

HYBRID - HIGH RELIABILITY RADIATION TOLERANT DC/DC CONVERTER

Description

The M3L-Series of DC/DC converters are radiation tolerant, high reliability devices designed for moderate radiation environments such as those encountered by low earth orbit satellites and launch vehicles. For higher radiation environments, the M3G-Series of DC/DC converters is recommended. Features include small size, low weight and a high tolerance to total ionizing dose, single event effects and environmental stresses such as temperature extremes, mechanical shock, and vibration. All components are fully derated to meet the requirements of MIL-STD-975 and MIL-STD-1547 and GSFC PPL-21 Appendix B. Extensive documentation including Radiation Susceptibility, Thermal Analysis, Stress Analysis and MTBF are available.

The converters incorporate a fixed frequency single forward topology with magnetic feedback and an internal EMI filter. These converters are capable of meeting the conducted emissions and conducted susceptibility requirements of MIL-STD-461C without any additional components. All models include an external inhibit port and have an adjustable output voltage. They are enclosed in a hermetic 1.5" x 2.3" x 0.425" steel package and weigh less than 85 grams. The package utilizes rugged ceramic feed-through copper core pins and is sealed using parallel seam welding.

Manufactured in a facility fully qualified to MIL-PRF-38534, these converters are fabricated utilizing DSAC qualified processes. For available screening options, refer to device screening table in the data sheet.

Non-flight versions of the M3L-Series converters are available for system development purposes. Variations in electrical specifications and screening to meet custom requirements can be accommodated. Consult IR Santa Clara for special requirements.

M3L-SERIES

+ 28V Input, Single/Dual Output



Features

- Total Dose > 25K Rad(Si)
- SEE Hardened to LET up to 37 MeV.cm²/mg
- Internal EMI filter; Converter Capable of meeting MIL-STD-461C CE03 and CS01
- Low Weight, < 85 grams
- Magnetically Coupled Feedback
- 16V to 50V DC Input Range
- Up to 25W Output Power
- Single and Dual Output Models Include 3.3, 5, 12, 15, ±5, ±12 and ±15V
- High Efficiency to 82%
- -55°C to +125°C Operating Temperature Range
- 100MΩ @ 500VDC Isolation
- Under-Voltage Lockout
- Short Circuit and Overload Protection
- Output Over Voltage Limiter
- Adjustable Output Voltage
- External Inhibit
- 1,500,000 Hour MTBF

Applications

- Low Earth Orbit Satellites (LEO)
- Launch Vehicles

Circuit Description

The M3L-Series converters utilize a single-ended forward topology with resonant reset. The nominal switching frequency is 500kHz. Electrical isolation and tight output regulation are achieved through the use of a magnetically coupled feedback. Voltage feed-forward with duty factor limiting provides high line rejection and protection against output over voltage in the event of an internal control loop failure. This mechanism limits the maximum output voltage to approximately 20% over the nominal regardless of the line voltage.

An internal EMI filter allows the converter to meet the conducted emissions requirements of MIL-STD-461C on the input power leads. A single-stage output filter reduces the typical output ripple to less than 50mV peak-to-peak.

Output current is limited under any load fault condition to approximately 125% of rated. An overload condition causes the converter output to behave like a constant current source with the output voltage dropping below nominal. The converter will resume normal operation when the load current is reduced below the current limit point. This protects the converter from both overload and short circuit conditions. The current limit point exhibits a slightly negative temperature coefficient to reduce the possibility of thermal runaway.

An external inhibit port is provided to control converter operation. The converter's operation is inhibited when this pin is pulled low. It is intended to be driven by an open collector logic device. The pin may be left open for normal operation and has a nominal open circuit voltage of 10.5V with respect to the input return (pin 2).

The output voltage of all models can be adjusted using a single external resistor.

Design Methodology

The M3L-Series was developed using a proven conservative design methodology which includes selecting radiation tolerance and established reliability components and fully derating to the requirements of MIL-STD-975 and MIL-STD-1547. Heavy derating of the power MOSFET gate and drain voltages minimize the possibility of SEGR and SEB. A magnetic feedback circuit is utilized instead of opto-couplers to minimize temperature, radiation and aging sensitivity. PSPICE was used extensively to predict and optimize circuit performance for both beginning and end-of-life. Thorough design analyses include Radiation Susceptibility (TREE), Stress, Thermal, and Reliability (MTBF).

Specifications

Absolute Maximum Ratings		Recommended Operating Conditions		
Input voltage range		Input voltage range		+16Vdc to +60Vdc
Output power		Internally limited		+16Vdc to +38Vdc
Lead temperature		+300°C for 10 seconds		0 to Max. Rated
Operating temperature		-55°C to +135°C		-55°C to +125°C
Storage temperature		-55°C to +135°C		-55°C to +70°C

¹ Meets derating per MIL-STD-1547

² For operation at +125°C, see table note 13

Electrical Performance Characteristics

Parameter	Group A Subgroup	Conditions -55°C ≤ T _C ≤ +85°C V _{IN} = 28V DC ± 5%, C _L = 0 unless otherwise specified	Limits			Unit
			Min	Nom	Max	
Input Voltage			18	28	50	V
Output Voltage (V _{OUT})	1	I _{OUT} = 100% rated load Note 4	3.27	3.30	3.33	V
			4.95	5.00	5.05	
			11.88	12.00	12.12	
			14.85	15.00	15.15	
			±4.95	±5.00	±5.05	
			±11.88	±12.00	±12.12	
			±14.85	±15.00	±15.15	
	2,3	I _{OUT} = 100% rated load Note 4	3.23		3.37	V
			4.90		5.10	
			11.76		12.24	
			14.70		15.30	
			±4.90		±5.10	
			±11.76		±12.24	
			±14.70		±15.30	
Output power (P _{OUT})	1,2,3	V _{IN} = 16, 28, 50 Volts, Note 2	0		20	W
M3L2803R3S			0		25	
All Others						
Output current (I _{OUT})	1,2,3	V _{IN} = 16, 28, 50 Volts, Note 2	0		6.06	A
			0		5.00	
			0		2.08	
			0		1.67	
			0		4.00	
			0		1.67	
			0		1.33	
Line regulation (VR _{LINE})	1,2,3	V _{IN} = 16, 28, 50 Volts I _{OUT} = 0, 50%, 100% rated, Note 4	-0.5		0.5	%
Load regulation (VR _{LOAD})	1,2,3	I _{OUT} = 0, 50%, 100% rated, Note 4 V _{IN} = 16, 28, 50 Volts	-1.0		1.0	%
Cross regulation (VR _{CROSS})	1,2,3	V _{IN} = 16, 28, 50 Volts Duals only, Note 5	-5.0		5.0	%
M3L2805D			-3.0		3.0	
M3L2812D			-3.0		3.0	
M3L2815D						

For Notes to Specifications, refer to page 5

M3L-SERIES

International
IR Rectifier

Electrical Performance Characteristics (continued)

Parameter	Group A Subgroup	Conditions $-55^{\circ}\text{C} \leq T_c \leq +85^{\circ}\text{C}$ $V_{IN} = 28\text{V DC} \pm 5\%$, $C_L = 0$ unless otherwise specified	Limits			Unit
			Min	Nom	Max	
Input current, no load (I_{IN}) M3L2803R3S M3L2805S M3L2812S M3L2815S M3L2805D M3L2812D M3L2815D	1,2,3	$I_{OUT} = 0$, Pin 4 open			60 70 70 70 70 100 100	mA
Input current inhibited	1,2,3	Pin 4 shorted to pin 2			8.0	mA
Output ripple (V_{RIP}) M3L2803R3S M3L2805S M3L2812S M3L2815S M3L2805D M3L2812D M3L2815D	1,2,3	$V_{IN} = 16, 28, 50$ Volts $I_{OUT} = 100\%$ rated load Notes 4, 6			35 50 70 80 80 80 80	mV p-p
Switching frequency (F_S)	1,2,3	Sync. Input (Pin 4) open	425	500	575	KHz
Efficiency (E_{FF}) M3L2803R3S M3L2805S M3L2812S M3L2815S M3L2805D M3L2812D M3L2815D	1,2,3	$I_{OUT} = 100\%$ rated load Note 4	68 75 75 75 75 75 75	75 79 80 81 79 79 80		%
Enable Input (Inhibit Function) open circuit voltage drive current (sink) voltage range	1,2,3	Note 1	9.5 -0.5		11.5 500 50	V μA V
Current Limit Point Expressed as a percentage of full rated load current	1,2,3	$V_{out} = 90\%$ of Nominal, Note 4	105		130	%
Power dissipation, load fault (P_D)	1,2,3	Short Circuit, Overload, Note 8			14	W
Output response to step load changes (V_{TLD})	4,5,6	Half Load to/from Full Load, Notes 4,9	-300		300	mV pk
Recovery time, step load changes (T_{TLD})	4,5,6	Half Load to/from Full Load, Note 4,9,10			200	μs
Output response to step line changes (V_{TLN})	4,5,6	16V to/from 50V $I_{OUT} = 100\%$ rated load, Notes 1,4,11	-300		300	mV pk
Recovery Time, step line changes (T_{TLN})	4,5,6	16V to/from 50V $I_{OUT} = 100\%$ rated load, Notes 1,4,10,11			200	μs
Turn-on Response Overshoot (V_{OS}) Turn-on Delay (T_{DLY})	4,5,6	No Load, Full Load Notes 4,12	2.0		500 10	mV ms

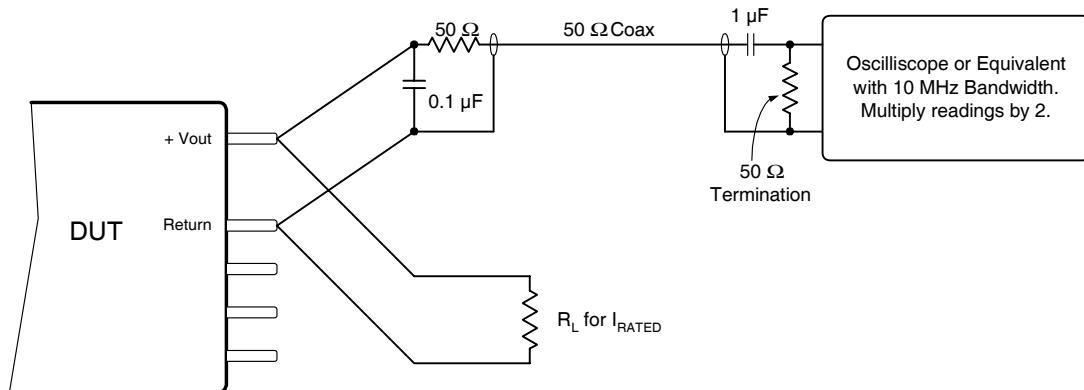
For Notes to Specifications, refer to page 5

Electrical Performance Characteristics (continued)

Parameter	Group A Subgroup	Conditions $-55^{\circ}\text{C} \leq T_c \leq +85^{\circ}\text{C}$ $V_{IN} = 28\text{V DC} \pm 5\%$, $C_L = 0$ unless otherwise specified	Limits			Unit
			Min	Nom	Max	
Capacitive Load (CL) M3L2803R3S M3L2805S M3L2812S M3L2815S M3L2805D M3L2812D M3L2815D	1	$I_{OUT} = 100\%$ rated load No effect on DC performance Notes 1, 4, 7 Each output on duals			2200 1000 180 120 500 90 60	μF
Line Rejection	1	$I_{OUT} = 100\%$ rated load DC to 50KHz, Notes 1, 4	40	50		dB
Isolation	1	Input to Output or Any Pin to Case except pin 3, test @ 500VDC	100			$\text{M}\Omega$
Device Weight					85	g
MTBF		MIL-HDBK-217F2, SF, 35°C	1.5×10^6			Hr

Notes. Electrical Performance Characteristics

- 1) Parameter is tested as part of design characterization or after design changes. Thereafter, parameter shall be guaranteed to the limits specified.
- 2) Parameter verified during line and load regulation tests.
- 3) Output load current must be distributed such that at least 20% of the total load current is being provided by one of the outputs.
- 4) Load current split equally between outputs on dual output models.
- 5) Cross regulation is measured with 20% rated load on output under test while changing the load on the other output from 20% to 80% of rated.
- 6) Guaranteed for a D.C. to 20MHz bandwidth. Tested using a 20KHz to 10MHz bandwidth using the circuit shown below.
- 7) Capacitive load may be any value from 0 to the maximum limit without compromising dc performance. A capacitive load in excess of the maximum limit may interfere with the proper operation of the converter's overload protection, causing erratic behavior during turn-on.
- 8) Overload power dissipation is defined as the device power dissipation with the load set such that $V_{OUT} = 90\%$ of nominal.
- 9) Load step transition time $\leq 10 \mu\text{s}$.
- 10) Recovery time is measured from the initiation of the transient to where V_{OUT} has returned to within $\pm 1\%$ of its steady state value.
- 11) Line step transition time $\leq 100 \mu\text{s}$.
- 12) Turn-on delay time from either a step application of input power or a logic low to a logic high transition on the inhibit pin (pin 4) to the point where $V_{OUT} = 90\%$ of nominal.
- 13) For operation at temperatures between $+85^{\circ}\text{C}$ and $+125^{\circ}\text{C}$, derate the maximum output power linearly from 100% to 75%.

Circuit for Measuring Output Ripple Voltage**Radiation Performance Characteristics**

Test	Conditions	Min	Typ	Highest Level Tested	Unit
Total Ionizing Dose (Gamma)	MIL-STD-883, Method 1019 Operating bias applied during exposure, Full Rated Load, $V_{IN} = 28V$	25	40	60	KRads (Si)
Single Event Effects SEU, SEL, SEGR, SEB	Heavy ions (LET) Operating bias applied during exposure, Full Rated Load, $V_{IN} = 28V$	37	82	82	MeV•cm ² /mg
Dose Rate (Gamma Dot) Temporary Saturation Survival	MIL-STD-883, Method 1023 Operating bias applied during exposure, Full Rated Load, $V_{IN} = 28V$	1E8 1E10		1.5E9	Rads (Si)/sec
Neutron Fluence	MIL-STD-883, Method 1017	3E12		8E12	Neutrons /cm ²
Proton Fluence	$E > 10\text{MeV}$	TBD		N/A	protons /cm ²

International Rectifier currently does not have a DSAC certified Radiation Hardness Assurance Program.

Figure 1. Block Diagram - Single Output

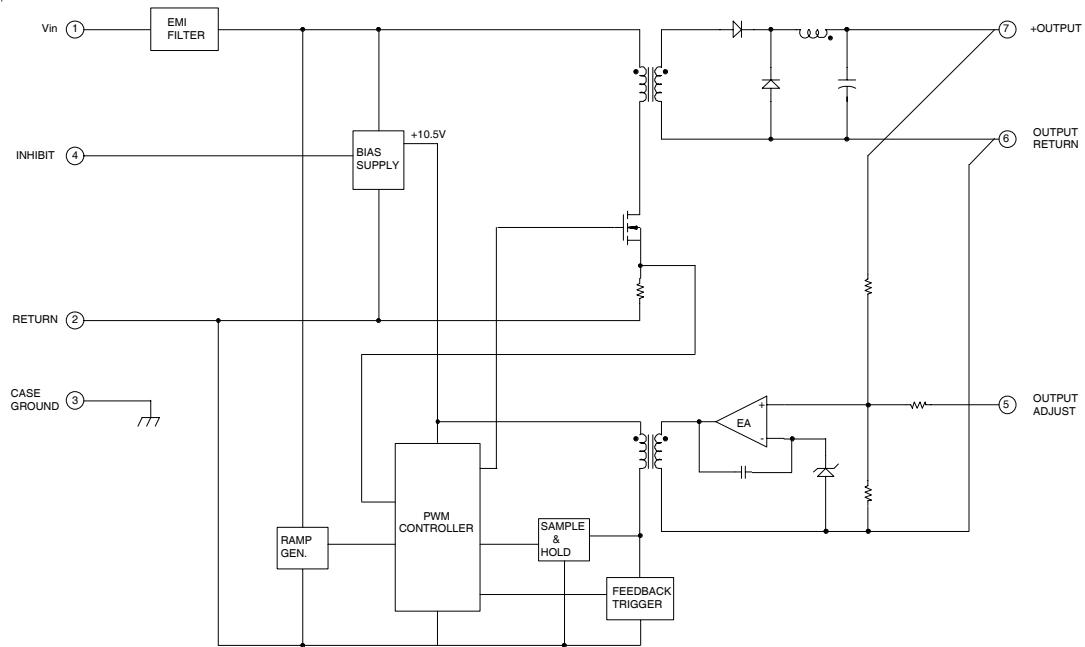


Figure 2. Block Diagram - Dual Output

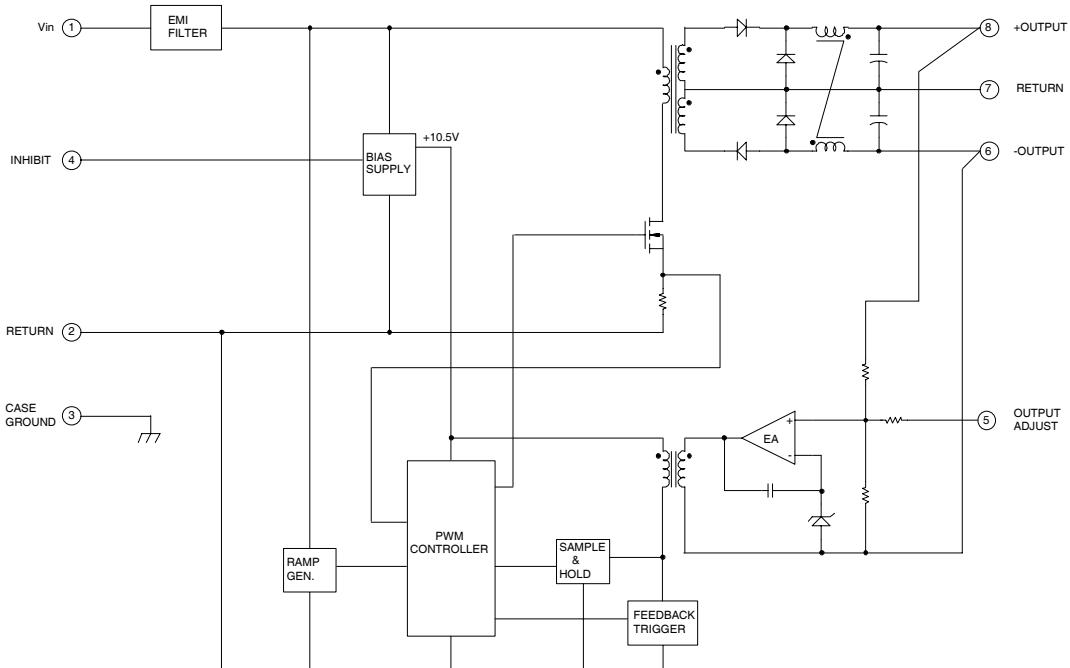


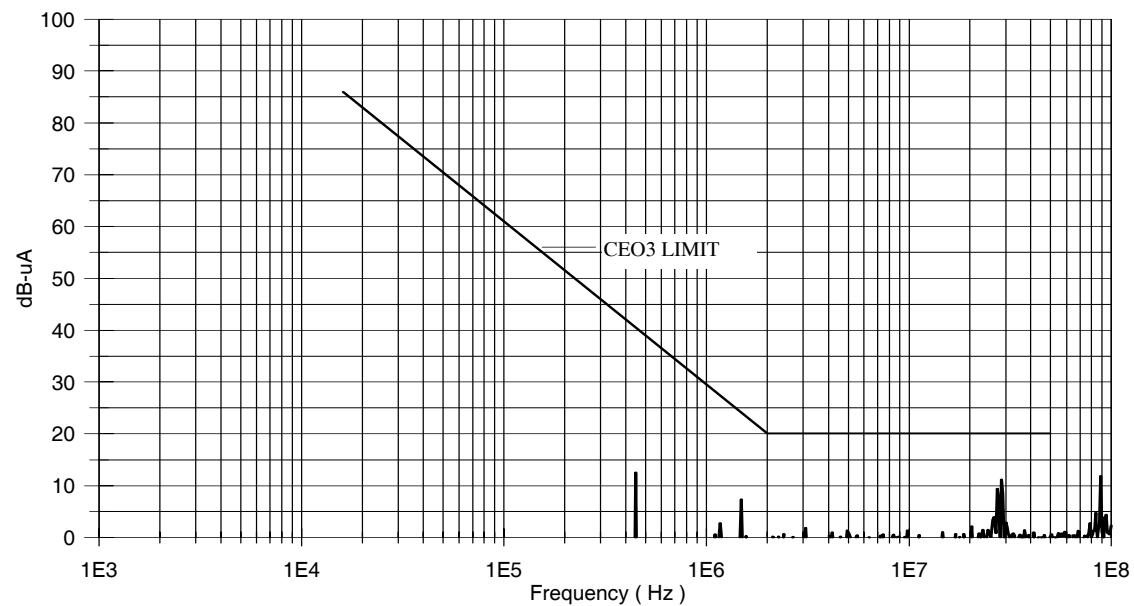
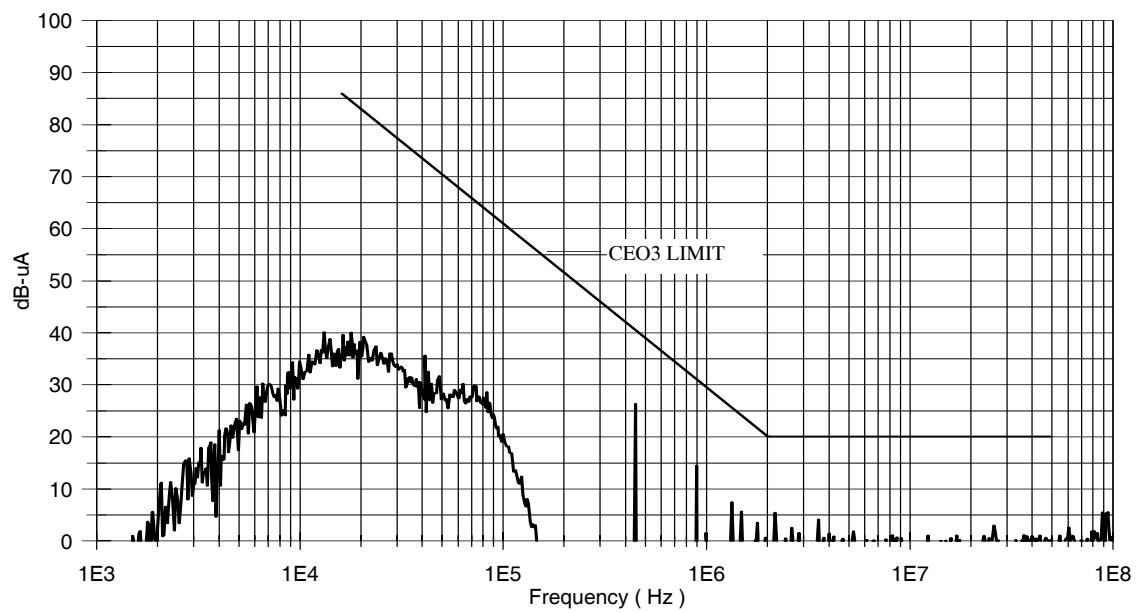
Figure 3. Conducted Emissions, Common Mode**Figure 4. Conducted Emissions, Normal Mode**

Figure 5. M3L2805S Line Rejection (CS01)

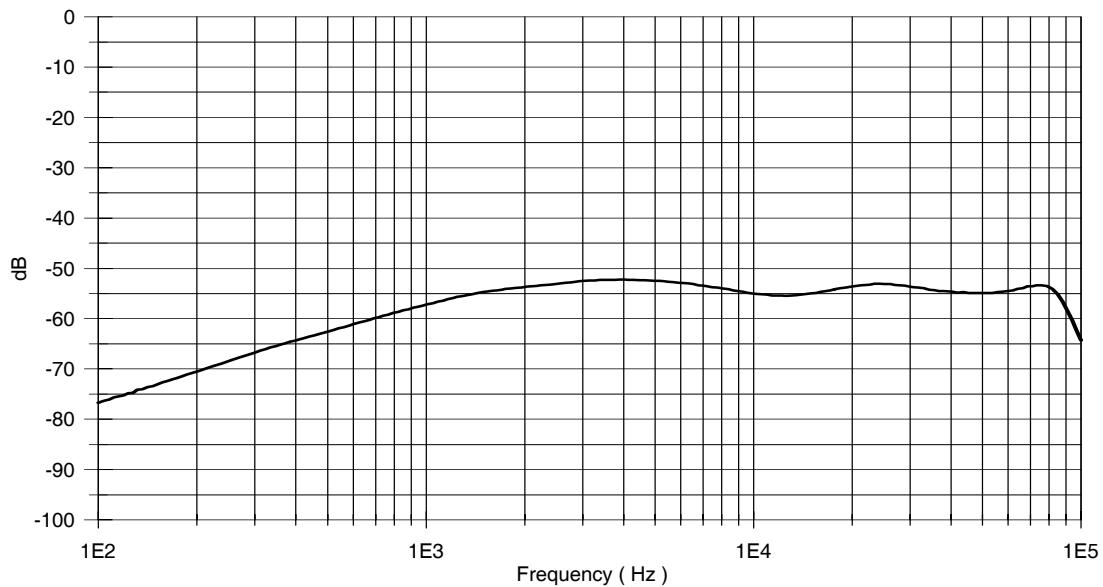


Figure 6. M3L2815D Line Rejection (CS01)

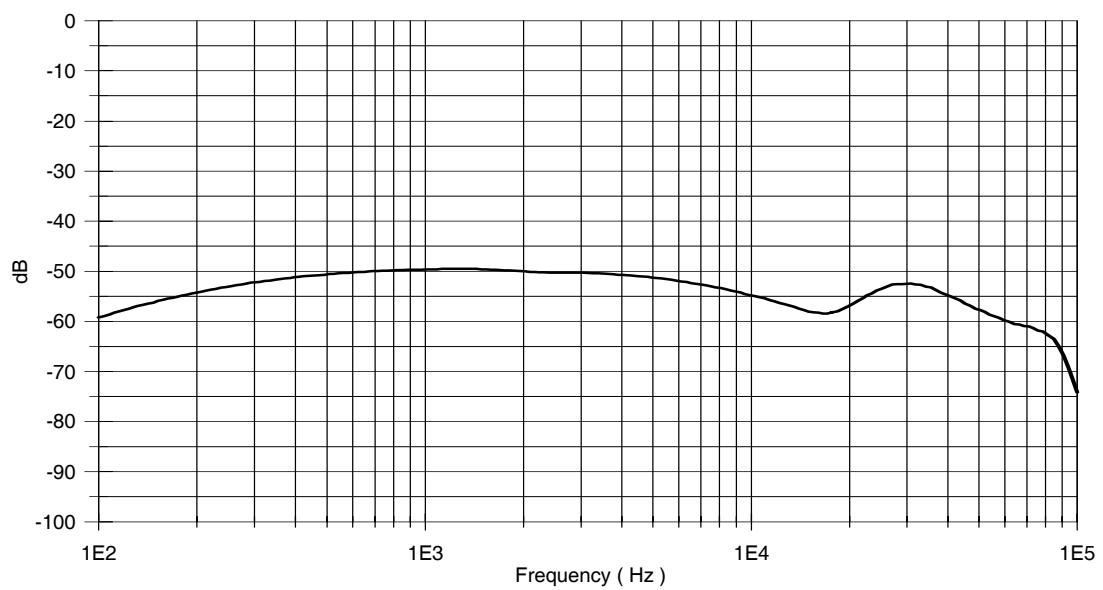
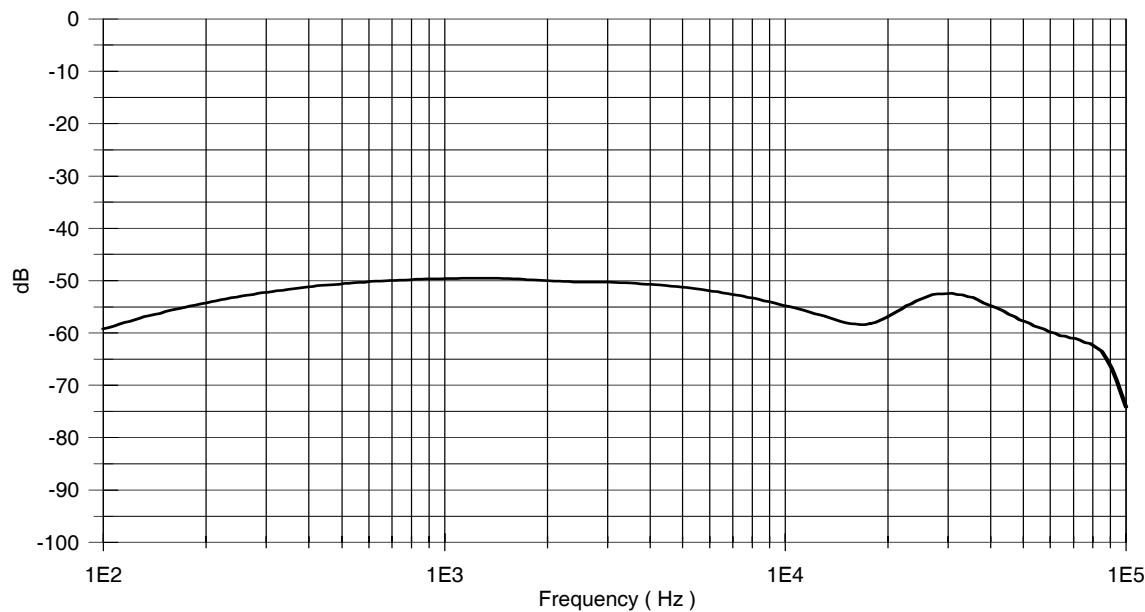
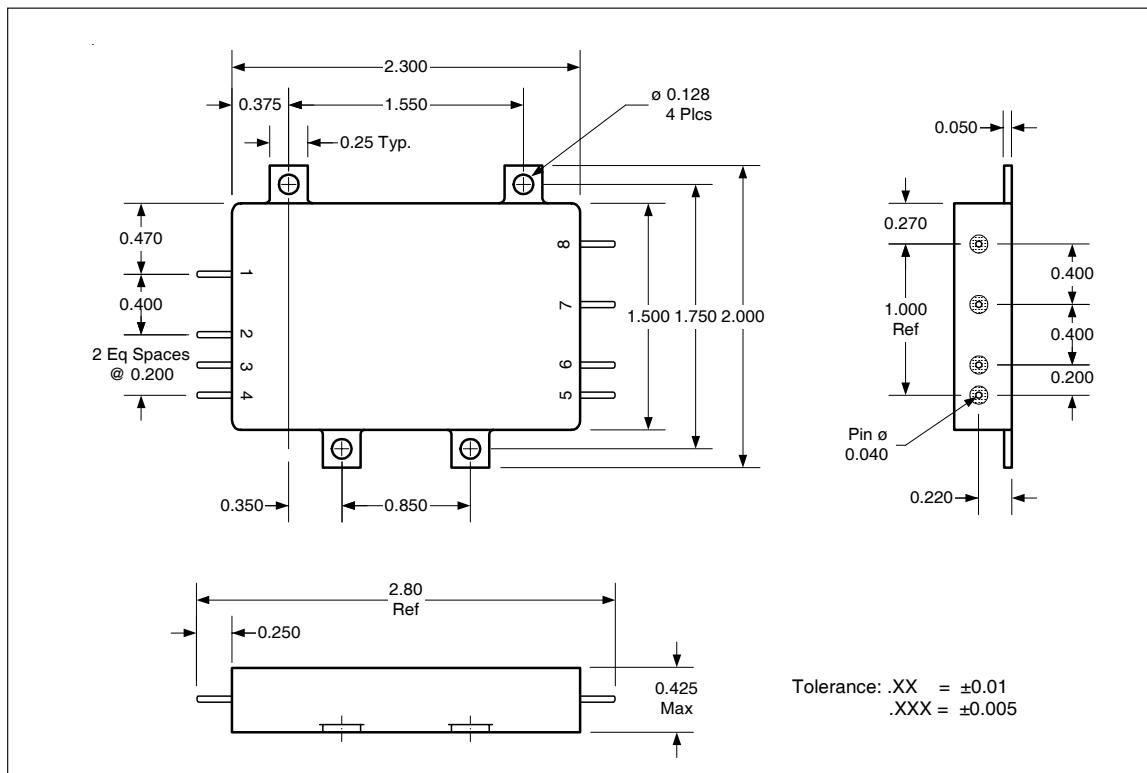


Figure 7. M3L2815D Line Rejections (CS01)



Mechanical outline



Pin Designation (Single/Dual)

Pin #	Single	Dual
1	+ Input	+ Input
2	Input Return	Input Return
3	Case	Case
4	Inhibit	Inhibit
5	Output Adjust	Output Adjust
6	Output Return	- Vout
7	+ Vout	Output Return
8	NC	+ Vout

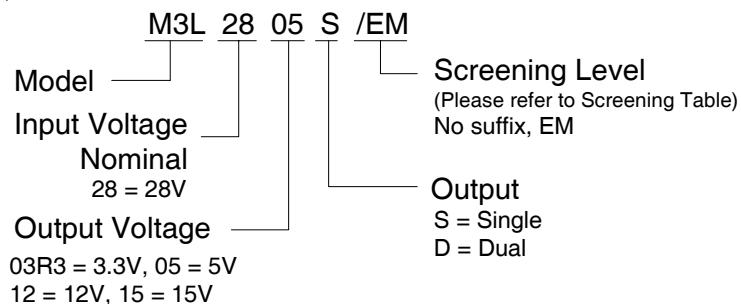
Device Screening

Requirement	MIL-STD-883 Method	No Suffix	EM
Temperature Range	—	-55°C to +85°C	-55°C to +85°C
Element Evaluation	MIL-PRF-38534	Class H w/SEM	N/A
Non-Destructive Bond Pull	2023	Yes	N/A
Internal Visual	2017	Yes	①
Temperature Cycle	1010	Cond C	Cond C
Constant Acceleration	2001, Y1 Axis	3000 Gs	3000 Gs
PIND	2020	N/A	N/A
Burn-In	1015	160 hrs @ 125°C	48 hrs @ 125°C
Final Electrical (Group A)	MIL-PRF-38534 & Specification	-55°C, +25°C, +85°C	-55°C, +25°C, +85°C
PDA	MIL-PRF-38534	N/A	N/A
Seal, Fine and Gross	1014	A1, C	Cond A
Radiographic	2012	N/A	N/A
External Visual	2009	Yes	①

Notes:

① Best commercial practice.

International Rectifier currently does not have a DSCC certified Radiation Hardness Assurance Program.

Part Numbering

International
IR Rectifier

WORLD HEADQUARTERS: 233 Kansas St., El Segundo, California 90245, Tel: (310) 252-7105

IR SANTA CLARA: 2270 Martin Av., Santa Clara, California 95050, Tel: (408) 727-0500

Visit us at www.irf.com for sales contact information.

Data and specifications subject to change without notice. 09/2006