Advanced Analog / M-3 Magnitude-3

An IOR International Rectifier Company

70V G-Series

High Reliability Radiation Hardened DC/DC Converters

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 input filter that utilizes metallized film capacitors instead of large multilayer ceramic capacitors for improved reliability. By using two stage filtering these converters produce low input and output noise. 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 80 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 electrical specifications and screening to meet custom requirements can be accommodated.

FEATURES

- # Total Dose > 200K rad(Si), typically usable to > 1M rad(Si)
- # SEE > 82 MeV·cm^2/mg
- # Low weight, < 90 grams
- # Low input & output noise
- # Magnetically coupled feedback
- # 60 to 120V DC input range
- # Up to 40W 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
- # 100MÙ @ 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

APPLICATIONS

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

COMPANY HISTORY

Advanced Analog/Magnitude-3 is part of the International Rectifier Hi-Rel Components and Subsystems group since its acquisition in 2000. Magnitude-3 was founded in 1997 and manufactures thick-film hybrids for radiation-sensitive environments with the principal intent of developing and manufacturing high-reliability and high-performance DC-DC converters for the aerospace industry. Advanced Analog has been making high-value-added power management systems and technology for aerospace, aviation, and other high-reliability applications since 1969. International Rectifier is a world leader in power management devices and systems and has been serving the high-reliability market since the 1950s.

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 reduces the conducted emissions to less than 5mA rms 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 58 volts and will shut down when the input voltage drops below 54 volts. The four volts of hysteresis reduce 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 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 +150Vdc
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 - +60Vdc to +120Vdc
Input voltage range[1] - +60Vdc to +100Vdc
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 13

Electrical Performance Characteristics

Parameter	Group A Subgroup	Conditions -55°C ≤ T_C ≤ +85°C V_{IN} = 70V DC ± 5%, C_L = 0 unless otherwise specified	Limits			Unit
			Min	Nom	Max	
Input Voltage			60	70	100	
Output Voltage (Vout)						
M3G7003S	1		3.28	3.30	3.32	
M3G7005S	1		4.98	5.00	5.02	
M3G7012S	1		11.95	12.00	12.05	
M3G7015S	1		14.94	15.00	15.06	
M3G7005D	1		±4.98	±5.00	±5.02	
M3G7012D	1		±11.95	±12.00	±12.05	
M3G7015D	1	I_{OUT} = 100% rated load Note 4	±14.94	±15.00	±15.06	V
M3G7003S	2,3		3.24		3.36	
M3G7005S	2,3		4.93		5.07	
M3G7012S	2,3		11.84		12.16	
M3G7015S	2,3		14.80		15.20	
M3G7005D	2,3		±4.93		±5.07	
M3G7012D	2,3		±11.84		±12.16	
M3G7015D	2,3		±14.80		±15.20	
Output power (P_{OUT})						
M3G7003S	1,2,3	V_{IN} = 60, 70, 100 Volts, Note 2	0		30	W
All Others			0		40	
Output current (I_{OUT})		V_{IN} = 60, 70, 100 Volts, Note 2				
M3G7003S			0		9.1	
M3G7005S			0		8	
M3G7012S			0		3.34	
M3G7015S	1,2,3		0		2.67	A
M3G7005D		Either Output, Note 3	0		6.4	
M3G7012D		Either Output, Note 3	0		2.67	
M3G7015D		Either Output, Note 3	0		2.14	
Line regulation (VR_{LINE})	1,2,3	V_{IN} = 60, 70, 100 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} = 60, 70, 100 Volts	-0.5		0.5	%
Cross regulation (VR_{CROSS})						
M3G7005D	1,2,3	Duals only, Note 5	-5.0		5.0	%
M3G7012D		V_{IN} = 60, 70, 100 Volts	-3.0		3.0	
M3G7015D			-3.0		3.0	
Input current (I_{IN})	1,2,3	I_{OUT} = 0, Pin 3 open		30	50	mA
		Pin 3 shorted to pin 2		2	5	
Output ripple (V_{RIP})						
M3G7003S				15	35	
M3G7005S				20	50	
M3G7012S	1,2,3	V_{IN} = 60, 70, 100 Volts I_{OUT} = 100% rated load Notes 4, 6		25	60	mV p-p
M3G7015S				25	80	
M3G7005D				20	50	
M3G7012D				30	60	
M3G7015D				30	60	

Electrical Performance Characteristics (continued)

Parameter	Group A Subgroup	Conditions $-55°C \le T_C \le +125°C$ V_{IN} = 70V DC ± 5%, C_L = 0 unless otherwise specified	Limits			Unit
			Min	Nom	Max	
Input Ripple Current	1,2,3	I_{OUT} = 100% rated load		2	5	mA rms
Switching frequency (F_S)	1,2,3	Sync. Input (Pin 4) open	450	500	550	KHz
Efficiency (E_{FF}) M3G7003S M3G7005S M3G7012S M3G7015S M3G7005D M3G7012D M3G7015D	1,2,3	I_{OUT} = 100% rated load Note 4	 70 77 78 79 77 78 79	 75 81 82 83 81 82 83		%
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 load current	1,2,3	V_{out} = 90% of Nominal, Note 4			135	%
Power dissipation, load fault (P_D)	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 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		50	200	µS
Output response to step line changes (V_{TLN})	4,5,6	60V to/from 100V I_{OUT} = 100% rated load, Notes 4,11	-300		300	mV pk
Recovery time, step line changes (T_{TLN})	4,5,6	60V to/from 100V I_{OUT} = 100% rated load, Notes 4,10,11		50	200	µS
Turn-on Response Overshoot (V_{OS}) Turn-on Delay (T_{DLY})	4,5,6	No Load, Full Load Notes 4,12	 1		10 5	% mS
Capacitive Load (CL) M3G7003S M3G7005S M3G7012S M3G7015S M3G7005D M3G7012D M3G7015D	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	60		dB
Isolation	1	Input to Output or Any Pin to Case except pin 6, test @ 500VDC	100			MÙ
Device Weight					90	grams
MTBF		MIL-HDBK-217F2, SF, 35°C	5×10^6			Hours

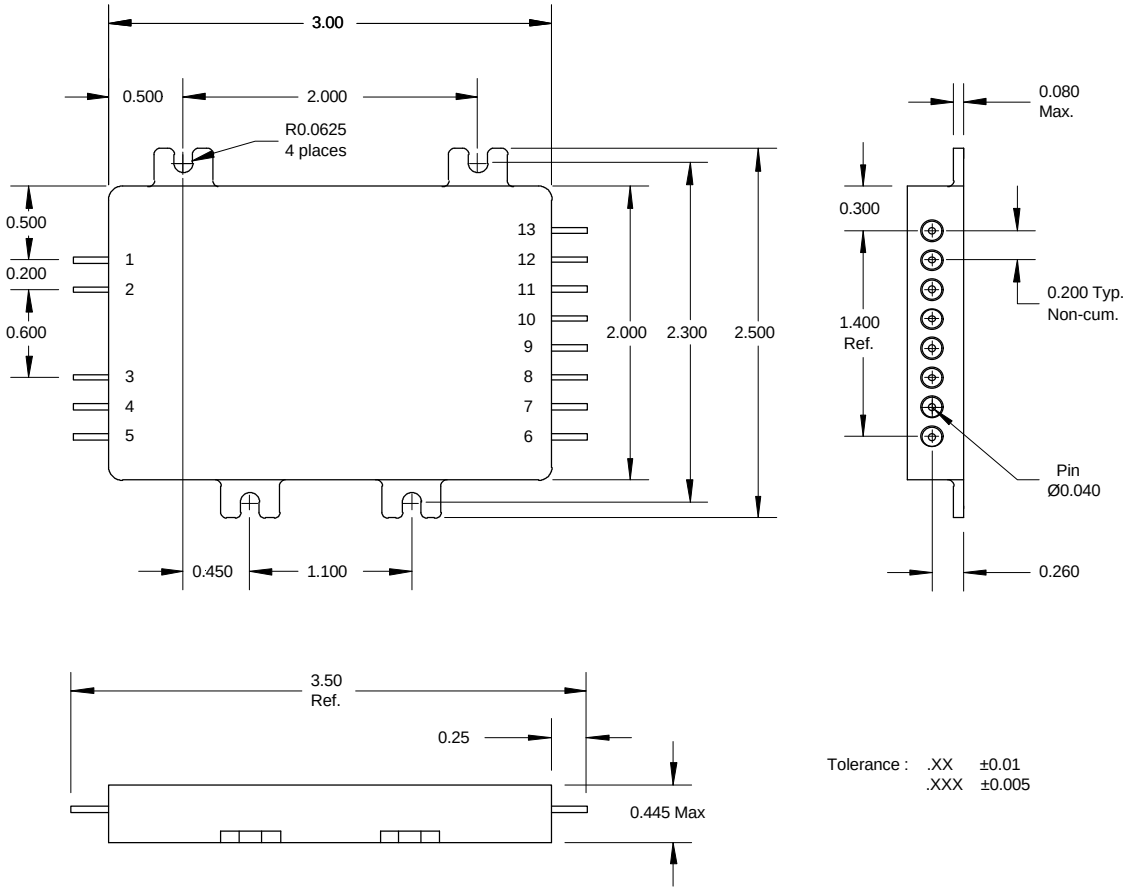
Table I. Electrical Performance Characteristics - notes

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.
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 $\geq$ 10 µSec.
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 $\geq$ 100 µSec.
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. For operation at temperatures between +85°C and +125°C, derate the maximum input voltage linearly from 120V to 80V.

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	100	300		Krads (Si)
Dose Rate (Gamma Dot) Temporary Saturation Survival	MIL-STD-883, Method 1023	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)	>82			MeV·cm^2 /mg

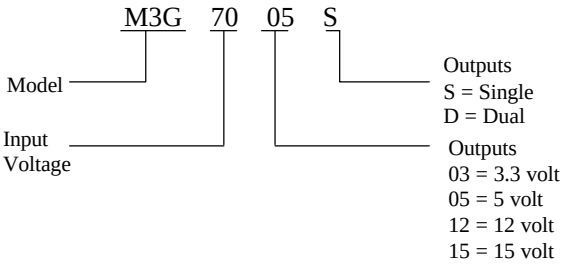
Mechanical Diagram



Pin Designation (Single/Dual)

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

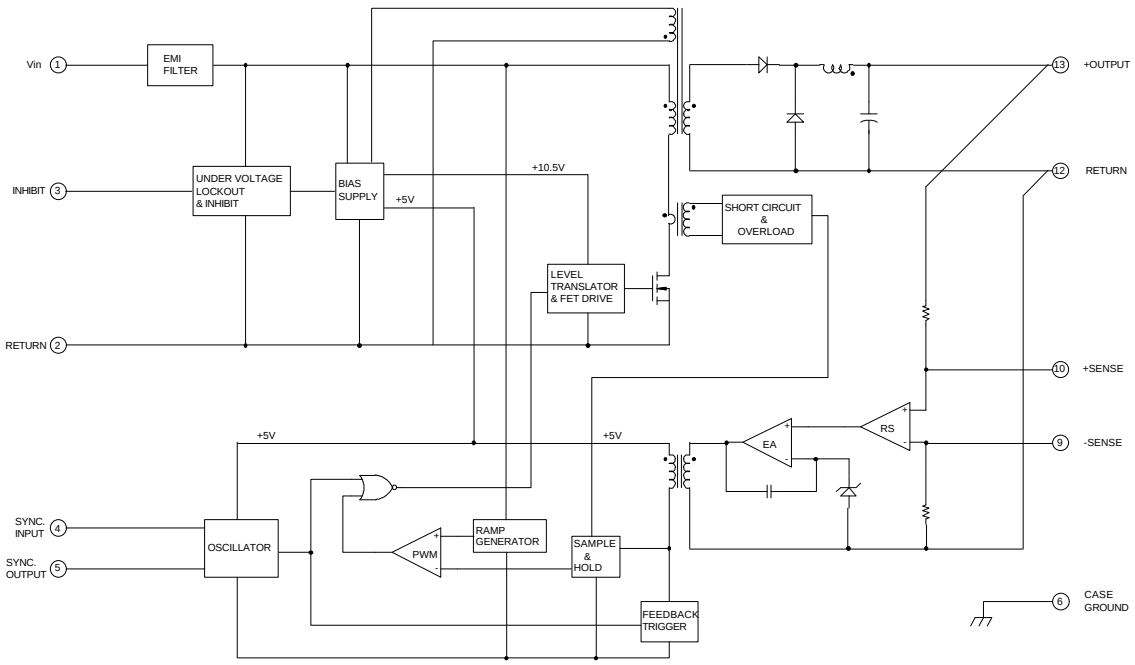
Part Number



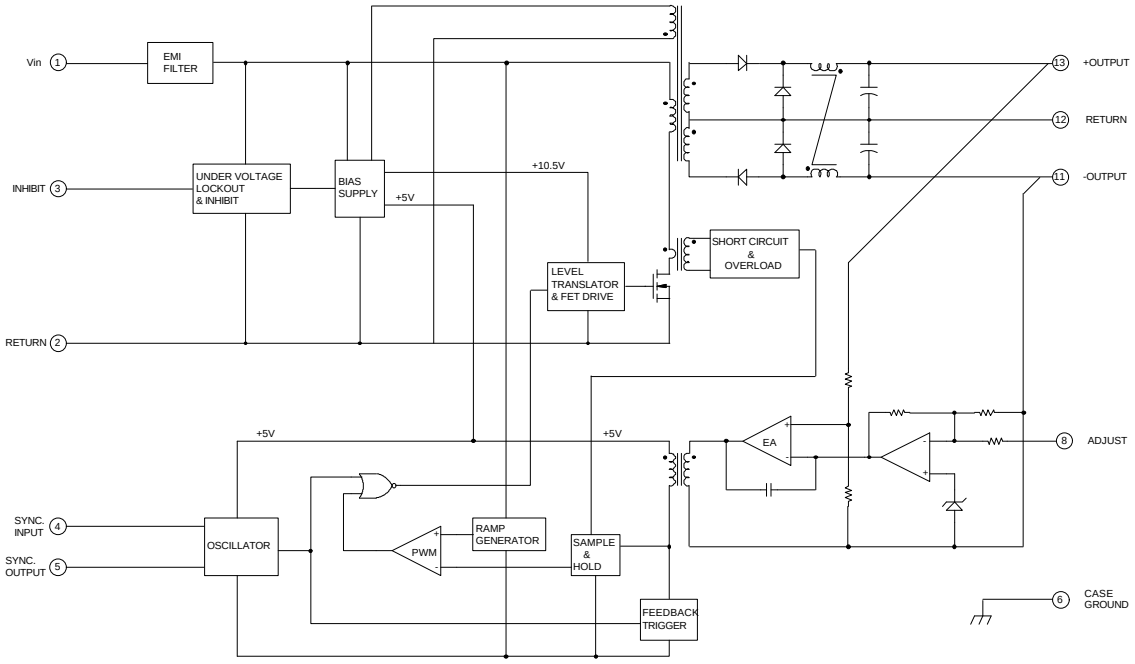
Device Screening

Test Inspection	Method	Condition
Element Evaluation	MIL-PRF-38534 class K equivalent	
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 - Single Output



Block Diagram - Dual Output



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