

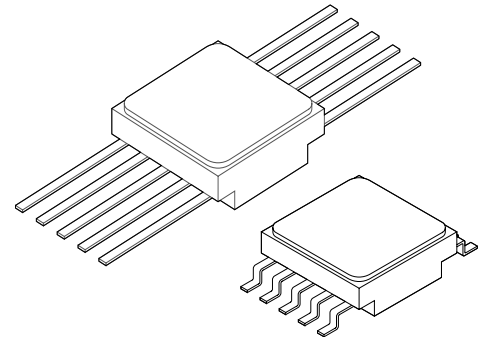


# RAD HARD POSITIVE 0.9A, LOW NOISE, LDO ADJ VOLTAGE REGULATOR

# 5965RH

## FEATURES:

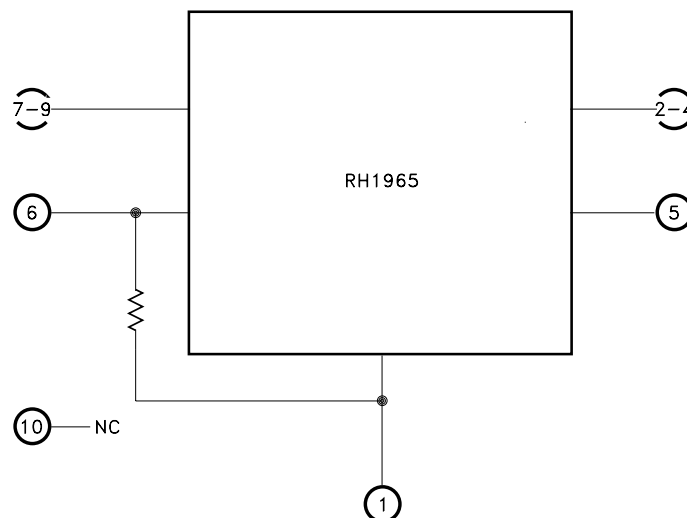
- Manufactured using  Space Qualified RH1965 Die
- MIL-PRF-38534 Class K and H Processing & Screening
- Total Dose Hardened to 100 Krads(Si) (Method 1019.7 Condition A)
- Characterized to 300 Krads(Si) Total Dose
- Low Dropout of 250mV at 0.5A
- Output Adjustable from 1.2V to 19.5V
- Internal Short Circuit Current Limit
- Low Noise: 40uVRMS (10Hz to 100kHz)
- Output Current Capability  $\leq 0.9A$
- Internal Thermal Overload Protection
- Shutdown Pin Active Low
- Available in Straight or Gull Wing Lead Form
- Contact MSK for MIL-PRF-38534 Qualification Status



## DESCRIPTION:

The MSK5965RH is a radiation hardened low dropout adjustable linear regulator. This device features a low noise, adjustable output voltage range of 1.2V to 19.5V. The dropout voltage is typically 250mV with a 0.5A load. This, combined with the low  $R_{\theta JC}$ , allows increased output current while providing exceptional device efficiency. Additionally, the MSK5965RH offers internal short circuit current and thermal limiting, which provides circuit protection and eliminates the need for excessive derating. The shutdown pin provides a method for sequencing the supply with minimal external components. The MSK5965RH is packaged in a hermetically sealed 10 pin flatpack with straight or gull wing leads and specifically designed for space/satellite applications.

## EQUIVALENT SCHEMATIC



## TYPICAL APPLICATIONS

- High Efficiency Linear Regulators
- Constant Voltage/Current Regulators
- Space System Power Supplies
- Switching Power Supply Post Regulators
- Very low Voltage Power Supplies
- Low Noise Instrumentation

## PIN-OUT INFORMATION

1	GND	10	NC
2	VOUT	9	VIN
3	VOUT	8	VIN
4	VOUT	7	VIN
5	ADJ	6	SHDN

CASE=ISOLATED

## ABSOLUTE MAXIMUM RATINGS

⑧ ⑨ ⑩

V <sub>IN</sub>	Pin Voltage	±22V
V <sub>OUT</sub>	Pin Voltage	±22V
	Input to Output Differential Voltage	±22V
I <sub>OUT</sub>	Output Current	+0.9A
ADJ	Pin Voltage	±9V
SHDN	Pin Voltage	±22V

T <sub>ST</sub>	Storage Temperature Range	-65°C to +150°C
T <sub>LD</sub>	Lead Temperature Range	(10 Seconds) 300°C
T <sub>C</sub>	Case Operating Temperature	
	MSK5965RH	-40°C to +85°C
	MSK5965K/HRH	-55°C to +125°C
	ESD Rating	Class 1B

## ELECTRICAL SPECIFICATIONS

Parameter	Test Conditions ① ⑪	Group A Subgroup	MSK5965RH			Units			
			Min.	Typ.	Max.				
Minimum Input Voltage	V <sub>OUT</sub> = V <sub>ADJ</sub>	I <sub>LOAD</sub> = 0.9A	1, 2, 3	-	-	2.3	V		
Adj Pin Voltage	V <sub>IN</sub> = 2.1V, V <sub>OUT</sub> = V <sub>ADJ</sub>	I <sub>LOAD</sub> = 1mA	1	1.182	-	1.218	V		
			2, 3	1.164	-	1.236			
			Post Irradiation	1	1.176	-		1.224	
Line Regulation	ΔV <sub>IN</sub> = 2.1V TO 20V, V <sub>OUT</sub> = V <sub>ADJ</sub>	I <sub>LOAD</sub> = 1mA	1	-	-	6	mV		
			2, 3	-	-	8			
Load Regulation	V <sub>IN</sub> = 2.3V, V <sub>OUT</sub> = V <sub>ADJ</sub>	ΔI <sub>LOAD</sub> = 1mA TO 0.9A	1	-	-	8	mV		
			2, 3	-	-	16			
			Post Irradiation	1	-	-		12	
Dropout Voltage	V <sub>IN</sub> = V <sub>OUT</sub> (NOMINAL) + 1 ΔV <sub>OUT</sub> = 1%	I <sub>LOAD</sub> = 1mA	1	-	-	80	mV		
			2, 3	-	-	140			
		I <sub>LOAD</sub> = 100mA	1	-	-	185	mV		
			2, 3	-	-	295			
		I <sub>LOAD</sub> = 500mA	1	-	-	190	mV		
			2, 3	-	-	300			
		I <sub>LOAD</sub> = 0.9A	1	-	-	430	mV		
			2, 3	-	-	320			
		Gnd Pin Current ⑤	V <sub>IN</sub> = V <sub>OUT</sub> (NOMINAL) + 1	I <sub>LOAD</sub> = 1mA	1	-	-	435	mA
					2, 3	-	-	600	
I <sub>LOAD</sub> = 100mA	1			-	-	465	mA		
	2, 3			-	-	1.1			
I <sub>LOAD</sub> = 500mA	1			-	-	1.5	mA		
	2, 3			-	-	4.6			
I <sub>LOAD</sub> = 0.9A	1			-	-	5.5	mA		
	2, 3			-	-	7			
Adj Pin Bias Current ⑥	V <sub>OUT</sub> = V <sub>ADJ</sub>			I <sub>LOAD</sub> = 0.9A	1	-	-	16.5	mA
					2, 3	-	-	20	
Shutdown Pin Threshold	SHDN ≥ 1.5V, V <sub>OUT</sub> = ON	I <sub>LOAD</sub> = 0.9A	1	-	-	25	P/F		
			2, 3	-	-	30			
			Post Irradiation	1	-	-		38	
Shutdown Pin Bias Current	SHDN ≤ 0.37V, V <sub>OUT</sub> = OFF	I <sub>LOAD</sub> = 0.9A	1	-	-	45	mA		
			2, 3	-	-	4.5			
Quiescent Current in Shutdown	V <sub>IN</sub> = 6V, V <sub>SHDN</sub> = 0V	I <sub>LOAD</sub> = 0.9A	1	-	210	215	uA		
Current Limit	V <sub>IN</sub> = V <sub>OUT</sub> (NOMINAL) + 1, ΔV <sub>OUT</sub> = -0.1V	I <sub>LOAD</sub> = 0.9A	1, 2, 3	0.9	-	-	A		
Reverse-Output Current ⑦	V <sub>IN</sub> = 0V, V <sub>OUT</sub> = V <sub>ADJ</sub>	I <sub>LOAD</sub> = 0.9A	1	-	-	400	uA		
Thermal Resistance ②	JUNCTION TO CASE @ 125°C		-	-	10.4	12.1	°C/W		

### NOTES:

- ① U.O.S. V<sub>OUT</sub> = 2.5V, V<sub>IN</sub> = 6V, I<sub>LOAD</sub> = 1mA
- ② Guaranteed by design but not tested. Typical parameters are representative of actual device performance but are for reference only. Not applicable to post irradiation performance.
- ③ Industrial grade devices shall be tested to subgroup 1 unless otherwise specified.
- ④ Subgroup 1, 7 T<sub>A</sub> = T<sub>C</sub> = +25°C  
2, 8a T<sub>A</sub> = T<sub>C</sub> = +125°C  
3, 8b T<sub>A</sub> = T<sub>C</sub> = -55°C
- ⑤ GND Pin current increases in Dropout.
- ⑥ ADJ pin bias current flows into the ADJ pin.
- ⑦ Reverse output current is tested with the V<sub>IN</sub> pin grounded and the V<sub>OUT</sub> pin forced to 1.2V. This current flows into the V<sub>OUT</sub> pin and out of the GND pin.
- ⑧ Absolute maximum input to output differential voltage is not achievable with all combinations of rated V<sub>IN</sub> pin and V<sub>OUT</sub> pin voltages. With the V<sub>IN</sub> pin at 22V, the V<sub>OUT</sub> pin may not be pulled below 0V. The total measured voltage from V<sub>IN</sub> to V<sub>OUT</sub> must not exceed ±22V
- ⑨ Maximum junction temperature limits operating conditions. The regulated output voltage specification does not apply for all possible combinations of input voltage and output current. Limit the output current range if operating at the maximum input voltage. Limit the input to output voltage differential if operating at the maximum output current.
- ⑩ Continuous operation at or above absolute maximum ratings may adversely affect the device performance and/or life cycle.
- ⑪ Pre and Post irradiation limits at 25°C, up to 100 Krad(Si) TID, are identical unless otherwise specified. Post irradiation performance is guaranteed by design with a 2X radiation design margin.

## APPLICATION NOTES

### PIN FUNCTIONS

**VIN** - The VIN pins are the input supply pins for all of the internal circuitry. Decoupling capacitors are recommended to provide a low impedance source. All three pins must be connected for proper operation.

**GND** - Connect the bottom of the output voltage feedback divider directly to GND for optimum regulation. Connect the GND pin to the load ground trace outside of the primary power return path.

**VOUT** - The VOUT pins supply power to the load. A 10µF capacitor on the output with an ESR of less than 1Ω is typically adequate to ensure stability. Applications with large output load transients require larger output capacitor value to minimize output voltage transients. All VOUT pins must be connected for proper operation.

**ADJ** - The Adjust pin is the input to the error amplifier. Connect to the center of the output voltage feedback divider. The ADJ pin voltage is 1.2V referenced to GND. It has a typical bias current of 1.3µA that flows into the pin.

**SHDN** - Pulling the SHDN pin low puts the device into a low power state and turns the output off. Drive the SHDN pin with either logic or an open collector/drain with a pull-up resistor. If unused, connect the SHDN pin to VIN. The SHDN pin cannot be driven below GND unless it is tied to the VIN pin. If the SHDN pin is driven below GND while VIN is powered, the output will turn on. SHDN pin logic cannot be referenced to a negative supply rail.

### TYPICAL APPLICATION CIRCUIT

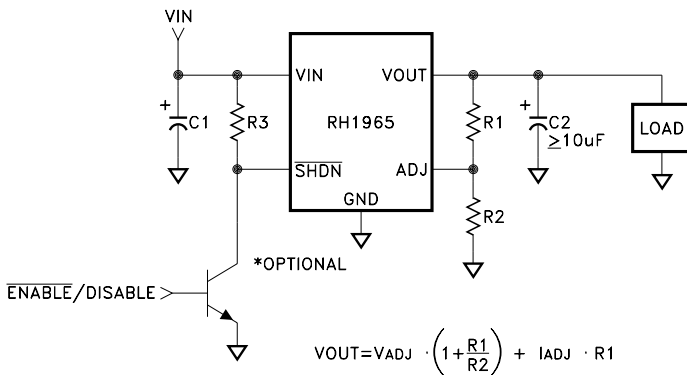


FIGURE 1

### OUTPUT VOLTAGE SELECTION

As noted in the above typical applications circuit, the formula for output voltage selection is:

$$V_{OUT} = V_{ADJ} \times \left[ 1 + \frac{R_1}{R_2} \right] + I_{ADJ} \times R_1$$

### OVERLOAD RECOVERY

Like many IC power regulators, the MSK5965RH has safe operating area protection. The safe operating area protection decreases current limit as the input-to-output voltage increases and keeps the power transistor inside a safe operating region for all values of input-to-output voltage. The protective design provides some output current at all values of input-to-output voltage up to the device breakdown. When power is first applied, as input voltage rises, the output follows the input, allowing the regulator to start up into very heavy loads. During start-up, as the input voltage is rising, the input-to-output voltage differential is small, allowing the regulator to supply large output currents.

With a high input voltage, a problem can occur wherein removal of an output short will not allow the output to recover. Other regulators, such as the LT1083/LT1084/LT1085 family, also exhibit this phenomenon, so it is not unique to the MSK5965RH. The problem occurs with a heavy output load when the input voltage is high and the output voltage is low. Common situations occur immediately after the removal of a short-circuit or if the shutdown pin is pulled high after the input voltage has already been turned on. The load line for such a load may intersect the output current curve at two points. If this happens, there are two stable output operating points for the regulator. With this double intersection, the input power supply may need to be cycled down to zero and brought up again to make the output recover.

### HEAT SINK SELECTION

To select a heat sink for the MSK5965RH, the following formula for convective heat flow may be used.

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

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

$T_A$  = Ambient Temperature

$$\text{Power Dissipation} = (V_{IN} - V_{OUT}) \times I_{OUT} + (I_{GND} \times V_{IN})$$

Next, the user must select a maximum junction temperature. The absolute maximum allowable junction temperature is 150°C. The equation may now be rearranged to solve for the required heat sink to ambient thermal resistance ( $R_{\theta SA}$ ).

### EXAMPLE:

An MSK5965RH is connected for  $V_{IN} = +5V$  and  $V_{OUT} = +3.3V$ .  $I_{OUT}$  is a continuous 0.5A DC level and  $I_{GND} = 20mA$ . The ambient temperature is +25°C. The maximum desired junction temperature is +125°C. Power Dissipation =  $(5V - 3.3V)(0.5A) + (0.02A \times 5V) = 0.95Watts$

$R_{\theta JC} = 12.08^\circ C/W$  and  $R_{\theta CS} = 0.15^\circ C/W$  for a most thermal grease.

Solve for  $R_{\theta SA}$ :

$$\left[ \frac{125^\circ C - 25^\circ C}{0.95W} \right] - 12.08^\circ C/W - 0.15^\circ C/W = 93.3^\circ C/W$$

In this example, a heat sink with a thermal resistance of no more than 93.0°C/W must be used to maintain a junction temperature of no more than 125°C.

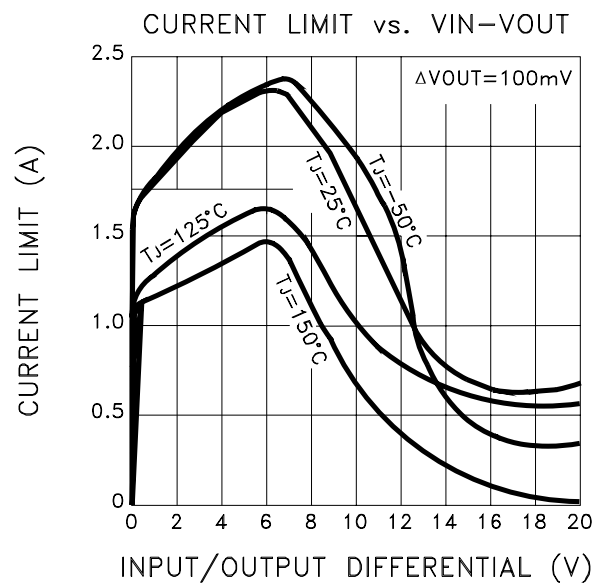
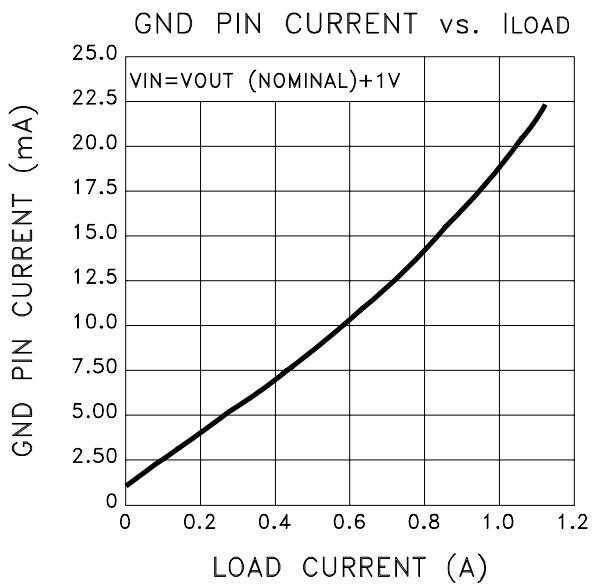
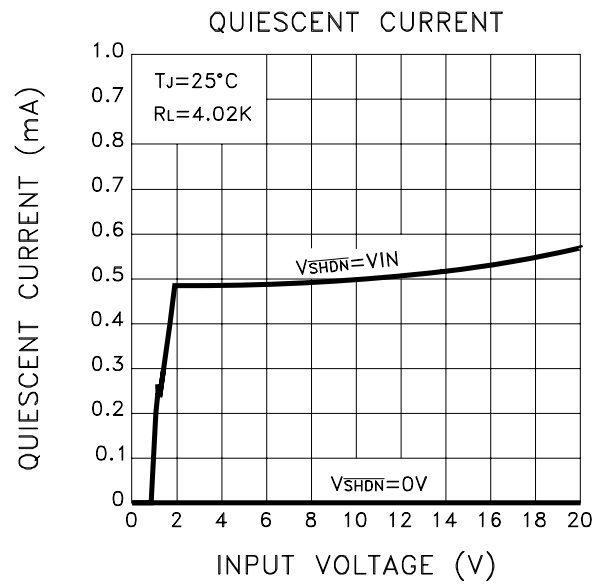
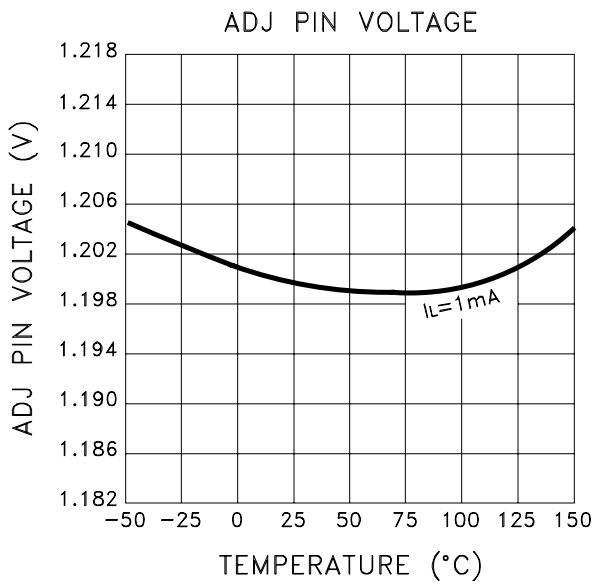
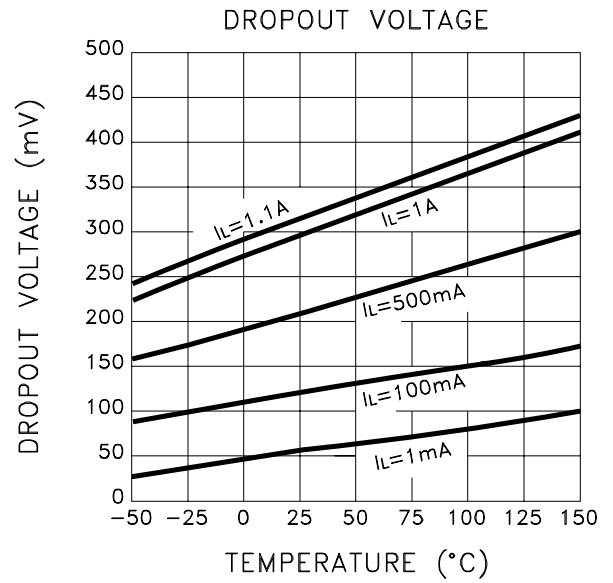
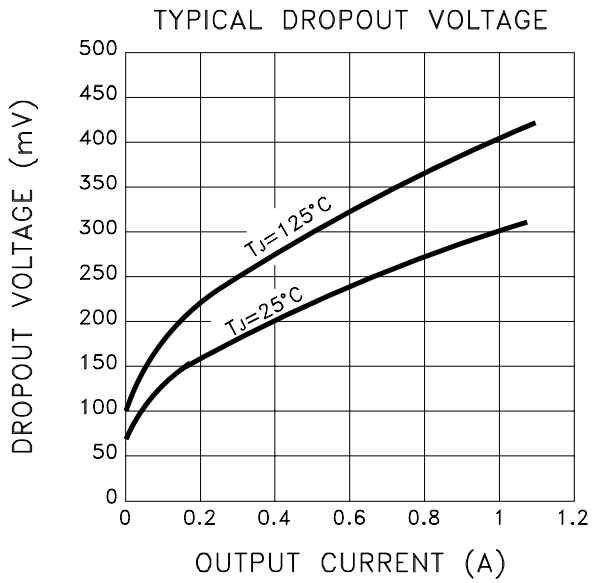
### TOTAL DOES RADIATION TEST PERFORMANCE

Radiation performance curves for TID testing will be generated for all radiation testing performed by MSK. These curves show performance trends throughout the TID test process and can be located in the MSK5965RH radiation test report. The complete radiation test report will be available in the RAD HARD PRODUCTS section on the MSK website.

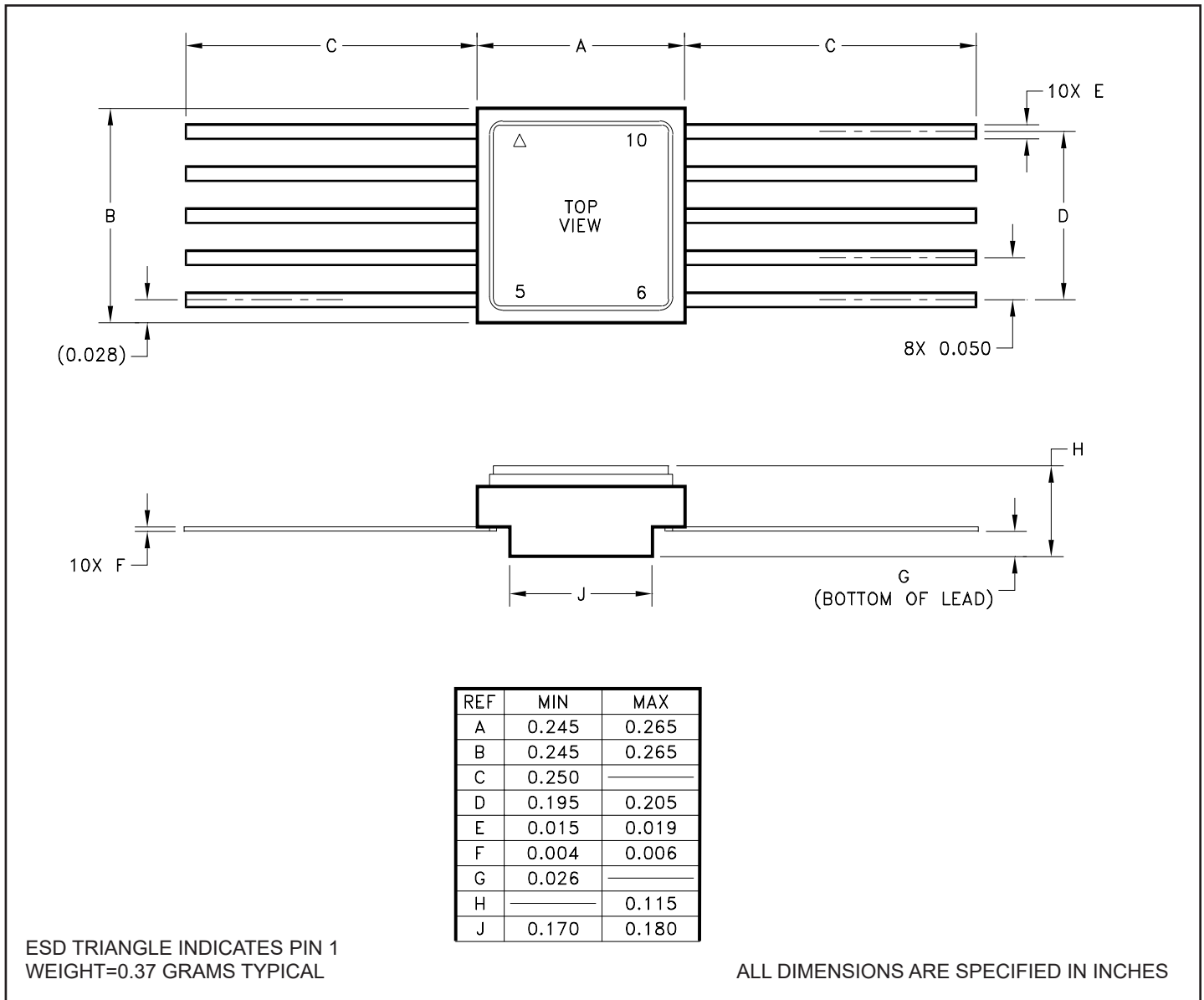
### ADDITIONAL APPLICATION

For additional applications information, please reference Linear Technology Corporation's® LT1965 and RH1965 data sheets.

# TYPICAL PERFORMANCE CURVES



# MECHANICAL SPECIFICATIONS



## ORDERING INFORMATION

MSK5965 K RH

**LEAD CONFIGURATIONS**

BLANK = STRAIGHT

**RADIATION HARDENED**

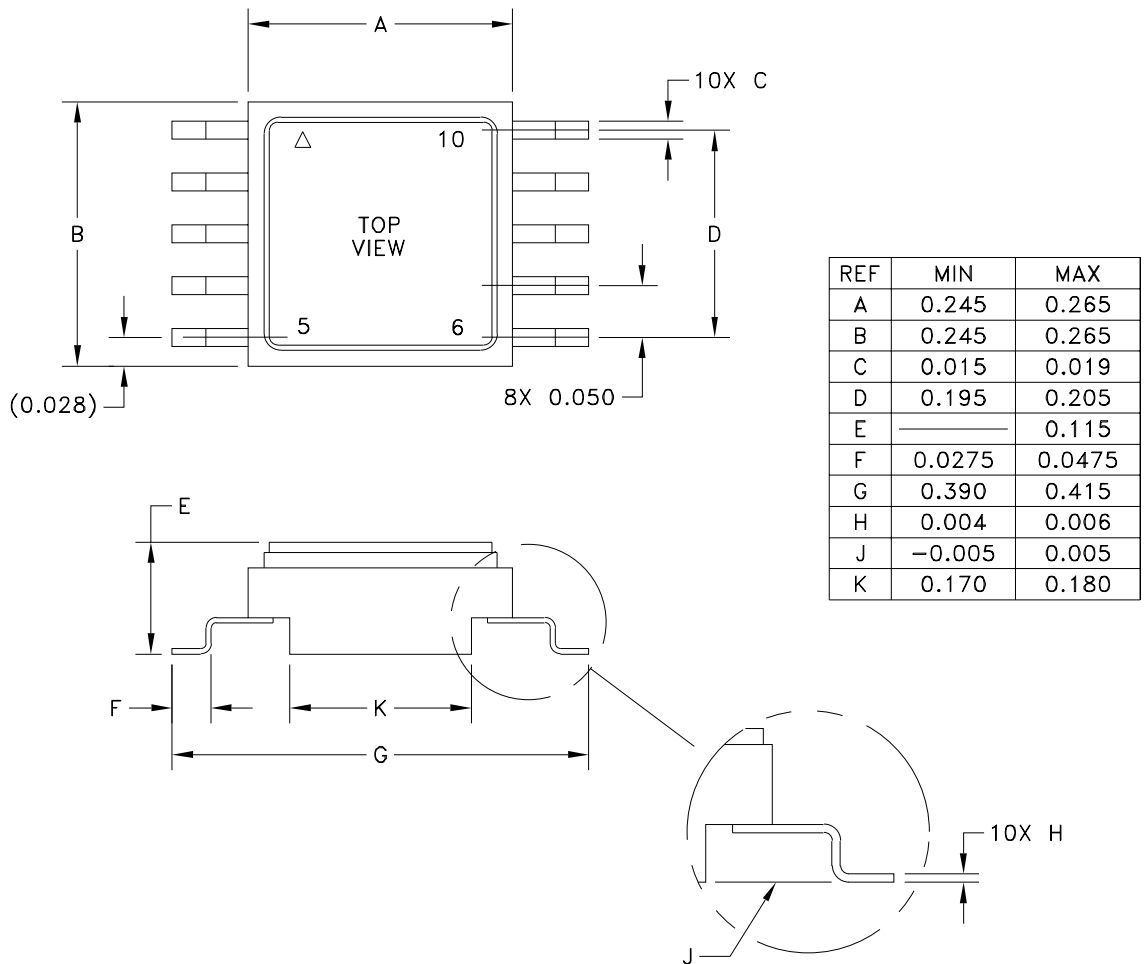
**SCREENING**

BLANK = INDUSTRIAL

K = MIL-PRF-38534 CLASS K; H = MIL-PRF-38534 CLASS H

**GENERAL PART NUMBER**

## MECHANICAL SPECIFICATIONS



**NOTE: LEADS SHALL BE COPLANAR (J) WITH THE PACKAGE**

ESD TRIANGLE INDICATES PIN 1  
WEIGHT=0.35 GRAMS TYPICAL

ALL DIMENSIONS ARE SPECIFIED IN INCHES

## ORDERING INFORMATION

MSK5965 K RH G

LEAD CONFIGURATIONS

G = GULL WING

RADIATION HARDENED

SCREENING

BLANK = INDUSTRIAL

K = MIL-PRF-38534 CLASS K; H = MIL-PRF-38534 CLASS H

GENERAL PART NUMBER

## REVISION HISTORY

REV	STATUS	DATE	DESCRIPTION
A	Preliminary	05/15	Initial Release
B	Preliminary	09/15	Initial Release
C	Preliminary	09/16	Initial Release
D	Released	08/17	Update radiation performance, release preliminary status.
E	Released	11/18	Update mechanical specifications
F	Released	05/19	Correct typo in Electrical Table Parameter description - Shutdown Pin Threshold

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Please visit our website for the most recent revision of this datasheet.

Contact Anaren, MSK Products for MIL-PRF-38534 Class K qualification status.