

## HYBRID - HIGH RELIABILITY RADIATION HARDENED DC/DC CONVERTER

### Description

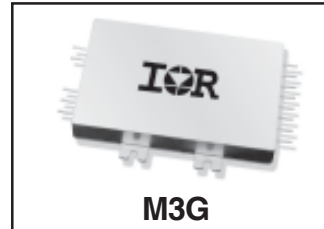
The M3G-Series of DC/DC converters are radiation hardened, high reliability converters designed for extended operation in hostile environments. Their small size and low weight make them ideal for applications such as geostationary earth orbit satellites and deep space probes. They exhibit a high tolerance to total ionizing dose, single event effects and environmental stresses such as temperature extremes, mechanical shock, and vibration. All components are fully derated to meet the requirements of MIL-STD-975, MIL-STD-1547 and GSFC PPL-21 Appendix B.

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 DSCC 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.

## M3G-SERIES 28V Input, Single/Dual Output



### Features

- Total Dose > 200 KRad(Si), typically usable to > 300 KRad(Si)
- SEE Hardened to LET up to 82 MeV.cm<sup>2</sup>/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,  $\pm 5$ ,  $\pm 7$ ,  $\pm 12$  and  $\pm 15V$
- High Efficiency - to 82%
- -55°C to +125°C Operating Temperature Range
- 100M $\Omega$  @ 500VDC Isolation
- Under-Voltage Lockout
- Short Circuit and Overload Protection
- Output Over Voltage Limiter
- Remote Sense on Single Output Models
- Adjustable Output Voltage for Duals
- Synchronization Input and Output
- 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. 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		Recommended Operating Conditions	
Input voltage range	-0.5Vdc to +80Vdc	Input voltage range	+18Vdc to +60Vdc
Output power	Internally limited	Input voltage range <sup>1</sup>	+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 <sup>2</sup>	-55°C to +125°C
Storage temperature	-55°C to +135°C	Operating temperature <sup>1</sup>	-55°C to +70°C

<sup>1</sup> Meets derating per MIL-STD-975

<sup>2</sup> For operation at +125°C see table note 13

### Electrical Performance Characteristics

Parameter	Group A Subgroup	Conditions -55°C ≤ T <sub>C</sub> ≤ +85°C V <sub>IN</sub> = 28V DC ± 5%, C <sub>L</sub> = 0 unless otherwise specified	Limits			Unit
			Min	Nom	Max	
Input Voltage			18	28	50	V
Output Voltage ( V <sub>OUT</sub> )						
M3G2803R3S	1	I <sub>OUT</sub> = 100% rated load Note 4	3.28	3.30	3.32	V
M3G2805S	1		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	
M3G2803R3S	2,3	I <sub>OUT</sub> = 100% rated load 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 <sub>OUT</sub> )						
M3G2803R3S	1,2,3	V <sub>IN</sub> = 18, 28, 50 Volts, Note 2	0		30	W
All Others			0		40	
Output current ( I <sub>OUT</sub> )						
M3G2803R3S	1,2,3	V <sub>IN</sub> = 18, 28, 50 Volts, Note 2	0		9.10	A
M3G2805S			0		8.00	
M3G2805R2S			0		7.70	
M3G2812S			0		3.34	
M3G2815S			0		2.67	
M3G2805D			0		6.40	
M3G2807D			0		4.57	
M3G2812D			0		2.67	
M3G2815D			0		2.14	
		Either Output, Note 3	0		6.40	
			0		4.57	
			0		2.67	
			0		2.14	
Line regulation ( V <sub>RLINE</sub> )	1,2,3	V <sub>IN</sub> = 18, 28, 50 Volts I <sub>OUT</sub> = 0, 50%, 100% rated, Note 4	-10		10	mV
Load regulation ( V <sub>RLOAD</sub> )	1,2,3	I <sub>OUT</sub> = 0, 50%, 100% rated, Note 4 V <sub>IN</sub> = 18, 28, 50 Volts	-0.5		0.5	%
Cross regulation ( V <sub>RCROSS</sub> )						
M3G2805D	1,2,3	Duals only, Note 5 V <sub>IN</sub> = 18, 28, 50 Volts	-5.0		5.0	%
M3G2807D			-5.0		5.0	
M3G2812D			-3.0		3.0	
M3G2815D			-3.0		3.0	

For Notes to Specifications, refer to page 5

## M3G-SERIES

International  
**IR** Rectifier

### Electrical Performance Characteristics ( continued )

Parameter	Group A Subgroup	Conditions -55°C ≤ T <sub>C</sub> ≤ +85°C V <sub>IN</sub> = 28V DC ± 5%, C <sub>L</sub> = 0 unless otherwise specified	Limits			Unit
			Min	Nom	Max	
Input current ( I <sub>IN</sub> )	1,2,3	I <sub>OUT</sub> = 0, Pin 3 open		40	80	mA
		Pin 3 shorted to pin 2		2.0	5.0	
Switching frequency ( F <sub>S</sub> )	1,2,3	Sync. Input (Pin 4) open	450	500	550	KHz
Output ripple ( V <sub>RIP</sub> ) M3G2803R3S M3G2805S M3G2805R2S M3G2812S M3G2815S M3G2805D M3G2807D M3G2812D M3G2815D	1,2,3	I <sub>OUT</sub> = 100% rated load Notes 4, 6		15 20 25 25 25 20 25 30 30	35 50 50 60 80 50 55 60 60	mV p-p
Efficiency ( E <sub>FF</sub> ) M3G2803R3S M3G2805S M3G2805R2S M3G2812S M3G2815S M3G2805D M3G2807D M3G2812D M3G2815D	1	I <sub>OUT</sub> = 100% rated load Note 4	68 75 75 75 77 75 75 76 77	72 77 77 78 80 78 78 79 80		%
Inhibit Input open circuit voltage drive current ( sink ) voltage range		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		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 load current	1,2,3	V <sub>out</sub> = 90% of Nominal, Note 4		125	135	%
Power dissipation, load fault (P <sub>D</sub> )	1,2,3	Short Circuit, Overload, Note 8		14	20	W
Output response to step load changes (V <sub>TLD</sub> )	4,5,6	Half Load to/from Full Load, Notes 4, 9	-300		300	mV pk
Recovery time, step load changes (T <sub>TLD</sub> )	4,5,6	Half Load to/from Full Load, Notes 4, 9, 10		50	200	μs
Output response to step line changes (V <sub>TLN</sub> )		18V to/from 50V I <sub>OUT</sub> = 100% rated load, Notes 1,4,11	-300		300	mV pk
Recovery time, step line changes (T <sub>TLN</sub> )		18V to/from 50V I <sub>OUT</sub> = 100% rated load, Notes 1,4,10,11		50	200	μs
Turn-on Response Overshoot (V <sub>OS</sub> ) Turn-on Delay (T <sub>DLY</sub> )	4,5,6	No Load, Full Load Notes 4,12	1.0		10 5.0	% ms

For Notes to Specifications, refer to page 5

**Electrical Performance Characteristics ( continued )**

Parameter	Group A Subgroup	Conditions -55°C ≤ T <sub>C</sub> ≤ +85°C V <sub>IN</sub> = 28V DC ± 5%, C <sub>L</sub> = 0 unless otherwise specified	Limits			Unit
			Min	Nom	Max	
Capacitive Load (CL) M3G2803R3S M3G2805S M3G2805R2S M3G2812S M3G2815S M3G2805D M3G2807D M3G2812D M3G2815D		I <sub>OUT</sub> = 100% rated load No effect on DC performance Notes 1, 4, 7  Each output on duals			2200 1000 1000 180 120 500 300 90 60	μF
Line Rejection		I <sub>OUT</sub> = 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 x 10 <sup>6</sup>			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<sub>OUT</sub> = 90% of nominal.
9. Load step transition time ≥ 10 μs.
10. Recovery time is measured from the initiation of the transient to where V<sub>OUT</sub> 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<sub>OUT</sub> = 90% of nominal.
13. Although operation at temperatures between +85°C and +125°C is guaranteed, no parametric limits are specified.

Figure 1. Block Diagram - Single Output

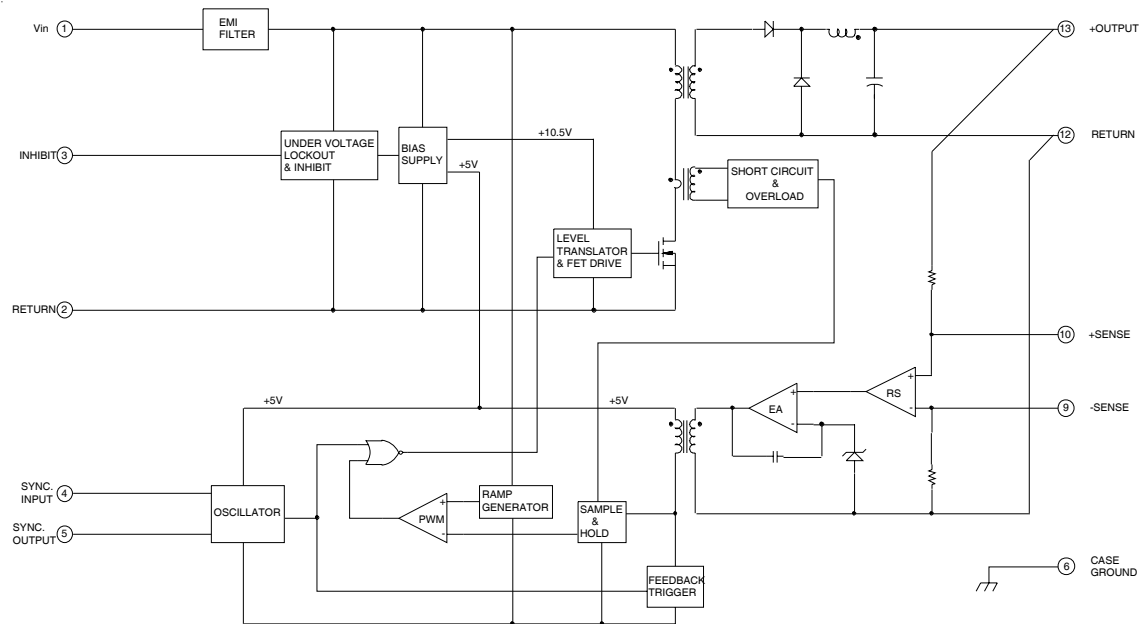


Figure 2. Block Diagram - Dual Output

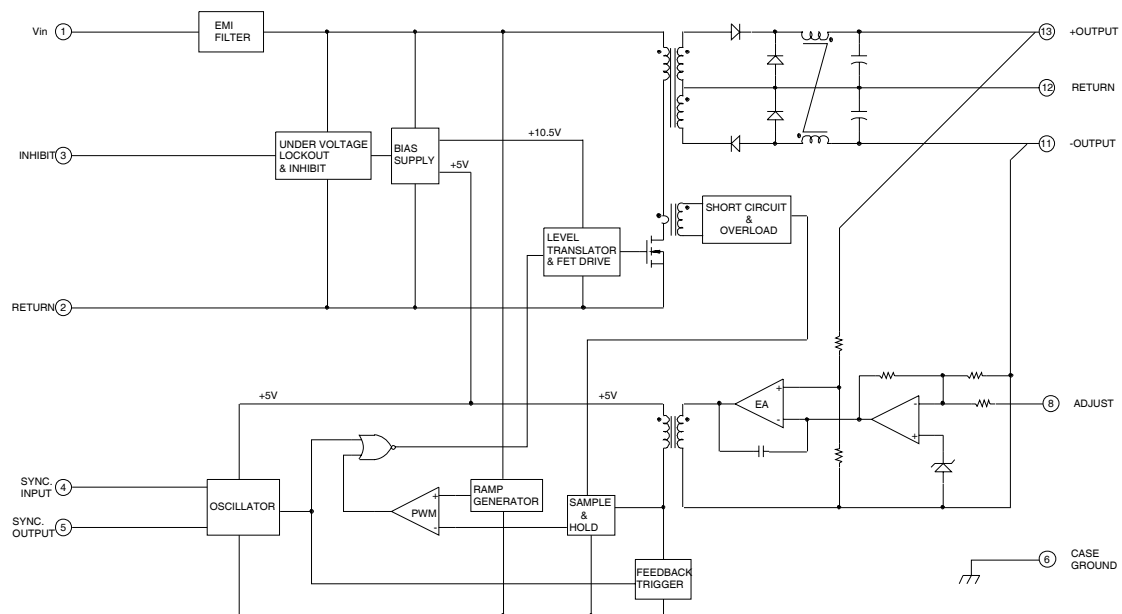


Figure 3. Conducted Emissions, Positive Lead

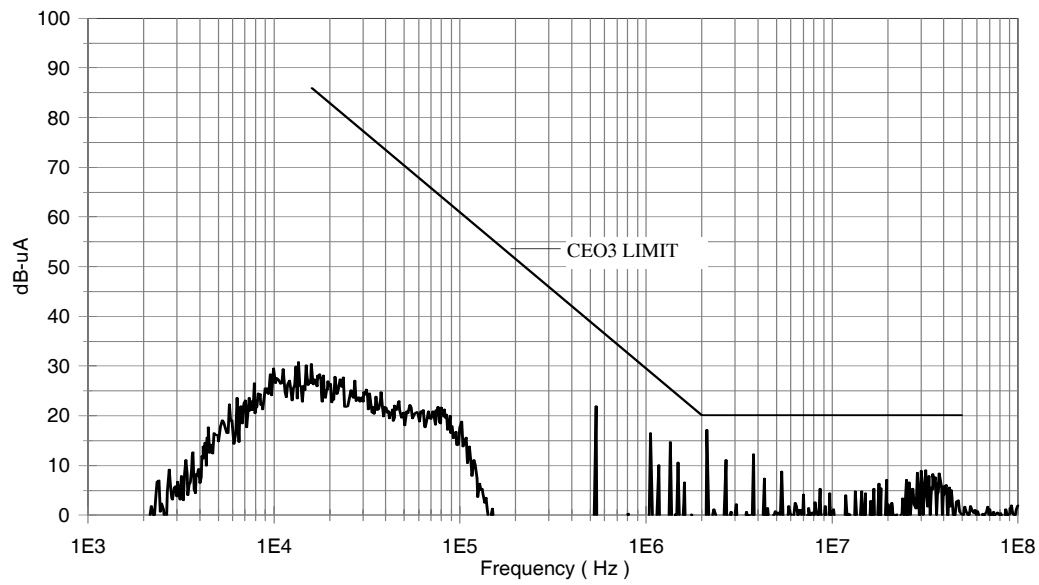


Figure 4. Line Rejection, 28Vdc + 8Vacp-p

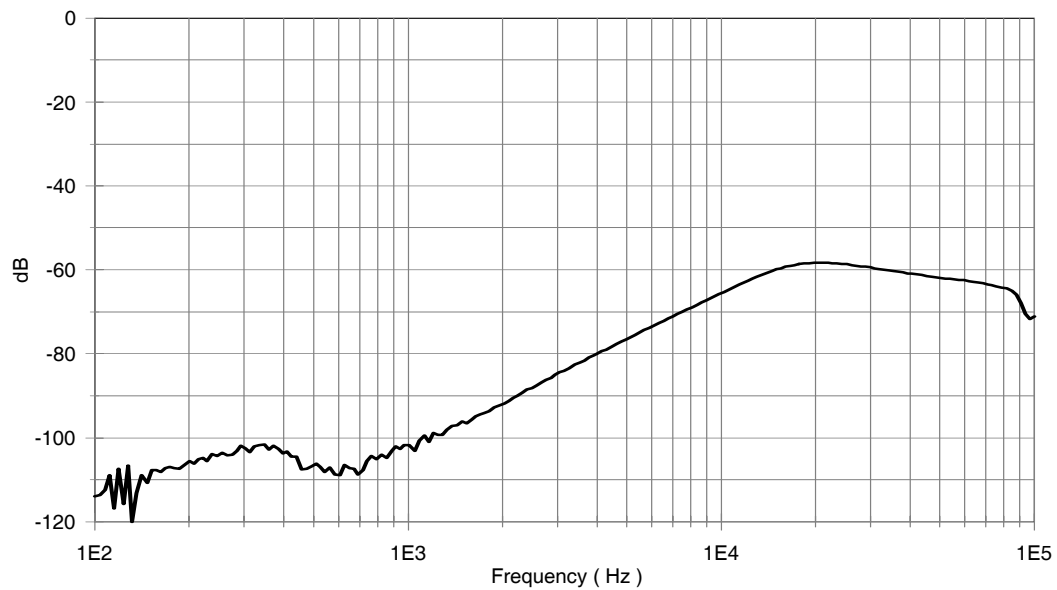


Figure 5. M3G2803R3S Efficiency

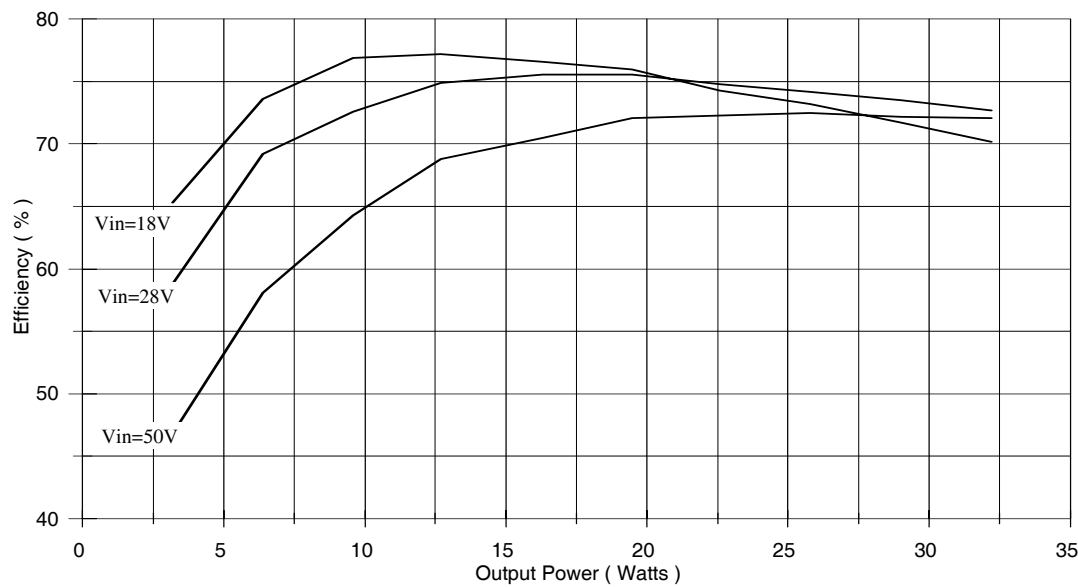
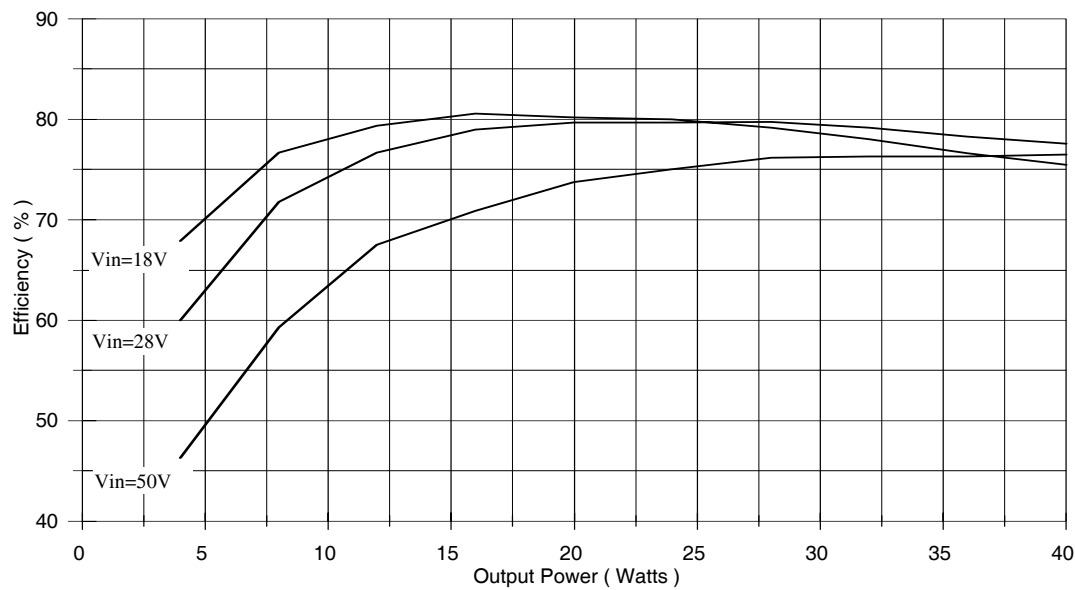
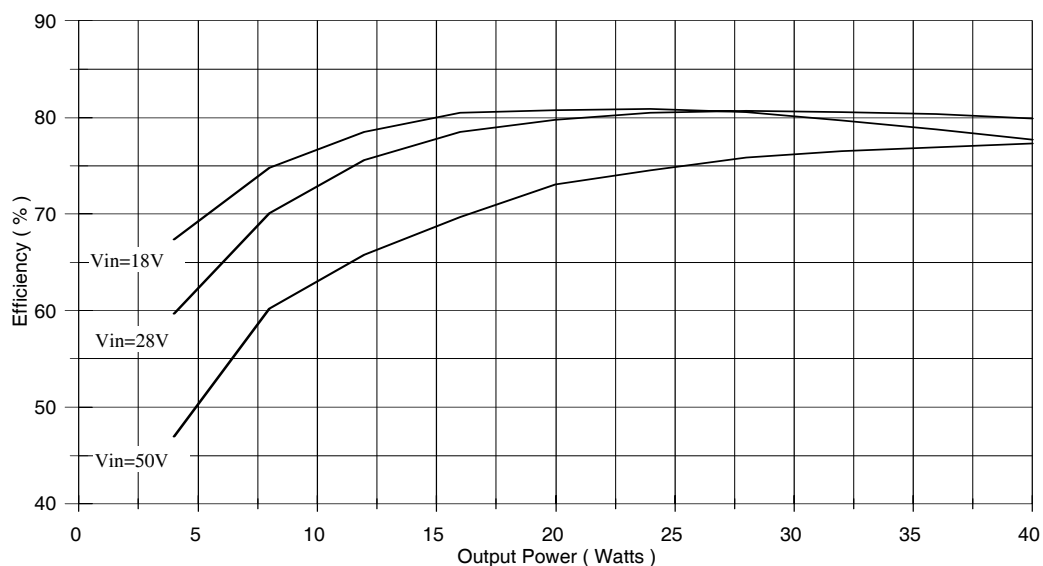


Figure 6. M3G2805S Efficiency





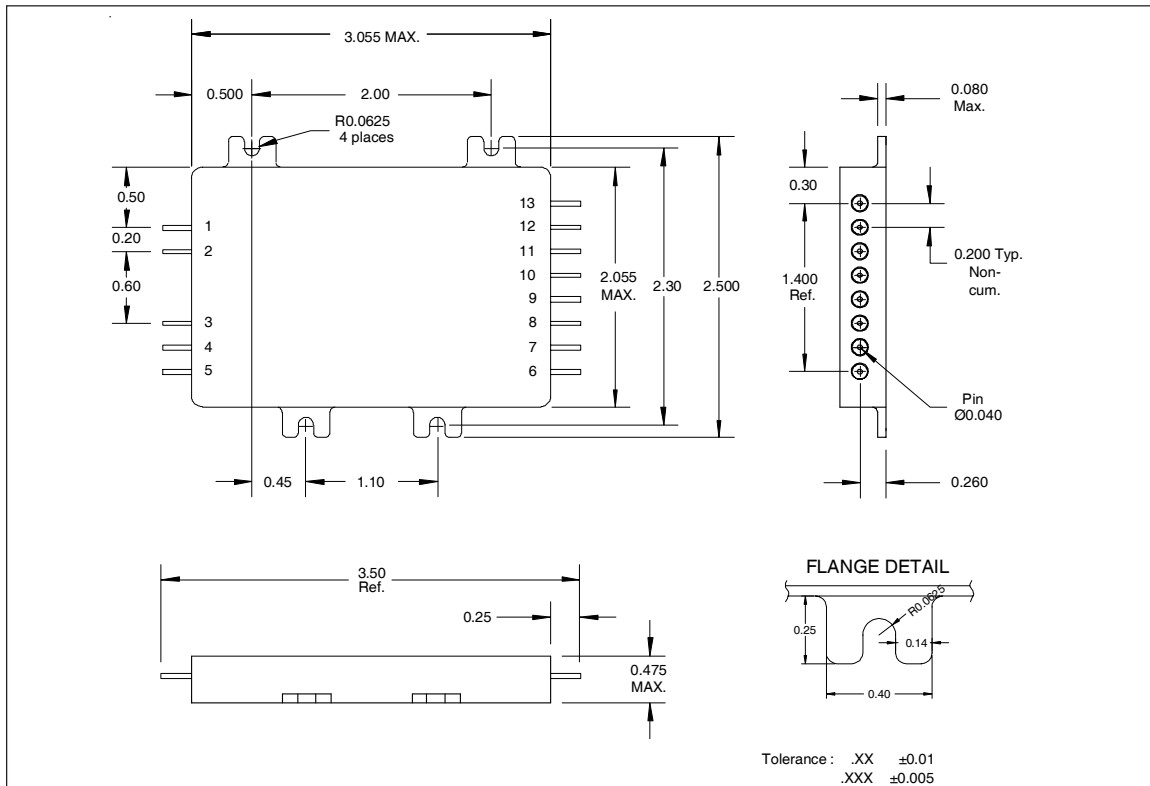
**Figure 7. M3G2812S Efficiency**



### 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 <sup>2</sup>
Single Event Effects SEU, SEL, SEGR, SEB	Heavy ions (LET) Operating bias applied during exposure, Full Rated Load, $V_{IN} = 28V$	82		MeV·cm <sup>2</sup> /mg

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

**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		

**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

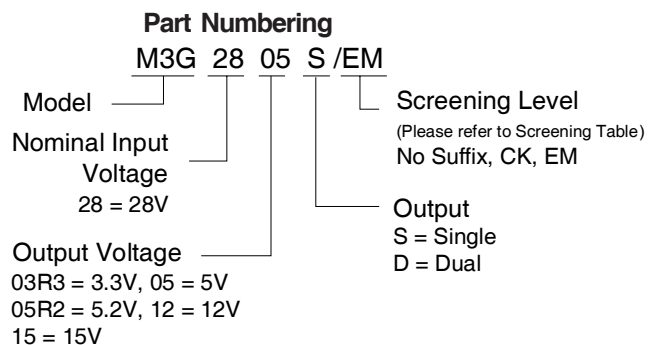
**Notes:**

- ① Best commercial practice.  
 ② CK is DSCC class K compliant without radiation performance. No Suffix is a radiation rated device but not available as a DSCC qualified SMD per MIL-PRF-38534.

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

**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



International  
**IR** Rectifier

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Visit us at [www.irf.com](http://www.irf.com) for sales contact information.

*Data and specifications subject to change without notice. 10/2007*