

**ADVANCED ANALOG
HIGH RELIABILITY RADIATION
HARDENED DC/DC CONVERTER**

G-SERIES

28V Input, Triple Output



Description

The G-Series of DC/DC converters are radiation hardened, high reliability converters designed for extended operation in hostile environments. Their small size and low weight make them ideal for applications such as geostationary earth orbit satellites and deep space probes. They exhibit 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, MIL-STD-1547 and GSFC PPL-21 Appendix B. Extensive documentation including Radiation Susceptibility, Thermal, Stress, Worst Case, Failure Modes and Effects analyses and MTBF are available for customer review and included with each order.

The converters incorporate a fixed frequency single ended forward topology with magnetic feedback and an internal EMI filter that utilizes multilayer ceramic capacitors that are subjected to extensive lot screening for optimum reliability. These converters are capable of meeting the conducted emissions and conducted susceptibility requirements of MIL-STD-461C without any additional components. External inhibit and synchronization input and output allow these converters to be easily incorporated into larger power systems. They are enclosed in a hermetic 3" x 2" x 0.4" package constructed of an Aluminum/Silicon-Carbide (Al/SiC) base and an Alloy 48 ring frame and they weigh less than 90 grams. The package utilizes rugged ceramic feed-through copper core pins and is sealed using parallel seam welding.

Full environmental screening includes temperature cycling, constant acceleration, fine and gross leak, particle impact noise detection (PIND), radiographic and 320 hours burn-in.

Non-flight versions of the G-Series converters are available for system development purposes. Variations in

Features

- Total Dose > 200K Rad(Si), typically usable to > 300K Rad(Si)
- SEE 82 MeV.cm²/mg
- Internal EMI filter; Converter Capable of meeting MIL-STD-461C CE03 and CS01
- Low Weight, < 90 grams
- Magnetically Coupled Feedback
- 18V to 50V DC Input Range
- Up to 40W Output Power
- Triple Output Models Include +5V and $\pm 12V$ or $\pm 15V$
- Main Output Isolated from Dual Outputs
- High Efficiency - to 80%
- -55°C to +125°C Operating Temperature Range
- 100M Ω @ 500VDC Isolation
- Under-Voltage Lockout
- Synchronization Input and Output
- Short Circuit and Overload Protection
- Output Over Voltage Limiter
- External Inhibit
- > 5,000,000 Hour MTBF

Applications

- Geostationary Earth Orbit Satellites (GEO)
- Deep Space Satellites / Probes
- Strategic Weapons and Communication Systems

electrical specifications and screening to meet custom requirements can be accommodated.

Circuit Description

The G-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 two-stage output filter reduces the typical output ripple to less than 20mV peak-to-peak.

The main (+5 volt) output is regulated by the control loop and typically exhibits better than 1% regulation. The auxiliary (± 12 volt or ± 15 volt) outputs are maintained through tight coupling in the power transformer and main output filter inductor and typically exhibit better than 5% regulation. The main output and auxiliary outputs are isolated from each other.

Output power 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 under-voltage lockout circuit prohibits the converter from operating when the line voltage is too low to maintain the output voltage. The converter will not start until the line voltage rises to approximately 16.5 volts and will shut down when the input voltage drops

below 15.5 volts. The one volt of hysteresis reduces the possibility of line noise interfering with the converter's start-up and shut down.

An external inhibit port is provided to control converter operation. The nominal threshold relative to the input return (pin 2) is 1.4V. If 2.0 volts or greater are applied to the Inhibit pin (pin 3) then the converter will operate normally. A voltage of 0.8V or less will cause the converter to shut-down. The pin may be left open for normal operation and has a nominal open circuit voltage of 4.0V.

Synchronization input and output allow multiple converters to operate at a common switching frequency. Converters can be synchronized to one another or to an externally provided clock. This can be used to eliminate beat frequency noise or to avoid creating noise at certain frequencies for sensitive systems.

Design Methodology

The G-Series was developed using a proven conservative design methodology which includes selecting radiation tolerant and established reliability components and fully derating to the requirements of MIL-STD-975 and MIL-STD-1547. Careful sizing of decoupling capacitors and current limiting resistors minimizes the possibility of photo-current burn-out. Heavy derating of the radiation hardened power MOSFET virtually eliminates the possibility of SEGR and SEB. A magnetic feedback circuit is utilized instead of opto-couplers to minimize temperature, radiation and aging sensitivity. PSpice and RadSpice were used extensively to predict and optimize circuit performance for both beginning and end-of-life. Thorough design analyses include Radiation Susceptibility (TREE), Worst Case, Stress, Thermal, Failure Modes and Effects (FMEA) and Reliability (MTBF).

Absolute Maximum Ratings

| | |
|-------------------------|-----------------------|
| Input voltage range - | -0.5Vdc to +80Vdc |
| Output power - | Internally limited |
| Lead temperature - | +300°C for 10 seconds |
| Operating temperature - | -55°C to +135°C |
| Storage temperature - | -55°C to +135°C |

Recommended Operating Conditions

| | |
|--------------------------------------|-----------------|
| Input voltage range - | 18Vdc to +60Vdc |
| Input voltage range ¹ - | 18Vdc to +50Vdc |
| Output power - | 0 to Max. Rated |
| Operating temperature ² - | -55°C to +125°C |
| Operating temperature ¹ - | -55°C to +70°C |

¹ Meets derating per MIL-STD-975

² For operation at +125°C see table note 14

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 | 1,2,3 | Note 2 | 18 | 28 | 50 | V |
| Output Voltage (V _{OUT}) (main) | 1 | I _{OUT} = 100% rated load, Note 5 | 4.98 | 5.00 | 5.02 | V |
| 2812T (aux.) | | | ±11.50 | ±11.80 | ±12.10 | V |
| 2815T (aux.) | | | ±14.60 | ±14.90 | ±15.20 | V |
| (main) | 2,3 | | 4.93 | | 5.07 | V |
| 2812T (aux.) | | | ±11.30 | | ±12.30 | V |
| 2815T (aux.) | | | ±14.40 | | ±15.40 | V |
| Output power (P _{OUT}) | 1,2,3 | V _{IN} = 18, 28, 50 Volts, Note 2 | 0 | | 40 | W |
| Output current (I _{OUT}) (main) | 1,2,3 | V _{IN} = 18, 28, 50 Volts, Notes 2,3,4,5 | 400 | | 4000 | mA |
| 2812T (aux.) | | | 83 | | ±833 | mA |
| 2815T (aux.) | | | 67 | | ±667 | mA |
| Line regulation (VR _{LINE}) (main) | 1,2,3 | V _{IN} = 18, 28, 50 Volts I _{OUT} = 10, 50%, 100% rated Note 5 | -10 | | 10 | mV |
| 2812T (aux.) | | | -120 | | 120 | mV |
| 2815T (aux.) | | | -150 | | 150 | mV |
| Load regulation (VR _{LOAD}) (main) | 1,2,3 | I _{OUT} = 10%, 50%, 100% rated V _{IN} = 18, 28, 50 Volts Notes 5,13 | -50 | | 50 | mV |
| 2812T (aux.) | | | -400 | | 400 | mV |
| 2815T (aux.) | | | -500 | | 500 | mV |
| Cross regulation (VR _{CROSS}) (2812T aux.) | 1,2,3 | V _{IN} = 18, 28, 50 Volts I _{OUT} = 2.5A to 1A and 2.5 to 4A on main and ±half rated on aux. outputs | -3.5 | | 3.5 | % |
| (2815T aux.) | | | -3.0 | | 3.0 | % |
| Total regulation (VR) (main) | 1,2,3 | All conditions of Line, Load, and Cross Regulation, and Temperature | 4.90 | | 5.10 | V |
| 2812T (aux.) | | | ±11.00 | | ±13.00 | V |
| 2815T (aux.) | | | ±13.50 | | ±16.50 | V |
| Input current (I _{IN}) | 1,2,3 | I _{OUT} = 0, Pin 3 open | | | 80 | mA |
| | | Pin 3 shorted to pin 2 | | | 5 | |

For Notes to Specifications, refer to page 5

G-SERIES

International
IR Rectifier

Electrical Performance Characteristics (continued)

| Parameter | Group A Subgroup | Conditions -55°C ≤ T _c ≤ +125°C V _{IN} = 28V DC ± 5%, C _L = 0 unless otherwise specified | Limits | | | Unit |
|--|------------------|--|--------------------------------|----------------|--------------------------|----------------------------|
| | | | Min | Nom | Max | |
| Output ripple (V _{rip}) (main) 2812T (aux.) 2815T (aux.) | 1,2,3 | V _{IN} = 18, 28, 50 Volts I _{OUT} = 100% rated load, Notes 5, 6 | | 25 30 30 | 50 60 75 | mV p-p mV p-p mV p-p |
| Switching frequency (F _s) | 1,2,3 | Sync. Input (Pin 4) open | 450 | 500 | 550 | KHz |
| Efficiency (E _{FF}) | 1,2,3 | I _{OUT} = 100% rated load Note 5 | 75 | 79 | | % |
| Inhibit Input open circuit voltage drive current (sink) voltage range | 1,2,3 | Note 1 | 3.0 -0.5 | | 5.0 100 50 | V μA V |
| Synchronization Input frequency range pulse high level pulse low level pulse transition time pulse duty cycle | 1,2,3 | Ext. Clock on Sync. Input (Pin 4) Note 1 | 450 4.0 -0.5 40 20 | | 600 10.0 0.5 80 | Khz V V V/μS % |
| Current Limit Point Expressed as a percentage of full rated output power | 1,2,3 | V _{out} = 90% of Nominal, Note 5 | | | 135 | % |
| Power dissipation, load fault (P _o) | 1,2,3 | Short Circuit, Overload, Note 8 | | | 20 | W |
| Output response to step load changes (V _{TLD}) | 4,5,6 | Half Load to/from Full Load, Notes 5,9 | -300 | | 300 | mV pk |
| Recovery time, step load changes (T _{TLD}) | 4,5,6 | Half Load to/from Full Load, Note 5,9,10 | | | 100 | μS |
| Output response to step line changes (V _{TUN}) | 4,5,6 | 18V to/from 50V I _{OUT} = 100% rated load, Notes 1,5,11 | -300 | | 300 | mV pk |
| Recovery time, step line changes (T _{TUN}) | 4,5,6 | 18V to/from 50V I _{OUT} = 100% rated load, Notes 1,5,10,11 | | | 100 | μS |
| Turn-on Response Overshoot (V _{os}) (main) (aux.) Turn-on Delay (T _{DLY}) | 4,5,6 | No Load, Full Load Notes 5,12 | 1 | | 500 750 5 | mV mV mS |
| Capacitive Load (CL (main) (Each aux. output) | 1 | I _{OUT} = 100% rated load, No effect on DC performance, Notes 1, 5, 7 | | | 1000 200 | μF μF |

For Notes to Specifications, refer to page 5

Electrical Performance Characteristics (continued)

| Parameter | Group A Subgroup | Conditions -55°C ≤ T _C ≤ +125°C V _{IN} = 28V DC ± 5%, C _L = 0 unless otherwise specified | Limits | | | Unit |
|----------------|---------------------|--|---------------------|-----|-----|-------|
| | | | Min | Nom | Max | |
| Line Rejection | 1 | I _{OUT} = 100% rated load DC to 50KHz, Notes 1,5 | 40 | 60 | | dB |
| Isolation | 1 | Input to Output or any pin to case Except pin 10, test @500VDC | 100 | | | MΩ |
| Device Weight | | | | | 90 | grams |
| MTBF | | MIL-HDBK-217F2, SF, 35°C | 5 x 10 ⁶ | | | Hours |

Table I. Electrical Performance Characteristics - notes

- Parameter is tested as part of design characterization or after design changes. Thereafter, parameter shall be guaranteed to the limits specified.
- Parameter verified during line and load regulation tests.
- Although operation with no load is permissible, **light** loading on the main (+5 volt) output may cause the output voltage of the auxiliary outputs (±12 volt or ±15 volt) to drop out of regulation. It is therefore recommended that at least 200 mA or 20 percent of the total output power, whichever is greater, be taken from the main (+5 volt) output.
- Although operation with no load is permissible, **heavy** loading on the main (+5 volt) output may cause the output voltage of the auxiliary outputs (±12 volt or ±15 volt) to rise out of regulation. It is therefore recommended that at least 50 mA or 20 percent of the total output power, whichever is greater, be taken from the auxiliary (±12 volt or ±15 volt) outputs.
- Unless otherwise specified, "Rated" load is 20W on the main (+5 volt) output and 10 watts each on the auxiliary (±12 volt or ±15 volt) outputs. Load currents of up to 5A and ±1A on the main and auxiliary outputs respectively are acceptable as long as the total output power does not exceed 40 watts.
- Guaranteed for a D.C. to 20MHz bandwidth. Tested using a 20KHz to 10MHz bandwidth.
- 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.
- Overload power dissipation is defined as the device power dissipation with the load set such that V_{OUT} = 90% of nominal.
- Load step transition time ≤ 10 μSec.
- Recovery time is measured from the initiation of the transient to where V_{OUT} has returned to within ±1% of its steady state value.
- Line step transition time ≤ 100 μSec.
- 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 3) to the point where V_{OUT} = 90% of nominal.
- Load is varied for output under test while the remaining outputs are loaded at 50% of rated. Regulation relative to output voltage at 50% rated load.
- For operation at temperatures between +85°C and +125°C, derate the maximum input voltage linearly from 60V to 40V and the maximum output power linearly from 100% to 75%.

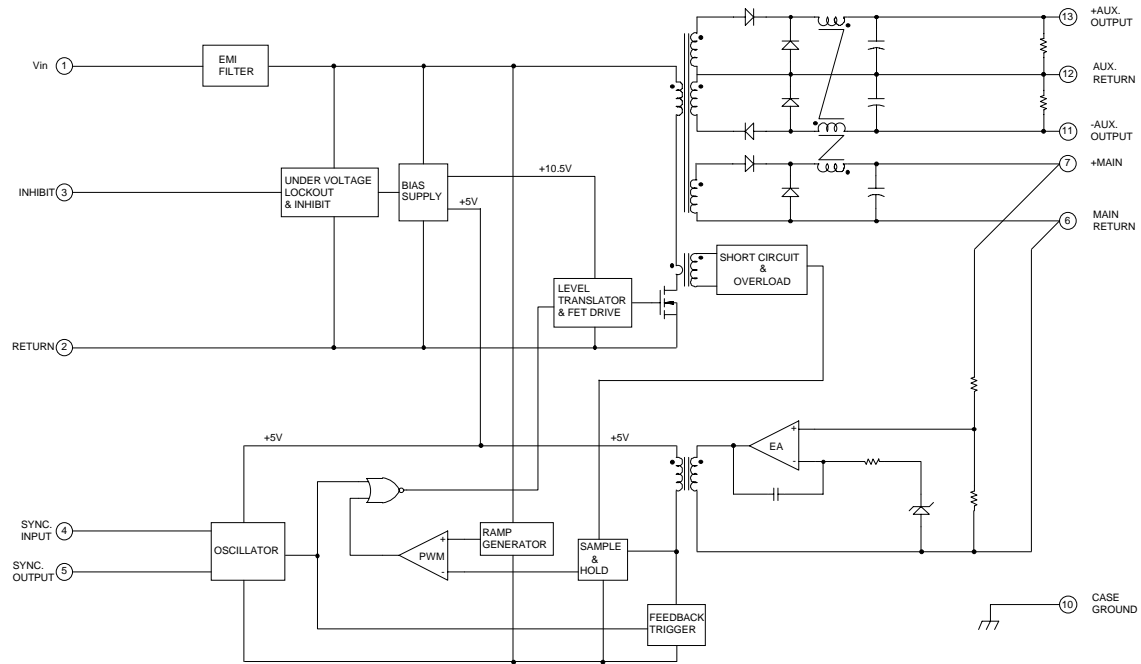
Radiation Performance Characteristics

| Test | Conditions | Min | Typ | Unit |
|---|--|-------------|------|------------------------------|
| Total Ionizing Dose (Gamma) | MIL-STD-883, Method 1019 Operating bias applied during exposure, Full Rated Load, $V_{IN} = 28V$ | 200 | 300 | KRads (Si) |
| Dose Rate (Gamma Dot) Temporary Saturation Survival | MIL-STD-883, Method 1023 Operating bias applied during exposure, Full Rated Load, $V_{IN} = 28V$ | 1E8 4E10 | 1E11 | Rads (Si)/sec |
| Neutron Fluence | MIL-STD-883, Method 1017 | 8E12 | 1E13 | Neutrons /cm ² |
| Single Event Effects SEU, SEL, SEGR, SEB | Heavy ions (LET) Operating bias applied during exposure, Full Rated Load, $V_{IN} = 28V$ | 82 | | MeV•cm ² /mg |

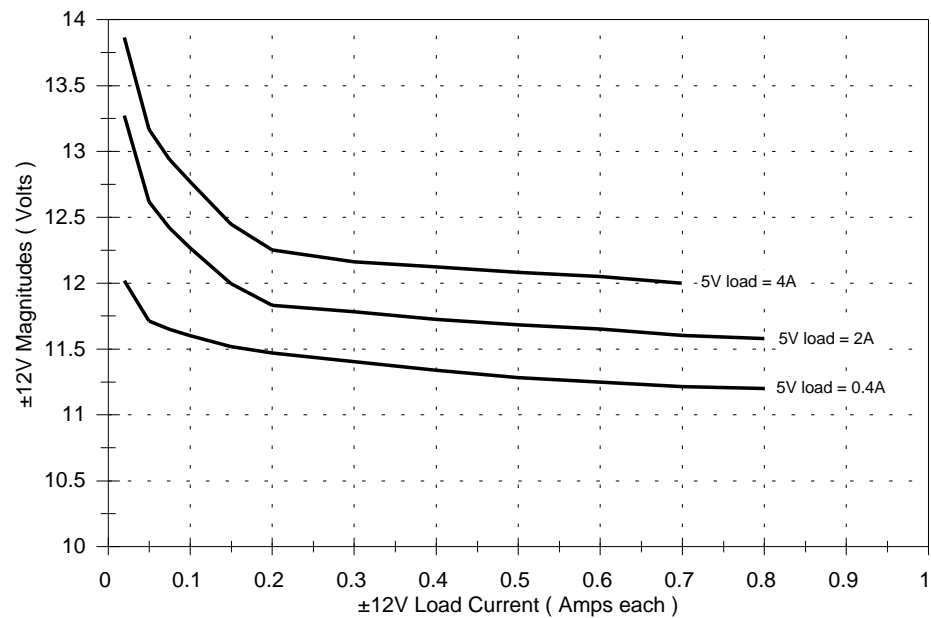
Device Screening

| Test Inspection | Method | Condition |
|---------------------------------|--|-----------------|
| Element Evaluation | MIL-PRF-38534 Space Requirement | |
| Nondestructive Bond Pull | MIL-STD-883, Method 2023 | |
| Internal Visual | MIL-STD-883, Method 2017 | |
| Temperature Cycling | MIL-STD-883, Method 1010 | C |
| Constant Acceleration | MIL-STD-883, Method 2001 | A, Y1 axis only |
| PIND | MIL-STD-883, Method 2020 | A |
| Electrical | In accordance with device specification | |
| Burn-in | MIL-STD-883, Method 1015 | 320 Hours |
| Final Electrical (Group A) | In accordance with device specification | |
| Seal Fine Leak Gross Leak | MIL-STD-883, Method 1014 | A1 C |
| Radiographic | MIL-STD-883, Method 2012 | |
| External Visual | MIL-STD-883, Method 2009 | |

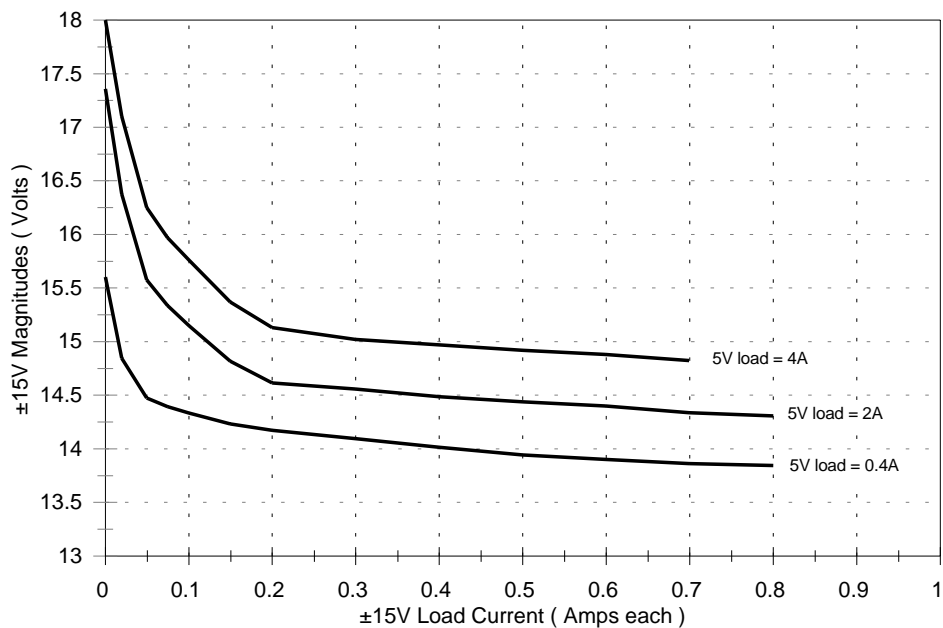
Block Diagram -Triple Output



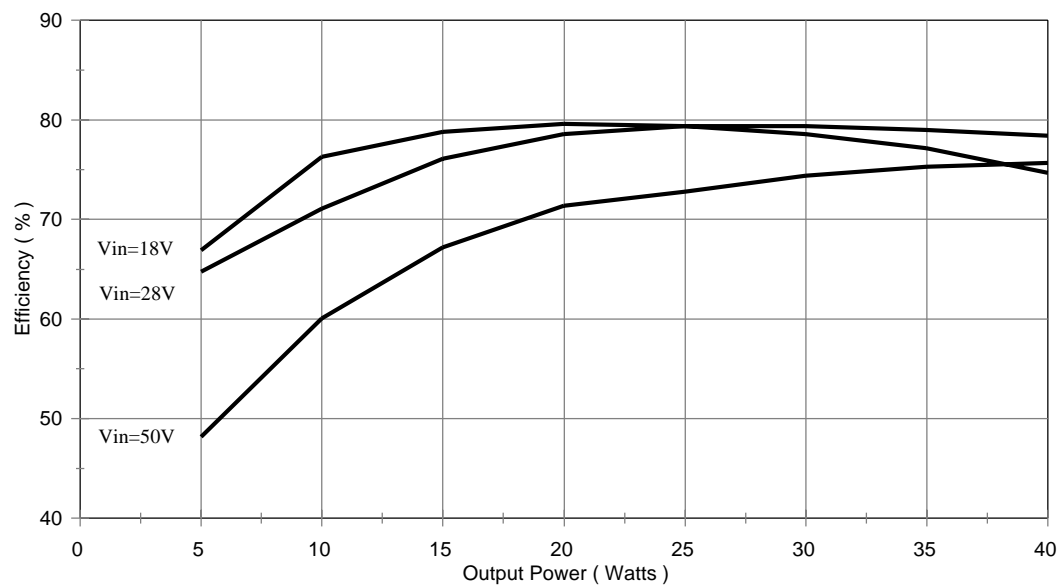
±12V Load Regulation vs 5V Load



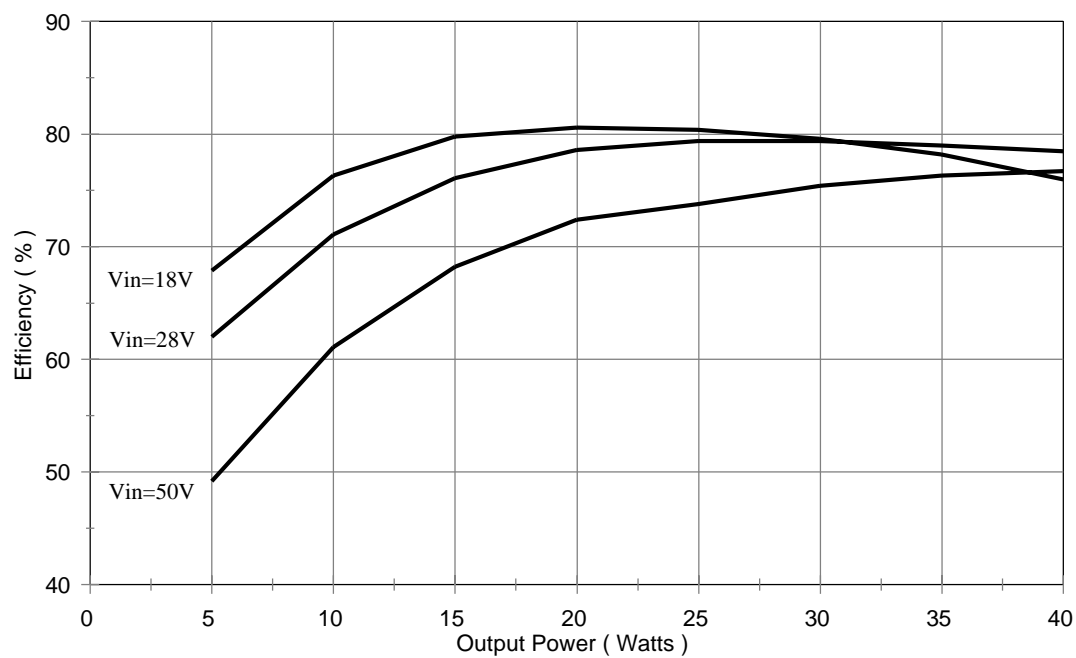
±15V Load Regulation vs 5V Load



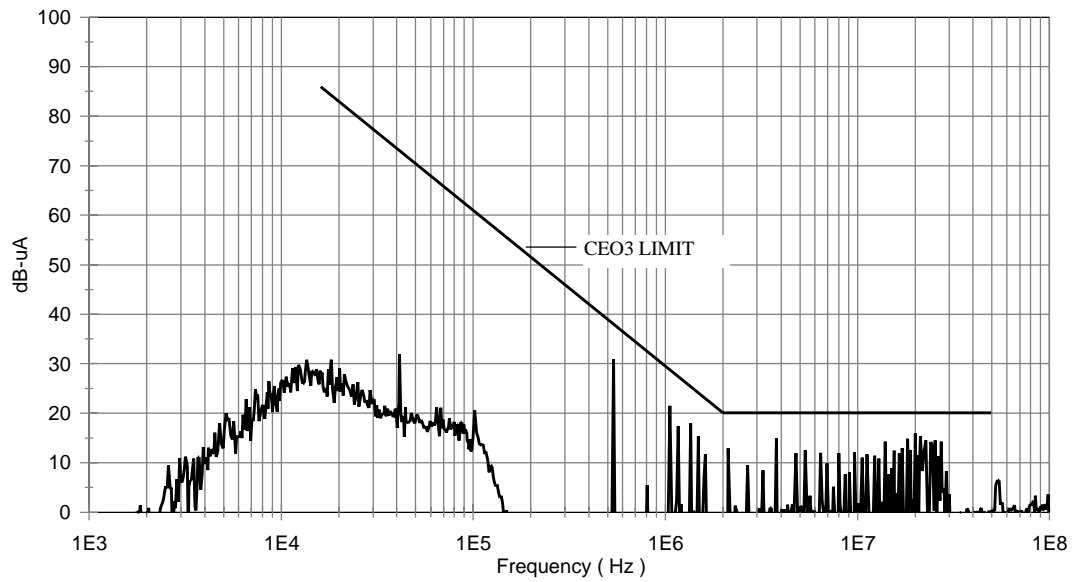
M3G2812T Efficiency vs Line and Load



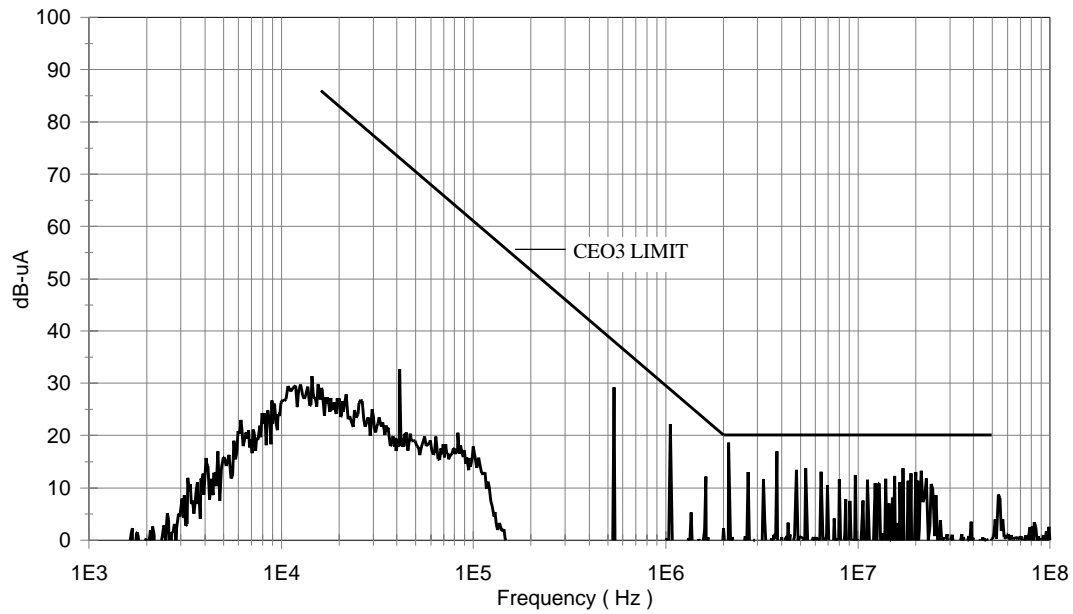
M3G2815T Efficiency vs Line and Load



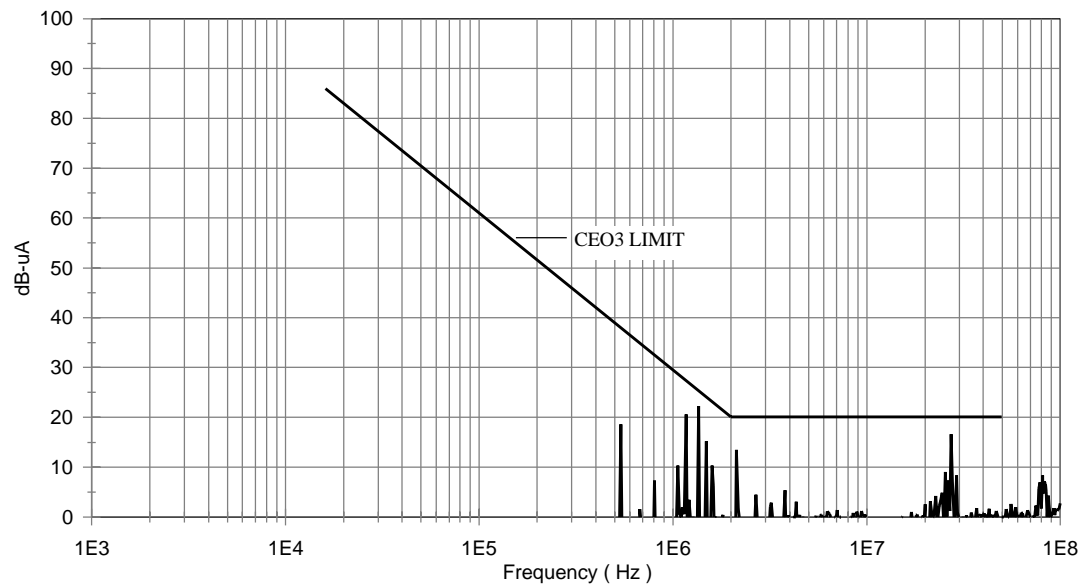
Conducted Emissions, Positive Lead



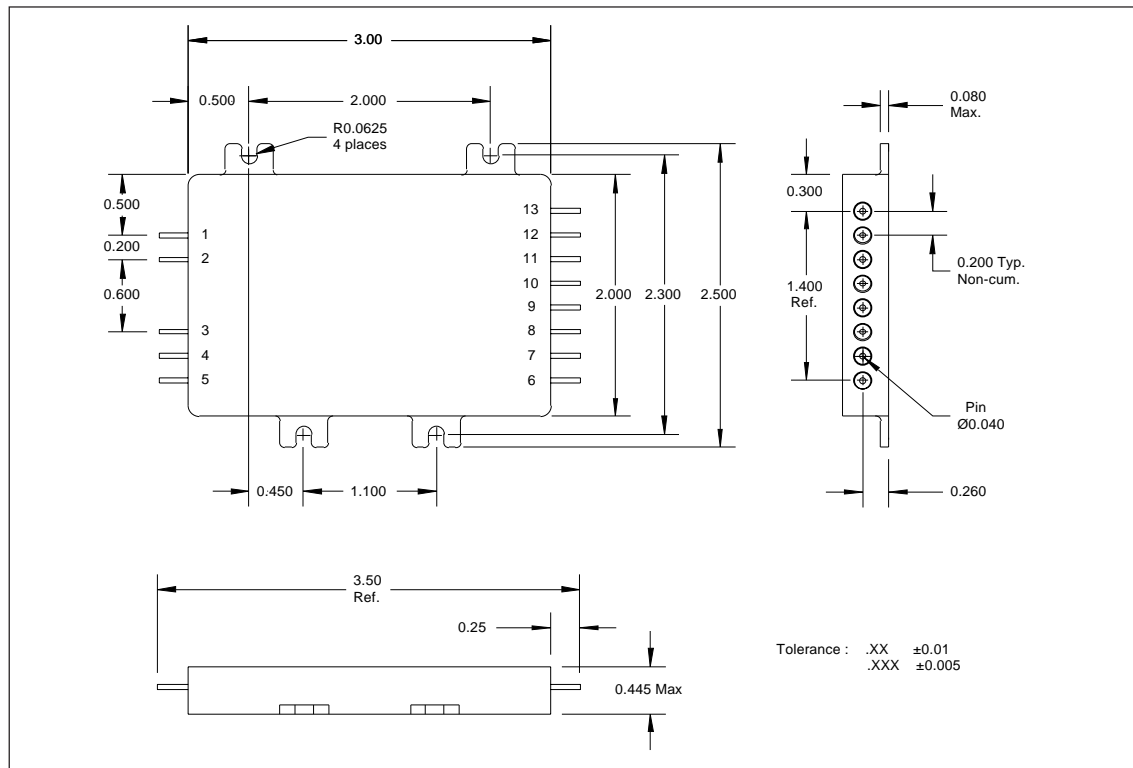
Conducted Emissions, Return Lead



Conducted Emissions, Common Mode



Mechanical Diagram



Pin Designation (Triple Output)

| Pin | Signal | Pin | Signal |
|-------|--------------|--------|--------------------|
| Pin 1 | +V | Pin 8 | N/C |
| Pin 2 | Input Return | Pin 9 | N/C |
| Pin 3 | Inhibit | Pin 10 | Case Ground |
| Pin 4 | Sync. Input | Pin 11 | -Aux. Output |
| Pin 5 | Sync. Output | Pin 12 | Aux. Output Return |
| Pin 6 | Main Return | Pin 13 | +Aux. Output |
| Pin 7 | +Main Output | | |

Part Number

M3G 28 0515 T

Model ————

Input Voltage ———— 28 = 28V Nominal

Outputs ———— T = Triple

Output Voltage ———— 0512 = 5V, ±12V
0515 = 5V, ±15V

International
IOR Rectifier

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