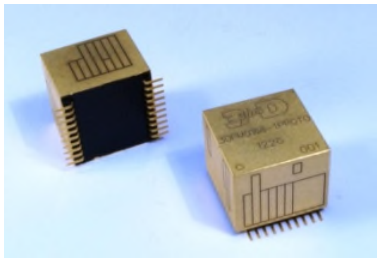
Hi-Rel Latch-Up Current Limiter (LCL)
High Input Voltage Range, 2A Output Current
Radiation Hardened Design

3DPM0168-2-XX

Features

- Protection device to power sensitive load with automatic disconnection in case of over-current
- Large input voltage range : 0.8V to 5.5V
- Output current up to 2A
- Low voltage drop (95mV @ 1A)
- Fast Switch OFF time (10µs max) in case of over-current
- 2 adjustable current threshold (Run & Standby) by external resistors.
- Active threshold selection through external digital command
- External ON/OFF command
- Manual or Automatic reconnection (after a delay adjustable by the user through external capacitor)
- Digital status for system monitoring
- Aux. Supply (3.2V to 5.5V and up to 15V with serial R) to power the device for Vin < 3.3V
- Space Qualified Technology
- Radiation Hardened design
- Temperature Range -40°C / +115°C



- Compact Size and Low Weight
- 20-pins SOP package 1.27mm
- ITAR Free Product
- Size: 15 x 15 x 12 mm
- Mass: 6.5 g

Applications

Protection of sensitive digital circuits, for example : ASICs, FPGAs, etc …

General Description

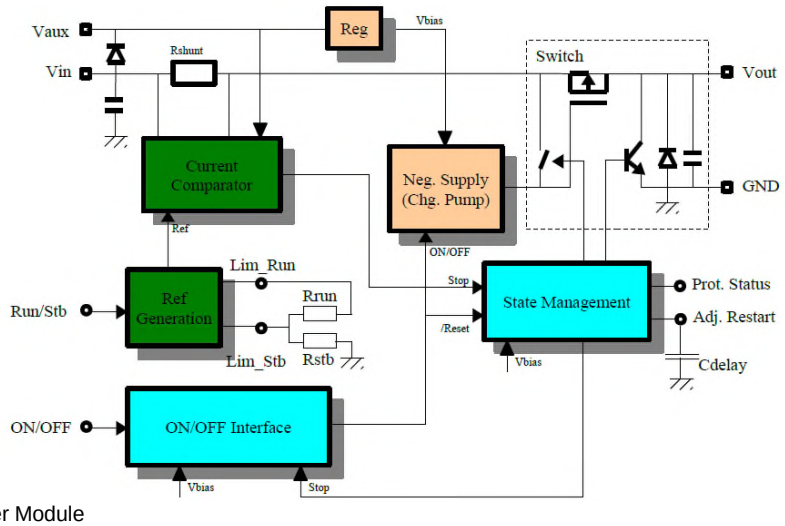
Advanced high performance semiconductor devices can be sensitive to Single Event Latch-Up (SEL) effect when exposed under radiation in the space environment. Even if SEL is a very rare event, it can lead to device destruction. A safe design for a mission critical application shall include a protection device called the Latch-Up current Limiter (LCL).

The 3DPM0168-2 LCL monitors the power supply line of the radiation sensitive device and switches it off instantaneously in case of “radiation induced SEL”.

Featuring specific radiation effect mitigation techniques and utilizing space design derating rules, the Rad Hard by Design 3DPM0168-2 LCL is an ITAR Free product and features a SEL/SET LETth of 80 Mev.cm2/mg and a TID of 50krad (Si).

The 3DPM0168-2 is manufactured with 3D Plus Space Qualified stacking technology designed for high reliability applications, and is available in a compact size and low weight 20-pins SOP package 1.27mm.

Block Diagram



Latch-up Current Limiter Module

Absolute Maximum Ratings

Operation beyond the following limits may cause module degradation, reliability reduction or permanent damage.

Parameter	*Conditions*	*Min*	*Typ*	*Max*	*Unit*
Input Voltage (Vin)	Continuous	-0.3		Vaux+0.2	V
Auxiliary Voltage (Vaux)	Continuous	-0.5		5.5	V
Output Current	Continuous			2	A
ON/OFF Command	Continuous	-0.3		7	V
Run/Stb Command	Continuous	-0.3		7	V
Storage Temperature	-	-55		+150	°C

Recommended Operating Conditions

For proper operation, the module should be used within the recommended operating conditions.

Parameter	*Conditions*	*Min*	*Typ*	*Max*	*Unit*
Input Voltage (Vin) see note (1)	Continuous	0.8		5.5	V
Auxiliary Voltage (Vaux) see note (2)	Continuous	3.2		5.5	V
Output Current	Continuous	0		1	A
ON/OFF Command	Continuous	0		Vaux	V
Run/Stb Command	Continuous	0		Vaux	V
Junction Temperature	-	-40		+115	°C

Note (1) *Vin shall not exceed Vaux voltage*

Note (2) *higher auxiliary voltage can be used (up to 15V), but an external resistor shall be added in series with the Vaux line*

Mechanical and Environmental Specification

Parameter	*Conditions*	*Typ*			*Unit*
Weight	-		6.5		g
Dimensions	Overall (pin not included)	15 (L)	15 (W)	12 (H)	mm

Parameter	*Conditions*	Min	Typ	Max	Unit
Total Irradiation Dose	-	50			krad
Latch-up Immune LET Threshold	-	80			Mev.cm^2/mg
SET Immune LET Threshold	-	80			Mev.cm^2/mg

Parameter	*Conditions*	*Remarks*
Thermal Cycles	Mil-std-883 Method 1010 Condition B	500 Cycles, -55°C/+125°C
High Temperature Storage	Mil-std-883 Method 1008 JESD22-A103-A	2000 hrs, 150°C
Shock	Mil-std-883 Method 2002 Condition B	Y1, 0.5 ms, 1500g
Sinusoidal Vibration	Mil-std-883 Method 2007 Condition A	20Hz - 2000Hz peak acceleration 20g – 3 axes
Random Vibration	Mil-std-883 Method 2026 Condition I	Level H/J
HAST	JEDEC STD 22TMA110	264 hrs, +110°C
Outgassing	ESA-PSS-01-702 MA	TML&RML<1%, CVCM<0,1%
Lead Integrity	Mil-std-883 Method 2004	
Solderability	Mil-std-883 Method 2003	
Marking Permanency	Mil-std-883 Method 2015	

Input & Output Specifications

Parameters are defined over the specified input voltage, output load and temperature range unless otherwise noted.

Parameter	*Conditions*	*Min*	*Typ*	*Max*	*Unit*
Supply Characteristics					
Input Voltage Range		0.8		5.5	V
Auxiliary Voltage Range	Higher voltage possible with serial resistor in Vaux line.	3.2		5.5	V
Auxiliary Supply Current	Vaux = 3.2V	1	3	9	mA
	Vaux = 5.5V	10	15	21	mA
Internal decoupling capacitor (Vin)	Ceramic capacitor implemented at module input		2.2		µF
Output Characteristics					
Output Current		0		2000	mA
Capacitive Load see note (3)		0		10	µF
Voltage Drop	Iload = 1A	70	80	95	mV
Free wheeling diode Vdrop	Iout = 1A @ 25°C			1.3	V
Internal decoupling capacitor	Ceramic capacitor implemented at module output		0.22		µF

Note (3) *Maximum response time of 10µs is not guaranteed if capacitive load exceeds 7 µF*

Commands and Status Specifications

Parameters are defined over the specified input voltage, output load and temperature range unless otherwise noted.

Parameter	*Conditions*	*Min*	*Typ*	*Max*	*Unit*
ON/OFF Commands Characteristics (LCL input)					
ON Voltage threshold see notes (4)	Vaux = 3,3V	2.32			V
	Vaux = 5V	3.32			V
OFF Voltage threshold see note (4)	Vaux = 3,3V			1.05	V
	Vaux = 5V			1.7	V
Input impedance	LCL not in protection mode		50		kΩ
	LCL in protection mode	4.8			kΩ
RUN/STB Commands Characteristics (LCL input)					
RUN Voltage level		2.0			V
STB Voltage level				0.35	V
PROT_STATUS Characteristics (LCL output)					
LCL not tripped		0		0.2	V
LCL tripped	High level is always lower than Vaux	3.1		5.4	V
Output impedance		4	4.7	5	kΩ

Note (4) *ON/OFF input is a Schmitt trigger type and allows slow rise/fall input signals*

Protections

Parameters are defined over the specified input voltage, output load and temperature range unless otherwise noted.

Parameter	*Conditions*	*Min*	*Typ*	*Max*	*Unit*
Current Protection					
Standby threshold Current	Ith_stb, adjustable by Rstb	100		Ith_run	mA
Run threshold Current	Ith_run, adjustable by Rrun	Ith_stb		2000	mA
Current threshold accuracy see note (5)	Ith = 100mA	-20		20	%
	Ith = 1A	-8		8	%
Automatic reconnection Delay	Adjustable by Cdelay	0.5		300	ms
Delay accuracy		-25		25	%
Performances					
Switch OFF time see note (6) (current protection activated)	Cload < 7µF see Figure 1			10	µs
dV/dt at switch ON	Output slope controlled at ON command	3		16	mV/µs

Note (5) *Vin accuracy shall be added to current threshold accuracy.*
For example : if Vin voltage is in a ± 5% range, current threshold accuracy for Ith = 1A will be ±13% (±5% added to initial ±8% accuracy).

Note (6) *switch OFF time is the delay between Iout > Ith and Vout = Vin/2*

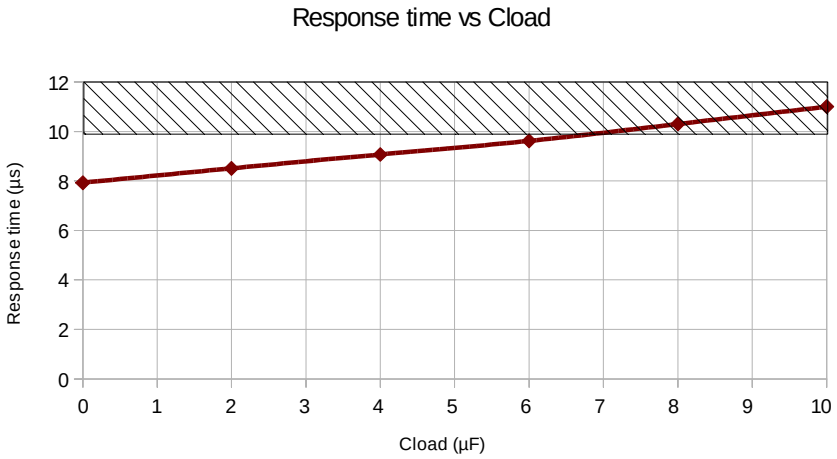
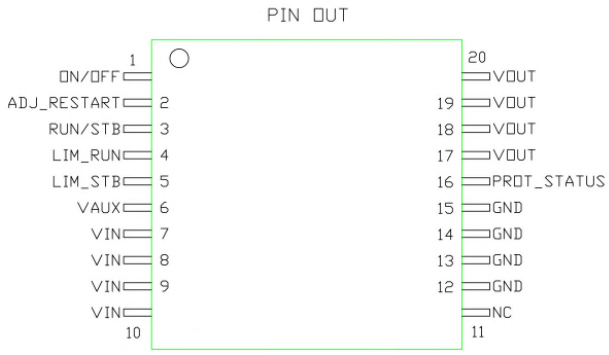


Figure 1: switch OFF time vs Cload

Pins definition & assignments



Pin 1: ON/OFF
ON/OFF command pin.
When left unconnected or connected to GND, LCL is in OFF state and load is disconnected from the Vin supply.
When connected to high level, LCL is started and load is connected to the Vin supply.
This is an input pin.

Pin 2: ADJ_RESTART
Pin used to select the automatic restart function provided by the LCL and to adjust the delay.
When connected directly to GND, automatic restart function is inhibited.
When connected to a capacitor, automatic restart is selected. Capacitor value set the delay for automatic reconnection (see automatic restart setting section).
This is an input pin.

Pin 3: RUN/STB
Pin used to select the active current protection threshold.
When this pin is connected to a low level voltage, low level current threshold corresponding to standby mode is selected (Ith_stb).
When this pin is connected to a high level voltage, high level current threshold corresponding to run mode is selected (Ith_run).
This is an input pin.

Pin 4: LIM_RUN
Pin used to set the high level current threshold (Ith_run).
Ith_run value is set by a resistor (see current limitation setting section) connected between this pin and the LIM_STB pin.
This is an input pin.

Pin 5: LIM_STB
Pin used to set the low level current threshold (Ith_stb).
Ith_stb value is set by a resistor (see current limitation setting section) connected between this pin and GND.
This is an input pin.

Pin 6: VAUX
Auxiliary supply pin used to power the internal control circuits of the LCL.
Internal control circuit needs at least 3.2V to run correctly.
When input voltage (Vin) is greater than 3.2V, this pin can be connected to Vin pins.
When input voltage is lower than 3.2V an auxiliary supply needs to be connected to this pin.
Auxiliary supply voltage shall be between 3.2V and 5.5V. If higher voltage is used, a serial resistor shall be added to limit the auxiliary supply current and to reduce internal LCL power dissipation.
This is an input pin.

Pin 7, 8, 9 & 10: VIN
Input voltage pins. Connect the load supply voltage to these pins.
These are input pins.

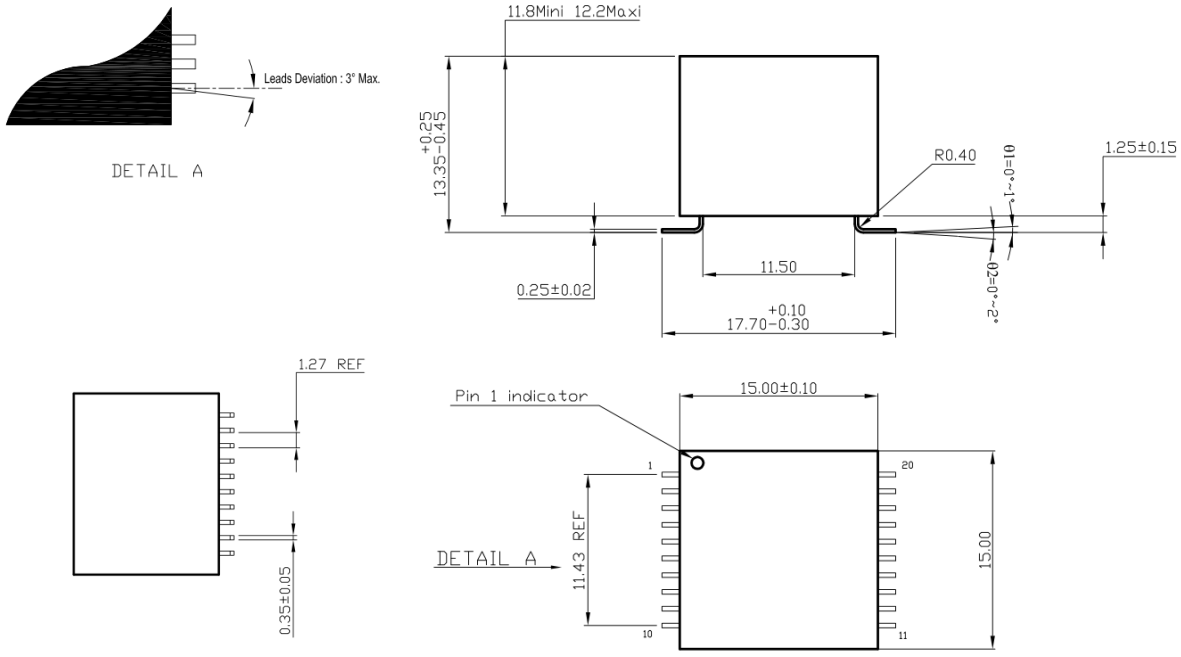
Pin 11: NC
Not used pin.

Pin 12, 13, 14 & 15: GND
Reference grounds for the LCL module (load current is not going through this pin).

Pin 16: PROT_STATUS
Protection Status pin. The signal at this pin is used to survey the LCL state. Signal is pulled to GND when LCL is not tripped. Signal is pulled to high level when LCL is tripped (load disconnected after overcurrent).
This is an output pin.

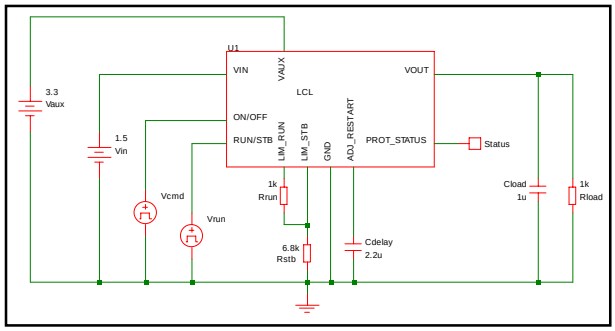
Pin 17, 18, 19 & 20: Vout
Output voltage pins. This is the protected supply to power the LCL load.
These are output pins.

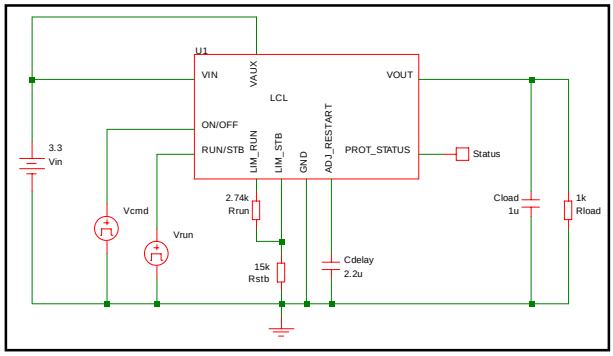
Module Mechanical Drawing



Typical application schematic

Case 1:
Vin voltage is lower than 3.3V (1.5V in this case).
Internal circuits need to be powered by an auxiliary supply (Vaux) of 3.3V minimum.
Ith_stb is set to 0.2A.
Ith_run is set to 1.25A.
Delay is set to 85ms.
ON/OFF state and RUN/STB mode are selected by dedicated commands.





Case 2:
Vin voltage is equal to 3.3V. Internal circuits are also powered from Vin.
Ith_stb is set to 0.2A.
Ith_run is set to 1.2A.
Delay is set to 85ms.
ON/OFF state and RUN/STB mode are selected by dedicated commands.

Current Limitation Setting

LCL has two current thresholds:

- a low level current threshold to protect the load when it is in standby mode (Ith_stb).
- a high level current threshold to protect the load when it is in run mode (Ith_run).

User selects the active threshold through the RUN/STB command.

Threshold values are set by the user through two resistors:

- Rstb connected between LIM_STB and GND for standby current threshold.
- Rrun connected between LIM_STB and LIM_RUN for run current threshold.

Rstb is function of the standby current threshold (Ith_stb) and input voltage value (Vin). Value is calculated using the following formulae:

$$R_{stb} = \left[\frac{V_{in}}{I_{th\_stb}} \cdot 940 \right] - 267 \quad (1)$$

Rrun is function of the run current threshold (Ith_run), input voltage value (Vin) and Rstb value. Value is calculated using the following formulae:

$$R_{eq} = \left[\frac{V_{in}}{I_{th\_run}} \cdot 940 \right] - 267$$

$$R_{run} = \frac{1}{\frac{1}{R_{eq}} - \frac{1}{R_{stb}}} \quad (2)$$

Rem: For the two previous equations, Vin value is in Volt, Ith is in Ampere and R is in Ohm.

Example:
If we have Vin = 2.5V, Ith_stb = 200mA and Ith_run = 1200mA.
Equation (1) gives Rstb = 11.483kΩ. Selected standard value is 11.5kΩ (0.1%).
Equation (2) gives Req = 1.69kΩ and Rrun =1.983kΩ. Selected standard value is 2kΩ (0.1%).

Automatic Restart Setting

Automatic restart function allows the LCL to automatically reconnect the load to the input voltage supply after a delay (Tdelay) in case of protection activation (load disconnected following detection of load current above the active threshold). Delay is set by the user through a capacitor (Cdelay) connected between ADJ_RESTART and GND.

Cdelay is calculated using the following formulae :

$$C_{delay} = 26 \cdot T_{delay} \quad (3)$$

Rem: For equation 3, Tdelay is in ms and Cdelay in nF.

Tdelay values for standard capacitor values are provided in the following table:

Cdelay (nF)	Tdelay (ms)
10	0.38
22	0.85
33	1.3
47	1.8
68	2.6

Cdelay (nF)	Tdelay (ms)
100	3.8
220	8.5
330	12.7
470	18.1
680	26.2

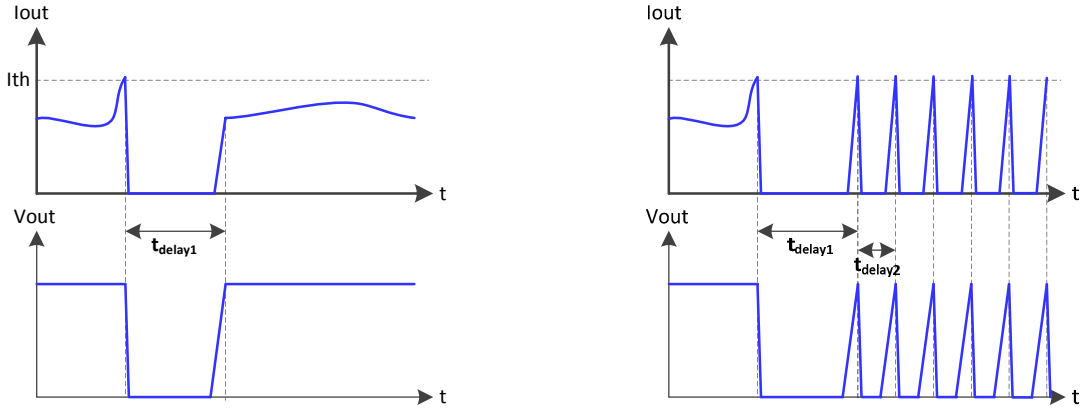
Cdelay (nF)	Tdelay (ms)
1000	38.5
2200	84.6
3300	127
4700	181
6800	262

Example:

- for Tdelay of 8.5ms, uses Cdelay = 220nF
- for Tdelay of 180ms, uses Cdelay = 4.7µF

Note :

T_{delay} corresponds to the first time automatic reconnection delay after protection activation (t_{delay1} in the following example).



Latch-up event condition *Permanent overload condition*

Figure 2 : Reconnection delay for latch-up event or "permanent" overload condition

If the defect will not disappear after a first deconnection/reconnection in the circuit to protect, protection is activated again after a shorter delay (t_{delay2} in the example).
If the defect is persistent, the following shorter delays will remain at the same value as the first short delay (t_{delay2} in the example).

Tdelay2 is also function on the capacitor delay but limited in duration when Cdelay value increases (see curves provided on the following page).

Curves of first and remaining auto reconnection delays are given below (notice the different time scale between the two curves) :

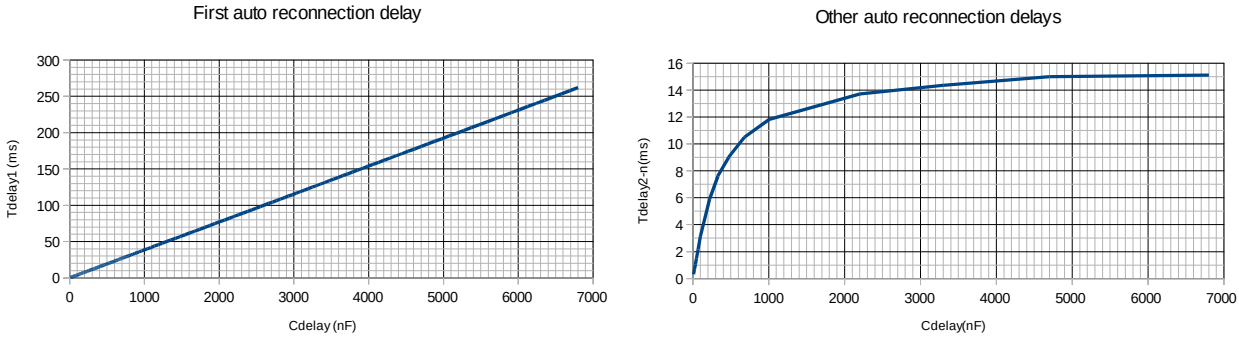


Figure 3: First and other auto reconnection delay curves

Resistor in Vaux line for auxiliary supply voltage greater than 5.5V

A shunt regulator is implemented on the auxiliary supply (Vaux) to limit the internal voltage which powers the LCL internal circuits (Vbias).

Regulator is activated when bias voltage is greater than 4.5V and increases the current consumption on Vaux.

From 5.5V, an external serial resistor shall be added in the Vaux line to limit the auxiliary supply current and to reduce internal LCL power dissipation.

Table below gives resistor value according to Vaux voltage range.

Vaux	Rserial
3.2 V ≤ Vaux < 5.5 V	0 Ω
5.5 V ≤ Vaux < 6.0 V	18 Ω
6.0 V ≤ Vaux < 6.5 V	68 Ω
6.5 V ≤ Vaux < 7.5 V	120 Ω

Vaux	Rserial
7.5 V ≤ Vaux < 9.0 V	220 Ω
9.0 V ≤ Vaux < 11.0 V	360 Ω
11.0 V ≤ Vaux < 13.0 V	560 Ω
13.0 V ≤ Vaux < 17.0 V	750 Ω

Vaux consumption will be limited to less than 17mA. 17mA shall be considered to determine the resistor power rating. Designer shall verify on the product that Vaux at LCL module level is lower than 5.5V.

Features description

The LCL module is a protection module for load sensitive to Single Event Latch-Up (SEL).

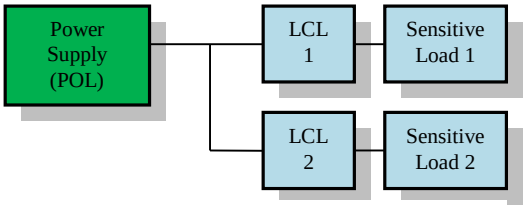


Figure 4 : Power Distribution scheme

The module shall be inserted between the load and its power supply. It implements a serial switch and a shunt resistor for current monitoring.
If a high energy particle hits the sensitive load and induces a Latch-Up, its supply current rises quickly. The LCL module detects this abnormal current and disconnects instantaneously the load from the supply. Additionally, any load decoupling capacitors are also quickly unloaded by the integrated LCL parallel output switch to further limit energy dissipation at load level.

LCL module offers two current limitation thresholds. A low level current threshold called “I threshold Standby” (Ith_stb) and a high level current threshold called “I threshold run” (Ith_run). Ith_stb should be selected when load is in low consumption mode (standby). Ith_run should be selected when the load is in normal or run mode. Active threshold level is selected by an external command (RUN/STB).
Threshold currents are adjustable by the user through two external resistors. Rstb connected between LIM_STB pin and GND pin to define the standby current threshold. Rrun connected between LIM_RUN pin and LIM_STB pin to define the run current threshold.

When the active threshold is reached, load is disconnected from the input supply and the protection status is activated to warn the system that the LCL module has trigged its current protection. LCL behaviour at this stage is function of the automatic reconnection mode selection.
If automatic reconnection mode is not selected (ADJ_RESTART pin connected to GND), LCL stays in OFF State. To reconnect the load to its supply voltage, ON/OFF command shall be put in OFF state (low level) and then brought again to the ON state (high level). This OFF and ON command cycle reset the Protection status.
If automatic reconnection mode is selected (ADJ_RESTART pin connected to a capacitor - Cdelay), LCL stays in OFF state for a duration function of Cdelay capacitor value. After this duration, LCL is automatically switched OFF and ON again. The load is reconnected to its supply voltage. Protection status is reset at the same time.
If a new over-current is detected, LCL switch OFF again for a new time delay and then reconnect the load to its supply voltage automatically.

LCL can also be used to switch ON and OFF the load thanks to the ON/OFF command.
When commanded ON, voltage at LCL module level rises slowly to limit inrush current from the load supply and avoid tripping the LCL current protection.
When commanded OFF, the internal LCL serial switch is switched OFF smoothly and the internal output parallel switch is not activated. The output voltage profile is function of the load behaviour and of the additional decoupling capacitor.

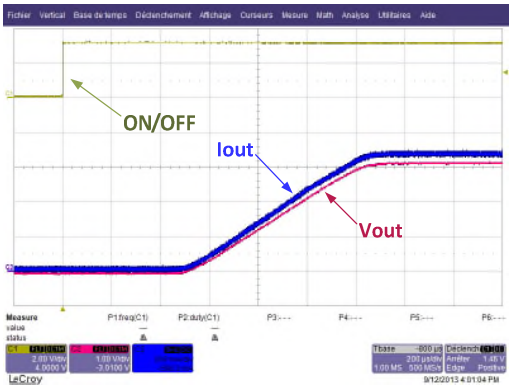


Figure 5 : Behaviour at ON command

LCL is designed to accept a maximum output decoupling capacitor of 10µF and implement internally a capacitor of 220nF. Higher decoupling capacitor value may prevent the LCL to be switched ON properly.

A free wheeling diode is also implemented at LCL module output to allow disconnection of inductive load. Free wheeling is implemented to protect the LCL module.

Block Diagram

LCL Block diagram is given in Figure 6.

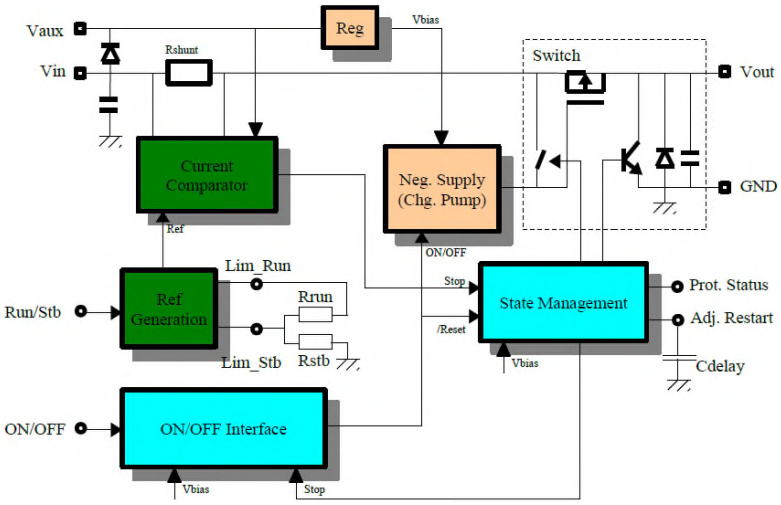


Figure 6: LCL Block Diagram

Main switch to connect or disconnect the load is a P channel MOSFET. Parallel output switch used to unload output decoupling capacitor is a NPN bipolar transistor. 2.2µF filtering capacitor is integrated into the module at LCL input and 220nF at LCL output. A free wheeling diode is also implemented to switch OFF inductive load.

P channel MOSFET is driven from a negative supply provided by a charge pump circuit. This circuit is powered from auxiliary voltage through a shunt regulator.

Load current is measured through a shunt. A current comparator checks if the load current is higher or lower than a reference current (current threshold) provided by the Ref. generation bloc. If current is higher than the threshold, a stop command is sent to the State management block which initiates a switch OFF sequence.

Reference current provided by the Ref. generation block is adjusted by the two resistors Rrun and Rstb (which set respectively Ith_run and Ith_stb). The issued reference current is function of the RUN/STB command.

State management block drives the serial and parallel switches and generates the Protection Status signal. State management block also decides to restart automatically the LCL, after current protection activation, if automatic reconnection mode is selected. Delay for automatic reconnection is set by Cdelay value.

ON/OFF interface monitors the ON/OFF signal to start or stop the LCL. When LCL is started, charge pump circuit is activated. At LCL start, state management is also reset to clear any fault condition.

Over-Current Protections

Behaviour of the LCL in case of short circuit event is detailed in this section. The short circuit event can be assimilated to a latch-up event applicable to a sensitive load.

Plot in Figure 7 shows the LCL response to an output short circuit. At short circuit application, output current rises and output voltage decreases. After the response time delay, LCL is switched OFF and output voltage falls quickly. Output current is going down at the same time.

LCL response time is impacted by the decoupling capacitor at module output. LCL can tolerate up to 10µF but maximum response time of 10µs is guarantee if output capacitor is limited to 7µF.

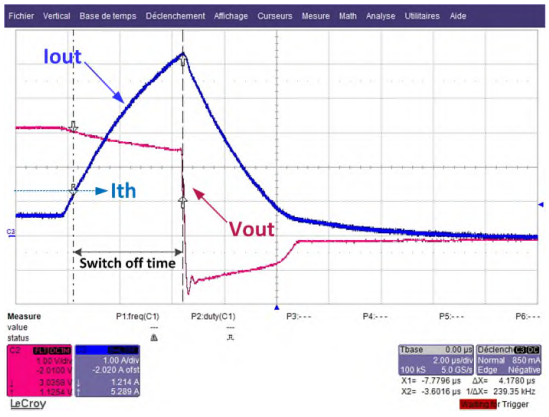


Figure 7: Behaviour in case of short circuit

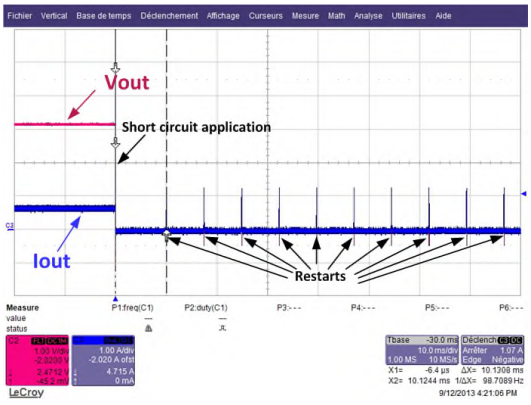


Figure 8 : Behaviour at short circuit application

When a short circuit is detected by the LCL Module, output is disconnected. If automatic reconnection mode is selected, LCL module reconnects the load to its supply voltage after a delay defined by Cdelay capacitor value. This behaviour is illustrated in Figure 8.
Delay for automatic reconnection is set to 8.5ms. After 8.5ms (Tdelay1), LCL tries to reconnect the load to its supply. As long as short circuit is present, load is disconnected again and a new cycle restarts after 6.5ms (Tdelay2, as described in section "Automatic Restart Setting"). This process continues up to short circuit removal.
Low duty cycle operation (short ON time, long OFF time) allows limiting internal heating to non critical value for module reliability. This mode can be used during all product life without module reliability reduction.

When the short circuit is removed, load is reconnected to its supply voltage and can continue its normal operation. This behaviour is illustrated in Figure 9.

If automatic reconnection mode is not selected, LCL module stays OFF after over-current detection. An OFF then an ON command cycle is needed to restart the LCL and clear the fault.

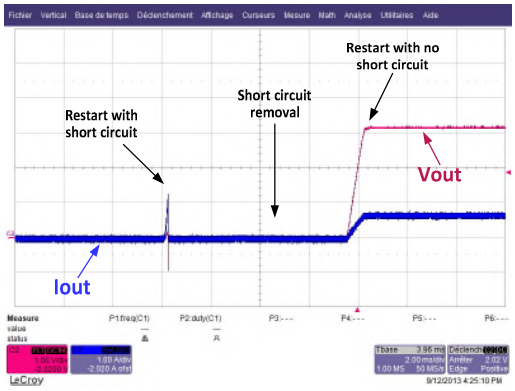


Figure 9 : Behaviour at short circuit removal

Layout Recommendations

Critical event for LCL module is load disconnection in case of over-current event (load in Latch-up). In this case, high di/dt are experienced at module input and output.
Impedance at LCL module input shall be maintained low. Module shall be mounted close to the voltage source or properly decoupled by capacitors connected between VIN and GND (TES low ESR tantalum capacitors from AVX or T530 tantalum capacitor from KEMET are recommended). These capacitors shall be mounted closely to the module VIN and GND pins. It is also recommended to use copper planes for both VIN and GND or at least large conductor traces with minimum loop area. If resonances may occur between the decoupling capacitors and the parasitic inductance between the module and the Vin voltage source, they have to be damped (serial RC circuit between module and ground).
Inductance between LCL module output and load shall be maintained low to avoid negative voltage at module output during load disconnection. Again copper planes are recommended or large conductor traces with local decoupling capacitor at load level (they shall not exceed 10µF). If load has an inductive part, and is sensitive to negative voltage, a free wheeling diode shall be added at load level (free wheeling diode integrated at module may not be sufficient to limit negative voltage value).

Part Number / Ordering Information

3DPM0168-2-XX

Temperature Range
- C : 0°C /+70°C
- I : -40°C / + 85°C
- S : -40°C / +115°C

Quality Grade (Screening Level)
- N : Commercial
- B : Industrial
- S : Space

Main Sales Office

FRANCE	3D PLUS 408, rue Hélène Boucher ZI. 78532 BUC Cedex	Tel : 33 (0)1 30 83 26 50	Fax : 33 (0)1 39 56 25 89	Web : www.3d-plus.com e-mail : sales@3d-plus.com	
USA	3D PLUS U.S.A, Inc 6633 West Eldorado Parkway Suite 420 Mckinney, TX 75070	Tel : (214) 733-8505	Fax : (214) 733-8506	e-mail : jquinn@3d-plususa.com	