MIL-PRF-38534 CERTIFIED

M.S.KENNEDY CORP.

RAD HARD 4.5A SWITCHING REGULATOR 5052RH

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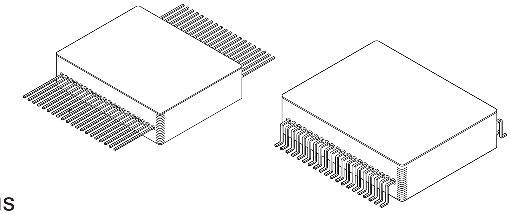
FEATURES:

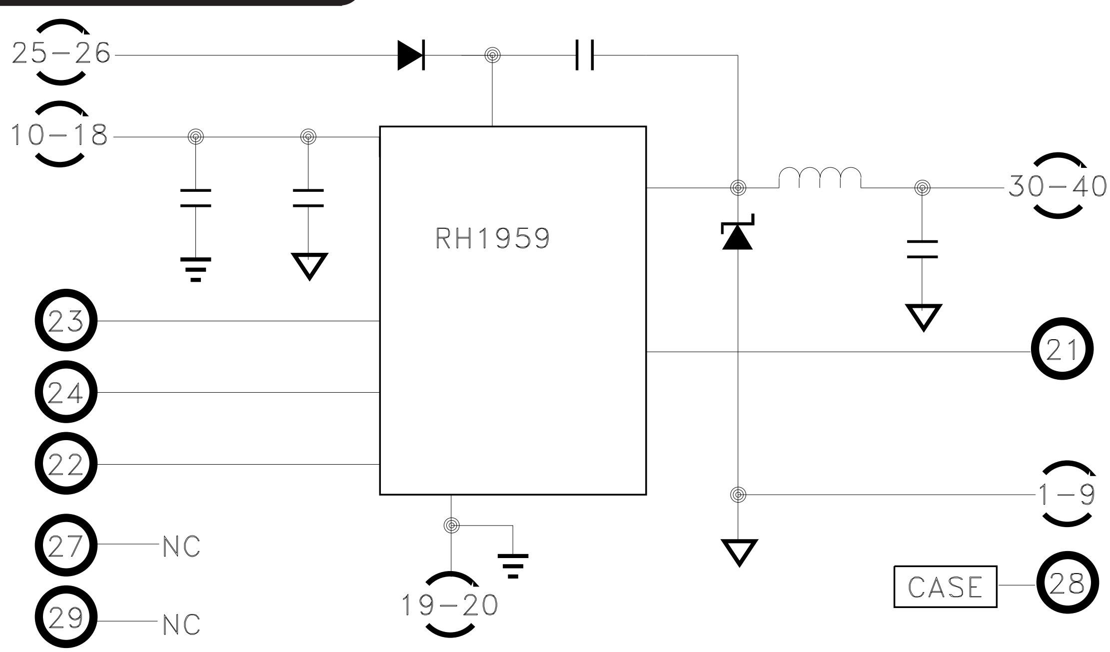


- Manufactured using Linear Technology Rad Hard RH1959MILDICE
- Total Dose Tested to TBD Krad(Si) (Method 1019.7 Condition A)
- Adjustable Output Voltage Down to 1.21V
- Input Voltage Range from 4.3V to 16V
- 500KHz or Externally Synchronizable Switching Frequency
- Shutdown Pin
- Short Circuit and Thermal Limit Protection
- Contact MSK for MIL-PRF-38534 Qualification Status and Radiation Status

DESCRIPTION:

The MSK 5052RH is a radiation hardened adjustable output voltage switching regulator. A wide input and output voltage range with 4.5A output current capability make these regulators suitable for many applications. Excellent efficiency and a reduced output capacitance requirement are the results of a constant or synchronizable switching frequency. The switching frequency can be controlled by an external signal through the SYNC pin or be set to a constant 500KHz. The regulator output can be turned on and off remotely with logic levels via the shutdown pin for meeting power sequencing requirements. Short circuit current limit and thermal shutdown features provide fault protection. The MSK 5052RH is packaged in a hermetically sealed 40 pin flatpack with straight or gull wing leads and specifically designed for space/satellite applications.

EQUIVALENT SCHEMATIC



TYPICAL APPLICATIONS

- POL Applications
- Satellite System Power Supply
- Microprocessor, FPGA Power Source
- High Efficiency Low Voltage Subsystem
- Power Supply

PIN-OUT INFORMATION

1-9	POWER GND	24	SYNC
10-18	VIN	25-26	BOOST
19-20	SIGNAL GND	27	NC
21	FB	28	CASE
22	COMP	29	NC
23	$\overline{SHDN}$	30-40	VOUT

ABSOLUTE MAXIMUM RATINGS ⑩

V_{IN}	Input Voltage	16V
I_{OUT}	Output Current ⑨	4.5A
	SYNC Pin Voltage	7.0 V
	$\overline{SHDN}$ Pin Voltage	7.0V
	FB Pin Voltage	3.5V
	FB Pin Current	1mA
T_{ST}	Storage Temperature Range	-65°C to +150°C
T_{LD}	Lead Temperature Range (10 Seconds)	300°C
T_J	Junction Temperature	150°C
T_C	Case Operating Temperature Range	
	MSK 5052K/H RH	-55°C to +125°C
	MSK 5052RH	-40°C to +85°C

ELECTRICAL SPECIFICATIONS

Parameter	Test Conditions ① ⑪	Group A Subgroup	MSK 5052K/H RH Min.	MSK 5052K/H RH Typ.	MSK 5052K/H RH Max.	MSK 5052RH Min.	MSK 5052RH Typ.	MSK 5052RH Max.	Units
Feedback Voltage(V_{FB})		1,2,3	1.19	1.21	1.23	1.19	1.21	1.23	V
	Post Radiation	1	TBD	TBD	TBD	TBD	TBD	TBD	V
Line Regulation	$4.3V \leq V_{IN} \leq 15V$	1,2,3	-0.5	-	0.5	-0.5	-	0.5	%
	Post Radiation	1	TBD	-	TBD	TBD	-	TBD	%
Load Regulation	$1A \leq I_{OUT} \leq 3A$	1,2,3	-1.0	-	1.0	-1.0	-	1.0	%
	Post Radiation	1	TBD	-	TBD	-1.0	-	1.0	%
VIN Input Supply Range ② ⑧		1,2,3	4.3	-	15.0	4.3	-	15.0	V
Output Voltage Range ②	VIN=10.0V	1,2,3	-	TBD	-	-	TBD	-	V
Efficiency		1	80	TBD	-	80	TBD	-	%
	Post Radiation	1	TBD	TBD	-	TBD	TBD	-	%
Output Voltage Ripple		4	-	TBD	TBD	-	TBD	TBD	mVpp
	Post Radiation	4	-	TBD	TBD	-	TBD	TBD	mVpp
Switching Frequency	SYNC pin grounded	4	460	500	540	460	500	540	KHz
Synchronization Threshold ②		1,2,3	-	1.5	2.2	-	1.5	2.2	V
Synchronization Range ③		4	580	-	1000	580	-	1000	KHz
VIN Supply Current @ Shutdown	$V\overline{SHDN}=0V$	1,2,3	-	TBD	75	-	TBD	75	uA
(low power state)	Post Radiation	1	-	-	TBD	-	-	TBD	uA
Lockout Threshold	VC Open	1,2,3	2.3	2.38	2.46	2.3	2.38	2.46	V
Shutdown Threshold Voltage		1,2,3	0.13	TBD	0.60	0.13	-	0.60	V
(low power state)	Post Radiation	1	TBD	-	TBD	TBD	-	TBD	V
COMP Pin Switching Threshold ②	Duty Cycle=0	1	-	0.9	-	-	0.9	-	V
COMP Pin High Clamp ②		1	-	2.1	-	-	2.1	-	V
Frequency Shifting Threshold on FB Pin	$\Delta f=10KHz$	1,2,3	0.5	0.7	1.0	0.5	0.7	1.0	V
Current Limit		1,2,3	4.5	-	-	4.5	-	-	A
	Post Radiation	1	TBD	-	-	TBD	-	-	A
Thermal Resistance ②	Junction to Case @125°C Forward Switch	-	-	13.0	15.5	-	13.0	15.5	°C/W
Thermal Resistance ②	Junction to Case @125°C Catch Diode	-	-	6.1	7.3	-	6.1	7.3	°C/W

NOTES:

① Unless otherwise specified VIN=5.0V, VOUT=2.5V and I_{OUT}=1.0A. See Figure 1 for typical application circuit.
② Guaranteed by design but not tested. Typical parameters are representative of actual device performance but are for reference only.
③ Reference SYNC pin function in the Application Notes section herein.
④ Industrial grade devices shall be tested to subgroup 1 and 4 unless otherwise specified.
⑤ Military grade devices ("H" Suffix) shall be 100% tested to subgroups 1,2,3 and 4.
⑥ Subgroup 5 & 6 testing available on request.
⑦ Subgroup 1,4 $T_A=T_C=+25°C$
2,5 $T_A=T_C=+125°C$
3,6 $T_A=T_C=-55°C$
⑧ Verified during line regulation test.
⑨ The absolute maximum current of 4.5A applies for duty cycles of 0.75 or lower.
De-rate linearly from 4.5A at D=0.75 to 3.75A at D=93 (maximum duty cycle typical).
⑩ Continuous operation at or above absolute maximum ratings may adversely effect the device performance and/or life cycle.
⑪ Pre and Post irradiation limits at 25°C, up to TBD Krad(Si) TID, are identical unless otherwise specified.

PIN FUNCTIONS

VIN - VIN connects to the collector of the internal power switch and provides power to the internal control circuitry and internal regulator. Very high di/dt is seen at VIN during switch on and off transitions. High frequency decoupling capacitors are recommended to minimize voltage spikes. VIN should be connected to a low impedence source for best operation.

FB - The FB (feedback) pin's primary function is to set the output voltage to the desired level, see **"Setting The Output Voltage."** The FB pin provides two additional functions. If the voltage at the FB pin drops below 0.8V the switch current limit is reduced. When the voltage at the FB pin drops below 0.7V the switching frequency is reduced. The switching frequency reduces to approximately 100KHz at VFB<=0.4V.

SIGNAL GND - The SIGNAL GND provides a return path for all internal control current and acts as a reference to the error amplifier. It is important that it is at the same voltage potential as the load return to ensure proper regulation. Tie the SIGNAL GND to the POWER GND as close to the case as possible.

POWER GND- The power ground provides the high current load return path to the MSK 5052RH's internal catch diode. High speed switching transition occur on the power ground with every switching cycle. The load return current commutates between the input bus return and the POWER GND pins. Place a minimum of 0.1uF to 1.0uF of high frequency ceramic capacitance physically close to the POWER GND and VIN pins to maximize performance.

$\overline{\text{SHDN}}$ - The $\overline{\text{SHDN}}$ (shutdown) pin has two shutdown functions. The first function disables switching when the voltage on the pin drops below 2.38V (nominal). The second forces a complete shutdown minimizing power consumption when the voltage drops below 0.4V (nominal). Pull this pin high or leave open for normal operation. The 2.38V threshold can be used for UVLO functions by configuring a resistive divider to VIN and GND that holds the pin voltage below 2.38V until VIN rises to the minimum desired voltage.

BOOST- The BOOST pin connects to an internal diode-capacitor network that supplies voltage to the power switch driver circuit. This elevated voltage level ensures the power switch saturates. A minimum of 3V is required for proper operation. This can be power from the input power supply, the regulator output , or a seperate supply if desired. Overall power dissipation increases slightly with higher BOOST voltages. For a typical 5V input connect the BOOST pin to the input source. For a 12V input to 3.3V output regulator, efficiency may be improved by 1 to 2 percent by connecting the BOOST pin to the regulator output.

VOUT - VOUT is the output of the regulator. External capacitance between the VOUT pin and GND is required to maintain stability and minimize output ripple voltage, see **"Selecting The Output Capacitor."** Provide a low impedance path between VOUT and the load to minimize voltage drops.

COMP - The COMP pin is the output of the error amplifier and the input of the peak current comparator. This pin is typically used for frequency compensation but can also be used as a current clamp or as an override to the internal error amplifier control. The pin voltage is typically around 1V at light load and 2V at heavy load. Driving the pin low will shut down the regulator. Driving it high will increase the output current. The current into the COMP pin must be limited to 4mA when driving it high.

SYNC - The SYNC pin is used to synchronize the oscillator to an external clock. It is logic compatible and can be driven to any frequency between the free run frequency (500KHz nominal) and 1MHz. At frequencies greater than 700KHz the risk of sub harmonic oscillation increases for applications with duty cycles greater than 50%. This is the result of the magnitude of the slope compensation ramp generated by the control IC being limited at higher frequencies. The duty cycle of the input signal must be between 10% and 90% to ensure proper synchronization. Tie the SYNC pin to GND if it is not used.

SETTING THE OUTPUT VOLTAGE

The output voltage of the MSK 5052RH is set with a simple resistor divider network: see Figure 1 (Typical Application Circuit). Select the resistor values to divide the desired output down to equal VFB (1.21V nominal) at the FB pin. Use a 2.5K or lower value resistor for R2 to keep output error due to FB pin bias current less than 0.1%.

$$VOUT = VFB*(1+R1/R2)$$

$$R1 = R2*((VOUT/VFB)-1)$$

Given VFB = 1.21V Nominal

TYPICAL APPLICATION CIRCUIT

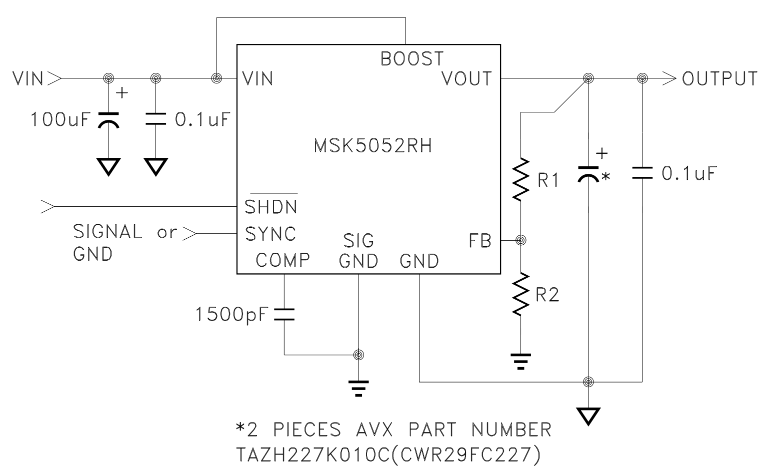


FIGURE 1

SELECTING THE OUTPUT CAPACITOR

The output capacitor filters the ripple current from the internal inductor to an acceptable ripple voltage seen by the load. The primary factor in determining voltage ripple is the ESR of the output capacitor. The voltage ripple can be approximated as follows:

$V_{P-P} = I_{P-P} * ESR$
Where $I_{P-P} = VOUT*(VIN-VOUT)/(1.65*VIN)$

The typical ESR range for an MSK 5052RH application is between 0.05 and 0.20 ohm. Capacitors within these ESR ranges typically have enough capacitance value to make the capacitive term of the ripple equation insignificant. The capacitive term of the output voltage ripple lags the ESR term by 90° and can be calculated as follows:

$V_{P-P}(CAP) = I_{P-P}/(8*F*C)$

Select
C = output capacitance in Farads
F = Switching Frequency in Hertz

Select a capacitor or combination of capacitors that can tolerate the worst-case ripple current with sufficient derating. When using multiple capacitors in parallel to achieve ESR and/or total capacitance, sharing of ripple current between capacitors will be approximately equal if all of the capacitors are the same type and preferably from the same lot. Low ESR tantalum capacitors are recommended over aluminum electrolytic. The zero created by the ESR of the capacitor is necessary for loop stabilty. A small amount of ceramic capacitance close to the load to decouple high frequency is acceptable but it should not cancel the ESR zero.

COMPENSATING THE LOOP

The current mode power stage from COMP node to VOUT can be modeled as a transconductance of gm = 5.3/V. The DC output gain will be the product of the transconductance times the load resistance. As frequency increases the output capacitance rolls off the gain until the ESR zero is reached. The error amplifier can be modeled as a transconductance amplifier with gm = 2000uMho and gain of 400 with finite output impedence. Typically a resistor and capacitor in series to ground are all that is needed to compensate the loop, but more complex compensation schemes are readily achieved.

POWER DISSIPATION

Power dissipation in the MSK 5052RH can be calculated as follows:

P_{DISS} = Switch loss + BOOST current loss + Quiescent current loss

$$= \frac{(R_{SW}(I_{OUT})^2\,(VOUT) + 24nS(I_{OUT})(VIN)(F))}{VIN} + \frac{((VBOOST)(VOUT)(I_{OUT}/A))}{VIN} + (VIN(0.001) + VOUT(0.005) + \frac{(VOUT^2)(0.002))}{VIN}$$

where,
RSW(Switch resistance) = 0.07Ω typ 0.13Ω max

24nS = Equivalent switch current/Voltage overlap time

F = Switch Frequency

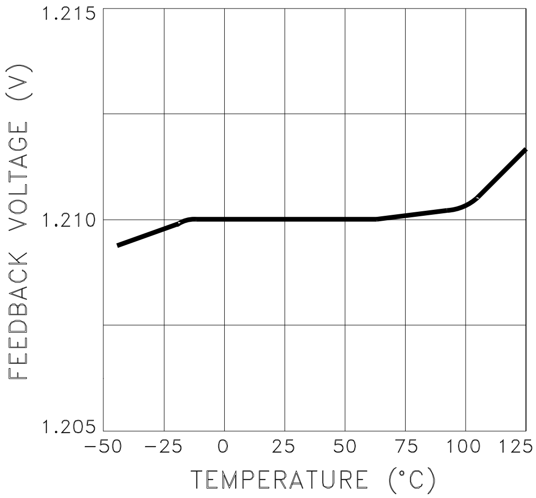
A = Current Gain ~ 50 typ 32 min

TOTAL DOSE RADIATION TEST PERFORMANCE

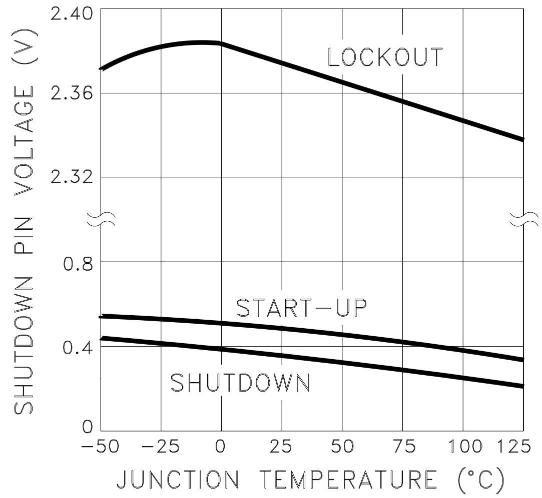
Radiation performance curves for TID testing will be generated for all radiation testing performed by MS Kennedy. These curves show performance trends throughout the TID test process and are located in the MSK 5052RH radiation test report. The complete radiation test report will be available in the RAD HARD PRODUCTS section on the MSK website.

http://www.mskennedy.com/store.asp?pid=9951&catid=19680

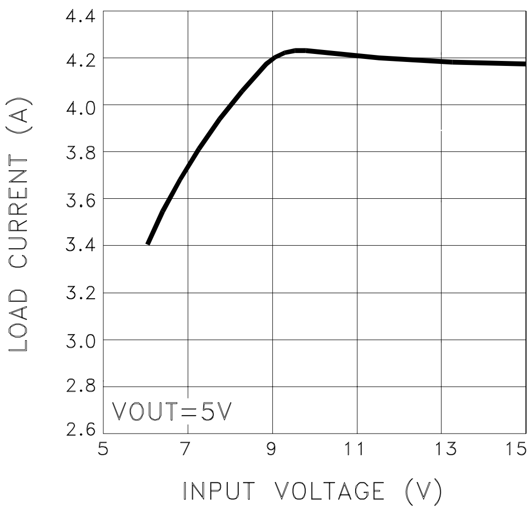
FEEDBACK PIN VOLTAGE
vs CASE TEMPERATURE



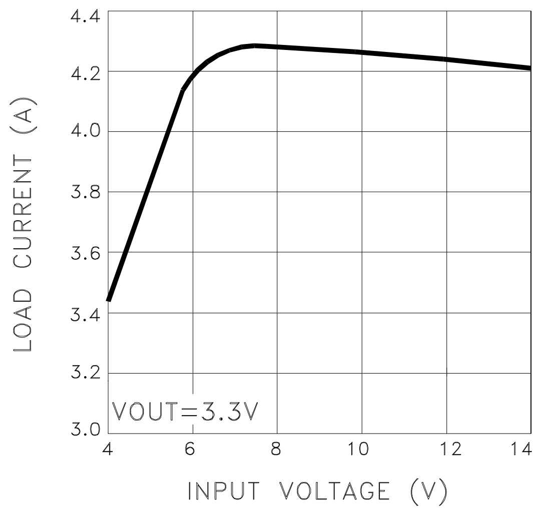
LOCKOUT AND SHUTDOWN THRESHOLDS
vs JUNCTION TEMPERATURE



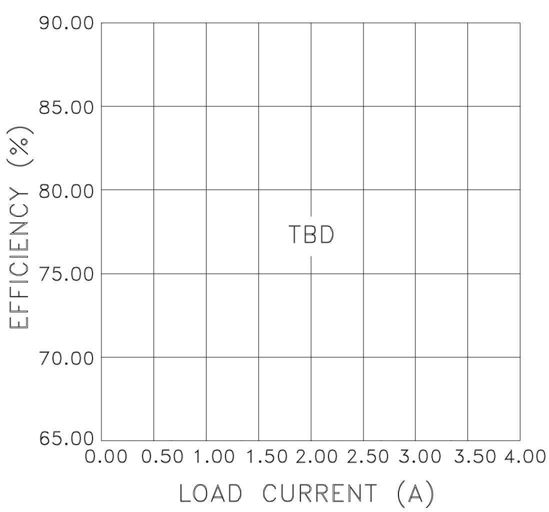
MAXIMUM LOAD CURRENT
vs INPUT VOLTAGE



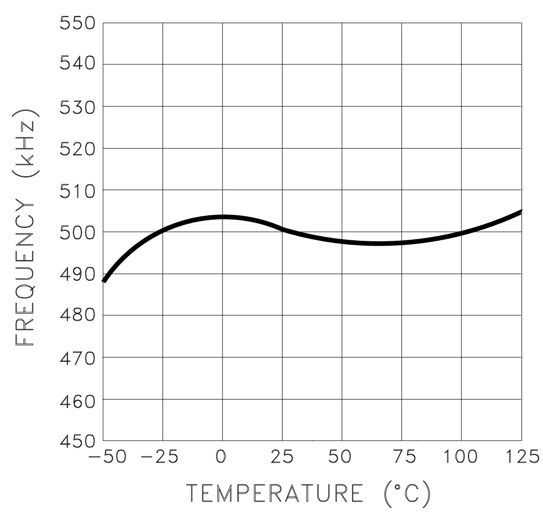
MAXIMUM LOAD CURRENT
vs INPUT VOLTAGE



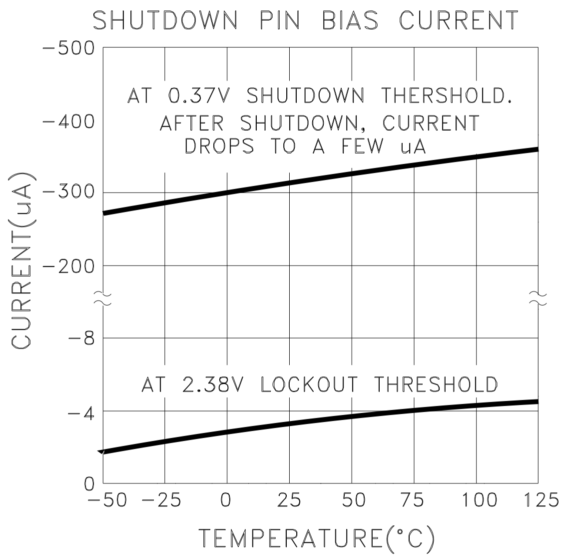
EFFICIENCY vs. LOAD CURRENT

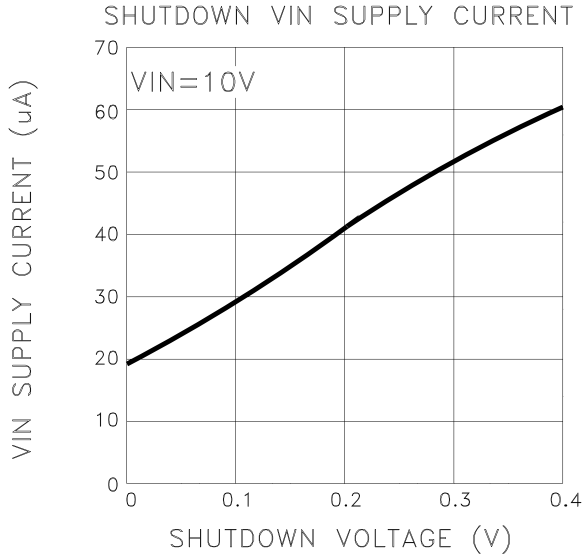


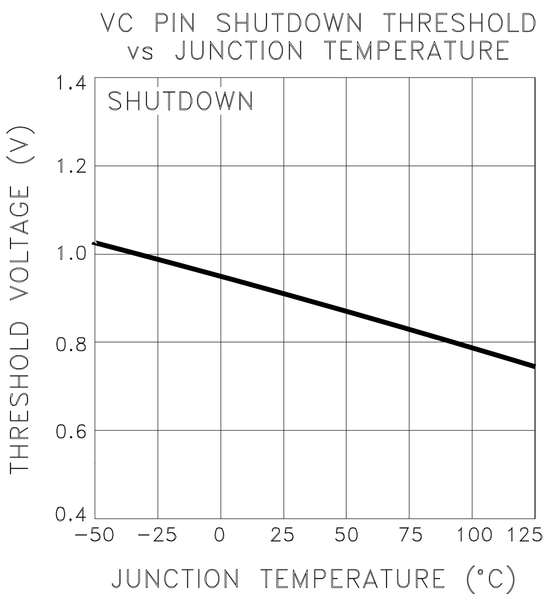
SWITCHING FREQUENCY

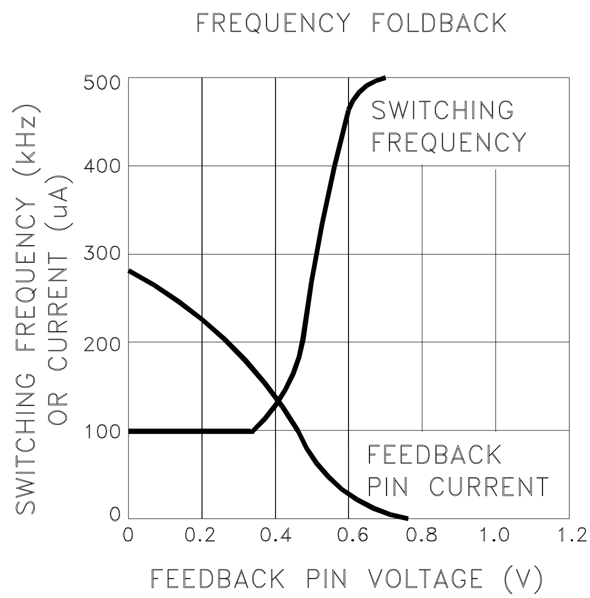


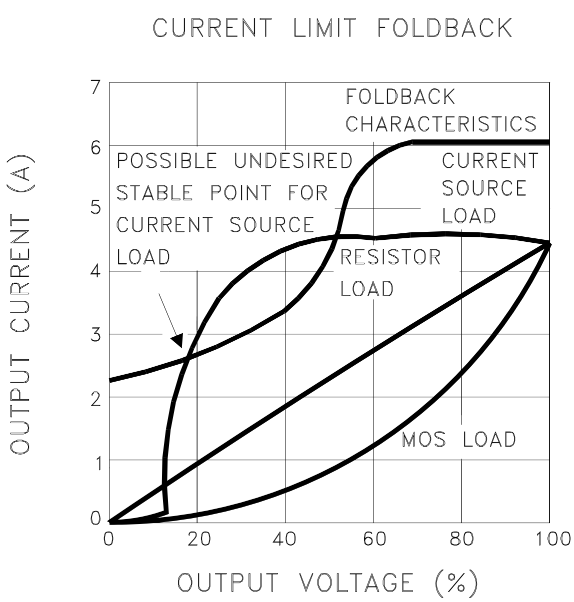
TYPICAL PERFORMANCE CURVES CONT'D

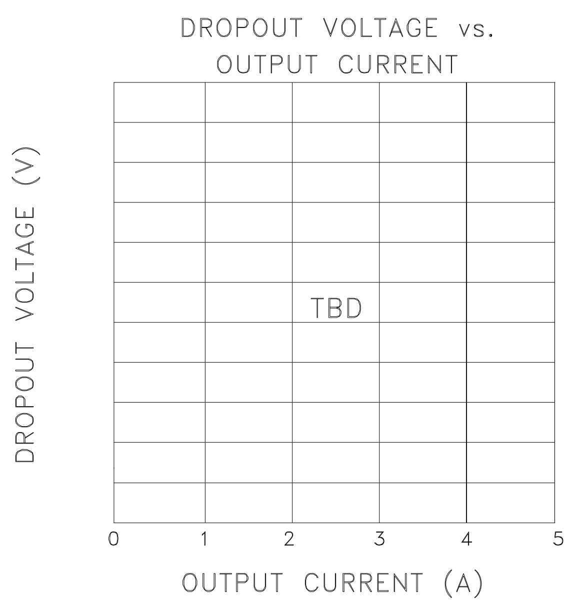






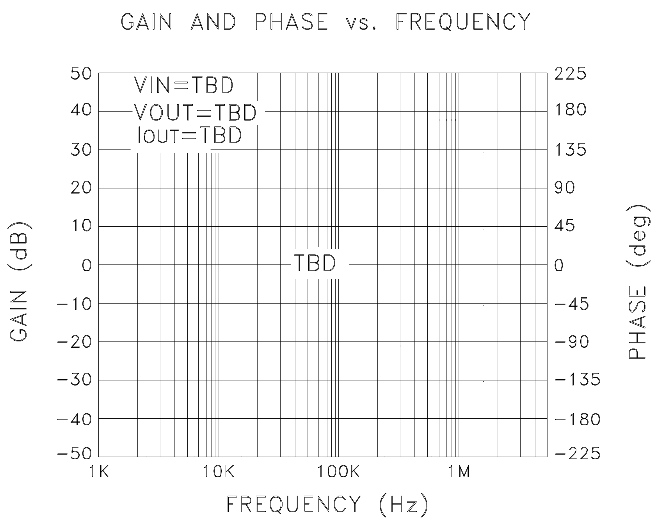


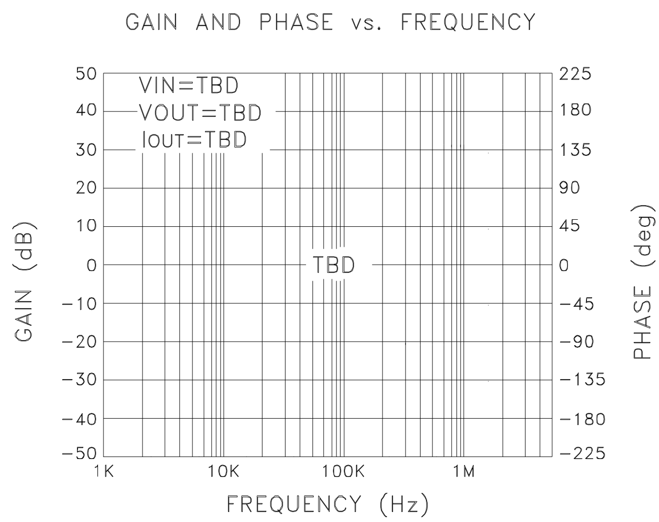


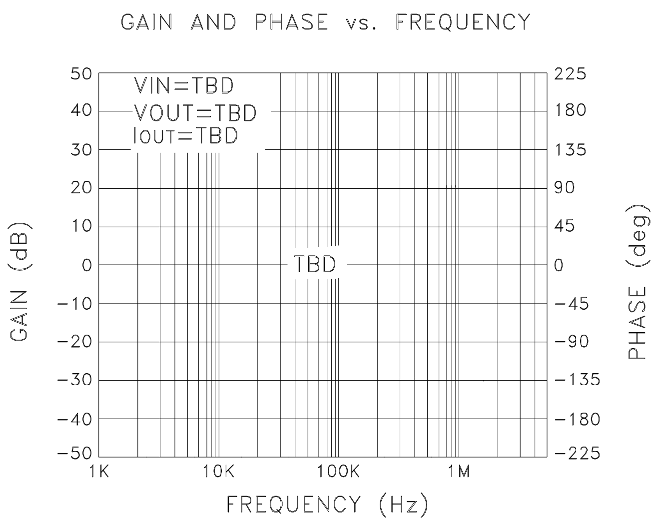


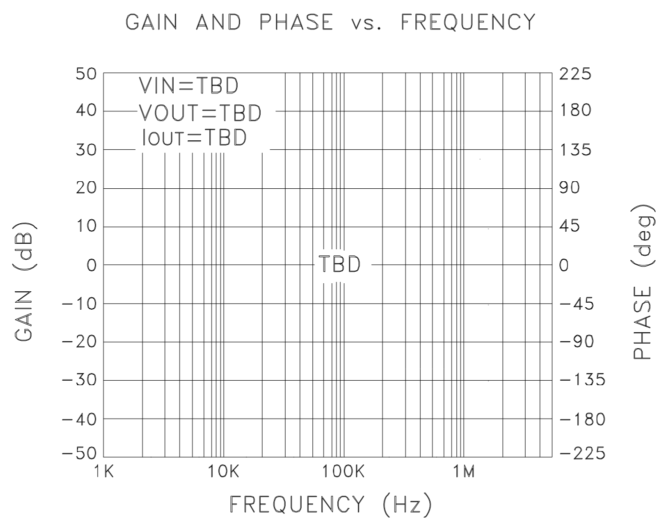
GAIN AND PHASE RESPONSE

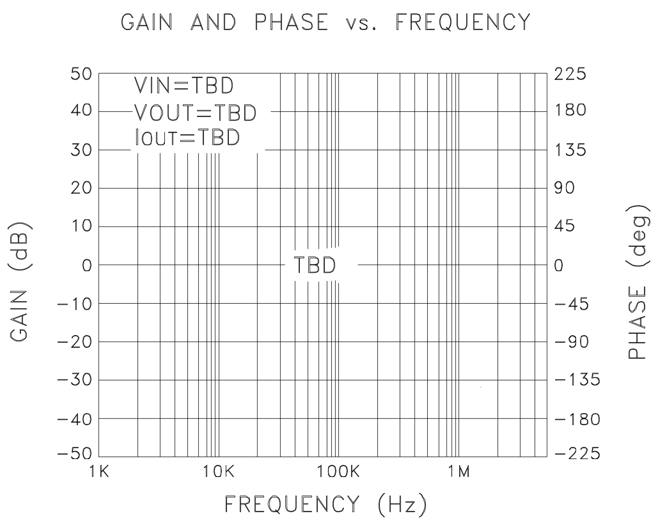
The gain and phase response curves are for the MSK typical application circuit and are representative of typical device performance, but are for reference only. The performance should be analyzed for each application to insure individual program requirements are met. External factors such as temperature, input and output voltages, capacitors, etc. all can be major contributors. Please consult factory for additional details.

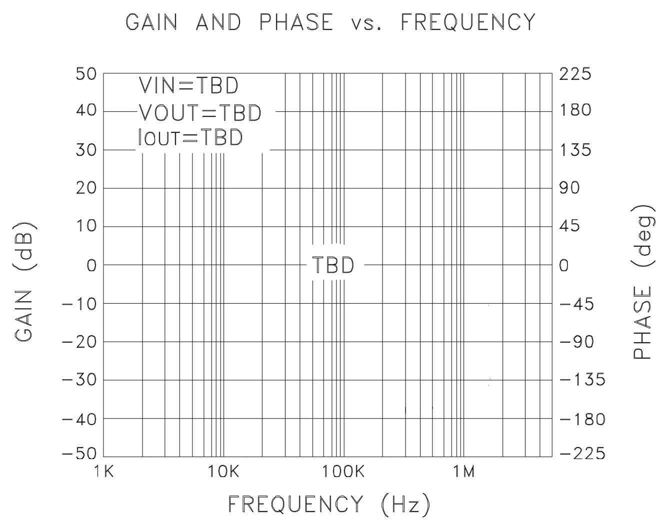




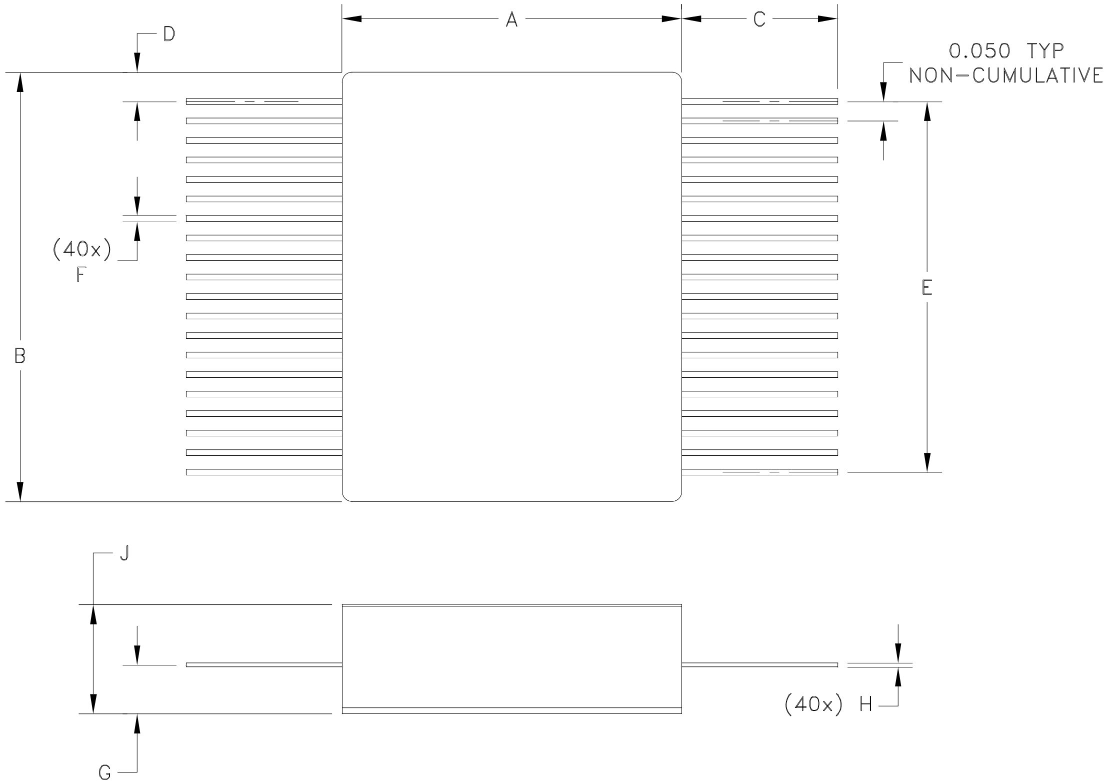








MECHANICAL SPECIFICATIONS



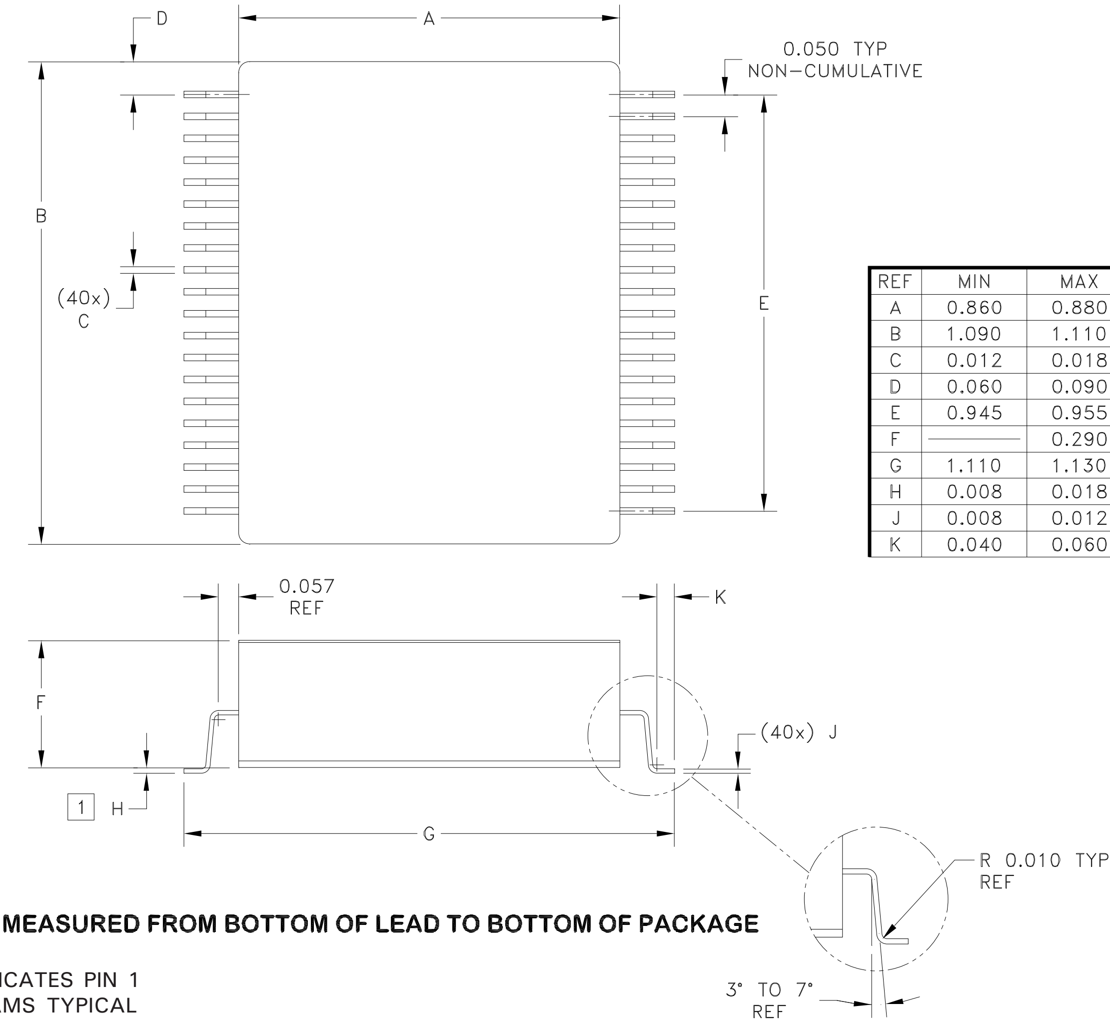
REF	MIN	MAX	REF	MIN	MAX
A	0.860	0.880	F	0.012	0.018
B	1.090	1.110	G	0.115	0.135
C	0.300	—	H	0.008	0.012
D	0.060	0.090	J	—	0.290
E	0.945	0.955			

ESD TRIANGLE INDICATES PIN 1
WEIGHT=TBD GRAMS TYPICAL

ORDERING INFORMATION

PART NUMBER	SCREENING LEVEL	LEADS
MSK5052RH	INDUSTRIAL	STRAIGHT
MSK5052HRH	MIL-PRF-38534 CLASS H	
MSK5052KRH	MIL-PRF-38534 CLASS K	

MECHANICAL SPECIFICATIONS



REF	MIN	MAX
A	0.860	0.880
B	1.090	1.110
C	0.012	0.018
D	0.060	0.090
E	0.945	0.955
F	————	0.290
G	1.110	1.130
H	0.008	0.018
J	0.008	0.012
K	0.040	0.060

NOTE:

1 **'H' IS MEASURED FROM BOTTOM OF LEAD TO BOTTOM OF PACKAGE**

ESD TRIANGLE INDICATES PIN 1
WEIGHT=TBD GRAMS TYPICAL

ORDERING INFORMATION

PART NUMBER	SCREENING LEVEL	LEADS
MSK5052RHG	INDUSTRIAL	GULL WING
MSK5052HRHG	MIL-PRF-38534 CLASS H	
MSK5052KRHG	MIL-PRF-38534 CLASS K	

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Contact MSK for MIL-PRF-38534 Class H and Class K qualification status.