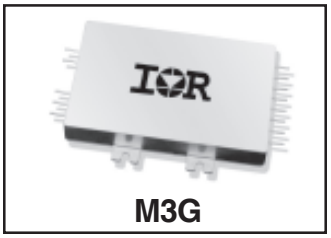
International
IOR Rectifier

PD-94534Q

HYBRID - HIGH RELIABILITY RADIATION HARDENED DC-DC CONVERTER

M3G-SERIES

28V Input, Single/Dual Output



M3G

Description

The M3G-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.

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 0.475" package constructed of an Aluminum-Silicon-Carbide (AlSiC) base and an Alloy 48 ring frame and they weigh less than 110 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 DLA Land and Maritime qualified processes. For available screening options, refer to device screening table in the data sheet.

Non-flight versions of the M3G-Series converters are available for system development purposes. Variations in electrical specifications and screening to meet custom requirements can be accommodated.

Features

- Total Dose > 200 KRad(Si), typically usable to > 300 KRad(Si)
- SEE Hardened to LET up to 82 MeV•cm^2/mg
- Internal EMI filter; Converter Capable of meeting MIL-STD-461C CE03
- Low Weight, < 110 grams
- Magnetically Coupled Feedback
- 18V to 50V DC Input Range
- Up to 40W Output Power
- Single and Dual Output Models Include 3.3, 5, 5.2, 12, 15, ±5, ±7, ±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
- Remote Sense on Single Output Models
- Adjustable Output Voltage for Duals
- Synchronization Input and Output
- Output Over Voltage Limiter
- External Inhibit
- > 5,000,000 Hour MTBF
- Standard Microcircuit Drawings Available

Applications

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

Circuit Description

The M3G-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.

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 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.

Remote sense is provided on the single output models to compensate for voltage drops in the interconnects between the converter and the load. The output voltage of dual output models can be adjusted by a single external resistor.

Design Methodology

The M3G-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 except for the CDR type ceramic capacitors, a capacitor with 50V rating is used for in-circuit voltage stress of less than 10V. 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).

Specifications

Absolute Maximum Ratings		Recommended Operating Conditions	
Input voltage range	-0.5Vdc to +80Vdc	Input voltage range	+18Vdc to +60Vdc
Output power	Internally limited	Input voltage range[1]	+18Vdc to +50Vdc
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-975
[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 (Vout)						
M3G2803R3S	1	I_{OUT} = 100% rated load	3.28	3.30	3.32	
M3G2805S	1	Note 4	4.98	5.00	5.02	
M3G2805R2S	1		5.17	5.20	5.23	
M3G2812S	1		11.95	12.00	12.05	
M3G2815S	1		14.94	15.00	15.06	
M3G2805D	1		±4.98	±5.00	±5.02	
M3G2807D	1		±6.97	±7.00	±7.03	
M3G2812D	1		±11.95	±12.00	±12.05	
M3G2815D	1		±14.94	±15.00	±15.06	
		I_{OUT} = 100% rated load				V
M3G2803R3S	2,3	Note 4	3.24		3.36	
M3G2805S	2,3		4.93		5.07	
M3G2805R2S	2,3		5.13		5.27	
M3G2812S	2,3		11.84		12.16	
M3G2815S	2,3		14.80		15.20	
M3G2805D	2.3		±4.93		±5.07	
M3G2807D	2,3		±6.90		±7.10	
M3G2812D	2,3		±11.84		±12.16	
M3G2815D	2,3		±14.80		±15.20	
Output power (P_{OUT})						
M3G2803R3S	1,2,3	V_{IN} = 18, 28, 50 Volts, Note 2	0		30	W
All Others			0		40	
Output current (I_{OUT})						
M3G2803R3S	1,2,3	V_{IN} = 18, 28, 50 Volts, Note 2	0		9.10	
M3G2805S			0		8.00	
M3G2805R2S			0		7.70	
M3G2812S			0		3.34	A
M3G2815S			0		2.67	
M3G2805D		Either Output, Note 3	0		6.40	
M3G2807D		Either Output, Note 3	0		4.57	
M3G2812D		Either Output, Note 3	0		2.67	
M3G2815D		Either Output, Note 3	0		2.14	
Line regulation (VR_{LINE})	1,2,3	V_{IN} = 18, 28, 50 Volts I_{OUT} = 0, 50%, 100% rated, Note 4	-10		10	mV
Load regulation (VR_{LOAD})	1,2,3	I_{OUT} = 0, 50%, 100% rated, Note 4 V_{IN} = 18, 28, 50 Volts	-0.5		0.5	%
Cross regulation (VR_{CROSS})						
M3G2805D	1,2,3	Duals only, Note 5	-5.0		5.0	
M3G2807D		V_{IN} = 18, 28, 50 Volts	-5.0		5.0	%
M3G2812D			-3.0		3.0	
M3G2815D			-3.0		3.0	

For Notes to Specifications, refer to page 5

Electrical Performance Characteristics (continued)

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 current (I_{IN})	1,2,3	I_{OUT} = 0, Pin 3 open		40	80	mA
		Pin 3 shorted to pin 2		2.0	5.0	
Switching frequency (F_S)	1,2,3	Sync. Input (Pin 4) open	450	500	550	KHz
Output ripple (V_{RIP})						
M3G2803R3S	1,2,3	I_{OUT} = 100% rated load Notes 4, 6		15	35	mV p-p
M3G2805S				20	50	
M3G2805R2S				25	50	
M3G2812S				25	60	
M3G2815S				25	80	
M3G2805D				20	50	
M3G2807D				25	55	
M3G2812D				30	60	
M3G2815D				30	60	
Efficiency (E_{FF})						
M3G2803R3S	1	I_{OUT} = 100% rated load Note 4	68	72		%
M3G2805S			75	77		
M3G2805R2S			75	77		
M3G2812S			75	78		
M3G2815S			77	80		
M3G2805D			75	78		
M3G2807D			75	78		
M3G2812D			76	79		
M3G2815D			77	80		
Inhibit Input						
open circuit voltage		Note 1	3.0		5.0	V
drive current (sink)					100	µA
voltage range			-0.5		50	V
Synchronization Input						
frequency range		Ext. Clock on Sync. Input (Pin 4) Note 1	450		600	KHz
pulse high level			4.0		10.0	V
pulse low level			-0.5		0.5	V
pulse transition time			40			V/µs
pulse duty cycle			20		80	%
Current Limit Point Expressed as a percentage of full rated load current	1,2,3	V_{out} = 90% of Nominal, Note 4		125	135	%
Power dissipation, load fault (P_D)	1,2,3	Short Circuit, Overload, Note 8		14	20	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, Notes 4, 9,10		50	200	µs
Output response to step line changes (V_{TLN})		18V to/from 50V I_{OUT} = 100% rated load, Notes 1,4,11	-300		300	mV pk
Recovery time, step line changes (T_{TLN})		18V to/from 50V I_{OUT} = 100% rated load, Notes 1,4,10,11		50	200	µs
Turn-on Response						
Overshoot (V_{OS})	4,5,6	No Load, Full Load			10	%
Turn-on Delay (T_{DLY})		Notes 4,12	1.0		5.0	ms

For Notes to Specifications, refer to page 5

Electrical Performance Characteristics (continued)

Parameter	Group A Subgroup	Conditions $-55°C \le T_C \le +85°C$ V_{IN} = 28V DC ± 5%, C_L = 0 unless otherwise specified	Limits			Unit
			Min	Nom	Max	
Capacitive Load (CL)						
M3G2803R3S		I_{OUT} = 100% rated load			2200	
M3G2805S		No effect on DC performance			1000	
M3G2805R2S		Notes 1, 4, 7			1000	
M3G2812S					180	µF
M3G2815S					120	
M3G2805D		Each output on duals			500	
M3G2807D					300	
M3G2812D					90	
M3G2815D					60	
Line Rejection		I_{OUT} = 100% rated load DC to 50KHz, Notes 1, 4	40	60		dB
Isolation	1	Input to Output or Any Pin to Case except pin 6, test @ 500VDC	100			MΩ
Device Weight					110	g
MTBF		MIL-HDBK-217F2, SF, 35°C	5.0×10^6			Hrs

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. Limit represents 80% of total rated output current. To achieve rated output power, the remaining 20% of the total rated output current must be provided by the other output.
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.
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 3) to the point where V_{OUT} = 90% of nominal.
13. Although operation at temperatures between +85°C and +125°C is guaranteed, no parametric limits are specified.

Fig 1. Block Diagram - Single Output

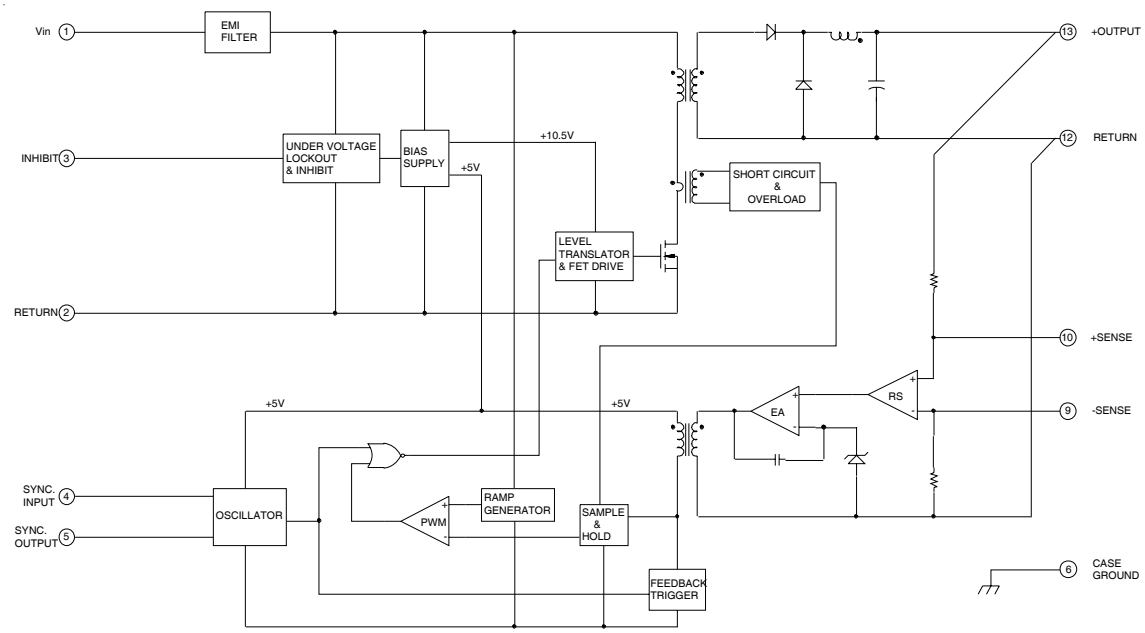


Fig 2. Block Diagram - Dual Output

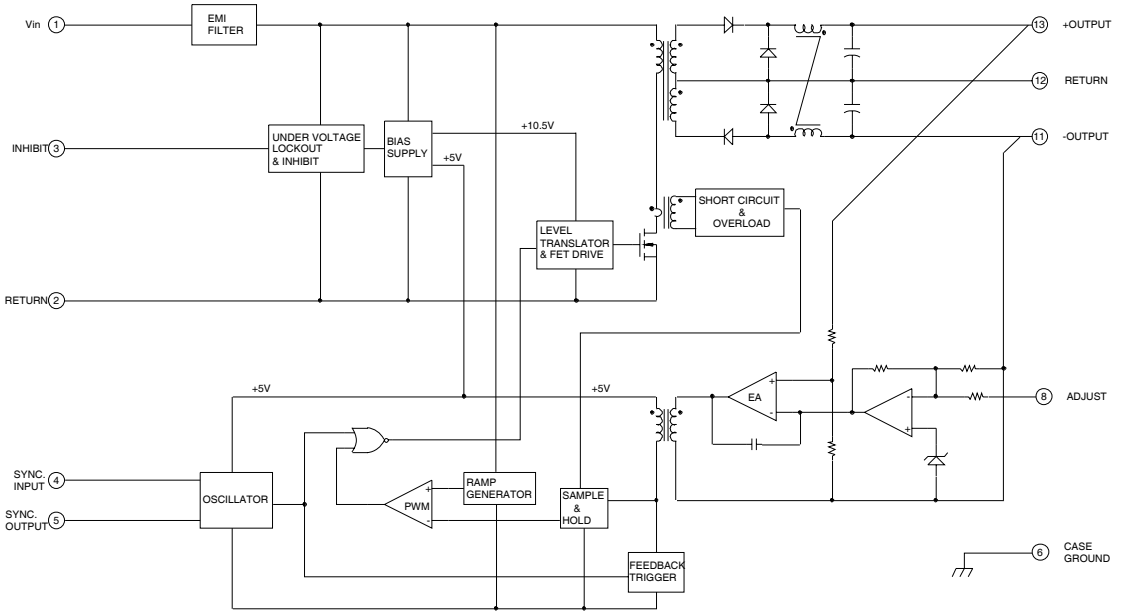


Fig 3. Conducted Emissions, Positive Lead

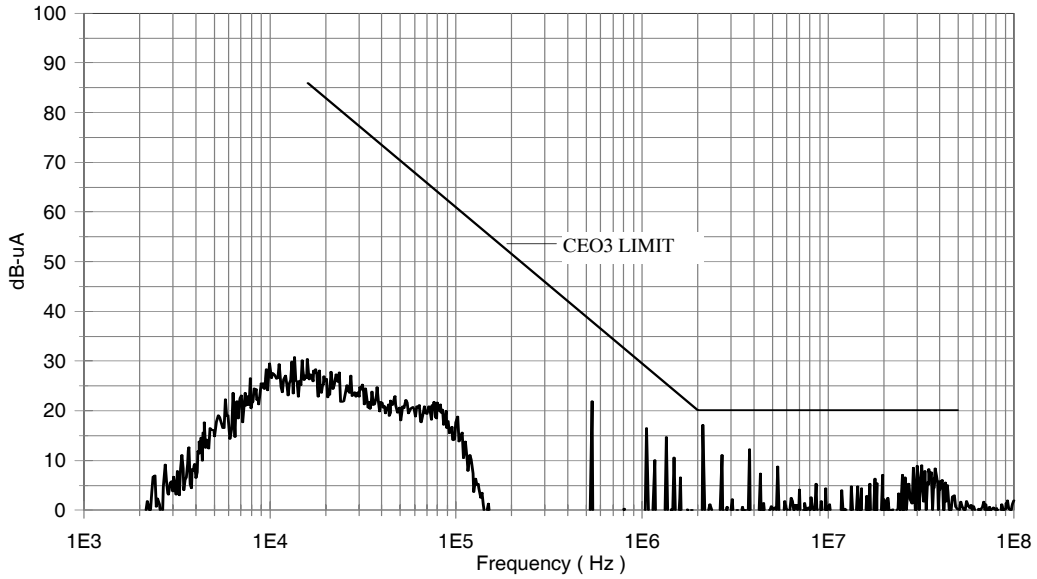


Fig 4. Line Rejection, 28Vdc + 8Vacp-p

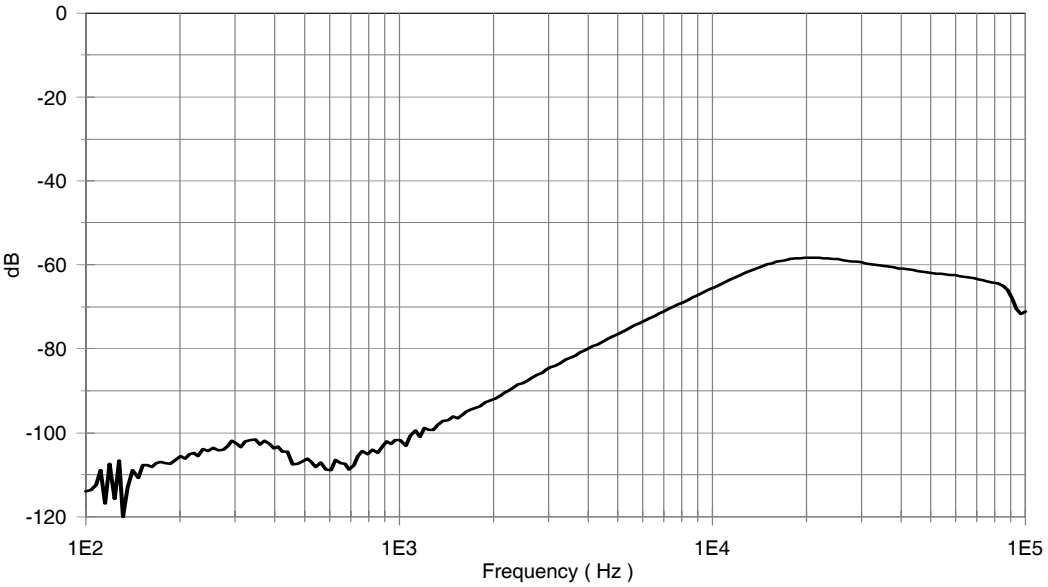


Fig 5. M3G2803R3S Efficiency

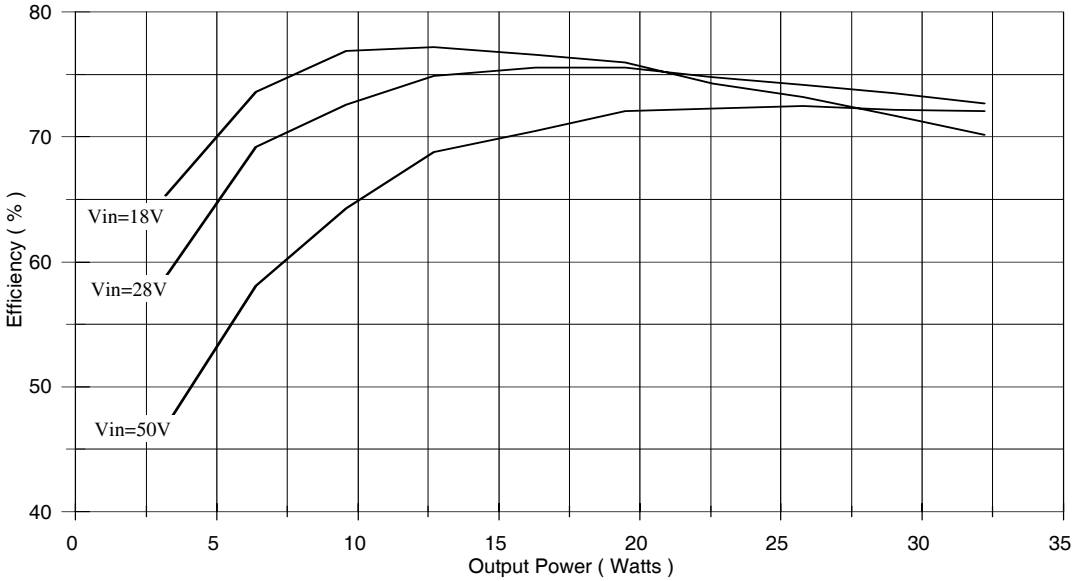


Fig 6. M3G2805S Efficiency

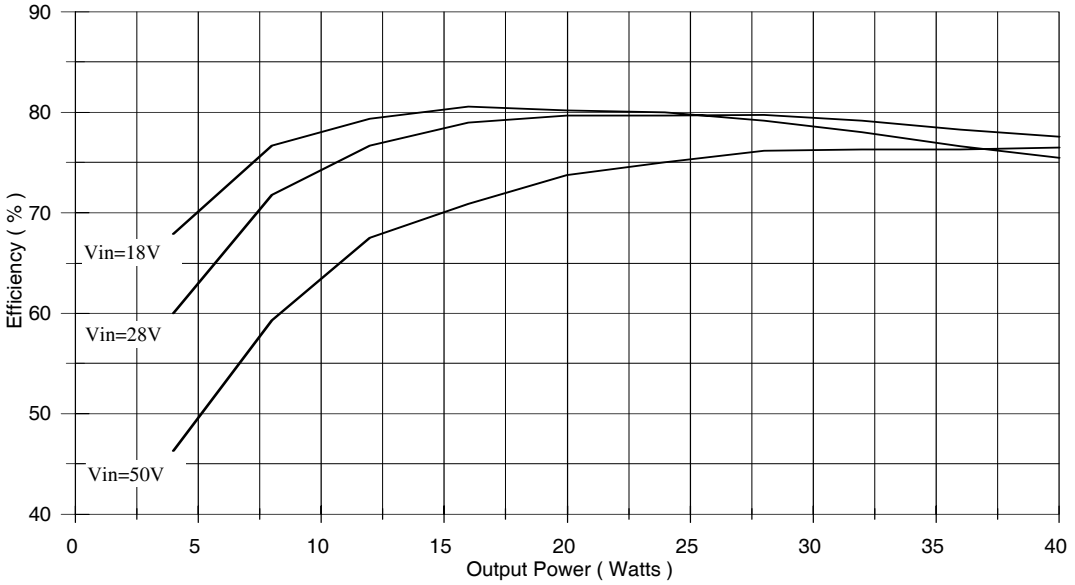
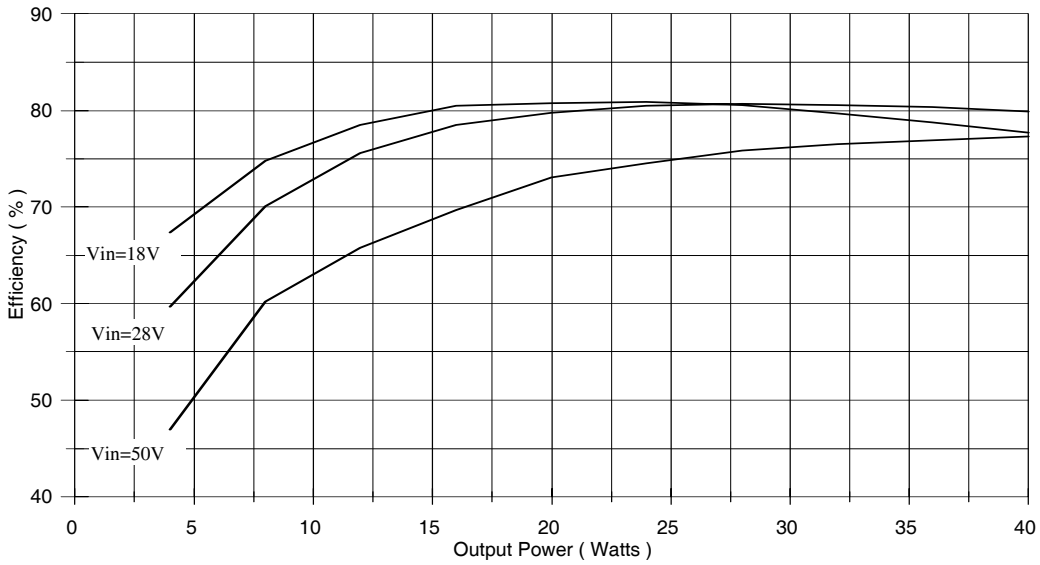


Fig 7. M3G2812S Efficiency



Radiation Performance Characteristics

Test Inspection	Method	Min	Typ	Unit
Total Ionizing Dose (Gamma)	MIL-PRF-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 **Test lab: Brookhaven National Laboratory,** **Tandem Van de Graaff Generator**	82		MeV•cm^2/mg

International Rectifier currently does not have a DLA Land and Maritime certified Radiation Hardness Assurance Program.

Application Notes:

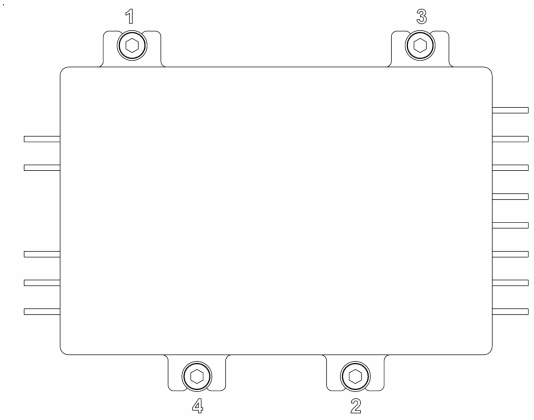
A) Attachment of the Converter.

The following procedure is recommended for mounting the converter for optimum cooling and to circumvent any potential damage to the converter.

Ensure that flatness of the plate where M3G converter to be mounted is no greater than 0.003" per linear inch. It is recommended that a thermally conductive gasket is used to promote the thermal transfer and to fill any voids existing between the two surfaces. IR recommends Sil-Pad 2000 with the thickness of 0.010". The shape of the gasket should match the footprint of the converter including the mounting flanges. The gasket is available from IR. The M3G-series converter requires either M3 or 4-40 size screws for attachment purposes.

The procedure for mounting the converter is as follows:

1. Check the mounting surfaces and remove foreign material, burrs if any or anything that may interfere with the attachment of the converter.
2. Place the gasket on the surface reserved for the converter and line it up with the mounting holes.
3. Place the converter on the gasket and line both up with mounting holes.
4. Install screws using appropriate washers and tighten by hand (~ 4 in·oz) in the sequence shown below.



5. Tighten the screws with an appropriate torque driver. Torque the screws up to 6 in·lb in the sequence shown above.

B) Output Voltage Adjustment.

Single Output:

Adjustment of the output voltage requires the +Sense pin be connected in one of two ways as shown in Figures 8 and 9 below. Use the equations and circuit configurations provided to calculate the required resistance (R_{ADJ}) for the applicable voltage adjust range. The output adjustment is limited to 0 to +10% range for reliable operation.

Fig 8. Configuration for Adjusting Single Output Voltage from +0.25V to +10%

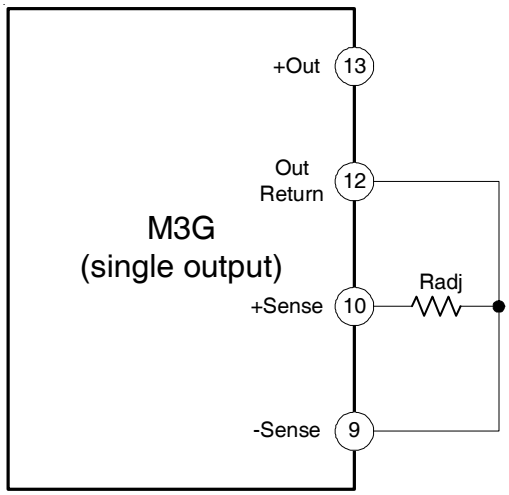
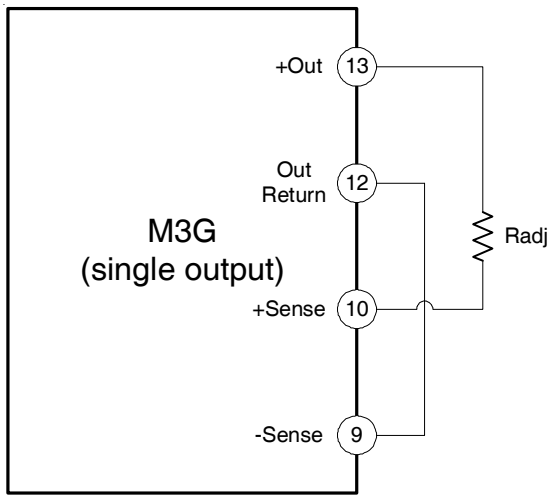


Fig 9. Configuration for Adjusting Single Output Voltage from 0 to +0.25V



For **M3GXX03R3S:**

Using the configuration of Fig 8 and where RADJ is in Ohms and 3.513 < VOUT < 3.630

$$R_{ADJ} = \frac{495}{V_{OUT} - 3.513}$$

Using the configuration of Fig 9 and where RADJ is in Ohms and 3.300 < VOUT < 3.513

$$R_{ADJ} = 150\frac{(V_{OUT} - 3.300)}{(3.513 - V_{OUT})}$$

For **M3GXX05S:**

Using the configuration of Fig 8 and where RADJ is in Ohms and 5.250 < VOUT < 5.500

$$R_{ADJ} = \frac{750}{V_{OUT} - 5.25}$$

Using the configuration of Fig 9 and where RADJ is in Ohms and 5.500 < VOUT < 5.250

$$R_{ADJ} = 150\frac{(V_{OUT} - 5.000)}{(5.250 - V_{OUT})}$$

For **M3GXX12S:**

Using the configuration of Fig 8 and where RADJ is in Ohms and 12.312 < VOUT < 13.200

$$R_{ADJ} = \frac{1800}{V_{OUT} - 12.312}$$

Using the configuration of Fig 9 and where RADJ is in Ohms and 12.000 < VOUT < 12.312

$$R_{ADJ} = 150\frac{(V_{OUT} - 12.000)}{(12.312 - V_{OUT})}$$

For **M3GXX15S:**

Using the configuration of Fig 8 and where RADJ is in Ohms and 15.315 < VOUT < 16.500

$$R_{ADJ} = \frac{2250}{V_{OUT} - 15.315}$$

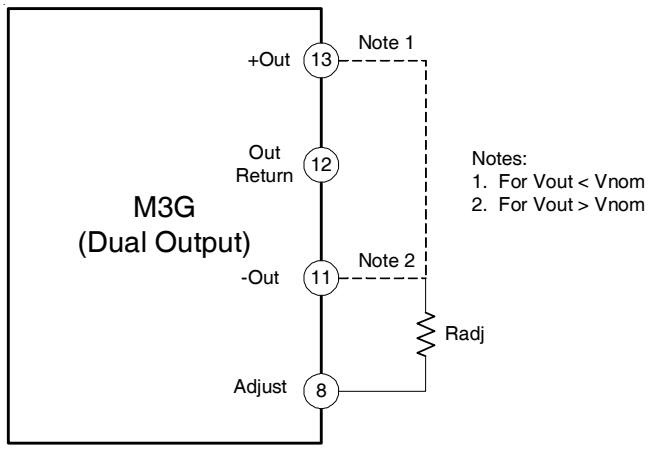
Using the configuration of Fig 9 and where RADJ is in Ohms and 15.000 < VOUT < 15.315

$$R_{ADJ} = 150\frac{(V_{OUT} - 15.000)}{(15.315 - V_{OUT})}$$

Dual Output:

The dual output models have an Adjust pin which can be connected through a resistor (RADJ) to either output. This allows the outputs to be reliably adjusted by approximately +10% to -25% of the nominal output voltage. Refer to Figure 10 and use equations provided to calculate the required resistance (RADJ).

Fig 10. Configuration for Adjusting Dual Output Voltage



For **all Dual Output Models,** to adjust the output voltage higher:

$$R_{ADJ} = \frac{3.48\ (1.64V_{NOM} - 1)}{V_{OUT} - V_{NOM}} - 51$$

where: RADJ is in KOhms

RADJ is connected to -Out pin and VNOM < VOUT < 1.1VNOM (Fig. 10, Note 2)
VNOM is the nominal output voltage with the Adjust pin left open
VOUT is the desired output voltage

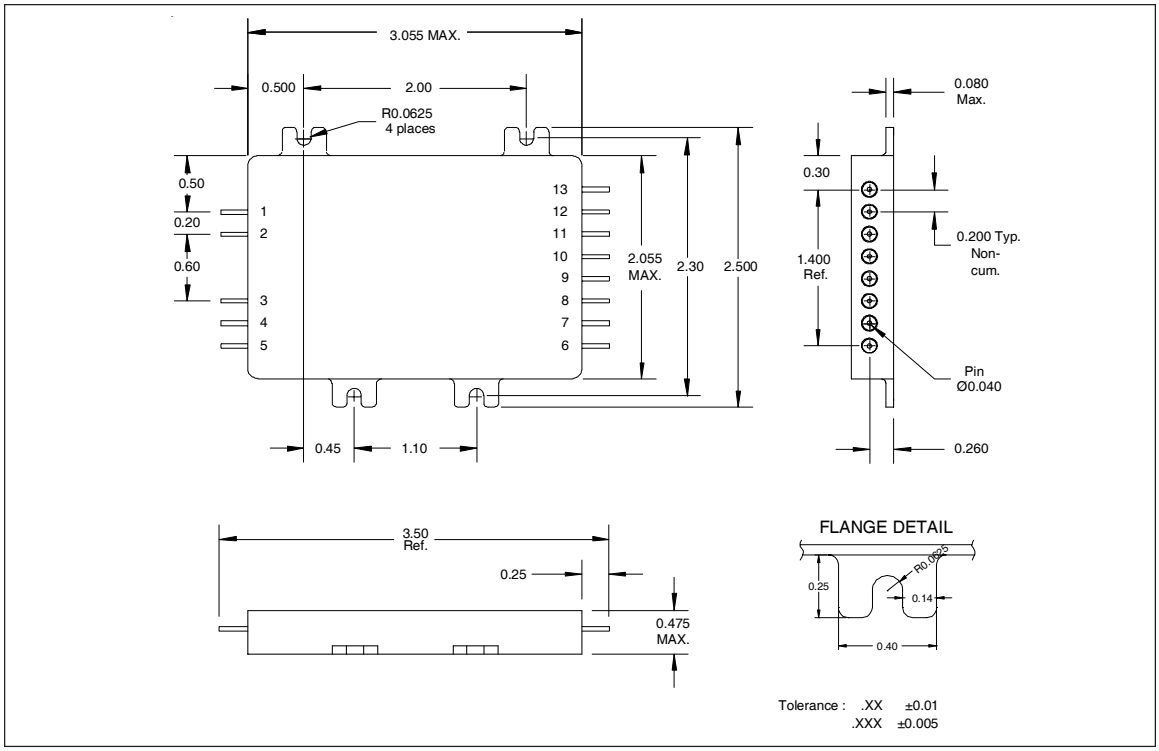
For **all Dual Output Models,** to adjust the output voltage lower:

$$R_{ADJ} = \frac{3.48\ (1.64V_{NOM} - 1)(1.64V_{OUT} - 1)}{V_{NOM} - V_{OUT}} - 51$$

where: RADJ is in KOhms

RADJ is connected to +Out pin and 0.75VNOM < VOUT < VNOM (Fig. 10, Note 1)
VNOM is the nominal output voltage with the Adjust pin left open
VOUT is the desired output voltage

Mechanical Diagram



Pin Designation (Single/Dual)

Pin #	Designation	Pin #	Designation
1	+ Input	8	NC / Adjust
2	Input Return	9	- Sense / NC
3	Inhibit	10	+ Sense / NC
4	Sync. Input	11	NC / - Output
5	Sync. Output	12	Output Return
6	Case Ground	13	+ Output
7	NC		

Standard Microcircuit Drawing Equivalence Table

Standard Microcircuit Drawing Number	IR Standard Part Number
5962-03218	M3G2803R3S
5962-03219	M3G2805S
5962-03220	M3G2805R2S
5962-03221	M3G2812S
5962-03222	M3G2815S
5962-03223	M3G2805D
5962-10216	M3G2815D

Device Screening

Requirement	MIL-STD-883 Method	No Suffix ②	CK ②	EM
Temperature Range	—	-55°C to +85°C	-55°C to +85°C	-55°C to +85°C
Element Evaluation	MIL-PRF-38534	Class K	Class K	N/A
Non-Destructive Bond Pull	2023	Yes	Yes	N/A
Internal Visual	2017	Yes	Yes	①
Temperature Cycle	1010	Cond C	Cond C	Cond C
Constant Acceleration	2001, Y1 Axis	3000 Gs	3000 Gs	3000 Gs
PIND	2020	Cond A	Cond A	N/A
Burn-In	1015	320 hrs @ 125°C (2 x 160 hrs)	320 hrs @ 125°C (2 x 160 hrs)	48 hrs @ 125°C
Final Electrical (Group A)	MIL-PRF-38534 & Specification	-55°C, +25°C, +85°C	-55°C, +25°C, +85°C	-55°C, +25°C, +85°C
PDA	MIL-PRF-38534	2%	2%	N/A
Seal, Fine and Gross	1014	Cond A, C	Cond A, C	Cond A
Radiographic	2012	Yes	Yes	N/A
External Visual	2009	Yes	Yes	①

Notes:

① Best commercial practice.

② CK is a DLA Land and Maritime (formerly DSCC) part marking used to designate a Class K compliant hybrid.
The CK marking does not indicate the hybrid is radiation certified.
No Suffix is a radiation rated device but not available as a DLA Land and Maritime qualified SMD per MIL-PRF-38534.
International Rectifier currently does not have a DLA Land and Maritime certified Radiation Hardness Assurance Program.

Part Numbering

M3G 28 05 S /XX X

Model

Nominal Input Voltage
28 = 28V

Output Voltage
03R3 = 3.3V, 05 = 5V
05R2 = 5.2V, 12 = 12V
15 = 15V

Output
S = Single
D = Dual

Screening Level
(Please refer to Screening Table)
No Suffix, CK, EM

Blank for No Suffix and EM
Lead Finish for No Suffix = Gold Plated
Lead Finish for EM is Gold Plated or
Solder Dipped depending on availability

Lead Finish for CK only
C = Gold Plated
A = Solder Dipped

International
IOR Rectifier

WORLD HEADQUARTERS: 233 Kansas St., El Segundo, California 90245, Tel: (310) 252-7105
IR SAN JOSE: 2520 Junction Avenue, San Jose, California 95134, Tel: (408) 434-5000
Visit us at www.irf.com for sales contact information.
Data and specifications subject to change without notice. 09/2012