M.S.KENNEDY CORP.

RADIATION HARDENED HIGH-POWER, HIGH EFFICIENCY DC-DC POWER CONVERTER

ISR2800D

4704 Dey Road Liverpool, N.Y. 13088 (315) 701-6751

FEATURES:

- 82.5W Output Power
- 18-40VDC Steady-state Input Voltage Range
- Adjustable Positive Output Voltage - 3.3V to 5.0V
- Fixed -5V Negative Output
- Typical 90% Efficiency from Half Load to Full Load
- Total Dose - 100krad(Si)(max)
- Single-Event Effects - LET > 82MeV-cm²/mg
- SEGR Hardened MOSFETs
- Integrated Circuits are SEL Immune
- Internal EMI Filter meets MIL-STD-461
- Input Inrush Current Limiting
- Remote Sense for Main Output Voltage
- Soft-start Circuitry Prevents Output Voltage Overshoot
- Input Undervoltage Lockout
- Output Overload and Short Circuit Protection
- Output Overvoltage Protection
- Synchronization Capability
- External Inhibit

DESCRIPTION:

The ISR2800D is the first in a series of radiation-hardened, high-reliability power supplies to be offered by MSK. The ISR2800D is specifically optimized to drive transmit/receive (T/R) modules in Phased Array Antennas (PAA), but as a result of its high-performance capabilities and numerous built-in features, it is ideal for many other applications. The ISR2800D utilizes two DC-DC converters to optimize power conversion efficiency and facilitate voltage sequencing necessary to protect T/R modules during power-up and power-down. A small flyback converter, referenced to input return and switching at 200kHz, is used to provide electrical input-output isolation, generate nominal +10VDC bias voltages for the input and output control circuits of the power supply, and generate a nominal -5VDC negative output voltage for the T/R modules. The negative output voltage for the T/R modules is cross-regulated via a tap on the flyback transformer and referenced to output return. A low drop-out (LDO) linear regulator is then used to further post-regulate this output voltage to ensure tight regulation and low ripple, typically less than 5mVp-p. A single transistor forward converter, referenced to output return and switching at 100kHz, provides the positive adjustable output voltage. They are enclosed in a hermetic Silicon Aluminum (SiAl) package and weigh less than TBD grams. The package utilizes rugged ceramic feed-through Glid-Cop pins and is sealed using parallel seam welding.

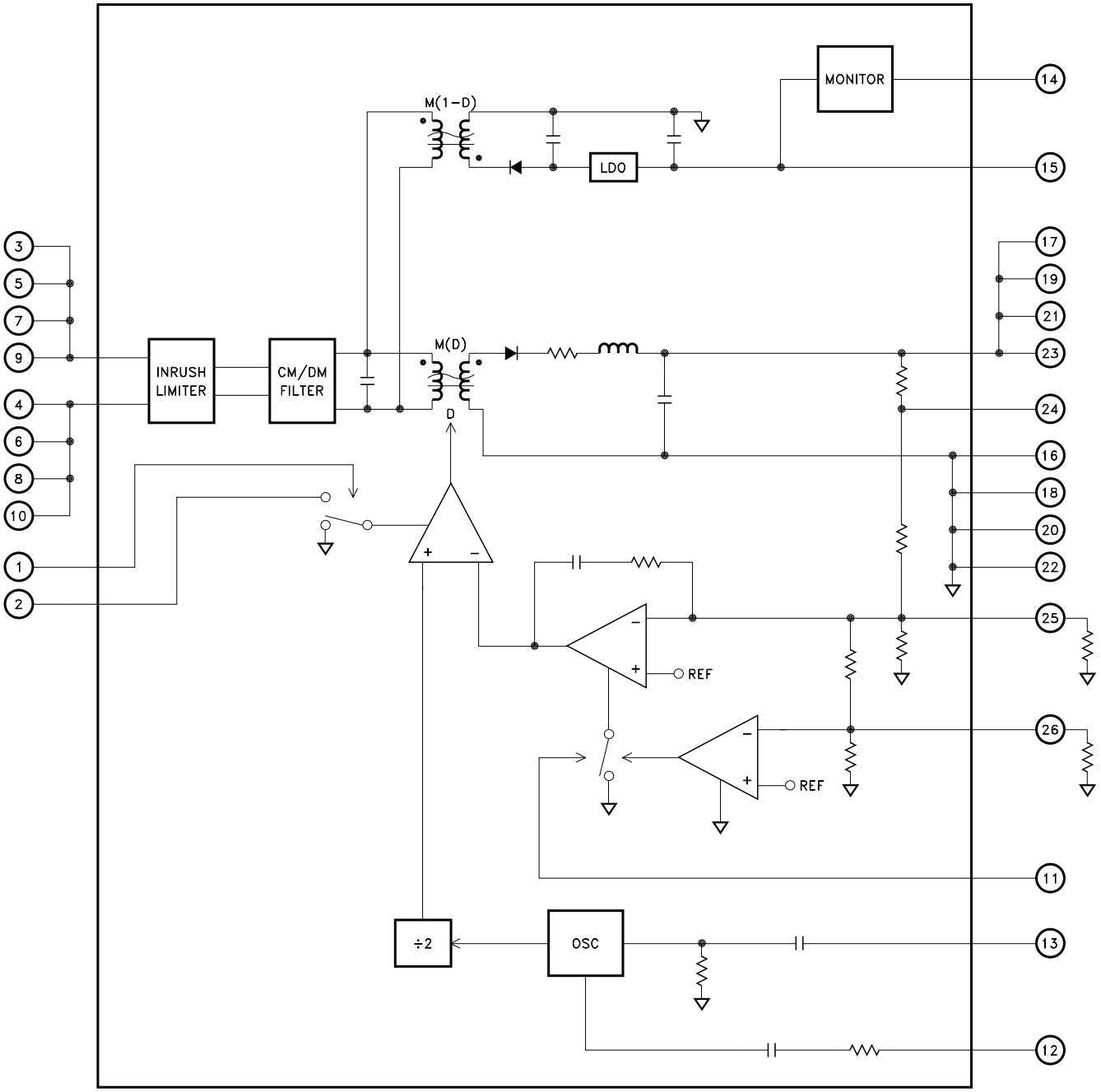
TYPICAL APPLICATIONS

- Geostationary (GEO) Earth Orbit Satellites
- Low Earth Orbit (LEO) Satellites
- Deep Space Satellites/Probes
- Communication Systems

PIN-OUT INFORMATION

1	PRI INHIBIT	14	CROW BAR
2	ETERM	15	-5V OUT
3	INPUT	16	VOUT RTN
4	INPUT RTN	17	+VOUT
5	INPUT	18	VOUT RTN
6	INPUT RTN	19	+VOUT
7	INPUT	20	VOUT RTN
8	INPUT RTN	21	+VOUT
9	INPUT	22	VOUT RTN
10	INPUT RTN	23	+VOUT
11	SEC ON/OFF	24	REM SENSE
12	SYNC OUT	25	VOUT ADJ
13	SYNC IN	26	VOUT OVP ADJ

EQUIVALENT SCHEMATIC



ABSOLUTE MAXIMUM RATINGS

Input Voltage Range	-0.5V to +50V
Ouput Power	Internally Limited
PRI Inhibit	-0.5V to +50V
Sec On/Off	-0.5V to +50V
Sync In	-0.5V to +5.0V
Rem Sense	+Vout ±0.5V
Lead Temperature	+300°C for 10 seconds
Operating Temperature	-55°C to 85°C
Storage Temperature	-55°C to 150°C

ELECTRICAL SPECIFICATIONS

Parameter	Test Conditions (1)	Group A Subgroup (5)	ISR2800D (4) Min.	Typ.	Max.	Units
INPUT CHARACTERISTICS						
Input Voltage (2)	Steady-state	1,2,3	18	28	40	V
Input Voltage (3)	Transient, ≤ 50ms	1,2,3	-0.5	-	50	V
-5VOUT						
Output Converter Frequency (3)		4,5,6	160	200	240	KHz
Output Voltage		1,2,3	-5.25	-5.00	-4.75	V
Output Current (2)		1,2,3	-	200	500	mA
Output Power (2)		1,2,3	-	1	2.5	W
Output Ripple		4,5,6	-	5	10	mVp-p
Output Current Limit		1,2,3	1.25	1.50	1.75	A
Output Over-voltage Limit		1,2,3	-6.50	-6.00	-5.50	V
+VOUT						
Output Converter Frequency		4,5,6	85	100	115	KHz
Output Voltage Adjustable Range		1,2,3	3.30	-	5.00	V
Output Voltage Regulation		1,2,3	-5.0	0.0	5.0	%Vo
Output Current (2)		1,2,3	16	-	-	A
Output Power (2)		1,2,3	-	-	80	W
Output Ripple		4,5,6	-	0.4	1.0	%Vo-p-p
Output Current Limit		1,2,3	16.0	21.3	24.0	A
Output Over-voltage Limit		1,2,3	110	120	130	%Vo
Output Step-load Response (3)	Zero Load to/from Half Load, V_{IN} = 22-40V_{DC}	4,5,6	-1.6	0.8	1.6	%Vo-p
Output Step-load Recovery Time (3)	Zero Load to/from Half Load, V_{IN} = 22-40V_{DC} Recovery to within ±1% of V_{OUT}	4,5,6	-	-	50	uS
Output Step-line Response (3)	18V to/from 40V	4,5,6	-1.6	0.8	1.6	%Vo-p
Output Step-line Recovery Time (3)	18V to/from 40V, Recovery to within 1% of V_{OUT}	4,5,6	-	-	50	uS
Output Efficiency (3)	+V_{OUT} = 5V, I_{OUT} = 8-16A; -I_{OUT} = -200mA	1,2,3	86	90	-	%
+VOUT						
Power Supply Efficiency (3)	+V_{OUT} = 5V, I_{OUT} = 16A; -I_{OUT} = -500mA	1,2,3	85	89	-	%
TURN-ON RESPONSE (3)	Input Voltage Stepped from 0 to 28V_{DC}					
-5V_{OUT} Output Overshoot		-	-	0	-	mV
-5V_{OUT} Output Turn-on Time		4,5,6	-	-	200	mS
+V_{OUT} Overshoot		-	-	0	-	mV
+V_{OUT} Turn-on Time		4,5,6	-	-	500	mS

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ELECTRICAL SPECIFICATIONS CONTINUED

Parameter	Test Conditions	Group A Subgroup ⑤	ISR2800D ④ Min.	Typ.	Max.	Units
PRI INHIBIT INPUT						
Input Voltage Range ②③		1,2,3	-0.5	-	50	V
Open Circuit Voltage		1,2,3	9	-	18	V
Input (Sink) Current		1,2,3	-	-	2	mA
SEC ON/OFF						
Input Voltage Range ②③		1,2,3	-0.5	-	50	V
Open Circuit Voltage		1,2,3	6	-	12	V
Input (Sink) Current		1,2,3	-	-	2.5	mA
POWER DISSIPATION						
Load Fault ③	Main Output Short Circuit	1,2,3	-	-	10	W
PRI Input Inhibit Active		1,2,3	-	-	0.05	W
Sec Output Inhibit Active	I_{OUT} = 0A	1,2,3	-	-	2	W
MISC						
Line Rejection ③	DC to 50KHz	4,5,6	40	60	-	dB
Isolation	Input to Output, Input to Case, Output to Case Tested at 100V_{DC}	1	100	-	-	MΩ
Unit Weight		-			TBD	grams
CAPACITIVE LOAD ③	No effect on DC Performance.					
-5V_{OUT}		-	-	-	TBD	μF
+V_{OUT}		-	-	-	288	μF
SHORT CIRCUIT RECOVERY TIME ③	Outputs returns to within 1% of nominal voltage					
-5V_{OUT}		4	-	-	200	mS
+V_{OUT}		4	-	-	500	mS
SYNC OUT						
Amplitude	I_{OUT}≤10mA	1,2,3	3.5	-	5.0	V
SYNC IN						
Input Threshold		1,2,3	3.5	-	-	V
Frequency Range		4,5,6	250	-	400	KHz
Input Current	V_{SYNC} = 3.5V	1,2,3	-	-	75	mA
Min Pulse Width ③		4,5,6	20	-	500	nS
CROW BAR						
Output High Voltage		1,2,3	9	-	12	V
Output High Current		1,2,3	10	-	20	mA

NOTES:

① -55°C ≤ Tc ≤ 85°C, V_{IN} = 18-40V_{DC}, $I_{OUT-MAIN}$ = 0-16A, $I_{OUT-AUX}$ = 0-500mA, unless otherwise specified
② This parameter is an operating condition and is verified during device testing.
③ This parameter shall be guaranteed by design and need not be tested.
④ Typical parameters are representative of actual device performance but are for reference only.
⑤ Subgroup 1,4 $T_A = T_C = +25°C$
2,5 $T_A = T_C = +125°C$
3,6 $T_A = T_C = -55°C$

APPLICATION NOTES

ISR2800D PIN DESCRIPTIONS

PRI INHIBIT - Allows on/off control from circuits referenced to the input return. Main and auxiliary outputs are on when this pin is left open and off when this pin is shorted to input return.

ETERM - Allows control of PRI Inhibit pin in electrically noisy environments. This pin bypasses the internal EMI filter to the internal ground reference and must be isolated. Connecting this pin to the PRI inhibit will disable the unit.

INPUT - Input power terminals to connect to primary power source. All of these pins must be connected by the user.

INPUT RTN - Input power terminals to connect to primary power source. All of these pins must be connected by the user.

SEC ON/OFF - Allows on/off control from circuits referenced to the output return. +Vout and -5Vout outputs are on when this pin is left open. +Vout is off when this pin is shorted to output return.

SYNC OUT - Allows user to synchronize other devices to the operating frequency of the converter. This AC coupled pin can drive up to 50Ω with an output level of 3.4V.

SYNC IN - Allows user control of the converter operating frequency within a limited range. If unused, connect to output return, or leave open. This pin has an input impedance of 50Ω.

CROW BAR - Allows user control to ensure proper voltage sequencing during fault conditions. This command may be used to activate a crowbar circuit on the main output to guarantee proper power down sequencing. This output should normally be buffered (e.g. to drive the gate of a FET) in timing critical sequencing applications. For non-critical timing or high impedance input devices, it may be used directly. Otherwise, it should be left open.

-5VOUT - Provides 2.5W of negative five volt, low noise bias power.

SEC RTN - Output power return terminals to connect to isolated secondary loads. This is the return ground reference for both the outputs. All of these pins must be connected by the user.

+VOUT - Main adjustable output voltage. Output power terminals connect to isolated secondary loads. This output is adjustable from 3.3V to 5V. All of these pins must be connected by the user.

REM SENSE - Remote sense allows user to connect to a remote location near the load for point of regulation. This overcomes a limited amount of voltage drop in the distribution network. Otherwise, connect this pin to the +Vout output.

VOUT ADJ - Allows adjustment of the +Vout voltage over the allowable range using an external resistor from this pin to the output return.

VOUT OVP ADJ - Allows adjustment of the over-voltage protection (OVP) threshold to match the (adjustable) main output voltage. Threshold is adjusted by connecting a resistor from this pin to the output return.

APPLICATION NOTES CONT'D

BASIC ARCHITECTURE:

MSK power converters utilize two DC-DC converters to optimize power efficiency and to provide internal housekeeping power while magnetically isolating the power bus from the load. A small flyback converter, referenced to input return, is used to provide electrical input-output isolation and will generate nominal +10VDC bias voltages for the input and output control circuits of the power supply. A single transistor forward converter, referenced to output return, provides the main output voltage.

FLYBACK CONVERTER:

The flyback converter uses peak current-mode Pulse Width Modulator (PWM) control and operates in discontinuous conduction-mode. Regulation is achieved by sampling the input bias voltage directly and feeding it back to the control circuit of the flyback converter, which is referenced to input return.

FORWARD CONVERTER:

The forward converter uses voltage Mode Pulse Width Modulator (PWM) control with input voltage feed-forward and operates in continuous conduction-mode. Regulation is achieved by sampling the output voltage directly and feeding it back to the control circuit of the forward converter, which is referenced to output return. Since the main output voltage is directly regulated without the use of magnetically-coupled feedback, superior voltage regulation can be achieved. A single-stage L-C output filter reduces the typical output ripple to less than 25mVp-p.

SYNCHRONOUS RECTIFICATION:

Synchronous rectification is used to achieve high-conversion efficiency over a half to full output load range and allows converter operation in continuous conduction-mode down to zero output load. This capability results in far superior dynamic performance when the load is stepped to or from a zero load condition, and is particularly critical in pulsed Phased Array Antenna and modern microprocessor applications which have high peak current demands and fast load transients.

INPUT EMI FILTER:

The input EMI filter is comprised of a multi-stage L-C filter which provides attenuation of the differential-mode emissions from the power supply. A balun, in conjuction with very small line-to-chassis and return-to-chassis capacitors, provides attenuation of the common-mode emissions from the power supply. Together these components enable the power supply to meet the conducted emission requirements of MIL-STD-461.

INRUSH CURRENT LIMITING:

Inrush current limiting circuitry limits initial peak input charging current at turn-on to less than two times maximum steady-state input current. Consequently, even when the input voltage to the power supply is instantaneously stepped, peak charging current is well controlled.

UNDERVOLTAGE LOCKOUT:

An undervoltage lockout circuit prevents the power supply from operating when the input line voltage is too low to maintain the output voltage. The converter will not start until the line voltage rises to approximately 17V and will shut down when the input voltage drops below approximatley 16V. The approximate 1V of hysteresis reduces the possibility of line noise interfereing with the converter during power-up and power-down.

SOFT-START:

Soft-start circuitry associated with both the flyback and forward converters is guaranteed to prevent output voltage overshoot during power-up for both the auxiliary and main output voltages.

USER-ADJUSTABLE MAIN OUTPUT:

The +VOUT output voltage is user-adjustable over a range of 3.3VDC to 5VDC. Setting the positive output voltage is accomplished by using a single external resistor. The output voltage may be programmed by the user to any desired voltage within this range. The table below shows the value of resistance necessary to set several common output voltages. The equation below may be used to determine the resistor value required for other set points. The output voltage may be adjusted up to 6V and down to 3V, but some performance specifications will not be met.

Output Voltage Adjust Resistor Value (in KΩ)

$$f(Vout) = \frac{2.5}{0.04975Vout-0.1484166} - 6.7$$

$f(3.0) = 2.98 \times 10^3$
$f(3.3) = 141.95$
$f(5.0) = 8.22$
$f(5.2) = 5.97$

OVERVOLTAGE PROTECTION (OVP):

Overvoltage protection is provided for both the negative and positive output voltages of the power supply. The overvoltage protection circuit for the negative output voltage limits peak voltage to approximately 120% of nominal. The overvoltage limit for the positive output voltage is programmable with a single external resistor. It is recommended that this overvoltage limit be set at approximately 120% of nominal.

The overvoltage protection is programmable over a limited range using only a single external resistor. The OVP voltage may be programmed by the user to any desired voltage within this range. The OVP set point should be coordinated with the positive output voltage and set to approximately 110% to 120% of the nominal output. The table below shows the value of resistance necessary to set the OVP to 120% for several common output voltages. The equation below may be used to determine the resistor value required for other set points.

Output Voltage Over-Voltage Protection (OVP) Adjust Resistor Value (in KΩ)

$$g(OVP) = \frac{10.4667}{OVP-3.55667} - 3.44$$

$g(3.6) = 238.12$
$g(3.96) = 22.51$
$g(6) = 0.84$
$g(6.24) = 0.46$

VOLTAGE SEQUENCING:

Output voltage sequencing is provided to protect T/R modules from damage when used in PAA applications. During power-up, the positive output voltage remains off until the negative output voltage has reached normal regulation limits. During power-down, a crowbar command is available to ensure that the positive output voltage falls to 10% or less of its steady state value before the negative output voltage falls more than 20% from its nominal value. During fault mode the crowbar command allows user control of the crowbar circuit on the positive output to ensure proper voltage sequencing for application specific requirements.

RADIATION PERFORMANCE

MSK converters give you superior radiation performance without the highs and lows of using "typical" DC-DC converters. The design represents a break from the traditional hardening method of simply replacing commercial die elements with radiation screened die in an off-the-shelf DC-DC converter design.

Special design techniques implemented at both the module level and the transistor circuit element level were used to harden the DC-DC converters. Here are some of the engineering steps taken to guarantee the radiation performance.

TOTAL DOSE HARDNESS:

The converters employ a fully magnetically-isolated configuration allowing the positive converter output to be regulated directly without the use of opto-couplers. Galvanic isolation between input and output is provided by the flyback converter and a small gate-drive transformer which couples the PWM drive signal to the main switching MOSFET. This approach provides optimum output voltage regulation and avoids the gain degrading effects of total ionizing dose on opto-couplers which can result in converter failure.

SINGLE-EVENT EFFECTS HARDNESS:

All critical ICs in the converter use a latch-up immune, dielectrically-isolated, BiCMOS process that prevents converter components from entering a potentially catastrophic latched state.

The heart of the DC-DC converter is the Single-Event Effects hardened PWM. The chip has SEU-immune CMOS soft-start control logic which will not upset in a heavy ion environment. The on-chip overcurrent comparator employs a redundant cross-checking comparator design. Error amp circuitry incorporates redundant wire OR differential input stages which prevent the amplifier output from over-ranging, which could cause excessive output pulse widths leading to overcurrent fault sequencing, transformer core saturation or power switch overstress. The toggle Flip/Flop (F/F) and all pulse control logic functions have been designed in SEU-immune CMOS to keep pulse phase integrity from being upset.

The PWM used in the flyback circuitry incorporates these same improvements with the exception of the soft-start function.

DC-DC converters use comparator ICs to control various converter functions such as input inrush current limiting, input undervoltage lockout, start-up regulator shutdown, output overvoltage protection, and main/auxiliary output voltage sequencing. A high-energy ion striking the comparator can cause any of these functions to fail or inadvertantly activate causing unwanted power supply interruptions. The MSK converters employ a new hardened, SEU immune, quad comparator. The chip uses triple redundant bipolar comparators for analog precision, and is backed by SEU-immune voting logic which ensures that no single-particle error can propagate to the output.

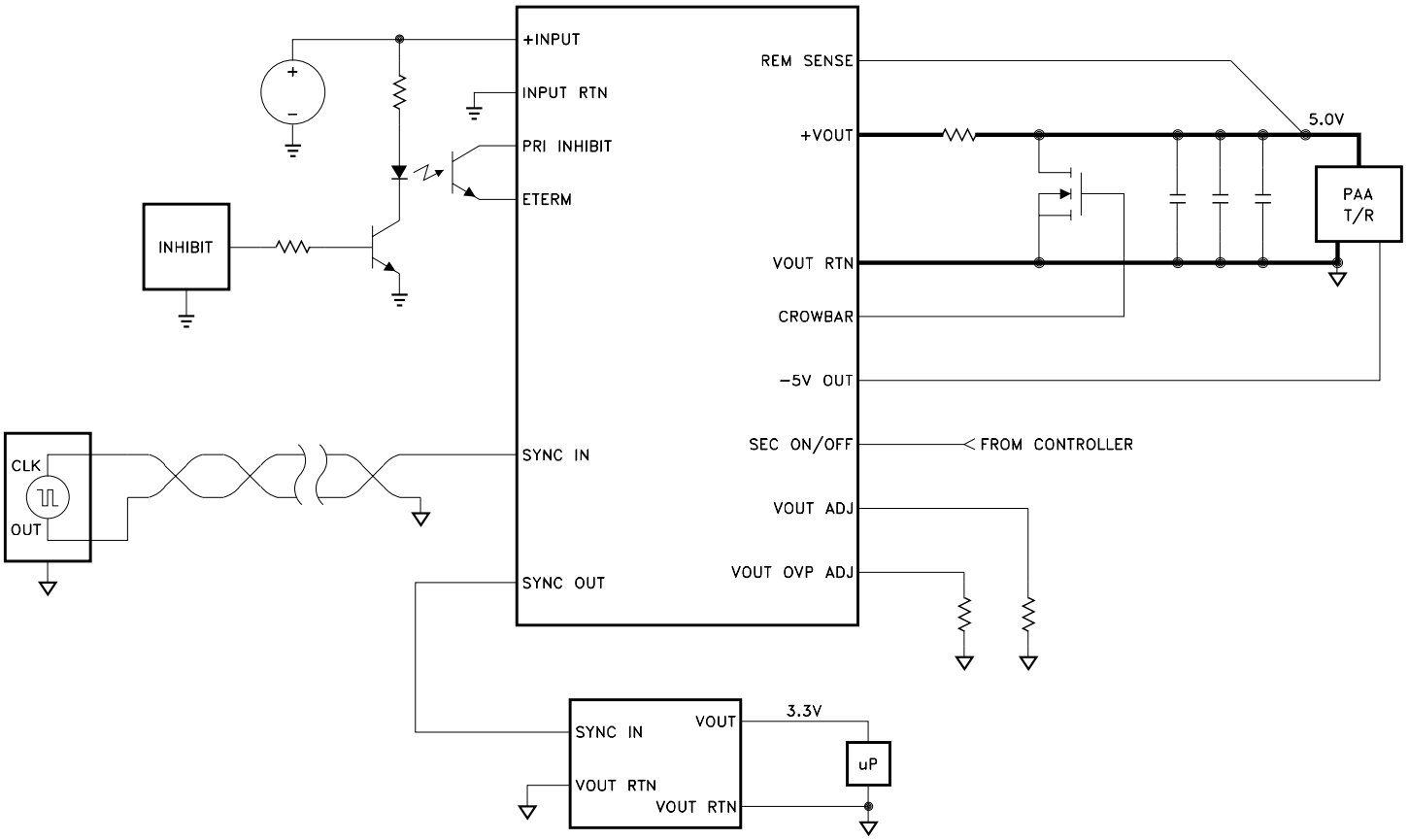
The potential for catastrophic single-event gate rupture in MOSFET's has led to the development of MOSFET's with oxide structures which resist breakdown up to fully rated MOSFET voltage potential under fully off-biased conditions. All MOSFET's used in the converters mitigate Single-Event Gate Rupture effects up to 82 MeV-cm²/mg.

A PROVEN DESIGN METHODOLOGY

The power supplies were developed using a proven, conservative design methodology which includes selecting radiation-hardened and established reliability components and fully de-rated to the requirements of MIL-STD-975, MIL-STD-1547 and GSFC PPL-21 Appendix B. Proprietary radiation-hardened silicon gate (RSG) process for integrated circuits ensures total dose capability to 300krads and immunity to single-event latch-up (SEL). Radiation-hardened power MOSFETs virtually eliminate the possibility of single-event gate rupture and single-event burn-out. Direct regulation is utilized instead of opto-couplers to minimize temperature, radiation and aging sensitivity. The Cadence Analog Work Bench (AWB) tool set, including Sensitivity/Worst Case and Monte Carlo tools, was used extensively to predict and optimize circuit performance for both beginning and end-of-life. Thorough design analysis include Worst Case, Component Stress and Reliability (MTBF).

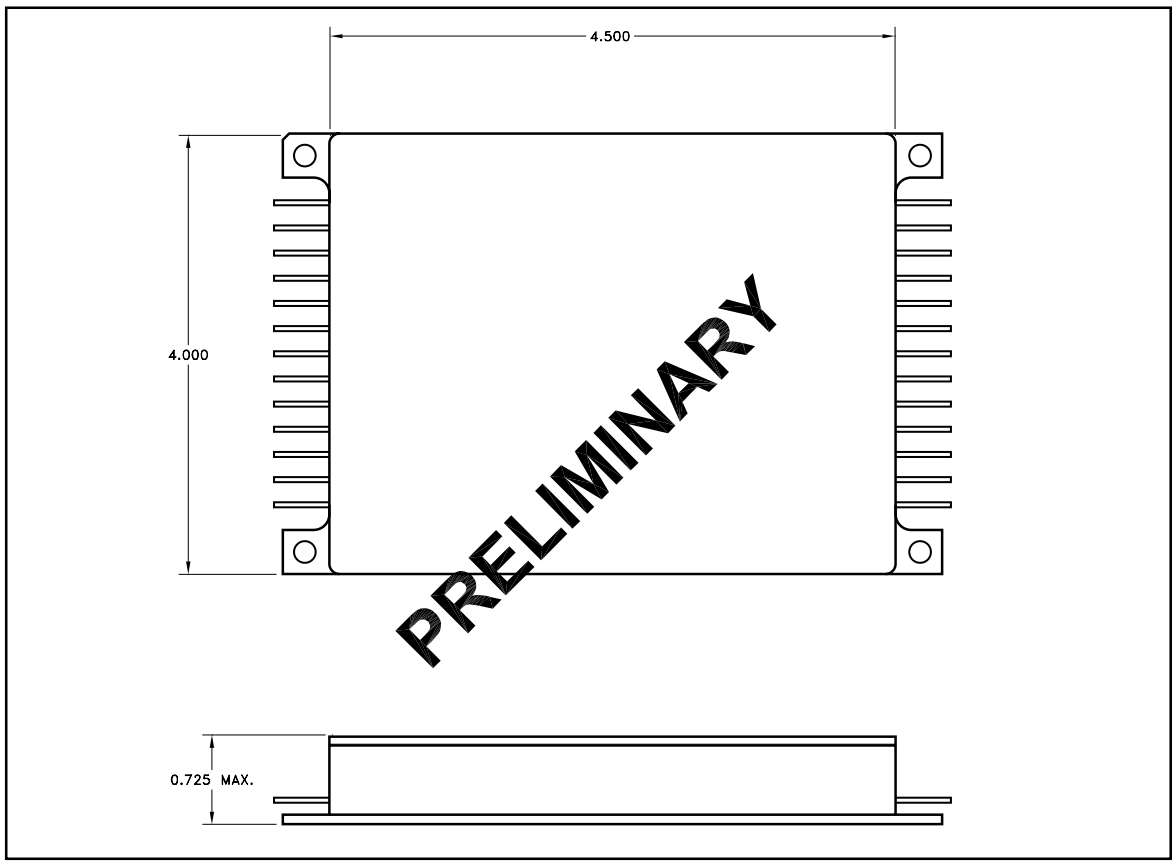
MSK's DC-DC converters offer high reliability through "tried and true" methods of passive component procurement and hybrid construction techniques. All stacked capacitors are procured, pre-assembled (stacked) and up screened by the capacitor manufacturer. Capacitor mounting procedures are performed per the supplier's guidelines. Magnetics, resistors and capacitors are all procured to the highest standards. Full component level traceability is maintained on all high-rel lots. Final hybrid assembly and screening is available up to MIL-PRF-38534 Class K or Class H requirements.

TYPICAL SYSTEM OPERATION



A typical application shows the ISR2805DSKE connections to an arbitrary load. The remote sense line is used to eliminate voltage drop in the positive distribution lead. The negative output provides bias to hold the gate of FET drive transistors off in radiation environments. A FET crowbar circuit is driven directly to discharge the filter capacitance at the load during shutdown. The two resistors connected to the OVP and VOUT ADJ pins set the output over voltage limit and output voltage to the required values. Also illustrated is a connection to synchronize two converters to a master clock. An isolated connection is shown to inhibit both converter outputs from the primary referenced input voltage as well as a secondary ON/OFF command referenced to the output to shutdown the positive output.

MECHANICAL SPECIFICATIONS



NOTE: ALL DIMENSIONS ARE ±0.010 INCHES UNLESS OTHERWISE LABELED.
ESD Triangle indicates Pin 1.

ORDERING INFORMATION

ISR2800DKSRH

- **RAD-HARD**
- **LEAD CONFIGURATIONS**
  S = STRAIGHT; U = BENT UP; D = BENT DOWN
- **SCREENING**
  BLANK = INDUSTRIAL; E = EXTENDED RELIABILITY;
  H = CLASS H; K = CLASS K
- **DUAL OUTPUT**
- **OUTPUT VOLTAGE**
  +ADJ/-5V
- **NOMINAL INPUT VOLTAGE**
- **GENERAL PART NUMBER**

The above example is a Class K adjustable dual output rad-hard converter

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