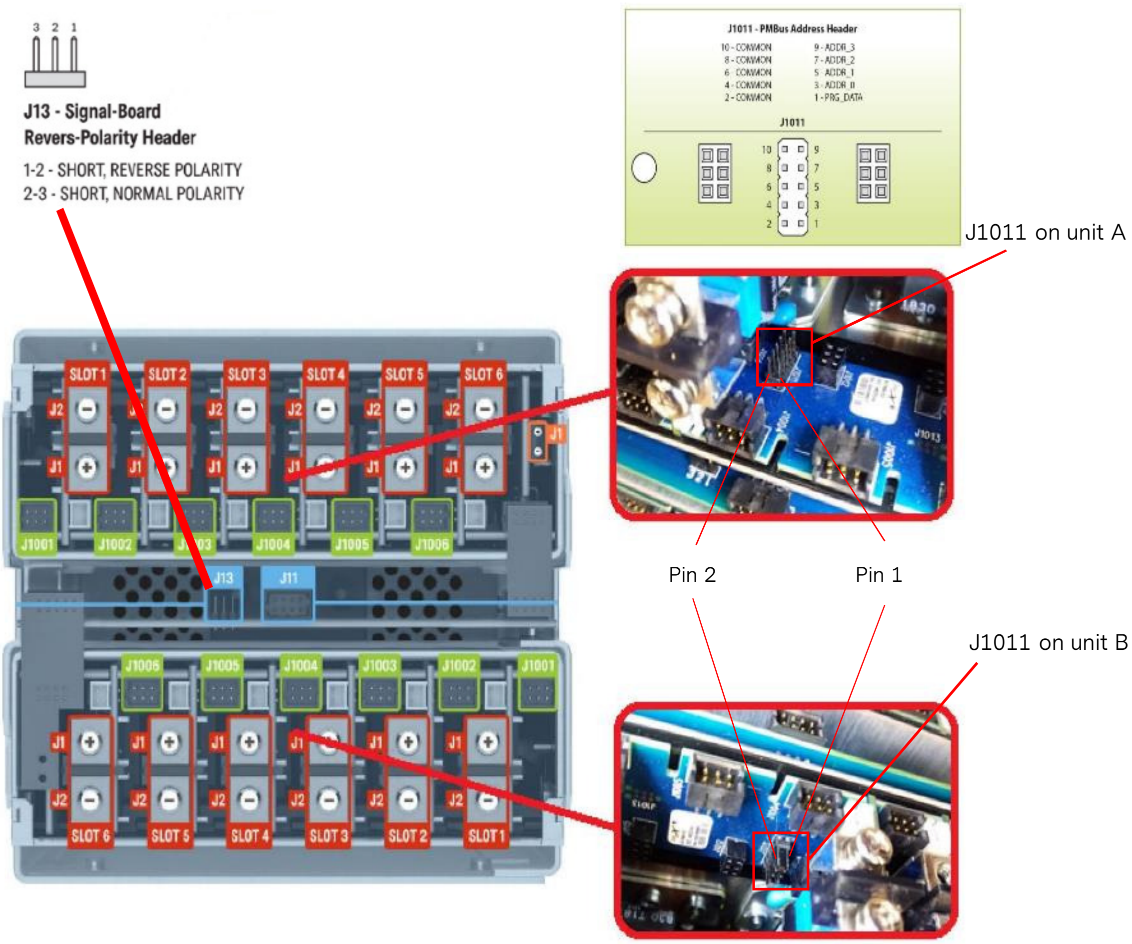
PRG_DATA - Reversing CoolMod Inhibit/Enable Logic - (Pin 1 of J1011)

Short Pin 1 & 2 of J1011 - Reverse Polarity - see table at page 68

Open Pin 1 to 2 - Normal Polarity - see table at page 68

The logic of the module Inhibit/Enable signals can be reversed by shorting pins 1 and 2 of J1011, on CoolX3000 CoolPacs with a jumper (the J1011 headers are located at the center of unit A and unit B Comms boards between slot 3 and 4). As well as shorting pins 1 and 2 on J13 (which is located on the System Signal Board), while leaving pins 2 to 3 of J13 open. (For normal polarity, pins 2 to 3 of J13 must be shorted). A logic level low must now be applied to the CONTRL pin of J11 (Pin 3) and COMMON (Pin1) to turn on the CoolX3000.

The recommended jumper for the J1011 and J13 connectors is a Harwin M22-1900005 2mm Jumper Socket.



SECTION 7 OPERATION - POWER, CONTROL AND COMMUNICATION CON'T

	J13 Pin 1,2,3	J1011 Pin 1 PRG_DATA	J11 Pin 3 Control Signal	J100x Pin 4 CoolMod Enable Signal	CoolMod Status
Reverse Polarity	Pin 1 to 2 short pin 2 to 3 open	Pin 1 to 2 short	0	0	Enabled
			0	1 or open	Disabled
			1 or open	0	Disabled
			1 or open	1 or open	Disabled
Normal Polarity	Pin 2 to 3 short Pin 1 to 2 open	Pin 1 to 2 open	0	0	Disabled
			0	1 or open	Disabled
			1 or open	0	Disabled
			1 or open	1 or open	Enabled

Reverse Polarity:

- J1011 pin 1 to pin 2 are short (Unit A comms board)
- J1011 pin 1 to pin 2 are short (Unit B comms board)
- J13 pin 1 to pin 2 are short and pins 2 to 3 are open (The System Signal Board)

Normal Polarity:

- J1011 pin 1 to pin 2 are open (Unit A comms board)
- J1011 pin 1 to pin 2 are open (Unit B comms board)
- J13 pin 2 to pin 3 are short and pins 1 to 2 are open (The System Signal Board)

SECTION 7 OPERATION - POWER, CONTROL AND COMMUNICATION CON'T

7.4 Module Operation

The CoolX has been designed to allow maximum flexibility in meeting the unique requirements of system designers. The inherent flexibility resulting from modular concepts allows users to configure solutions with multiple outputs that can be individually controlled.

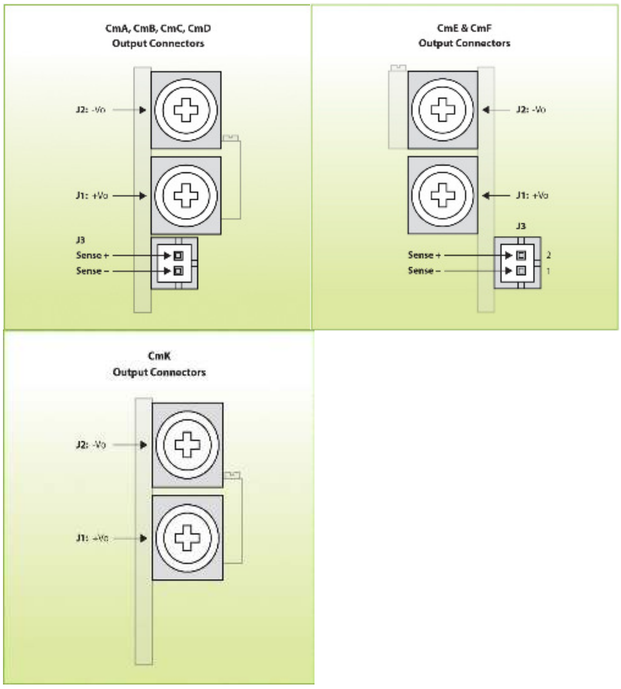
There are 13 CoolMods which provide discrete isolated DC outputs according to the CoolMod Summary Specifications table below.

Model	V_O (V)	$V_{O,adjust}$ (V)	OVP of Vset	OVP[1]	$I_{O,max}$ (A)	OCP	$P_{O,max}$ (W)
CmA	5.00	2.5 to 6.0	103 to 125%	125 to 160%	30.00	105 to 130%	150
CmB	12.00	6.0 to 15.0[2]	103 to 125%	110 to 140%	23.30	105 to 130%	280
CmC	24.00	15.0 to 28.0	103 to 125%	110 to 135%	12.50	105 to 130%	300
CmD	48.00	28.0 to 58.0	103 to 125%	105 to 120%	6.25	105 to 130%	300
CmE	24.00	24.0 to 25.2	102 to 120%	105 to 130%	37.50	105 to 130%	900
CmF	48.00	48.0 to 50.4	102 to 120%	105 to 125%	18.75	105 to 130%	900
CmG	24.00 24.00	3.0 to 30.0 3.0 to 30.0	NA	110 to 130%	4.00 4.00	135 to 250%	200[3]
CmH	5.00 24.00	3.0 to 6.0 3.0 to 30.0	NA	115 to 125% 110 to 130%	10.00 4.00	100 to 150% 135 to 250%	180[3]
CmA-W01	5.00	1.0 to 6.0	103 to 125%	125 to 160%	30.00	105 to 130%	150
CmB-W01	12.00	1.0 to 15.0	103 to 125%	110 to 140%	23.30	105 to 130%	280
CmC-W01	24.00	2.0 to 28.0	103 to 125%	110 to 135%	12.50	105 to 130%	300
CmD-W01	48.00	3.0 to 58.0	103 to 125%	105 to 120%	6.25	105 to 130%	300
CmK	200.00	175.0 to 205.0	105 to 110%	110 to 125%	1.00	105 to 130%	200

Note 1 - Specified as a percentage of maximum voltage
Note 2 - Full Dynamic Specifications may not be met at full load when output voltage is trimmed above 13 V.
Note 3 - Total max power of both channels

SECTION 7 OPERATION - POWER, CONTROL AND COMMUNICATION CON'T

7.5 Module Output/Signal



CmA to CmF and CmK Modules

J1 &J2 - Module Output Connector

J1 - +Vo - +Main Output

J2 - -Vo - Main output Return

CmA to CmF Modules

J3 - Module Sense Connector

1 - Sense - - Module Remote Sense Return

2 - Sense + - Module Remote sense

Remote sensing can be used to compensate for voltage drops in output leads. Remote sensing is available on Modules via the J3 Sense Connector. There is no remote sense on the CmG or CmH modules

Remote sensing will be implemented by connecting the Positive Sense pin (J3 pin2) to the positive side of the remote load and the Negative Sense pin (J3 pin1) to the negative side of the remote load. The maximum line drop, which can be compensated for by remote sensing is 0.5V, subject to not exceeding the maximum module voltage at the output terminals. Observe the following precautions when remote sensing:

- Use separate twisted pairs for power and sense wiring.
- Route the sensing leads to prevent pick up, which may appear as ripple on the output.
- Never disconnect the output power rail with the sensing still connected to the load.
- When using Remote Sense, output voltage should be set on the Sense Pins, not the Output Terminals

In certain applications where there is a high dynamic impedance along the power leads to the sensing point, remote sensing may cause system instability. This system problem can be overcome by using resistors in the sense leads (Positive sense lead: R1 = 10ohm, Negative sense lead: R2=10ohm), together with local AC sensing, by using 22uF capacitors between the remote sense pins and the output terminals.

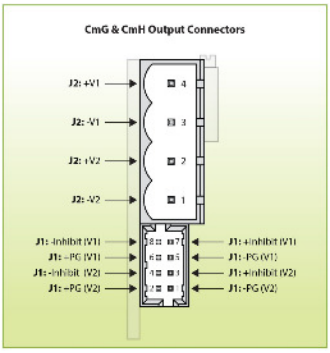
The resistance of the power cables must be so that the voltage drop across the cables is less than (Rcable) 0.5V (to ensure remote sensing operates correctly).

$$R_{cable} < \frac{0.5}{I_{out}}$$

E.g. for a CmA, 5V/30A, the Rcable must be less than 16.7mohm.

7.5 Module Output/Signal

CmG/CmH Modules



J2 - Dual Output Module Output Connector

1 - -V2 - Output 2 Return

2 - +V2 - Output 2

3 - -V1 - Output 1 Return

4 - +V1 - Output 1

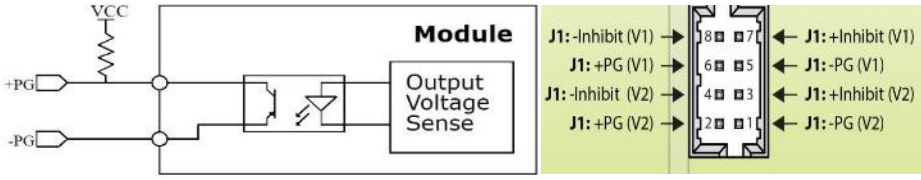
SECTION 7 OPERATION - POWER, CONTROL AND COMMUNICATION CON'T

J1 - Dual Output Module Signal Connector

+/- PG - Dual Output Module Power Good Signal - (Pins 1,2,5,6 of J1)

The Output Signal Connector (J1001-J1006) does not indicate Power Good status of the CmG or CmH modules, each output has a Power Good signal which indicates if there is a voltage on the output pins.

Note: The dual output module power good signal good status does not impact the global power



The Power Good signal is the unbiased open collector of an optocoupler that is available on the Module Signal Connector J1 via the collector on +PG and the emitter on -PG.

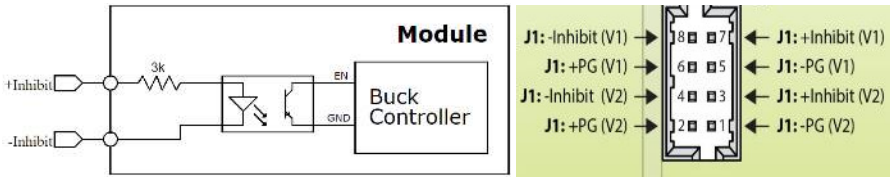
When there is a voltage present on the output pins of each output the transistor of the optocoupler is turned ON. If the output drops out of regulation the transistor turns OFF.

To monitor the Power Good of a channel, +PG should be pulled up to a reference voltage with a pull up resistor. The pull up resistor should be chosen to limit collector current to 0.5mA or less. For example, if the reference voltage is 5V, the pull up resistor should be 10K ohm or higher.

+/- Inhibit - Dual Output Module Enable/Inhibit - (Pins 3,4,7,8 of J1)

Each individual output voltage of the Dual Module will be enabled/inhibited by means of a signal applied to the Inhibit pins on the module signal connector J1. When the Inhibit pins are floating, or when the +Inhibit pin is tied to the -Inhibit pin, the channel is enabled.

Applying a signal voltage to the Inhibit pins will disable the channel. The specifications of this signal are shown in the table below.

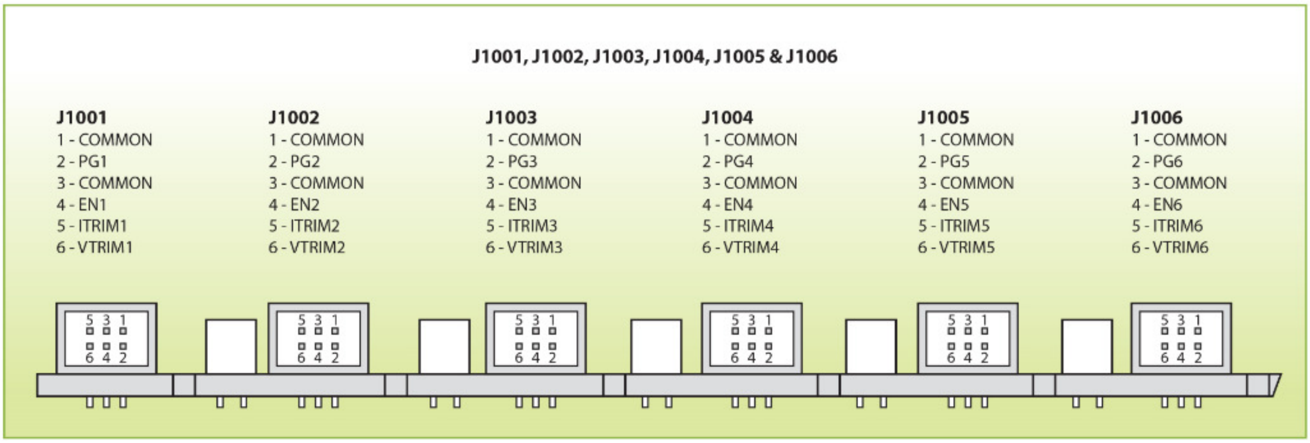


Model	Inhibit Signal Voltage	Inhibit Signal Current
Maximum	12 V	4.0 mA
Minimum	3 V	0.2 mA

SECTION 7 OPERATION - POWER, CONTROL AND COMMUNICATION CON'T

J100x - Single Module DC Output Signal Connector

The CoolX3000 Single Module Output Signals are available on the J100x Connector. (x = 1 to 6)

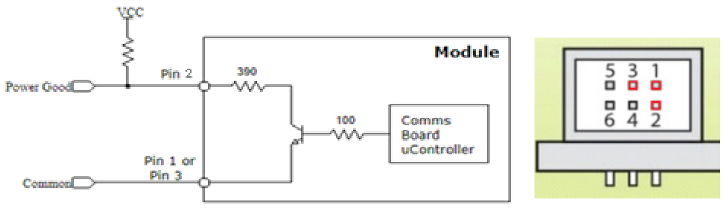


COMMON - (Pin 1, Pin 3 of J100x)

Ground reference of the system signal, this is connected to V- of the auxiliary output.

PGx - Module Power Good Signal (Standard, Wide -Trim and High Power modules) - (Pin 2 of J100x)

Each module has a Power Good Signal that is the output of an internal comparator which monitors the output voltage and determines whether this voltage is within normal operation limits. The PG signal is an unbiased open collector that is available on the Output Signal Connector (J100x) via the collector on Pin 2 and the emitter on Pin 1 or 3 (Common).



When the output voltage is within 10% of $V_{O,\,set}$ the transistor is turned ON. If the output drops out of regulation the transistor turns OFF. This can be used for power sequencing in many applications (enabling another CoolMod output when the first output is within regulation, as well as driving external circuitry.

The maximum collector voltage is 5V, and the maximum collector current is 12mA.

The dual module power good signal does not impact the global power good status.

Refer to the implementation circuit and table of logics at page 66 for recommendations for driving Logic Level circuits with open collector signal outputs.

SECTION 7 OPERATION - POWER, CONTROL AND COMMUNICATION CON'T

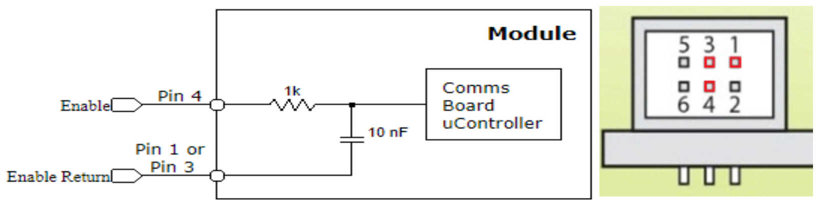
ENx - Module Enable/Inhibit - (Pin 4 of J100x)

Each module will be enabled/inhibited by means of a logic level signal applied to the enable input on Output Signal Connector J1001-J1006, Pin 4 (Positive), Pin 1 or 3 (Negative). The input has a 1K ohm series resistor and a 100nF filtering capacitor to filter noise on this signal. The input voltage must be limited to no greater than 5 volts.

If all modules have been disabled for more than 5 seconds, the CoolX will enter a low power consumption, Deep Sleep mode of operation. There is a max 700ms delay when enabling modules from Deep Sleep. When not in Deep Sleep, there is a max 30ms delay from change in signal logic to change in output voltage.

When there is no connection, Pin 4 is HIGH (5V) and the module is enabled. Pulling Pin 4 to Common will disable the module.

Disabling CmG-GmH modules in this way will disable both outputs.



The logic of the module Inhibit/Enable signals will be reversed if pins 1 and 2 of J1011 (which is located in the center of the Comms board between slot 2 and slot 3) are shorted with a jumper, and a logic low signal is applied between the CONTROL pin of J11 (Pin 3) and Common (Pin 1) - where J11 for the CoolX3000. Now when Pin 4 is HIGH, the module is disabled, and pulling Pin 4 to Common will enable the module. For details, please refer to page 68.

The recommended jumper for the J1011/J13 connector is a Harwin M22-1900005 2mm Jumper Socket.

SECTION 7 OPERATION - POWER, CONTROL AND COMMUNICATION CON'T

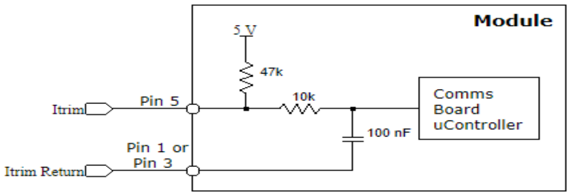
ITRIMx - Module Set Current Limit - (Pin 5 of J100x)

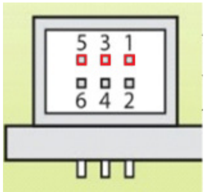
The current limit of the CoolMod can be set by applying a control voltage ITRIM across the Output Signal Connector pins ITRIM (Pin 5) and Common (Pin 1). The ITRIM voltage required for the users desired current limit can be calculated using the formula and table at page 75.

Note: Current limit adjustment is not available on CmE-CmH CoolMods.

Remote Current Limit Setting (Using External Voltage)

Available On: Standard Modules (CmA-CmD), Wide-Trim Modules (CmA-W01 to CmD-W01), High Voltage Module (CmK).





The current limit of the CoolMod can bet set by applying a control voltage I_{TRIM} across the Output Signal Connector (J100x) pins ITRIM (Pin 5) and Common (Pin 1 or Pin 3). The I_{TRIM} voltage required for the users desired current limit with the module can be calculated using the following formula.

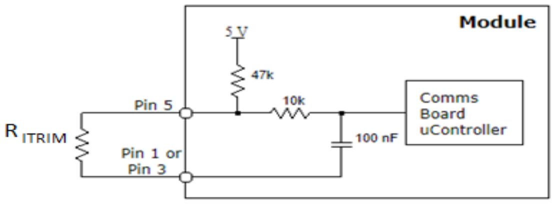
$$I_{trim} = \frac{I_{out}}{K}$$

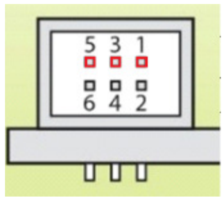
Module	K
CmA	14.79
CmB	10.65
CmC	5.75
CmD	2.89
CmA-W01	14.79
CmB-W01	10.65
CmC-W01	5.75
CmD-W01	2.89
CmK	0.46

SECTION 7 OPERATION - POWER, CONTROL AND COMMUNICATION CON'T

Remote Current Limit Setting (Using External Resistance)

Available On: Standard Modules (CmA-CmD), Wide-Trim Modules (CmA-W01 to CmD-W01), High Voltage Module (CmK).





The current limit of the CoolMod can bet set by placing a resistor R_{ITRIM} across the Output Signal Connector (J100x) pins ITRIM (Pin 5) and Common (Pin 1 or Pin3). The R_{ITRIM} resistance required for the users desired output current limit can be calculated using the following formula along with the same table used to calculate ITRIM .

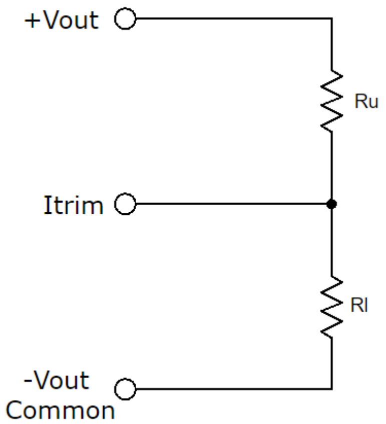
$$R_{ITRIM} = \frac{47000 \times I_{out}}{K - I_{out}}$$

Module	K
CmA	73.95
CmB	53.25
CmC	28.75
CmD	14.45
CmA-W01	73.95
CmB-W01	53.25
CmC-W01	28.75
CmD-W01	14.45
CmK	0.46

SECTION 7 OPERATION - POWER, CONTROL AND COMMUNICATION CON'T

Foldback Current Limit Programming (Standard and Wide-Trim Modules)

Foldback Current Limit can also be achieved with the CoolX but it requires the Common Pin of the Output Connector to be tied to the -V Output Connector of the module (remember that the Common Pin is also -Vo of the Auxiliary Voltage). Foldback Current Limiting can then be implemented by placing a resistor Ru across +Vout and ITRIM , and a Resistor Rl across ITRIM and -Vout/Common.



$$R_l = \frac{23500(I_{out})}{5K - I_{out}}$$

$$R_u = \frac{\left(47000(R_l)\right)\left(V_{out} - \frac{I_{out}}{K}\right)}{R_l(I_{trim}) - 5(R_l) + 47000\left(\frac{I_{out}}{K}\right)}$$

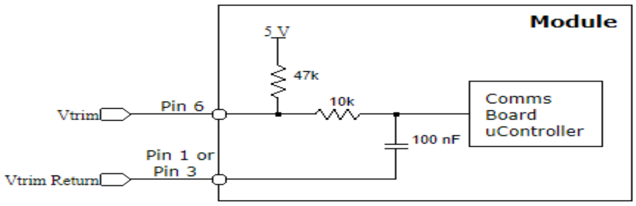
SECTION 7 OPERATION - POWER, CONTROL AND COMMUNICATION CON'T

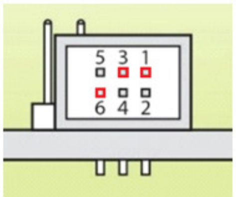
VTRIMx - CoolMod Voltage Adjustment - (Pin 6 of J100x)

The CoolX series CoolMods boast very wide output voltage adjustment ranges. Voltage setting, and dynamic voltage adjustment can be achieved in three ways; by adjusting the on board potentiometer, using the VTRIM pin of the Output Signal Connector (J1001 to J1006) or with PMBus™ commands applied to the System Signal Connector (J11).

Remote Voltage Setting (Using External Voltage)

Available On : Standard Modules (CmA-CmD), High Power Modules (CmE-CmF), Wide-Trim Modules (CmA-W01 to CmD-W01), High Voltage Module (CmK).





The output voltage of the module can be set by applying a control voltage VTRIM across the Output Signal Connector (J100x) pins VTRIM (Pin 6) and Common (Pin 1 or Pin 3). The VTRIM voltage required for the users desired output voltage can be calculated using the following formula

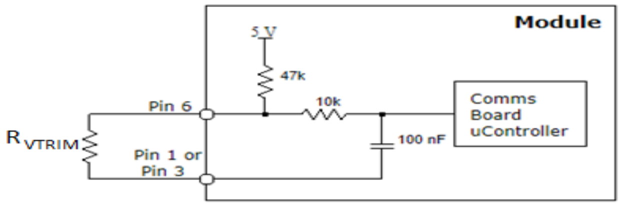
$$V_{trim} = \frac{V_{out} - F}{K}$$

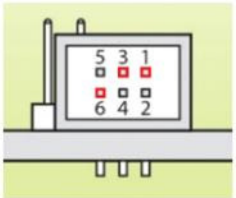
Module	K	F
CmA	1.59	2.43
CmB	3.84	5.85
CmC	6.3	13.82
CmD	13.2	26.13
CmE	1.19	22.45
CmF	0.28	43.06
CmA-W01	-1.61	3.23
CmB-W01	-3.90	7.84
CmC-W01	-2.17	12.77
CmD-W01	-6.42	26.25
CmK	154	20.47

SECTION 7 OPERATION - POWER, CONTROL AND COMMUNICATION CON'T

Remote Voltage Setting (Using External Resistance)

Available On: Standard Modules (CmA-CmD), High Power Modules (CmE-CmF), Wide-Trim Modules (CmA-W01 to CmD-W01), High Voltage Module (CmK).





The output voltage of the module can be set by placing a resistor R_{VTRIM} across the Output Signal Connector pins VTRIM (Pin 6) and Common (Pin 1 or Pin 3). The R_{VTRIM} resistance required for the users desired output voltage can be calculated using the following formula.

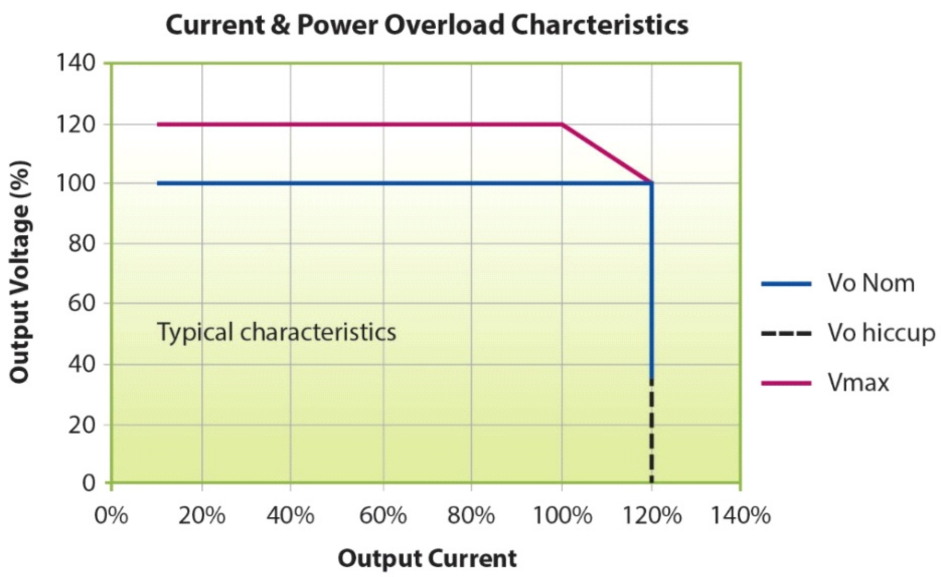
$$R_{VTRIM} = \frac{47000(V_{out} - F)}{F + 5K - V_{out}}$$

Module	K	F
CmA	1.59	2.43
CmB	3.84	5.85
CmC	6.3	13.82
CmD	13.2	26.13
CmE	1.19	22.45
CmF	0.28	43.06
CmA-W01	-1.61	3.23
CmB-W01	-3.90	7.84
CmC-W01	-2.17	12.77
CmD-W01	-6.42	26.25
CmK	154	20.47

SECTION 7 OPERATION - POWER, CONTROL AND COMMUNICATION CON'T

7.6 Power Limit

Each CoolMod has a number of levels of protection in order to ensure that CoolX is not damaged if used in overload conditions. Refer to Current and Overload Characteristics Graph.



When $V_{O,set}$ is less than or equal to $V_{O,nom,}$ current limit is employed at the current limit set point.

For Standard and Wide-Trim modules, if $V_{O,set}$ is greater than $V_{O, nom,}$ an intelligent power limit method is employed to ensure that the CoolMod does not exceed its power rating.

E.g. CmC is adjustable between 15V and 28V, $I_{O,max}$ is 12.5A, and Power rating is 300W.

- At 24V the CoolMod can deliver 12.5A continuously, i.e. 300W.
- At 28V, the CoolMod can still deliver 300W, however this equates to 10.7A continuous current.

CmE-CmH modules do not have a power limit and rely on current limit only.

SECTION 8 INSTALLATION

8.1 Installation Considerations

The CoolX series models may be mounted on any of its four surfaces using standard M4 screws. The chassis comes with four mounting points on the top and bottom surface, as well as three mounting points on both the right and left surface. Maximum allowable torque for mounting screws is 1.48Nm and maximum allowable penetration depth is 9mm.

Avoid excessive bending of output power cables after they are connected to the CoolMods. For high current outputs, use cable-ties to support heavy cables and minimize mechanical stress on output terminals. Be careful not to short-out to neighboring output terminals. The maximum torque allowed on output connectors is 0.74 Nm.

The CoolPac should be supplied by a power source of the type indicated on its label, and only used with a suitably rated mains cord. Double pole / neutral fusing is used in the CoolX platform. If the installation is not completely disconnected from power, parts may remain live even if one of the two mains fuses has blown.

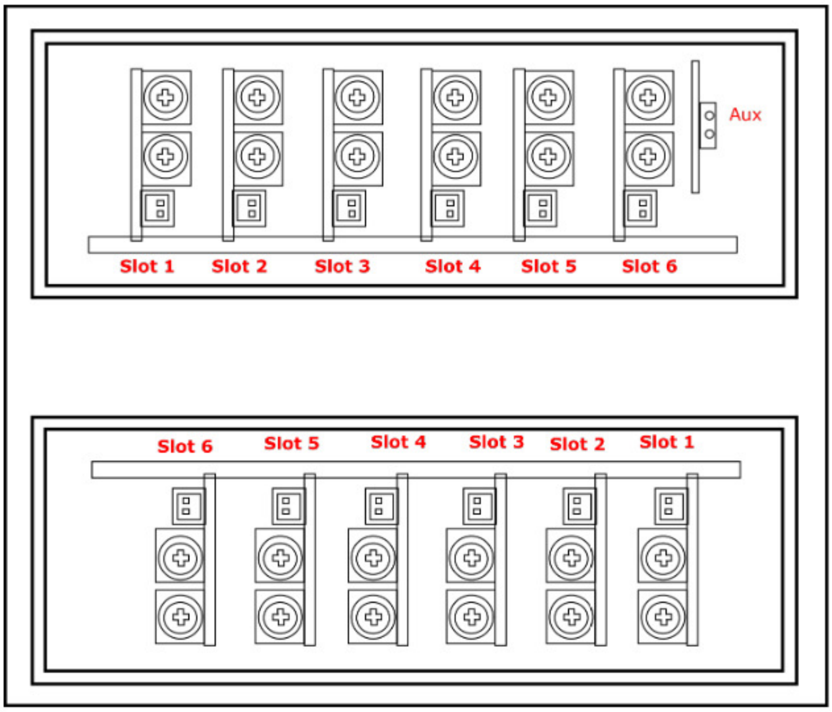
When adding or removing CoolMods from the CoolPac, care must be taken to handle the CoolMods by the output terminals only, ensuring that all the other surface mount components are not unduly damaged.

Parts of the unit will become hot during operation, allow time to cool before handling. After disconnecting the AC source, allow 4 minutes before disassembly to allow capacitors within the unit to discharge.

SECTION 8 INSTALLATION CON'T

8.2 Configuration Considerations

- Do not unplug CoolMods while input power is applied to the CoolPac. The CoolMods are not designed for hot-plug insertion.
- Always ensure that input and output screw terminals are properly torqued before applying power to the CoolX.
- Positive and negative power cables should be arranged as a twisted pair to minimize inductance.
- Wait 4 minutes after shutting off power before inserting or removing CoolMods.
- CoolX assemblies do not have user serviceable components. They must be returned to the factory for repairs. Contact Customer Service for an RMA number before returning the unit. Do not attempt to repair or modify the power supply in any manner other than the exchange of CoolMods as described in this Designers' Manual.
- Use proper size wires to avoid overheating and excessive voltage drop.
- Take appropriate precautions when touching the CoolX after it has been operating for a period of time. Due to the excellent conduction cooling methods to the chassis, the chassis will remain hot for some time after power has been removed.
- If a CmE or CmF module is to be configured in the CoolX3000, it must be used in Slot 6. This leaves Slot 1, Slot 2 and Slot 3 free for other modules.
- When a CmK module is used in Unit A or Unit B along with a CmE or CmF module, one module slot of that Unit must remain unpopulated.

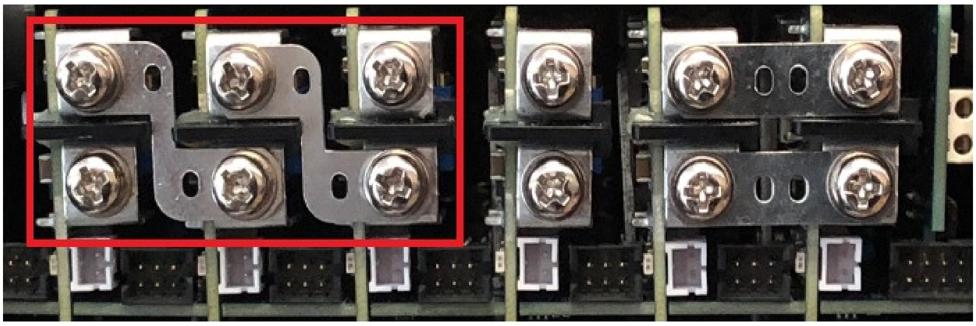


SECTION 9 APPLICATION NOTES

9.1 Series Connection of CoolMod outputs (Standard and Wide-Trim Modules)

It is possible to connect modules in series to increase output voltage. Standard, Wide-Trim and High Power module outputs are rated SELV (Safety Extra Low Voltage), that is, that output voltages are guaranteed to be less than 60V. If putting outputs in series this 60V limit can be exceeded and so appropriate precautions should be taken. It is good practice to stack modules with similar output current limits, so that in case of short circuit the outputs collapse together.

If remote sensing is required, the positive remote sense of the highest module and negative remote sense of the lowest module should be connected to the load. Special series connection (CX18S) links can be fitted to CoolMods modules to reduce wiring complexity. These Series Links can be fitted by the installer or added at the factory during configuration.



A maximum of three CmK modules can be connected in series.

CmE and CmF Modules should not be connected in series. CmF and CmG outputs can be connected in series to each other, but there are no dedicated links for this, and this should be done at a system level.

Modules can be series connected across CoolPacs units in the CoolX3000, but no links exist for this, so it should be done at a system level.

9.2 Parallel Connection for CoolMods (Standard, Wide-Trim Modules and High Voltage Modules)

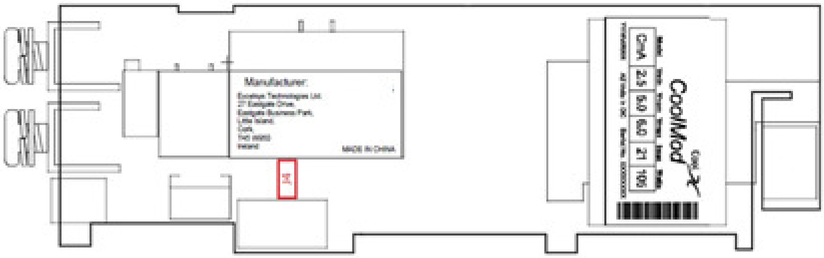
To achieve increased current capacity, simply parallel outputs using the standard parallel links. Active droop current sharing ensures that current hogging is not possible.

Note: There is a 10% derating imposed on parallel modules.

A maximum of three CmK modules may be connected in parallel.

To Parallel Connect CoolMods (Standard and Wide-Trim Modules)

- Turn on current sharing by adding a jumper on J4 Connector



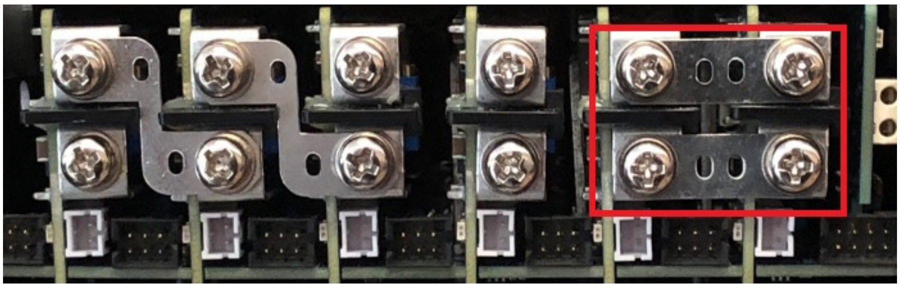
Jumper: Harwin - M22-1900005, 2 x 1 2.00 mm Pitch

- Connect Negative Parallel Busbar
- Adjust the output voltage of the first CoolMod to the required voltage
- Adjust the voltages of other CoolMods to be within the Parallel Voltage Tolerance (see below) of the first CoolMod output voltage
- Connect Positive Parallel Busbar
- If remote sensing is used in the application, connect all - Sense lines to the low side of the load and connect all + Sense lines to the high side of the load

Module	Parallel Voltage Tolerance
CmA	±10 mV
CmB	±10 mV
CmC	±10 mV
CmD	±20 mV
CmA-W01	±10 mV
CmB-W01	±10 mV
CmC-W01	±10 mV
CmD-W01	±20 mV
CmK	±40 mV

SECTION 9 APPLICATION NOTES

Special parallel connection links (CX18P) can be fitted to CoolMod modules to reduce wiring complexity. These Parallel Links can be fitted by the installer or added at the factory during configuration.



Note: CmE, CmF, CmG and CmH module outputs should not be paralleled.

Since all CoolMod signals are isolated from the CoolMod outputs, when CoolMods are connected in series or parallel, all CoolMod analog control functions (VTRIM, ITRIM , Enable/Inhibit) can be implemented by paralleling the appropriate signal pins of each CoolMod and providing a single control signal, i.e. connect all the VTRIM pins together and control VTRIM using a single control voltage. This can also be implemented using the PMBus™ interface.

SECTION 9 APPLICATION NOTES

9.3 CoolMod Start-Up and Shutdown

CoolMods are designed so that when input power is applied, all outputs rise to their set point voltage simultaneously. Likewise, when input power is removed all outputs commence to turn off simultaneously. Outputs can be sequenced using the enable function in order to allow controlled start up if required.

Turn-On Delays are as follows :

From AC	1000ms max
From Deep Sleep	700ms max
From Global Enable (CONTROL)	30ms max
From CoolMod Enable	30ms max

Power Good output signals from each module can be used to drive CoolMod Enable signals for sequenced outputs.

9.4 Over Voltage Protection (OVP)

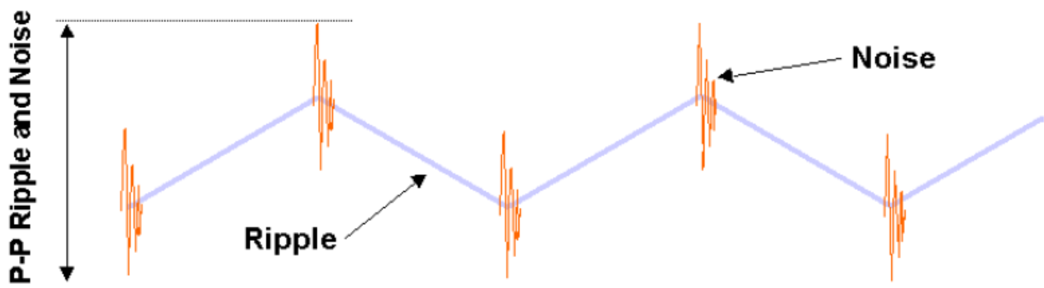
Standard and Wide-Trim modules have two levels of over-voltage protection (tracking and fixed), while the CmE-CmH have fixed over-voltage protection only.

The tracking OVP level is relative to the set output voltage and will turn off the CoolMod converter if the actual output voltage exceeds the set output voltage by more than 20%. When the fault condition has been removed the module will auto-recover.

The fixed OVP level is fixed relative to Vmax and will activate between 103-170% of the maximum output voltage. The fixed OVP will turn off all outputs of the CoolX3000 and, like the tracking OVP, will hiccup all outputs until the fault condition is removed.

SECTION 9 APPLICATION NOTES

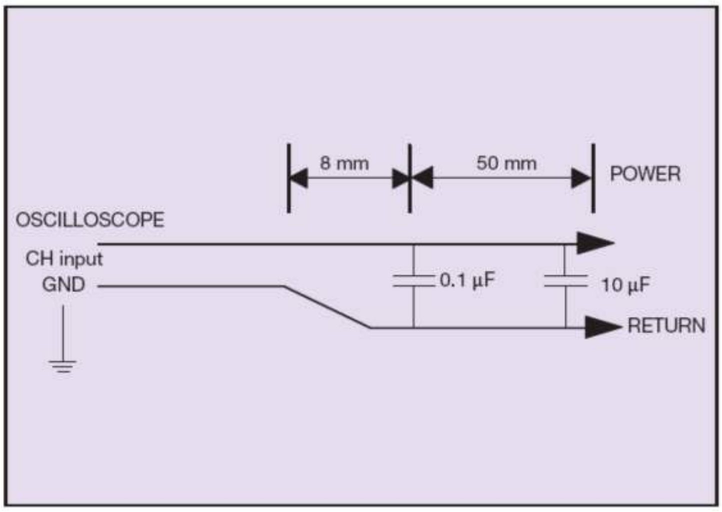
9.5 Ripple and Noise Measurement



As with all switched mode power supplies, it is important to ensure that the correct method is used to measure ripple & noise. Care should be taken to ensure that a loop antenna is not formed by the tip and ground lead of the oscilloscope probe as this would lead to erroneous readings consisting mainly of pickup from remnant radiation in the vicinity of the output connectors. Advanced Energy recommends the use of an x1 probe with the ground sheath of the probe tip used for ground connection. In some applications, further erroneous readings may result from Common Mode currents. These can be reduced by looping a few turns of the scope lead through a suitable high permeability ferrite ring. As most loads powered by a power supply will have at least small values of differential capacitance located near the load, We also recommends the use of small value of capacitance (approx.. 1uF) positioned at the point of measurement.

For further information refer to Application Note AN1105: Ripple and Noise for additional details on how to measure and reduce output ripple and noise.

The setup outlined in the diagram below has been used for output voltage ripple and noise measurements on the CoolX3000 series. When measuring output ripple and noise, a scope jack in parallel with a 0.1uF ceramic chip capacitor, and a 10uF tantalum capacitor will be used. Oscilloscope can be set to 20MHz bandwidth for this measurement.



SECTION 9 APPLICATION NOTES

Minimising System Noise

There are a number of causes of poor system noise performance. Some of the more common causes are listed below.

- Insufficient de-coupling on the PCB or load.
- Faulty wiring connection or poor cable terminations.
- Poor system earthing, system level grounding and shielding issues

There are some simple steps to eliminate, reduce or identify the causes of high frequency noise;

- Is the noise conducted or radiated? If changing the position of the power supply or screening improves performance, the noise is likely to be radiated. See Section 16: EMC Characteristics.
- Twist all pairs of power and sense cables separately.
- Ground connections (zero Volt) should be made with the shortest possible wiring via a capacitor to the nearest point on the chassis.

SECTION 10 RECORD OF REVISION AND CHANGES

Issue	Date	Description	Originators
1.0	06.24.2021	First Issue	K. Wang
1.1	01.26.2022	Add CmK Module	K. Zou
1.2	04.20.2022	Update Cmk Module and Correct Typo	K. Zou

ABOUT ADVANCED ENERGY

Advanced Energy (AE) has devoted more than three decades to perfecting power for its global customers. AE designs and manufactures highly engineered, precision power conversion, measurement and control solutions for mission-critical applications and processes.

Our products enable customer innovation in complex applications for a wide range of industries including semiconductor equipment, industrial, manufacturing, telecommunications, data center computing, and medical. With deep applications know-how and responsive service and support across the globe, we build collaborative partnerships to meet rapid technological developments, propel growth for our customers, and innovate the future of power.

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