



**RADIATION HARDENED  
HIGH POWER  
OP-AMP**

**106RH**

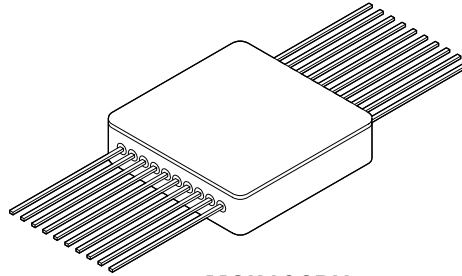
4707 Dey Road Liverpool, N.Y. 13088

(315) 701-6751

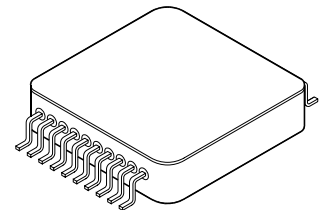
**MIL-PRF-38534 CERTIFIED**

**FEATURES:**

- Total Dose Rated to 100K Rad
- High Output Current - 2 Amps Peak
- Low Power Consumption-Class C Design
- Programmable Current Limit
- Rad Hard Design
- Output Short Circuit Capability
- Replacement for MSK0021FP
- Available as SMD #TBD



**MSK106RH**

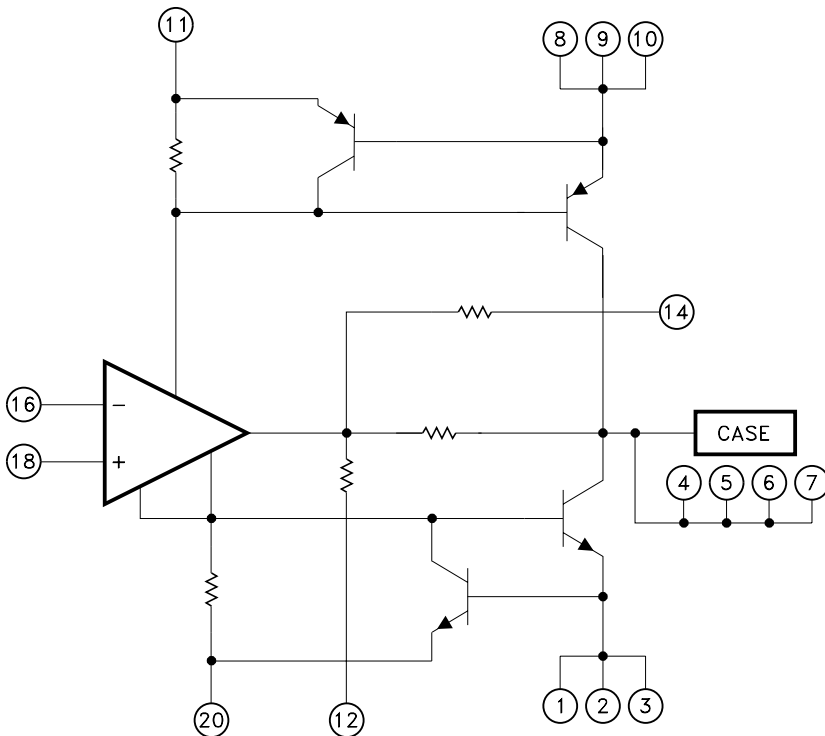


**MSK106RHG**

**DESCRIPTION:**

The MSK 106RH is a Radiation Hardened Class C power operational amplifier. This amplifier offers large output currents, making it an excellent choice for motor drive circuits. The amplifier and load can be protected from fault conditions through the use of internal current limit circuitry that can be user programmed with two external resistors. These devices are also compensated with a single external capacitor. The MSK 106RH is packaged in a 20 pin hermetic metal flatpack that is available with straight or gull wing leads.

**EQUIVALENT SCHEMATIC**



**PIN-OUT INFORMATION**

1 ISC-	20 -VCC
2 ISC-	19 NC
3 ISC-	18 +VIN
4 VOUT	17 NC
5 VOUT	16 -VIN
6 VOUT	15 NC
7 VOUT	14 Compensation
8 ISC+	13 NC
9 ISC+	12 GND
10 ISC+	11 +VCC

CASE IS ALSO VOUT

**TYPICAL APPLICATIONS**

- Servo Amplifier
- Audio Amplifier
- Motor Driver
- Programmable Power Supply

## ABSOLUTE MAXIMUM RATINGS <sup>⑨</sup>

$\pm V_{CC}$	Supply Voltage . . . . .	$\pm 22V$	T <sub>ST</sub>	Storage Temperature Range . . . . .	$-65^{\circ}$ to $+150^{\circ}C$
I <sub>OUT</sub>	Peak Output Current . . . . .	.2A	T <sub>LD</sub>	Lead Temperature Range . . . . .	300°C (10 Seconds)
V <sub>IN</sub>	Differential Input Voltage . . . . .	$\pm 30V$	T <sub>J</sub>	Junction Temperature . . . . .	150°C
V <sub>IN</sub>	Common Mode Input Voltage . . . . .	$\pm 15V$	T <sub>C</sub>	Case Operating Temperature Range	
R <sub>TH</sub>	Thermal Resistance. . . . .	6.0°C/W		Military Versions (K/H/E) . . . . .	$-55^{\circ}C$ to $+125^{\circ}C$
	Junction to Case (@ 125°C)			Industrial Versions . . . . .	$-40^{\circ}C$ to $+85^{\circ}C$

## ELECTRICAL SPECIFICATIONS

Parameter	Test Conditions <sup>⑧</sup>	Group A Subgroup	Military <sup>⑤</sup>			Industrial <sup>④</sup>			Units
			Min.	Typ.	Max.	Min.	Typ.	Max.	
<b>STATIC</b>									
Supply Voltage Range <sup>②</sup>		-	$\pm 5$	$\pm 15$	$\pm 22$	$\pm 5$	$\pm 15$	$\pm 22$	V
Quiescent Current	V <sub>IN</sub> = 0V	1	-	$\pm 1.7$	$\pm 3.5$	-	$\pm 1.7$	$\pm 4.0$	mA
		2,3	-	-	$\pm 7.5$	-	-	-	mA
Power Consumption <sup>②</sup>	V <sub>IN</sub> = 0V	1,2,3	-	75	225	-	75	225	mW
<b>INPUT</b>									
Input Offset Voltage	V <sub>IN</sub> = 0V	1	-	$\pm 0.5$	$\pm 3.0$	-	$\pm 0.5$	$\pm 5.0$	mV
		2,3	-	$\pm 2.0$	$\pm 5.0$	-	-	-	mV
Input Bias Current	V <sub>CM</sub> = 0V Either Input	1	-	$\pm 100$	$\pm 500$	-	$\pm 150$	$\pm 500$	nA
		2,3	-	$\pm 0.4$	$\pm 2.0$	-	-	-	$\mu A$
Input Offset Current	V <sub>CM</sub> = 0V	1	-	$\pm 2.0$	$\pm 100$	-	$\pm 2.0$	$\pm 300$	nA
		2,3	-	-	$\pm 300$	-	-	-	nA
Input Capacitance <sup>③</sup>	F = DC	-	-	3	-	-	3	-	pF
Input Resistance <sup>②</sup>	F = DC	-	0.3	1.0	-	0.3	1.0	-	M $\Omega$
Common Mode Rejection Ratio	F = 10Hz V <sub>CM</sub> = $\pm 10V$	4	70	90	-	70	90	-	dB
		5,6	70	90	-	-	-	-	dB
Power Supply Rejection Ratio	V <sub>CC</sub> = $\pm 5V$ to $\pm 15V$	1	80	95	-	80	95	-	dB
		2,3	80	-	-	-	-	-	dB
Input Noise Voltage <sup>③</sup>	F = 10Hz to 10KHz	-	-	5	-	-	5	-	$\mu V_{RMS}$
<b>OUTPUT</b>									
Output Voltage Swing	R <sub>L</sub> = 100 $\Omega$ F = 100Hz	4	$\pm 13.5$	$\pm 14$	-	$\pm 13.0$	$\pm 14$	-	V
		5,6	$\pm 13.5$	$\pm 14$	-	-	-	-	V
Output Short Circuit Current	R <sub>SC</sub> = 0.5 $\Omega$ V <sub>OUT</sub> = MAX	4	0.8	1.2	1.6	0.7	1.2	1.7	A
	R <sub>SC</sub> = 5 $\Omega$ V <sub>OUT</sub> = GND	4	50	150	250	50	150	250	mA
Settling Time <sup>③</sup>	0.1% 2V step	-	-	4	-	-	4	-	$\mu S$
<b>TRANSFER CHARACTERISTICS</b>									
Slew Rate	V <sub>OUT</sub> = $\pm 10V$ R <sub>L</sub> = 10 $\Omega$	4	1.2	1.6	-	1.2	1.6	-	V/ $\mu S$
Open Loop Voltage Gain	F = 10Hz R <sub>L</sub> = 1K $\Omega$	4	100	105	-	100	105	-	dB
		5,6	88	96	-	-	-	-	dB
Transition Times	1V to 2V P Rise and Fall	4	-	0.3	1.0	-	0.3	1.2	$\mu S$
Overshoot	1V to 2V P Small Signal		-	5	20	-	5	20	%

### NOTES:

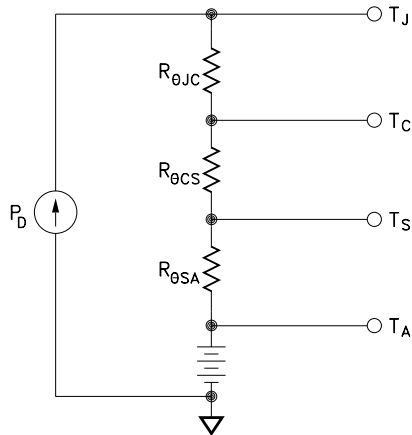
- ① Unless otherwise specified,  $\pm V_{CC} = \pm 15V$ , C<sub>c</sub> = 3000pF.
- ② Guaranteed by design but not tested.
- ③ Typical parameters are representative of actual device performance but are for reference only.
- ④ Industrial grade and "E" suffix devices shall be tested to subgroups 1 and 4 unless otherwise specified.
- ⑤ Military grade devices (K/H suffix) shall be 100% tested to subgroups 1, 2, 3 and 4.
  - Subgroup 1, 4 TA = Tc = +25°C
  - Subgroup 2, 5 TA = Tc = +125°C
  - Subgroup 3, 6 TA = Tc = -55°C
- ⑥ Reference DSCC SMD TBD for electrical specifications for devices purchased as such.
- ⑦ Subgroup 5 and 6 testing available upon request.
- ⑧ For complete radiation test data, consult "MSK 106RH Total Dose Test Report".
- ⑨ Continuous operation at or above absolute maximum ratings may adversely effect the device performance and/or life cycle.

## APPLICATION NOTES

### HEAT SINKING

To select the correct heat sink for your application, refer to the thermal model and governing equation below.

#### Thermal Model:



#### Governing Equation:

$$T_J = P_D \times (R_{\theta JC} + R_{\theta CS} + R_{\theta SA}) + T_A$$

Where

$T_J$	=	Junction Temperature
$P_D$	=	Total Power Dissipation
$R_{\theta JC}$	=	Junction to Case Thermal Resistance
$R_{\theta CS}$	=	Case to Heat Sink Thermal Resistance
$R_{\theta SA}$	=	Heat Sink to Ambient Thermal Resistance
$T_C$	=	Case Temperature
$T_A$	=	Ambient Temperature
$T_S$	=	Sink Temperature

#### Example:

In our example the amplifier application requires the output to drive a 10 volt peak sine wave across a 10 ohm load for 1 amp of output current. For a worst case analysis we will treat the 1 amp peak output current as a D.C. output current. The power supplies are  $\pm 15$  VDC.

##### 1.) Find Power Dissipation

$$\begin{aligned} P_D &= [(quiescent\ current) \times (+V_{CC} - (V_{CC}))] + [(V_s - V_o) \times I_{OUT}] \\ &= (3.5\ mA) \times (30V) + (5V) \times (1A) \\ &= 0.1W + 6W \\ &= 6.1W \end{aligned}$$

##### 2.) For conservative design, set $T_J = +125^\circ C$ .

##### 3.) For this example, worst case $T_A = +25^\circ C$ .

##### 4.) $R_{\theta JC} = 6.0^\circ C/W$

##### 5.) Rearrange governing equation to solve for $R_{\theta SA}$ :

$$\begin{aligned} R_{\theta SA} &= (T_J - T_A) / P_D - (R_{\theta JC}) - (R_{\theta CS}) \\ &= (125^\circ C - 25^\circ C) / 6.1W - (6.0^\circ C/W) - (0.15^\circ C/W) \\ &= 10.2^\circ C/W \end{aligned}$$

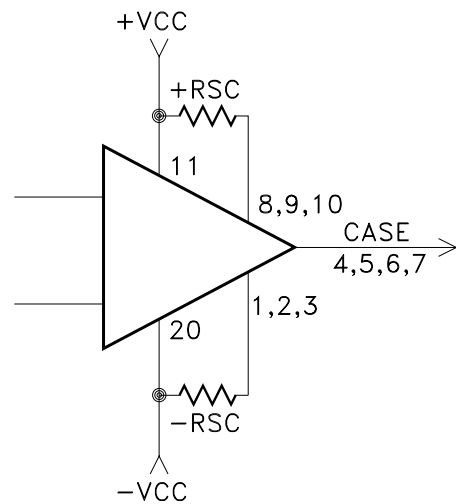
The heat sink in this example must have a thermal resistance of no more than  $10.2^\circ C/W$  to maintain a junction temperature of less than  $+125^\circ C$ .

### CURRENT LIMIT

The MSK 106RH has an on-board current limit scheme designed to limit the output drivers anytime output current exceeds a predetermined limit. The following formula may be used to determine the value of the current limit resistance necessary to establish the desired current limit.

$$R_{SC} = \frac{0.7}{I_{SC}}$$

#### Current Limit Connection

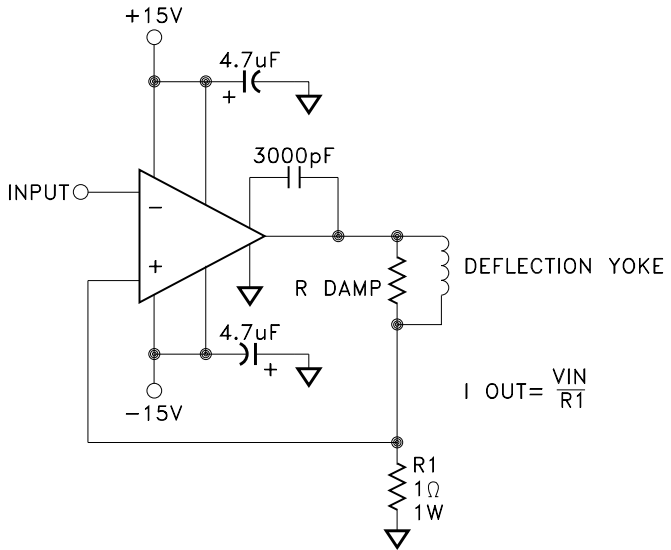


See "Application Circuits" in this data sheet for additional information on current limit connections.

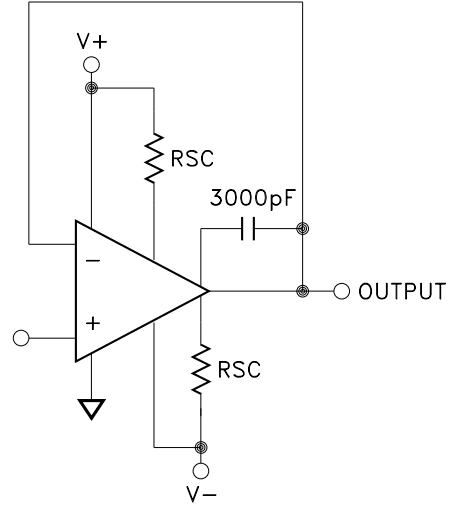
### POWER SUPPLY BYPASSING

Both the negative and the positive power supplies must be effectively decoupled with a high and low frequency bypass circuit to avoid power supply induced oscillation. An effective decoupling scheme consists of a 0.1 microfarad ceramic capacitor in parallel with a 4.7 microfarad tantalum capacitor from each power supply pin to ground. It is also a good practice with high power op-amps, such as the MSK 106RH, to place a 30-50 microfarad capacitor with a low effective series resistance, in parallel with the other two power supply decoupling capacitors. This capacitor will eliminate any peak output voltage clipping which may occur due to poor power supply load regulation. All power supply decoupling capacitors should be placed as close to the package power supply pins as possible.

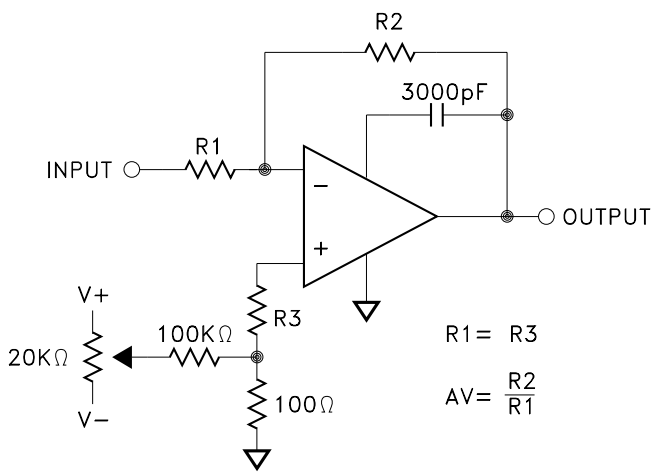
# APPLICATION CIRCUITS



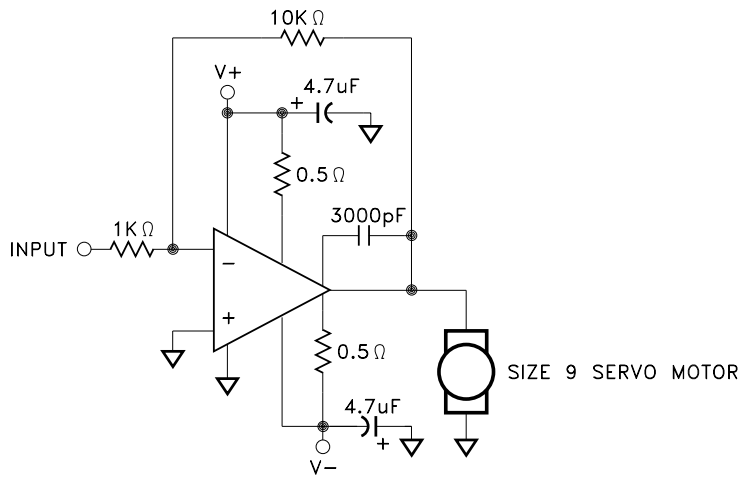
CRT DEFLECTION YOKE DRIVER



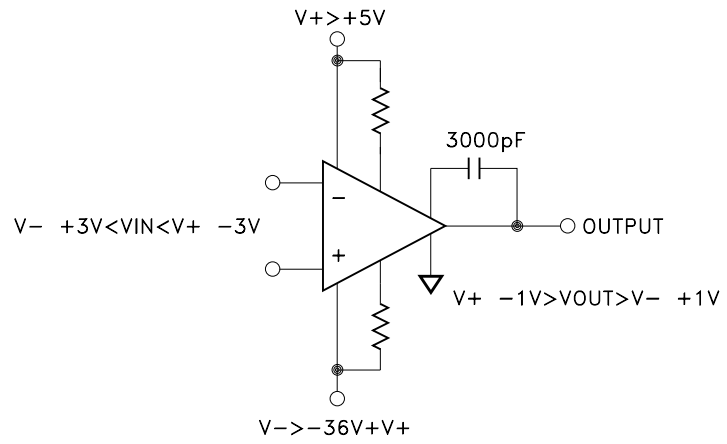
UNITY GAIN CIRCUIT WITH SHORT CIRCUIT LIMITING



OFFSET VOLTAGE NULL CIRCUIT



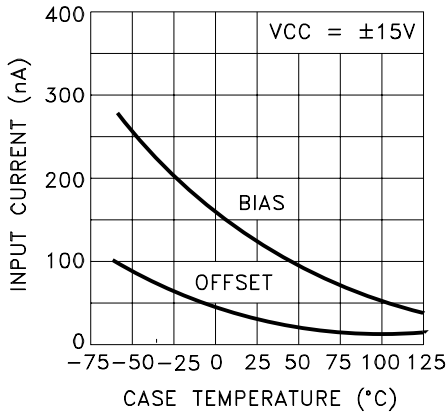
DC SERVO AMPLIFIER



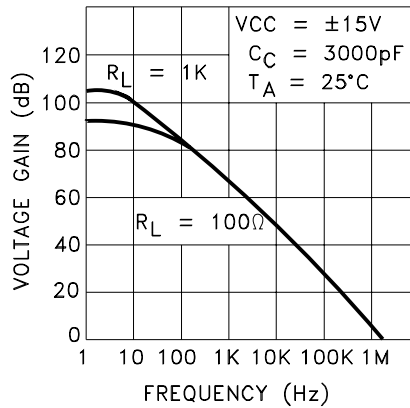
NON SYMMETRICAL SUPPLIES

# TYPICAL PERFORMANCE CURVES

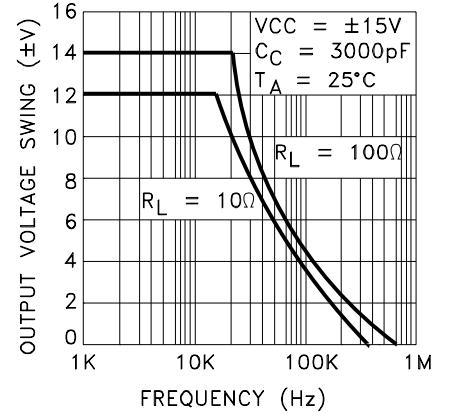
INPUT CURRENT vs TEMPERATURE



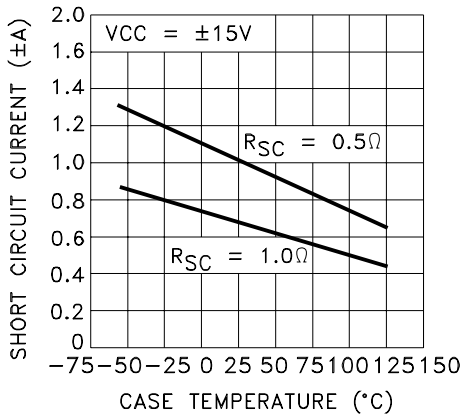
OPEN LOOP FREQUENCY RESPONSE



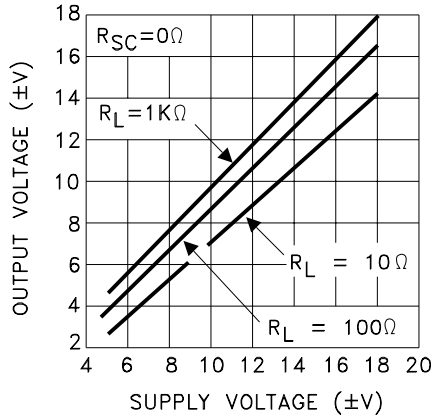
LARGE SIGNAL FREQUENCY RESPONSE



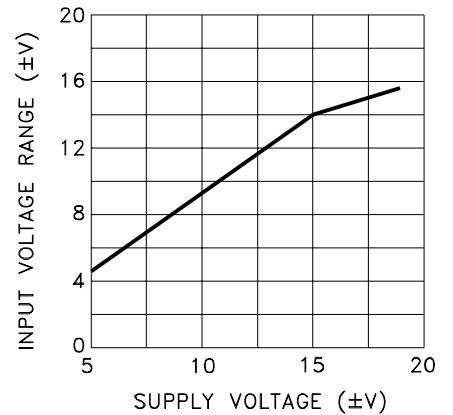
SHORT CIRCUIT CURRENT vs. TEMPERATURE



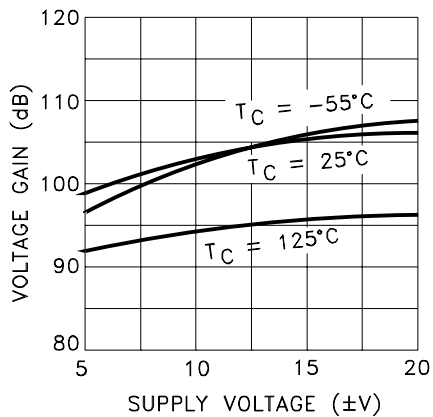
OUTPUT VOLTAGE SWING



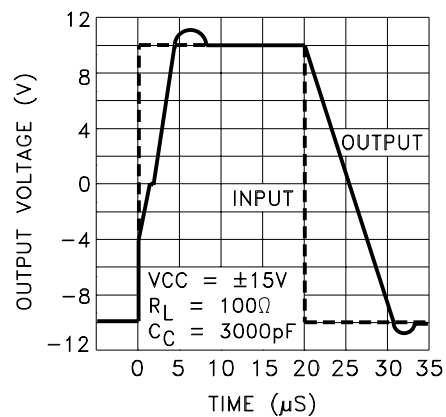
INPUT VOLTAGE RANGE



VOLTAGE GAIN

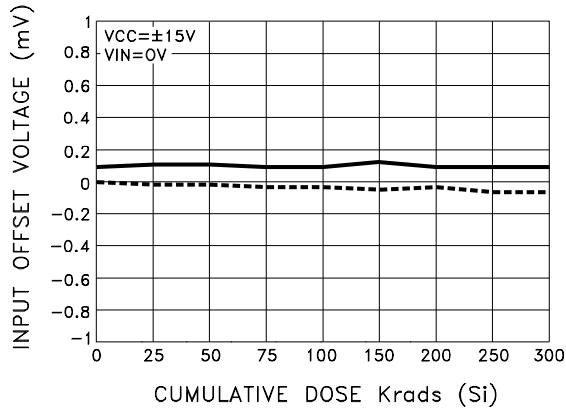


VOLTAGE FOLLOWER PULSE RESPONSE

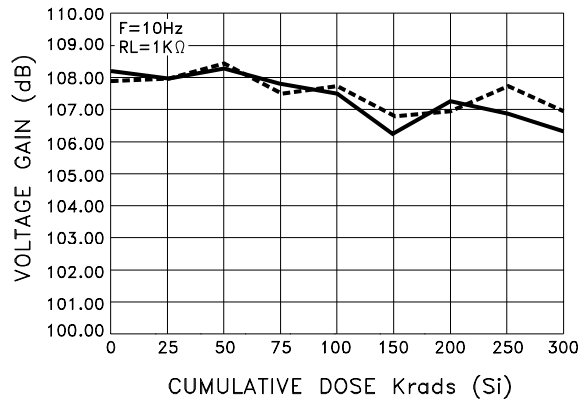


# RADIATION PERFORMANCE CURVES

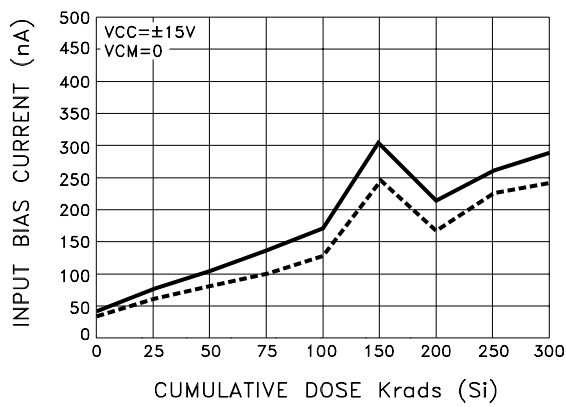
INPUT OFFSET VOLTAGE



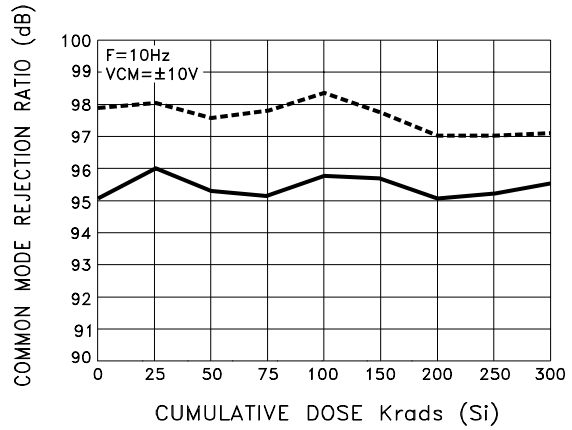
VOLTAGE GAIN



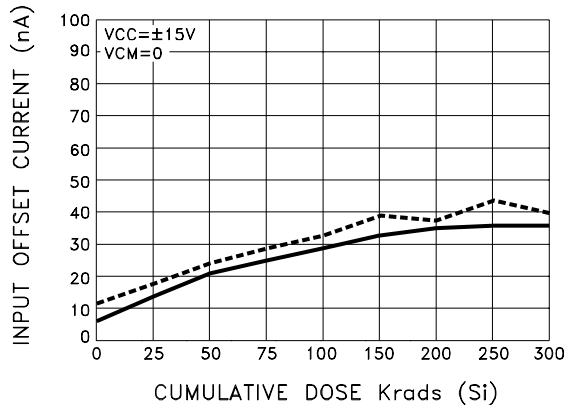
INPUT BIAS CURRENT



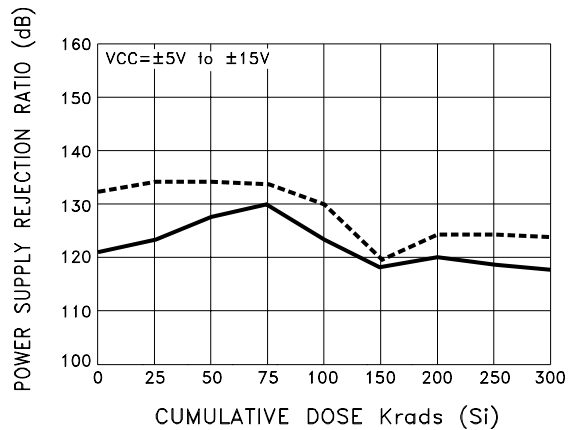
COMMON MODE REJECTION RATIO



INPUT OFFSET CURRENT



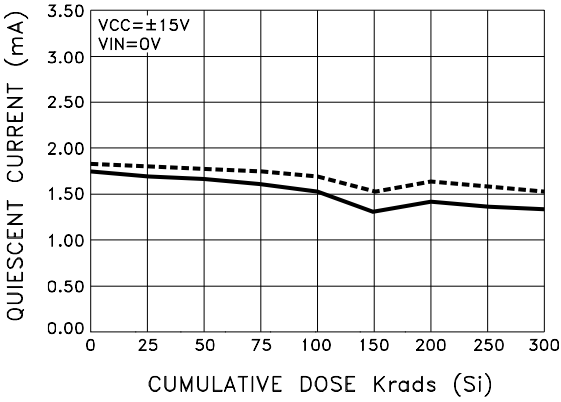
POWER SUPPLY REJECTION RATIO



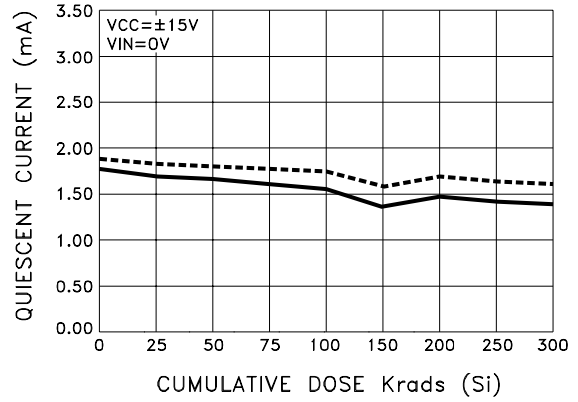
— AVERAGE BIASED  
 - - - AVERAGE UNBIASED

# RADIATION PERFORMANCE CURVES CONT'D

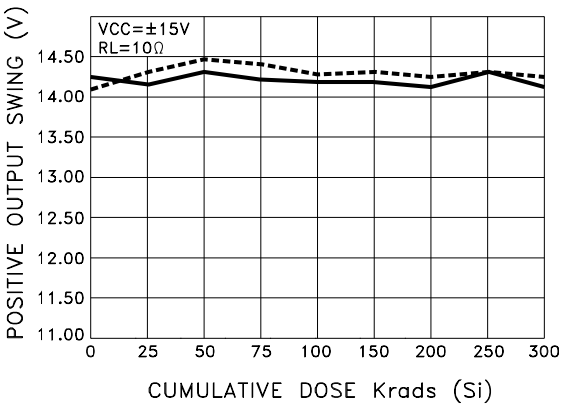
POSITIVE QUIESCENT CURRENT



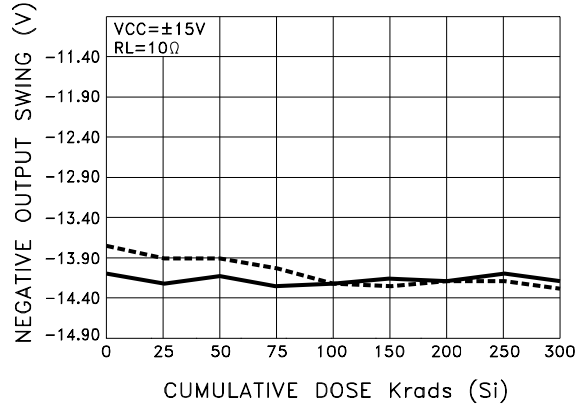
NEGATIVE QUIESCENT CURRENT



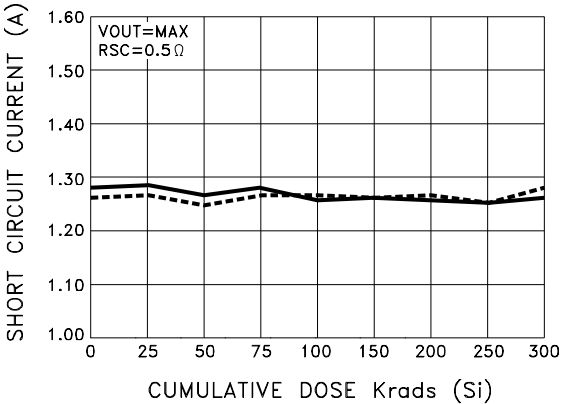
POSITIVE OUTPUT SWING



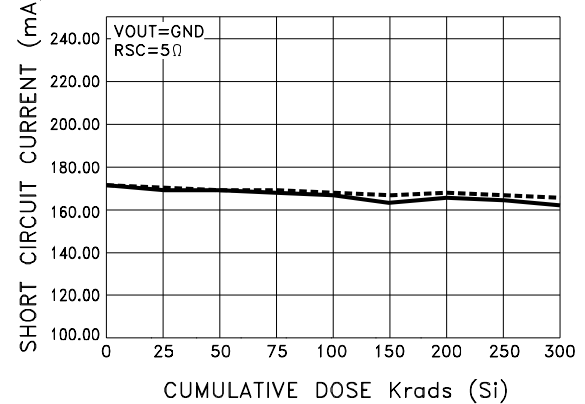
NEGATIVE OUTPUT SWING



SHORT CIRCUIT CURRENT

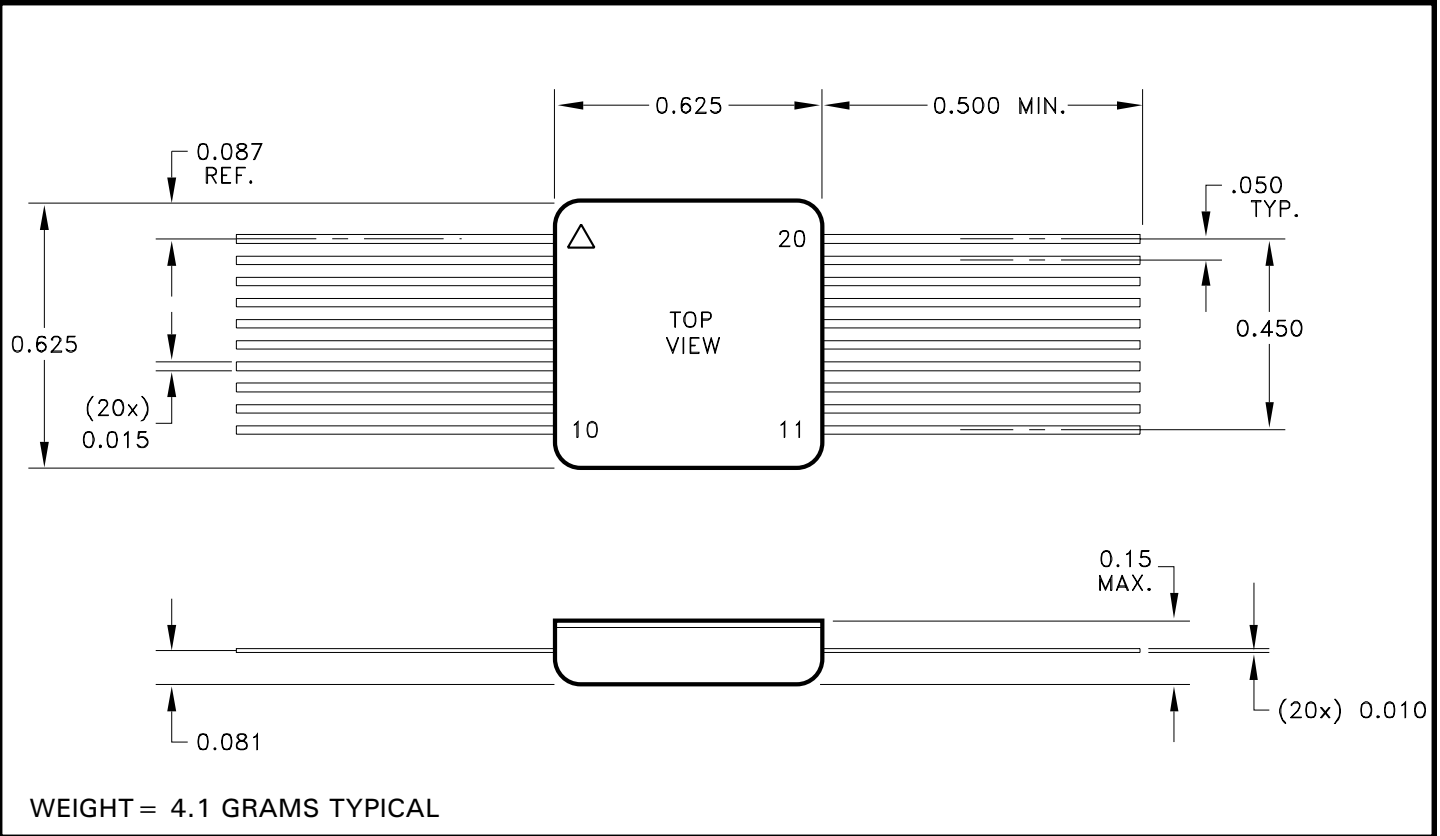


SHORT CIRCUIT CURRENT



— AVERAGE BIASED  
 - - - AVERAGE UNBIASED

**MECHANICAL SPECIFICATIONS CONTINUED**



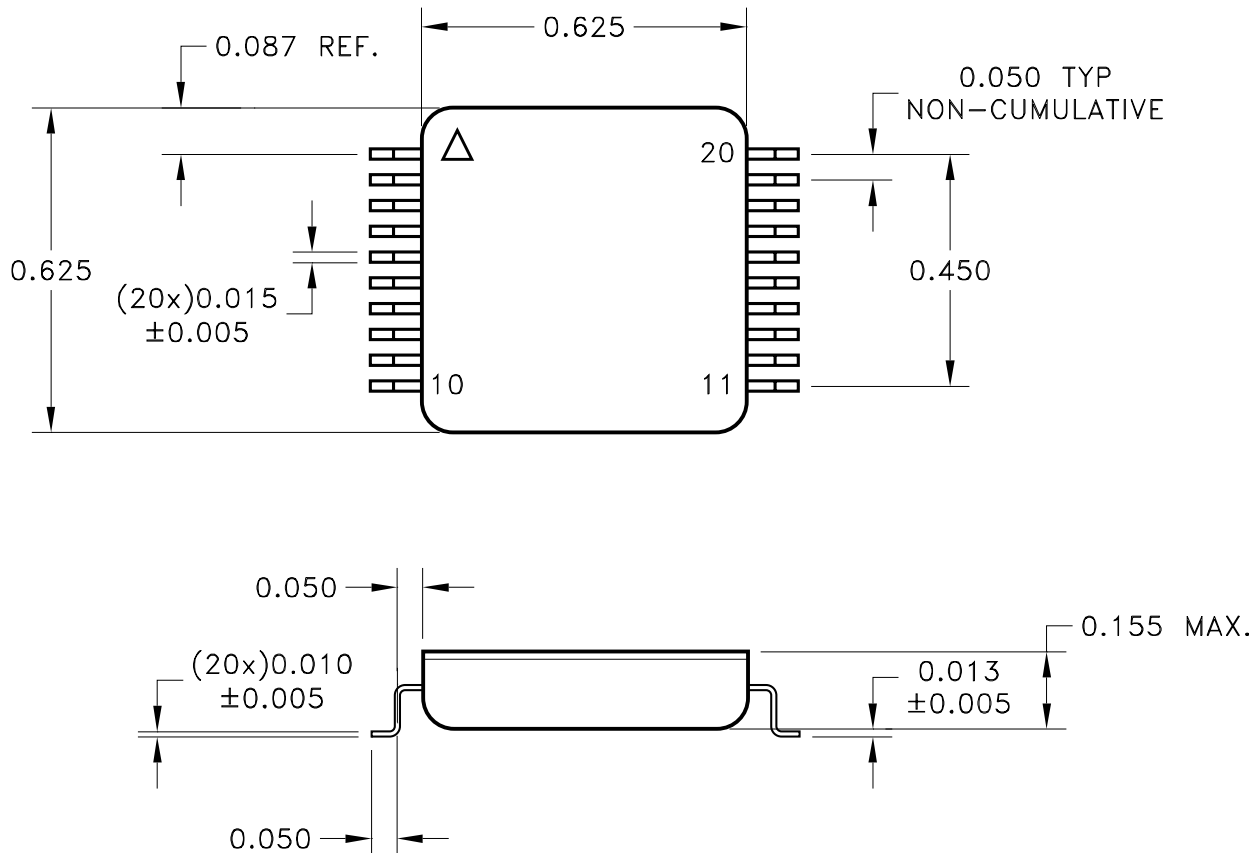
NOTE: ALL DIMENSIONS ARE  $\pm 0.010$  INCHES UNLESS OTHERWISE LABELED.  
ESD Triangle indicates pin 1.

**ORDERING INFORMATION**

Part Number	Screening Level
MSK106RH	INDUSTRIAL
MSK106E RH	EXTENDED RELIABILITY
MSK106H RH	MIL-PRF-38534 CLASS H
MSK106K RH	MIL-PRF-38534 CLASS K
SMD TBD	TBD



## MECHANICAL SPECIFICATIONS CONTINUED



WEIGHT = 4.1 GRAMS TYPICAL

NOTE: ALL DIMENSIONS ARE  $\pm 0.010$  INCHES UNLESS OTHERWISE LABELED.  
ESD Triangle indicates pin 1.

## ORDERING INFORMATION

Part Number	Screening Level
MSK106RHG	INDUSTRIAL
MSK106E RHG	EXTENDED RELIABILITY
MSK106H RHG	MIL-PRF-38534 CLASS H
MSK106K RHG	MIL-PRF-38534 CLASS K
SMD TBD	TBD

M.S. Kennedy Corp.  
4707 Dey Road, Liverpool, New York 13088  
Phone (315) 701-6751  
Fax (315) 701-6752  
www.mskennedy.com

The information contained herein is believed to be accurate at the time of printing. MSK reserves the right to make changes to its products or specifications without notice, however and assumes no liability for the use of its products. Please visit our website for the most recent revision of this datasheet.  
Contact MSK for MIL-PRF-38534 Class H, Class K and Appendix G (radiation) status.