International
IOR Rectifier

# M3L-SERIES

## + 28V Input, Single/Dual Output

# HYBRID - HIGH RELIABILITY RADIATION TOLERANT DC/DC CONVERTER




M3L

## 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 DSCC 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.

## Features

- Total Dose > 25K Rad(Si)
- SEE Hardened to LET up to 37 MeV.cm$^2$/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 | -0.5Vdc to +60Vdc | Input voltage range | +16Vdc to +60Vdc |
| Output power | Internally limited | Input voltage range [1] | +16Vdc to +38Vdc |
| Lead temperature | +300°C for 10 seconds | Output power | 0 to Max. Rated |
| Operating temperature | -55°C to +135°C | Operating temperature [2] | -55°C to +125°C |
| Storage temperature | -55°C to +135°C | Operating temperature [1] | -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<br>-55°C ≤ $T_C$ ≤ +85°C<br>$V_{IN}$ = 28V DC ± 5%, $C_L$ = 0<br>unless otherwise specified | Limits | | | Unit |
|---|---|---|---|---|---|---|
| | | | Min | Nom | Max | |
| Input Voltage | | | 18 | 28 | 50 | V |
| Output Voltage ( Vout ) | | | | | | |
| M3L2803R3S | 1 | $I_{OUT}$ = 100% rated load | 3.27 | 3.30 | 3.33 | |
| M3L2805S | 1 | Note 4 | 4.95 | 5.00 | 5.05 | |
| M3L2812S | 1 | | 11.88 | 12.00 | 12.12 | |
| M3L2815S | 1 | | 14.85 | 15.00 | 15.15 | |
| M3L2805D | 1 | | ±4.95 | ±5.00 | ±5.05 | |
| M3L2812D | 1 | | ±11.88 | ±12.00 | ±12.12 | |
| M3L2815D | 1 | | ±14.85 | ±15.00 | ±15.15 | V |
| M3L2803R3S | 2,3 | $I_{OUT}$ = 100% rated load | 3.23 | | 3.37 | |
| M3L2805S | 2,3 | Note 4 | 4.90 | | 5.10 | |
| M3L2812S | 2,3 | | 11.76 | | 12.24 | |
| M3L2815S | 2,3 | | 14.70 | | 15.30 | |
| M3L2805D | 2,3 | | ±4.90 | | ±5.10 | |
| M3L2812D | 2,3 | | ±11.76 | | ±12.24 | |
| M3L2815D | 2,3 | | ±14.70 | | ±15.30 | |
| Output power ( $P_{OUT}$ ) | | | | | | |
| M3L2803R3S | 1,2,3 | $V_{IN}$ = 16, 28, 50 Volts, Note 2 | 0 | | 20 | W |
| All Others | | | 0 | | 25 | |
| Output current ( $I_{OUT}$ ) | | | | | | |
| M3L2803R3S | 1,2,3 | $V_{IN}$ = 16, 28, 50 Volts, Note 2 | 0 | | 6.06 | |
| M3L2805S | | | 0 | | 5.00 | |
| M3L2812S | | | 0 | | 2.08 | |
| M3L2815S | | | 0 | | 1.67 | |
| M3L2805D | | Either Output, Note 3 | 0 | | 4.00 | A |
| M3L2812D | | Either Output, Note 3 | 0 | | 1.67 | |
| M3L2815D | | Either Output, Note 3 | 0 | | 1.33 | |
| Line regulation ( $VR_{LINE}$ ) | 1,2,3 | $V_{IN}$ = 16, 28, 50 Volts<br>$I_{OUT}$ = 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<br>$V_{IN}$ = 16, 28, 50 Volts | -1.0 | | 1.0 | % |
| Cross regulation ( $VR_{CROSS}$ ) | | | | | | |
| M3L2805D | 1,2,3 | $V_{IN}$ = 16, 28, 50 Volts | -5.0 | | 5.0 | |
| M3L2812D | | Duals only, Note 5 | -3.0 | | 3.0 | % |
| M3L2815D | | | -3.0 | | 3.0 | |

For Notes to Specifications, refer to page 5

## Electrical Performance Characteristics ( continued )

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

For Notes to Specifications, refer to page 5

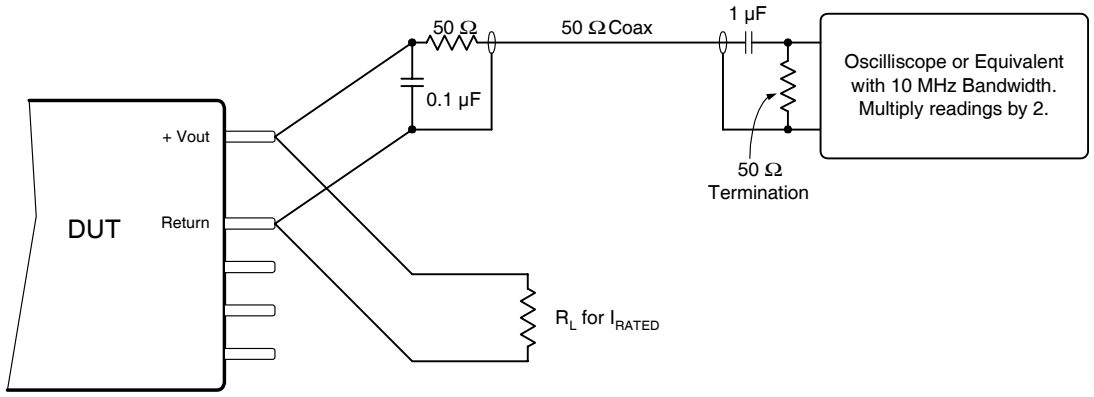
## Electrical Performance Characteristics ( continued )

| Parameter | Group A Subgroup | Conditions<br>-55°C ≤ $T_C$ ≤ +85°C<br>$V_{IN}$ = 28V DC ± 5%, $C_L$ = 0<br>unless otherwise specified | Limits | | | Unit |
|---|---|---|---|---|---|---|
| | | | Min | Nom | Max | |
| Capacitive Load (CL) | | | | | | |
| M3L2803R3S | 1 | $I_{OUT}$ = 100% rated load | | | 2200 | |
| M3L2805S | | No effect on DC performance | | | 1000 | |
| M3L2812S | | Notes 1, 4, 7 | | | 180 | |
| M3L2815S | | | | | 120 | µF |
| M3L2805D | | | | | 500 | |
| M3L2812D | | Each output on duals | | | 90 | |
| M3L2815D | | | | | 60 | |
| Line Rejection | 1 | $I_{OUT}$ = 100% rated load<br>DC to 50KHz, Notes 1, 4 | 40 | 50 | | dB |
| Isolation | 1 | Input to Output or Any Pin to Case<br>except pin 3, test @ 500VDC | 100 | | | MΩ |
| Device Weight | | | | | 85 | g |
| MTBF | | MIL-HDBK-217F2, SF, 35°C | $1.5 \times 10^6$ | | | 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 ≤ 10 µs.
10) Recovery time is measured from the initiation of the transient to where $V_{OUT}$ has returned to within ±1% of its steady state value.
11) Line step transition time ≤ 100 µs.
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°C and +125°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<br>Operating bias applied during exposure,<br>Full Rated Load, $V_{IN}$ = 28V | 25 | 40 | 60 | KRads (Si) |
| Single Event Effects<br>SEU, SEL, SEGR, SEB | Heavy ions (LET)<br>Operating bias applied during exposure,<br>Full Rated Load, $V_{IN}$ = 28V | 37 | 82 | 82 | MeV•cm$^2$ /mg |
| Dose Rate ( Gamma Dot )<br>Temporary Saturation<br>Survival | MIL-STD-883, Method 1023<br>Operating bias applied during exposure,<br>Full Rated Load, $V_{IN}$ = 28V | <br>1E8<br>1E10 | | 1.5E9 | Rads (Si)/sec |
| Neutron Fluence | MIL-STD-883, Method 1017 | 3E12 | | 8E12 | Neutrons /cm$^2$ |
| Proton Fluence | E > 10MeV | TBD | | N/A | protons /cm$^2$ |

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

**Figure 1. Block Diagram - Single Output**

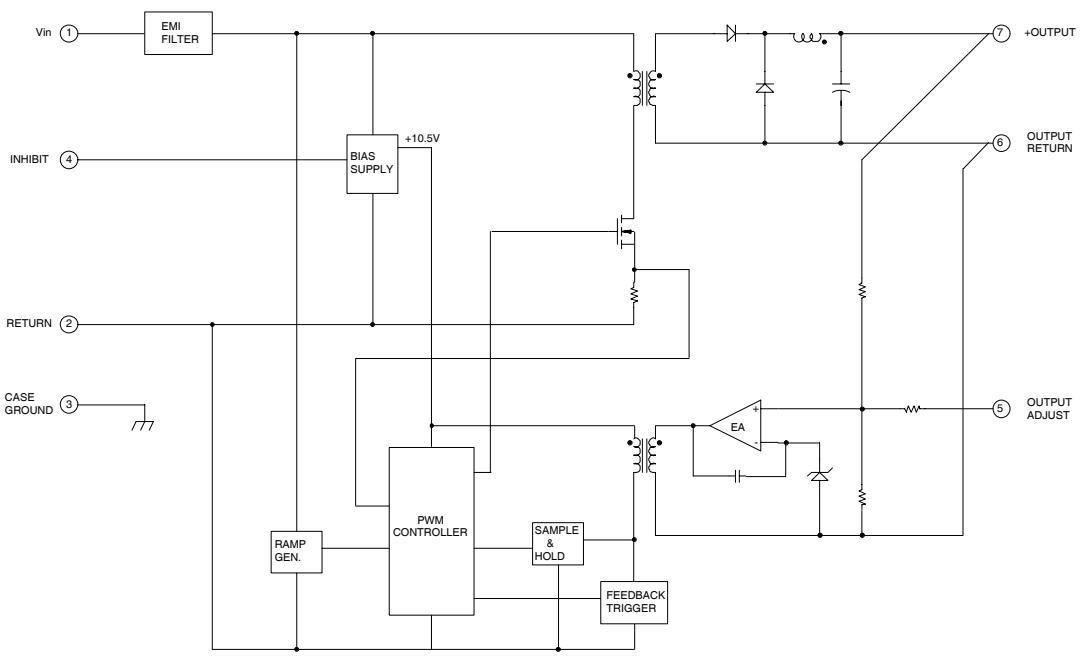



**Figure 2. Block Diagram - Dual Output**

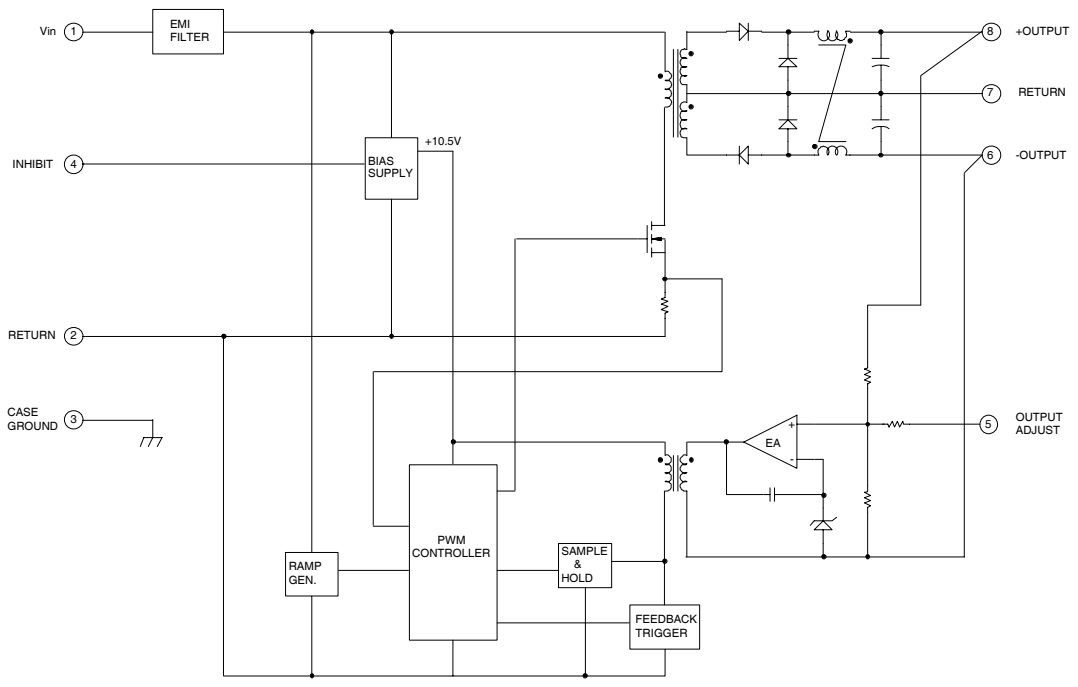


**Figure 3. Conducted Emissions, Common Mode**

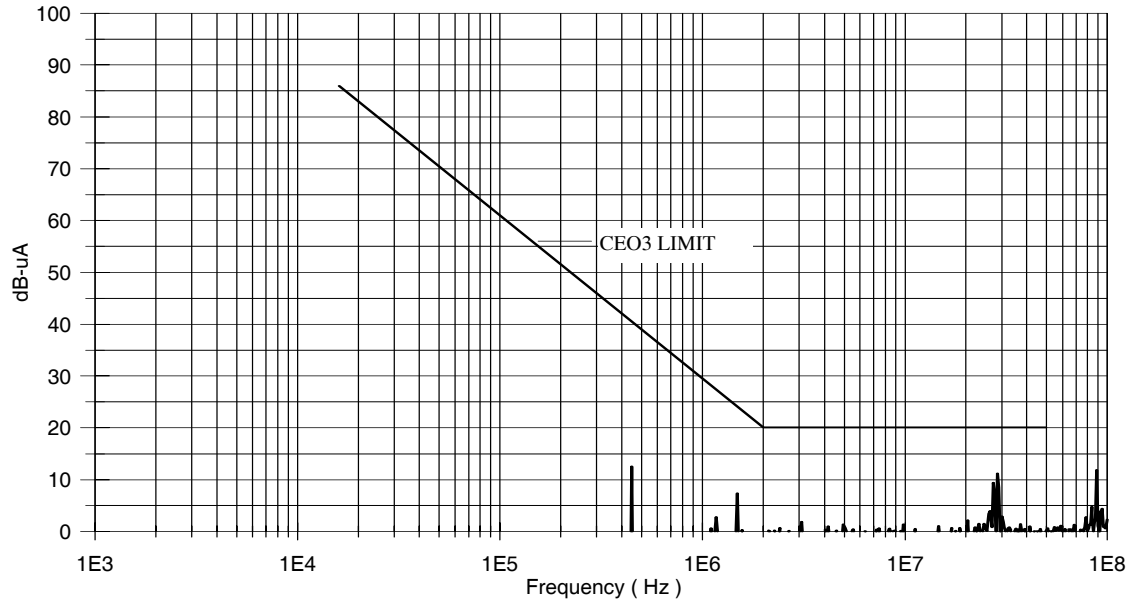



**Figure 4. Conducted Emissions, Normal Mode**

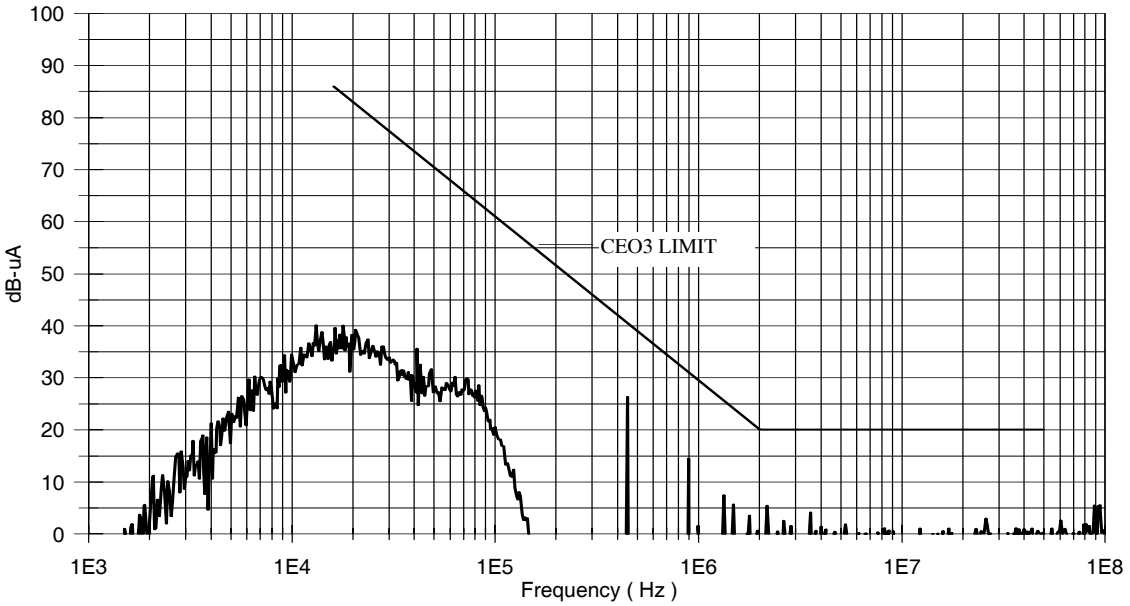


**Figure 5. M3L2805S Line Rejection (CS01)**

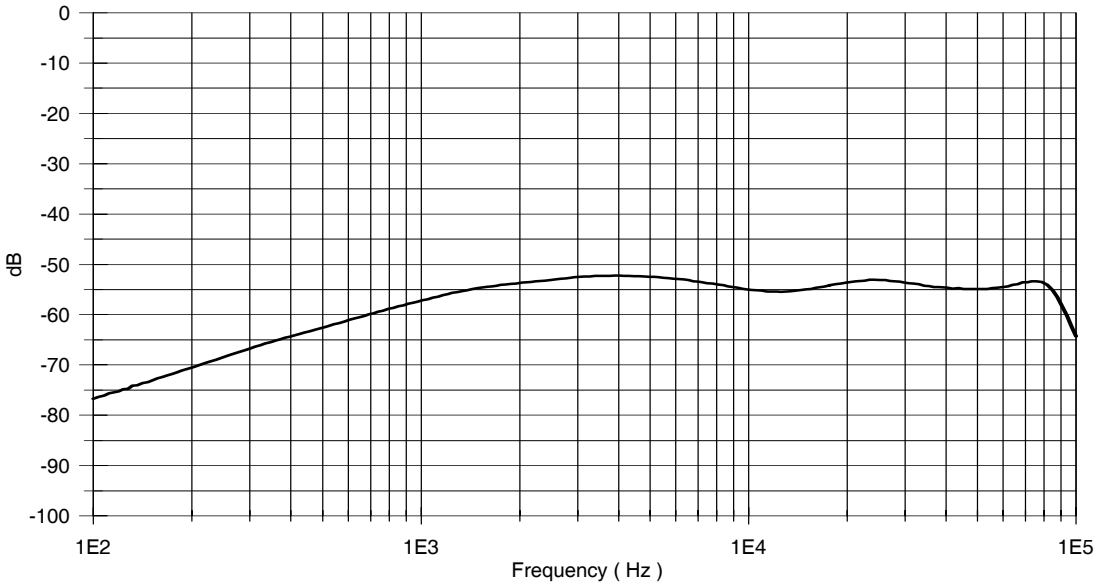



**Figure 6. M3L2815D Line Rejection (CS01)**

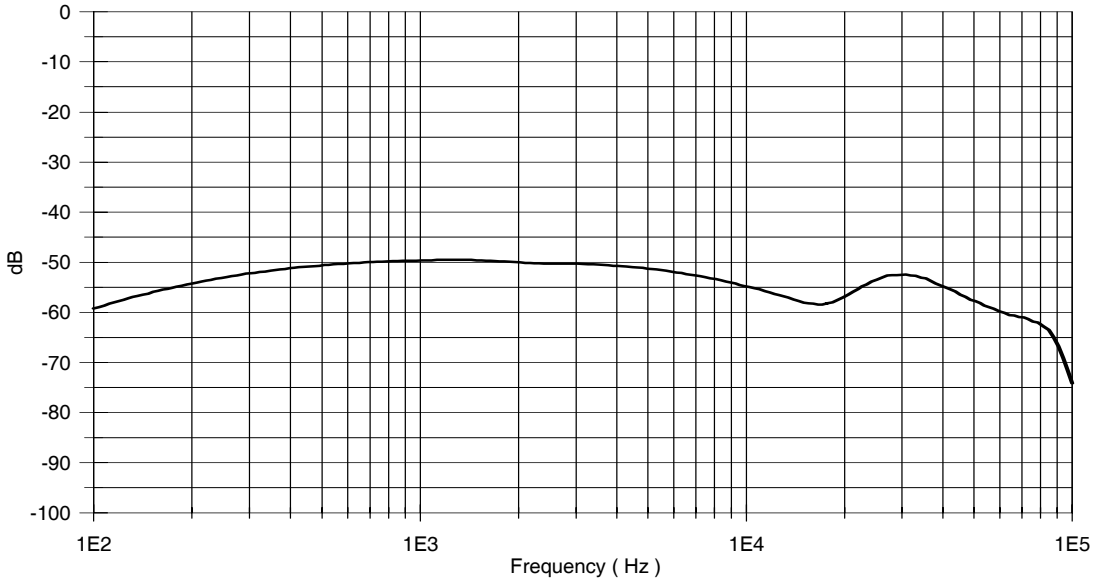
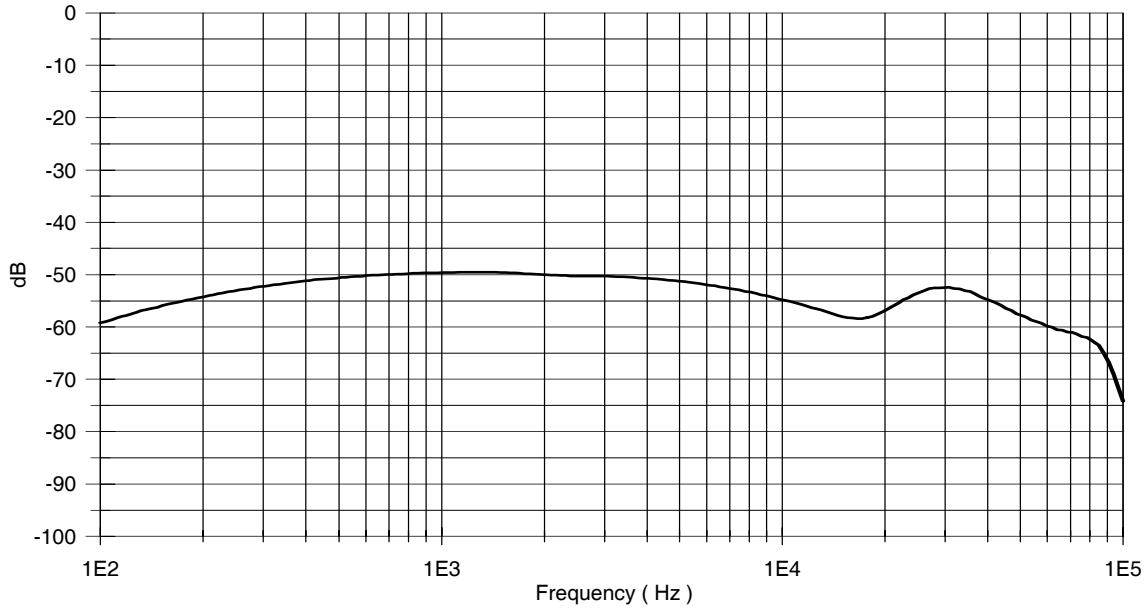
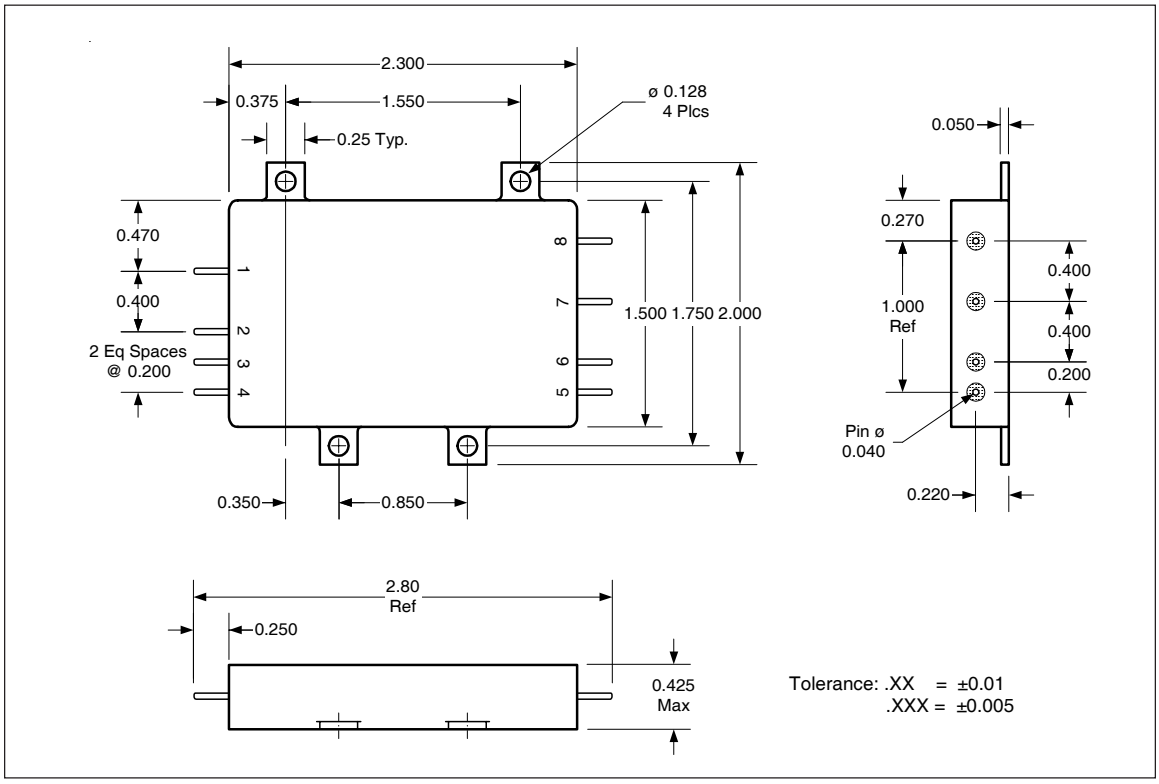


**Figure 7. M3L2815D Line Rejections (CS01)**



## 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

M3L 28 05 S /EM

- **Model**
- **Input Voltage**
  - Nominal
  - 28 = 28V
- **Output Voltage**
  - 03R3 = 3.3V, 05 = 5V
  - 12 = 12V, 15 = 15V
- **Output**
  - S = Single
  - D = Dual
- **Screening Level**
  - (Please refer to Screening Table)
  - No suffix, EM

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