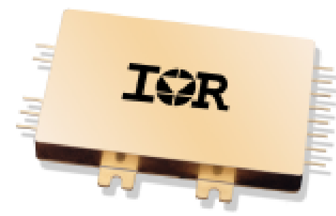
M3GB-SERIES

HYBRID-HIGH RELIABILITY RADIATION HARDENED DC-DC CONVERTER

70V Input, Single/Dual Output



M3GB

Description

The M3GB-Series of DC-DC converters are second generation design of the legacy M3G-Series product family but with enhanced overall performance. M3GB-Series is form, fit and functional equivalent to the first generation M3G-Series. It is designed to be backward compatible to the M3G-Series with the addition of an output voltage adjustment pin for the single output models. Much the same as the original M3G-Series, these 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. 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 (Al/SiC) base and an Alloy 48 ring frame and they weigh less than 100 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 M3GB-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 kRads(Si)
  typically usable to > 300 kRads(Si)
- SEE Hardened to LET up to 82 MeV·cm^2/mg
- Internal EMI filter
- Low Weight < 100 grams
- 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 83%
- -55°C to +125°C Operating Temperature Range
- 100MΩ @ 100VDC Isolation
- Under-Voltage Lockout
- Short Circuit and Overload Protection
- Remote Sense on Single Output Models
- Adjustable Output Voltage for all Models
- Synchronization Input and Output
- External Inhibit
- > 7,000,000 hour MTBF

Applications

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

Circuit Description

The M3BG-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.

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.

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 53 volts and will shut down when the input voltage drops below 48 volts. The 5V 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 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 M3GB-Series was developed using a proven conservative design methodology which includes selecting radiation tolerant and established reliability components and fully de-rating to the requirements of MIL-STD-1547 and MIL-STD-975 (except for the CDR type ceramic capacitors, where capacitors with 50V ratings may be used with voltage stresses of less than 10V). Careful sizing of decoupling capacitors and current limiting resistors minimizes the possibility of photo-current burn-out. Heavy de-rating 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	-0.5V_{DC} to +150V_{DC}	Input Voltage	+60V_{DC} to +120V_{DC}
Output power	Internally limited	Input Voltage [1]	+60V_{DC} to +100V_{DC}
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 de-rating 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 Min	Limits Nom	Limits Max	Unit
Input Voltage (V_{IN})			60	70	100	V
Output Voltage (V_{OUT}) M3GB7003R3S M3GB7005S M3GB7012S M3GB7015S M3GB7005D M3GB7012D M3GB7015D	 1 1 1 1 1 1 1	I_{OUT} = 100% rated load Note 4	 3.29 4.99 11.95 14.94 ±4.99 ±11.95 ±14.94	3.31 5.01 12.00 15.00 ±5.01 ±12.00 ±15.00	3.33 5.03 12.05 15.06 ±5.03 ±12.05 ±15.06	V
M3GB7003R3S M3GB7005S M3GB7012S M3GB7015S M3GB7005D M3GB7012D M3GB7015D	2,3 2,3 2,3 2,3 2.3 2,3 2,3	I_{OUT} = 100% rated load Note 4	3.26 4.95 11.88 14.85 ±4.95 ±11.88 ±14.85		3.34 5.05 12.12 15.15 ±5.05 ±12.12 ±15.15	
Output power (P_{OUT}) M3G7003R3S All Others	1,2,3	V_{IN} = 60, 70, 100 Volts, Note 2	 0 0		 30 40	W
Output current (I_{OUT}) M3GB7003R3S M3GB7005S M3GB7012S M3GB7015S M3GB7005D M3GB7012D M3GB7015D	1,2,3	V_{IN} = 60, 70, 100 Volts, Note 2 Either Output, Note 3 Either Output, Note 3 Either Output, Note 3	 0 0 0 0 0 0 0		 9.10 8.00 3.34 2.67 6.40 2.67 2.14	A
Line regulation (VR_{LINE}) Single Dual	1,2,3	V_{IN} = 60, 70, 100 Volts I_{OUT} = 0, 50%, 100% rated, Note 4	 -10 -20		 10 20	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	%

For Notes to Electrical Performance Characteristics, refer to page 5

Electrical Performance Characteristics (continued)

Parameter	Group A Subgroup	Conditions $-55°C \leq T_C \leq +85°C$ V_{IN} = 70V DC ± 5%, C_L = 0 unless otherwise specified	Limits Min	Nom	Max	Unit
Cross regulation (VR_{CROSS}) M3GB7005D M3GB7012D M3GB7015D	1,2,3	Duals only, Note 5 V_{IN} = 60, 70, 100 Volts	-5.0 -2.0 -2.0		5.0 2.0 2.0	%
Input current (I_{IN})	1,2,3	I_{OUT} = 0, Pin 3 open Pin 3 shorted to Pin 2		35 2.0	50 5.0	mA
Switching frequency (F_S)	1,2,3	Sync. Input (Pin 4) open	475	500	525	kHz
Output ripple (V_{RIP}) M3GB7003R3S M3GB7005S M3GB7012S M3GB7015S M3GB7005D M3GB7012D M3GB7015D	1,2,3	I_{OUT} = 100% rated load Notes 4, 6		15 20 25 25 20 30 30	35 50 60 80 50 60 60	mV p-p
Efficiency (E_{FF}) M3GB7003R3S M3GB7005S M3GB7012S M3GB7015S M3GB7005D M3GB7012D M3GB7015D	1,2,3	I_{OUT} = 100% rated load Note 4	70 77 78 78 77 78 79	75 81 82 83 81 82 83		%
Enable/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 0.5 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	118	125	130	%
Power dissipation, load fault (P_D)	1,2,3	Short Circuit, Overload, Note 8		12	18	W
Output response to step load changes (V_{TLD})	4,5,6	Half Load to/from Full Load, Notes 4, 9	-300		300	mVpk
Recovery time, step load changes (T_{TLD})	4,5,6	Half Load to/from Full Load, Notes 4, 9,10		50	200	ms
Output response to step line changes (V_{TLN})		60V to/from 100V I_{OUT} = 100% rated load, Notes 1,4,11	-200		200	mVpk
Recovery time, step line changes (T_{TLN})		60V to/from 100V I_{OUT} = 100% rated load, Notes 1,4,10,11		50	200	µs

For Notes to Electrical Performance Characteristics, refer to page 5

Electrical Performance Characteristics (continued)

Parameter	Group A Subgroup	Conditions $-55°C \le T_C \le +85°C$ V_{IN} = 70V DC ± 5%, C_L = 0 unless otherwise specified	Limits			Unit
			Min	Nom	Max	
Turn-on Response Overshoot (V_{OS}) Turn-on Delay (T_{DLY})	4,5,6	No Load, Full Load Notes 4,12	 1.0		 2.0 5.0	 % ms
Capacitive Load (C_L) M3GB7003R3S M3GB7005S M3GB7012S M3GB7015S M3GB7005D M3GB7012D M3GB7015D		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		I_{OUT} = 100% rated load DC to 50kHz, Notes 1, 4	40	50		dB
Isolation	1	Input to Output or Any Pin to Case except Pin 6, test @ 100VDC	100			MΩ
Device Weight					100	g
MTBF		MIL-HDBK-217F2, SF, 35°C	7.0×10^6			Hrs

Notes: Electrical Performance Characteristics Table

1. Parameter is guaranteed to the limits specified in table I by design, but not tested. Limits apply to the operating range specified in table I, unless otherwise specified. No Group A subgroups are specified for this test.
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

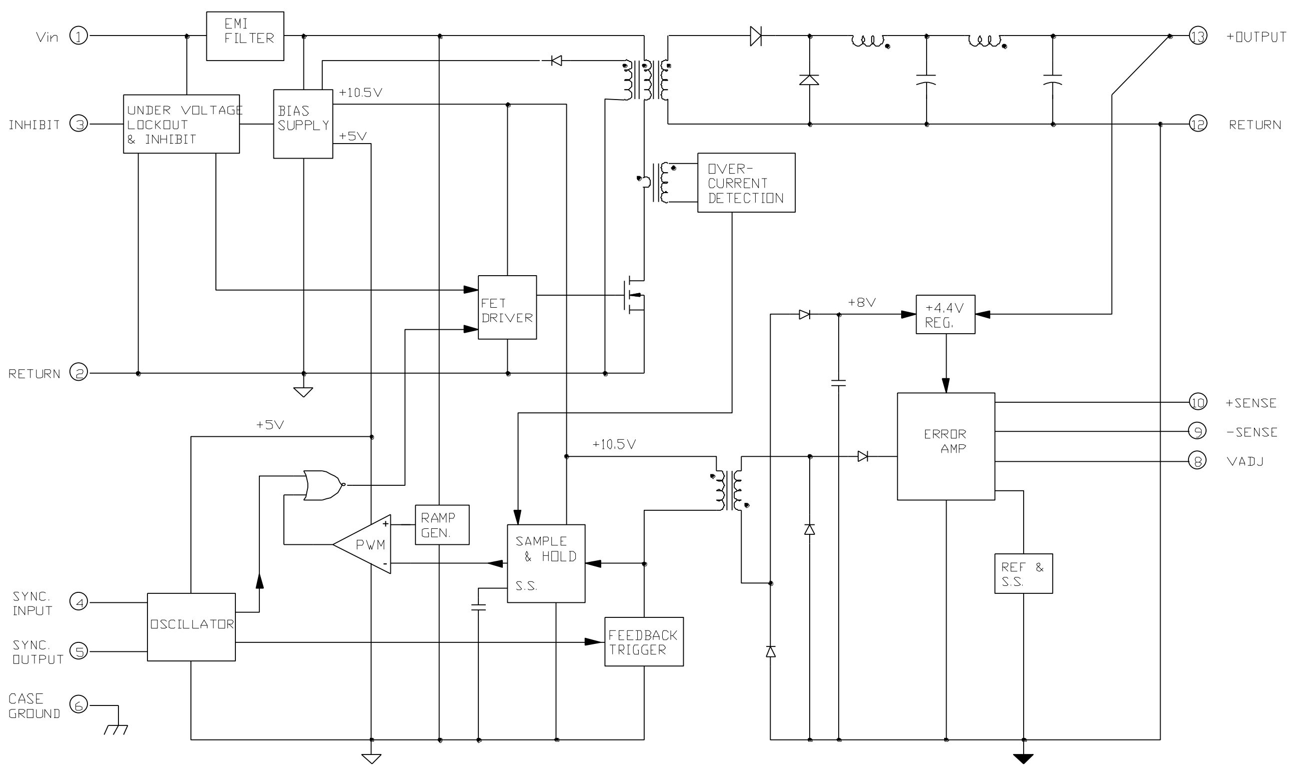
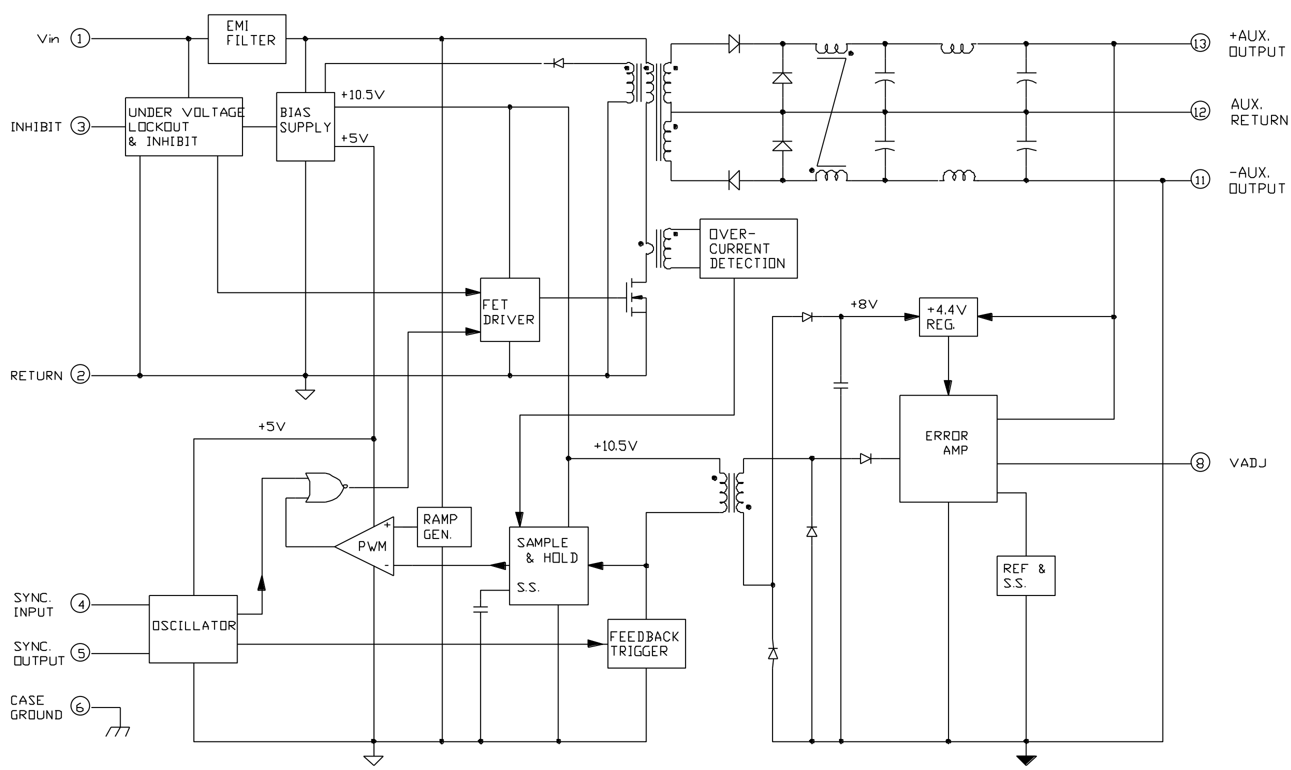


Fig 2. Block Diagram - Dual Output



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} = 70V	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} = 70V (supported by analysis)	1E8 4E10	 1E11	Rads (Si)/sec
Neutron Fluence	MIL-STD-883, Method 1017 (supported by analysis)	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} = 60, 70, 100V	82		MeV·cm^2/mg

Application Notes

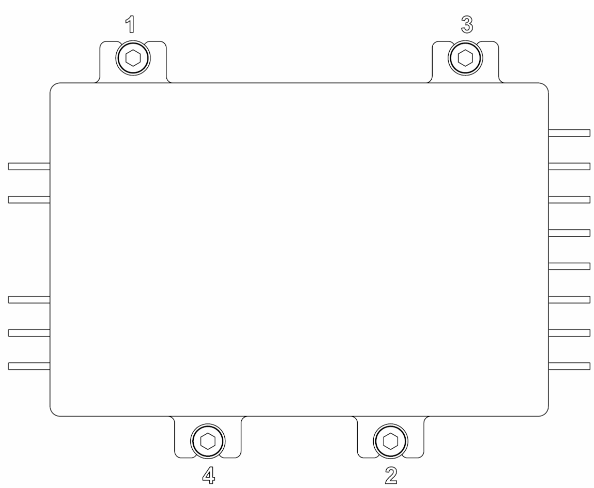
A) Attachment of the Converter:

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 M3GB 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 HiRel 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 HiRel. The M3GB-Series converter requires either M3 or 4-40 size screws of 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.

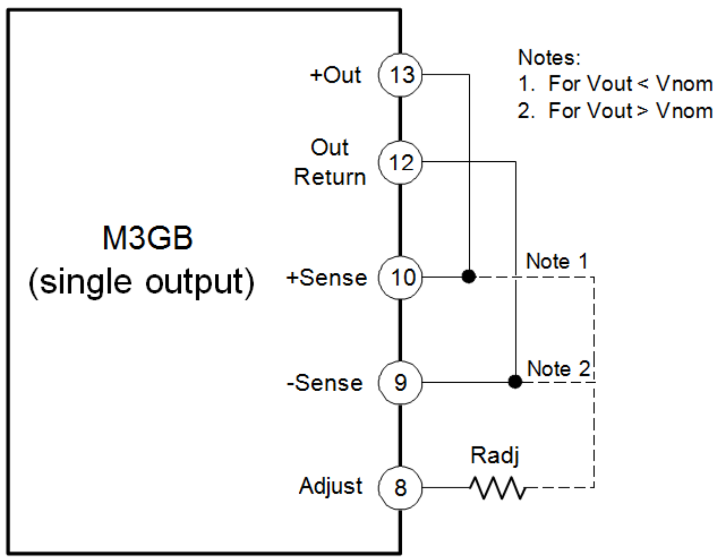
B) Output Voltage Adjustment

Single Output:

To adjust the output voltage of the single output models, a resistor (R_{ADJ}) is connected between the Adjust pin (Pin 8) and either the positive or negative remote sense pins, depending on whether the output voltage is to be adjusted higher or lower than the nominal set-point. This allows the outputs to be reliably adjusted by approximately +10% to -20% of the nominal output voltage. Refer to Fig. 3 and use equations provided to calculate the required resistance (R_{ADJ}).

Note: The output voltage adjust equation does not work as described for the 3.3V Single model. The adjust range for 3.3V model is limited to 3.252V to 3.460V.

Fig 3. Configuration for Adjusting Single Output Voltage



For **all Single Output Models**, to adjust the output voltages higher:

$$R_{ADJ} = \frac{10 \times (V_{NOM} - 2.5)}{V_{OUT} - V_{NOM}} - 50$$

Where: R_{ADJ} is in kOhms
R_{ADJ} is connected to the -Out pin and $V_{NOM} < V_{OUT} < 1.1V_{NOM}$ (Fig. 3, Note 2)
V_{NOM} is the nominal output voltage with the Adjust Pin left open
V_{OUT} is the desired output voltage

For **all Single Output Models**, to adjust the output voltages lower:

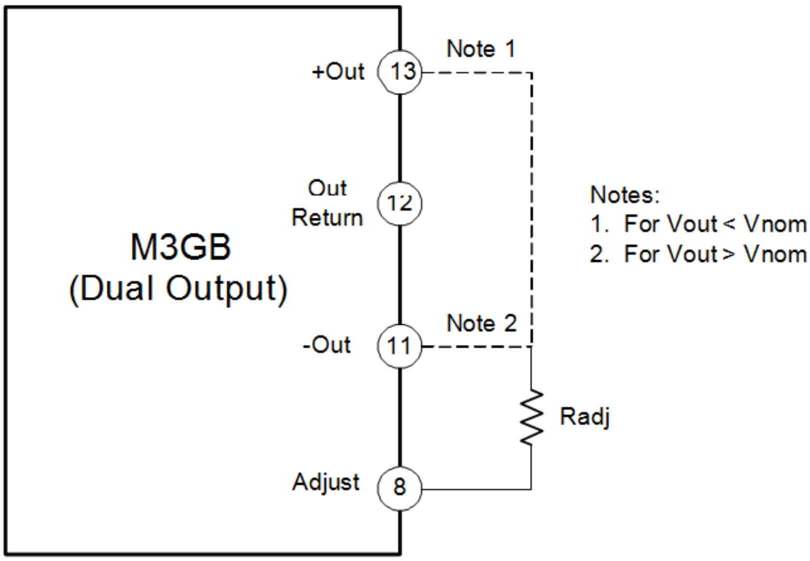
$$R_{ADJ} = \frac{4 \times (V_{NOM} - 2.5) \times (V_{OUT} - 2.5)}{V_{NOM} - V_{OUT}} - 50$$

Where: R_{ADJ} is in kOhms
R_{ADJ} is connected to the +Out pin and $0.8V_{NOM} < V_{OUT} < V_{NOM}$ (Fig. 3, Note 1)
V_{NOM} is the nominal output voltage with the Adjust Pin left open
V_{OUT} is the desired output voltage

Dual Output:

The dual output voltage of the dual output models, a resistor (R_{ADJ}) is connected between the Adjust pin (Pin 8) and either output. This allows the outputs to be reliably adjusted by approximately +10% to -20% of the nominal output voltage. Refer to Fig. 4 and use equations provided to calculate the required resistance (R_{ADJ}).

Fig. 4. Configuration for Adjusting Dual Output Voltage



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

$$R_{ADJ} = \frac{10 \times (V_{NOM} - 1.25)}{V_{OUT} - V_{NOM}} - 75$$

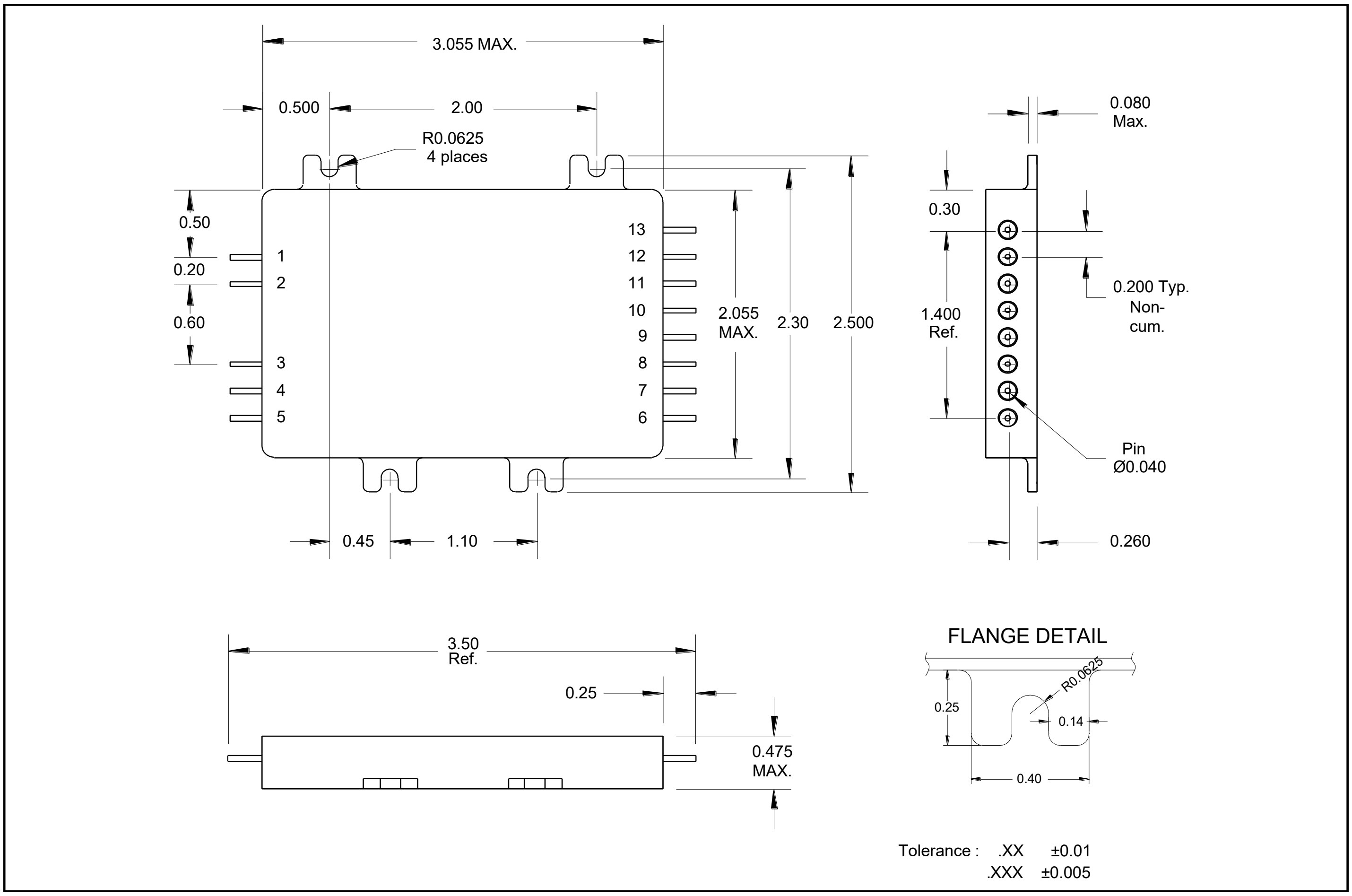
Where: R_{ADJ} is in kOhms
R_{ADJ} is connected to the -Out pin and $V_{NOM} < V_{OUT} < 1.1V_{NOM}$ (Fig. 4, Note 2)
V_{NOM} is the nominal magnitude of the output voltages with the Adjust pin left open
V_{OUT} is the desired magnitude of the output voltages

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

$$R_{ADJ} = \frac{8 \times (V_{NOM} - 1.25) \times (V_{OUT} - 1.25)}{V_{NOM} - V_{OUT}} - 75$$

Where: R_{ADJ} is in kOhms
R_{ADJ} is connected to the +Out pin and $0.8V_{NOM} < V_{OUT} < V_{NOM}$ (Fig. 4, Note 1)
V_{NOM} is the nominal magnitude of the output voltages with the Adjust pin left open
V_{OUT} is the desired magnitude of the output voltages

Mechanical Outline



Pin Designation (Single/Dual)

Pin #	Designation	Pin #	Designation
1	Vin	8	VADJ
2	RETURN	9	- SENSE / NC
3	INHIBIT	10	+ SENSE / NC
4	SYNC. INPUT	11	NC / - AUX.OUTPUT
5	SYNC. OUTPUT	12	AUX. RETURN
6	CASE GROUND	13	+ AUX. OUTPUT
7	NC		

Device Screening

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

Notes:

① **"EM" grade** shall only be form, fit and function equivalent to its Flight Model (FM) counterpart for electrical evaluation, and it may not meet the radiation performance. The EM Model shall not be expected to comply with MIL-PRF-38534 flight quality/workmanship standards, and configuration control. An EM build may use electrical equivalent commercial grade components

② **"CK" grade** is the flight model (FM) compliant to K Level screening as defined in the DLA Land and Maritime MIL-PRF-38534 requirements, but is not necessarily a DLA Land and Maritime qualified SMD per MIL-PRF-38534. The governing document for this part number designator is the IR HiRel datasheet (this document). Radiation rating as stated in the "Radiation Performance Characteristics" section, is verified by analysis and test per IR HiRel internal procedure. The part is marked with the IR base part number and the "CK" certification mark.

Part Numbering

M3GB 70 05 S /XX X

- Model: M3GB
- Nominal Input Voltage: 70 = 70V
- Output Voltage: 03R3 = 3.3V, 05 = 5V; 12 = 12V, 15 = 15V; 05 = ±5V,12 = ±12V, 15 = ±15V
- Output: S = Single, D = Dual
- Screening Level (Please refer to Screening Table): No Suffix, CK, EM
- Lead Finish:
  - C = Gold Plated
  - A = Solder Dipped
  - Blank for No Suffix and EM
  - Lead Finish for No Suffix = Gold Plated
  - Finish for EM is Gold Plated or Solder Dipped depending on availability

IMPORTANT NOTICE

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