MIL-PRF-38534 CERTIFIED

HIGH POWER OP-AMP

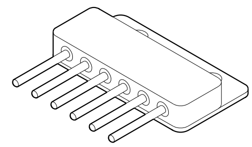
541 SERIES

M.S KENNEDY CORP.

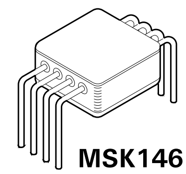
4707 Dey Road Liverpool, N.Y. 13088   (315) 701-6751

FEATURES:

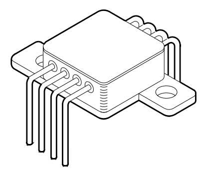
- Available to SMD #5962-88701
- High Output Current - 10 Amps Peak
- Wide Power Supply Range - ±10V to ±40V
- Programmable Current Limit
- FET Input
- Isolated Case
- Replacement for OMA 541SKB - MSK541
  OMA 541SDB - MSK146
  OMA 541SZB - MSK147



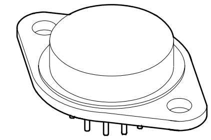
MSK145



MSK146



MSK147

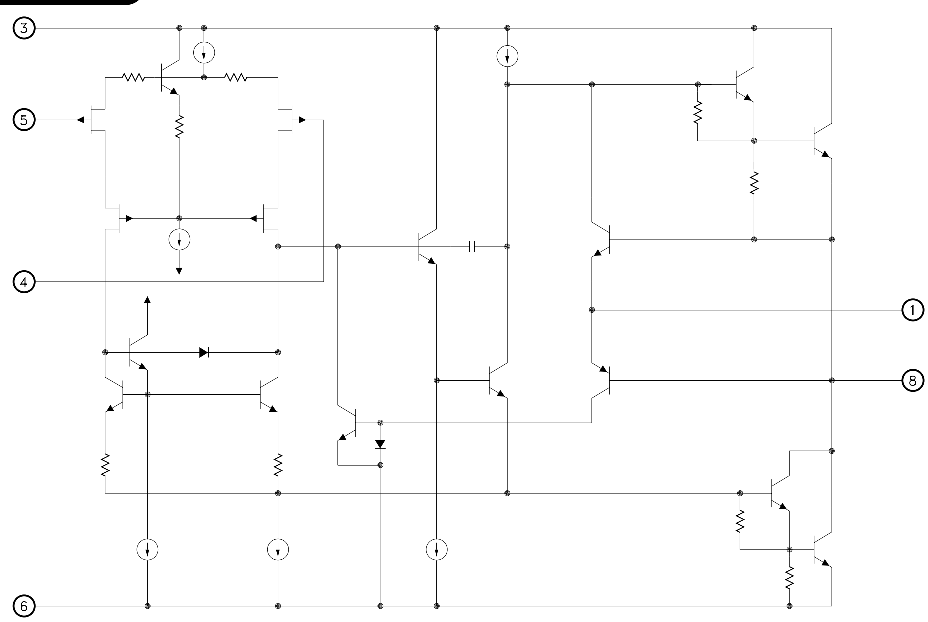


MSK541

DESCRIPTION:

The MSK 541 is a high power monolithic amplifier ideally suited for high power amplification and magnetic deflection applications. This amplifier is capable of operation at a supply voltage rating of 80 volts and can deliver guaranteed continuous output currents up to 5A, making the 541 series an excellent low cost 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 a single external resistor. The MSK 541 is pin compatible with popular op-amps such as the Burr-Brown OPA501, OPA511, OPA512, OPA541 and 3573. The MSK 541 is available in a hermetically sealed 8 pin TO-3 package. The MSK 145 is available in a 6 pin SIP Package. The MSK 146 is an 8 pin Power DIP Package and the MSK 147 is available in an 8 pin Power Z-TAB Package for applications requiring bolt down heat sinking. Other package styles are also available for a wide range of applications.

EQUIVALENT SCHEMATIC (TO-3 PIN-OUT SHOWN)



TYPICAL APPLICATIONS

- Servo Amplifer
- Motor Driver
- Audio Amplifier
- Programmable Power Supply
- Magnetic Deflection

PIN-OUT INFORMATION

1 Current Sense	5 Inverting Input
2 No Connection	6 Negative Power Supply
3 Positive Power Supply	7 No Connection
4 Non-Inverting Input	8 Output Drive

The above pin out table is for the MSK 541 (TO-3). Refer to the mechanical specifications page for the pin out information of additional package styles.

ABSOLUTE MAXIMUM RATINGS ⑩

±VCC	Supply Voltage	±40V
IOUT	Peak Output Current	See S.O.A.
VIN	Differential Input Voltage	±VCC
VIN	Common Mode Input Voltage	±VCC
TST	Storage Temperature Range	-65° to +150°C
TLD	Lead Temperature Range (10 Seconds)	300°
TJ	Junction Temperature	150°C
TC	Case Operating Temperature Range	
	Military and E Versions	-55°C to +125°C
	Industrial Versions	-40°C to +85°C

ELECTRICAL SPECIFICATIONS ⑨

Parameter	Test Conditions	Group A Subgroup	Military/E Min.	Military/E Typ.	Military/E Max.	Industrial ⑤ Min.	Industrial ⑤ Typ.	Industrial ⑤ Max.	Units
STATIC									
Supply Voltage Range ② ④		-	±10	±35	±40	±10	±35	±40	V
Quiescent Current	VIN = 0V	1, 2, 3	-	±20	±30	-	±20	-	mA
INPUT									
Input Offset Voltage	VIN = 0V	1	-	±0.1	±1.5	-	±1.0	±10	mV
Input Offset Voltage Drift	VIN = 0V	2, 3	-	±15	±50	-	±15	-	µV/°C
Input Bias Current ④	VCM = 0V	1	-	±4	±50	-	±4	±100	pA
	Either Input	2, 3	-	±0.2	±50	-	±0.2	-	nA
Input Offset Current ④	VCM=0V	1	-	2.0	30	-	2.0	30	pA
		2, 3	-	-	20	-	-	-	nA
Input Capacitance		-	-	5	-	-	5	-	pF
Input Impedance	F = DC	-	-	10^{12}	-	-	10^{12}	-	Ω
Common Mode Rejection Ratio ④	F = DC VCM = ±22V	-	95	113	-	90	113	-	dB
Power Supply Rejection Ratio	VCC = ±10V to ±40V	-	-	90	-	-	90	-	dB
Input Noise Voltage	F = 10 Hz to 1 KHz	-	-	10	-	-	10	-	µVRMS
OUTPUT									
Output Voltage Swing	RL = 5.6Ω F = 10 KHz	4	±28	±29	-	±28	±29	-	V
	RL = 10Ω F = 10 KHz	5, 6	±30	±31	-	-	-	-	V
Output Current	RL = 5.6Ω F = 10 KHz	4	±5	±8	-	±5	±8	-	A
	RL = 10Ω F = 10 KHz	5, 6	±3.0	-	-	-	-	-	A
Settling Time ③	0.1% 2V step	-	-	2	-	-	2	-	µS
Power Bandwidth ④	RL = 10Ω VO = 20 VRMS	4	45	55	-	40	50	-	KHz
TRANSFER CHARACTERISTICS									
Slew Rate	VOUT = ±10V RL = 10Ω	4	6	10	-	6	10	-	V/µS
Open Loop Voltage Gain ④	F = 10 Hz RL = 10 KΩ	4	96	100	-	90	100	-	dB
		5, 6	86	-	-	-	-	-	dB
Thermal Resistance	(541)	-	-	1.2	1.9	-	1.9	2.2	°C/W
	All Others	-	-	1.0	1.2	-	1.0	1.5	°C/W

NOTES:

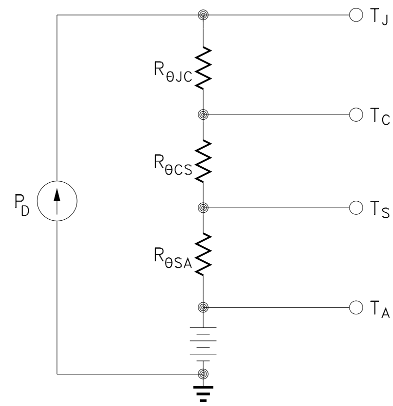
① Unless otherwise specified RCL = 0Ω, ±VCC = ±34 VDC
② Electrical specifications are derated for power supply voltages other than ±34 VDC.
③ AV = -1, measured in false summing junction circuit.
④ Devices shall be capable of meeting the parameter, but need not be tested. Typical parameters are for reference only.
⑤ Industrial and E grade devices shall be tested to subgroups 1 and 4 unless otherwise specified.
⑥ Military grade devices ('B' suffix) shall be 100% tested to subgroups 1, 2, 3 and 4.
⑦ Subgroup 5 and 6 testing available upon request.
⑧ Subgroup 1, 4 TA = TC = +25°C
Subgroup 2, 5 TA = TC = +125°C
Subgroup 3, 6 TA = TC = -55°C
⑨ Reference DSCC SMD 5962-88701 for electrical specifications for devices purchased as such.
⑩ Continuous operation at or above 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:

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

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: **(TO-3 PACKAGE)**

In our example the amplifier application requires the output to drive a 20 volt peak sine wave across a 5 ohm load for 4 amps of output current. For a worst case analysis we will treat the 4 amps peak output current as a D.C. output current. The power supplies are ±35 VDC.

1.) Find Power Dissipation
    P_D = [(quiescent current) X (+V_{CC} - (V_{CC}))] + [(V_S - V_O) X I_{OUT}]
    = (30 mA) X (70V) + (15V) X (4A)
    = 2.1W + 60W
    = 62.1W
2.) For conservative design, set T_J = +150°C
3.) For this example, worst case T_A = +25°C
4.) $R_{\theta JC}$ = 1.2°C/W typically for the TO-3 package
5.) $R_{\theta CS}$ = 0.15°C/W for most thermal greases
6.) Rearrange governing equation to solve for $R_{\theta SA}$
    $R_{\theta SA}$ = (T_J - T_A) / P_D - ($R_{\theta JC}$) - ($R_{\theta CS}$)
    = (150°C - 25°C) / 62.1W - (1.2°C/W) - (0.15°C/W)
    = 0.66°C/W

The heat sink in this example must have a thermal resistance of no more than 0.66°C/W to maintain a junction temperature of no more than +150°C. Since this value of thermal resistance may be difficult to find, other measures may have to be taken to decrease the overall power dissipation.

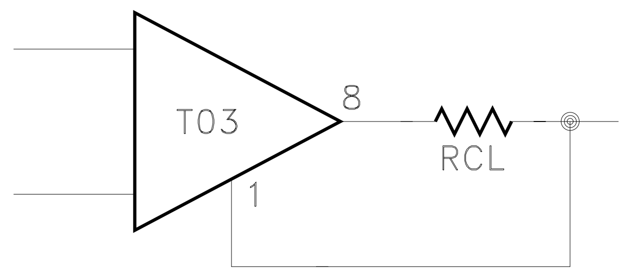
CURRENT LIMIT

The MSK 541 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_{CL} (OHMs) = (0.809 volts / current limit in amps) - 0.057 OHM

The 0.057 OHM term takes into account any wire bond and lead resistance. Since the 0.809 volt term is obtained from the base emitter voltage drop of a bipolar transistor, the equation only holds true for operation at +25°C case temperature. The effect that temperature has on current limit may be seen on the Current Limit vs. Case Temperature Curve in the Typical Performance Curves.

Current Limit Connection



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

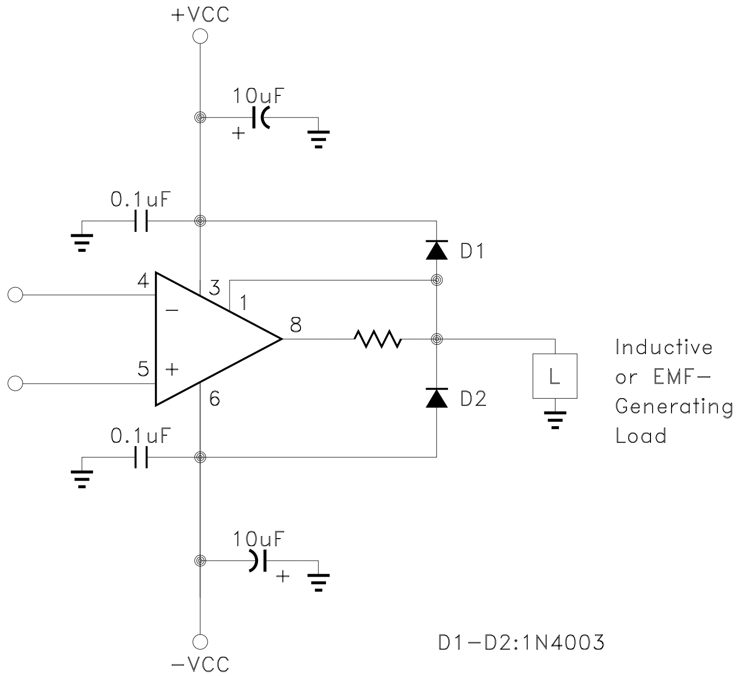
POWER SUPPLY BYPASSING

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 very high power op-amps, such as the MSK 541, to place a 30-50 microfarad nonelectrolytic 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 (pins 3 and 6 for the MSK 541).

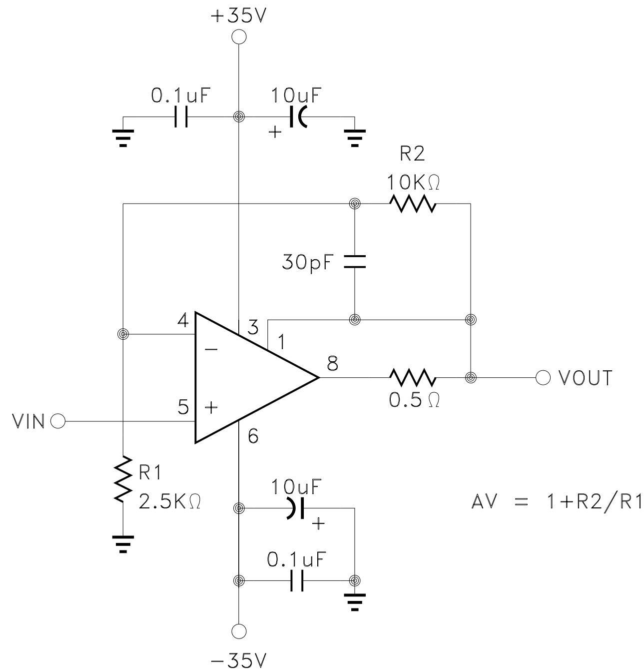
SAFE OPERATING AREA

The safe operating area curve is a graphical representation of the power handling capability of the amplifier under various conditions. The wire bond current carrying capability, transistor junction temperature and secondary breakdown limitations are all incorporated into the safe operating area curves. All applications should be checked against the S.O.A. curves to ensure high M.T.B.F.

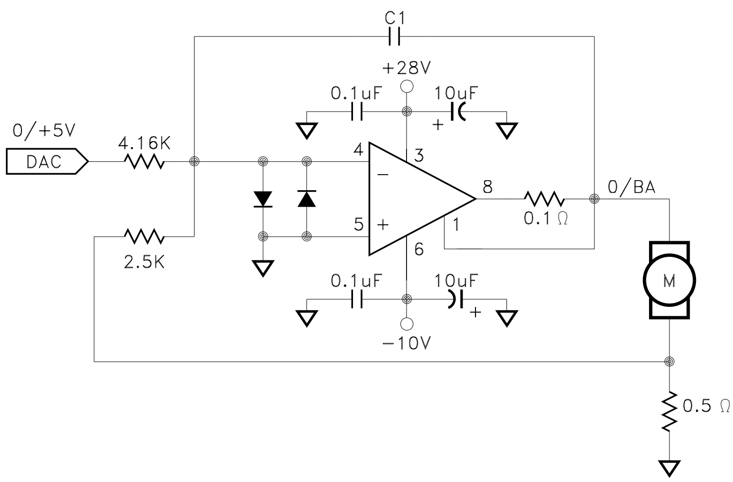
APPLICATION CIRCUITS



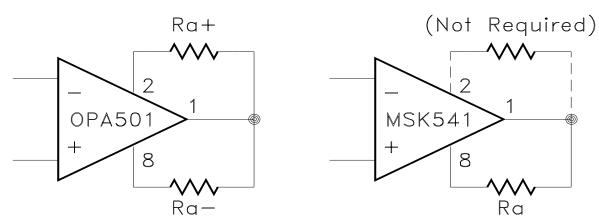
Clamping Output for EMF-Generating Loads



Isolating Capacitive Loads



Motor Current a Function of VIN
Programmable Torque Circuit



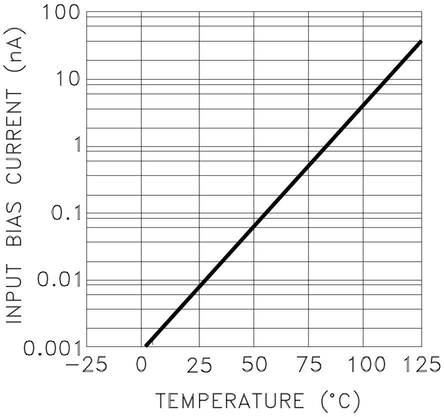
Replacing OPA501 with MSK 541

The linear relationship of torque output to current input of the modern torque motor makes this simple control circuit ideal for many material processing and testing applications. The sense resistor develops a feedback voltage proportional to motor current and the small signal properties of the Power Op Amp insure accuracy. With this closed loop operation, temperature induced impedance variations of the motor winding are automatically compensated.

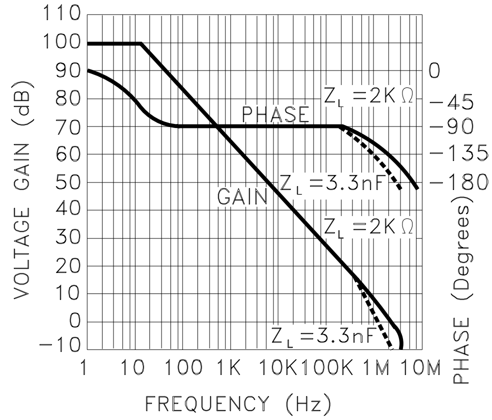
When replacing the OPA501, OPA511, OPA512 or 3573 with the MSK 541, it is not necessary to make any changes in the current limit scheme. Since pin 2 is not connected in the MSK 541, the current limit resistor connected from pin 1 to pin 2 can be left in the circuit or removed.

TYPICAL PERFORMANCE CURVES

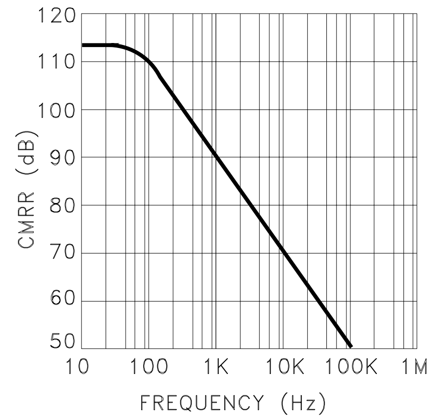
INPUT BIAS CURRENT
vs TEMPERATURE



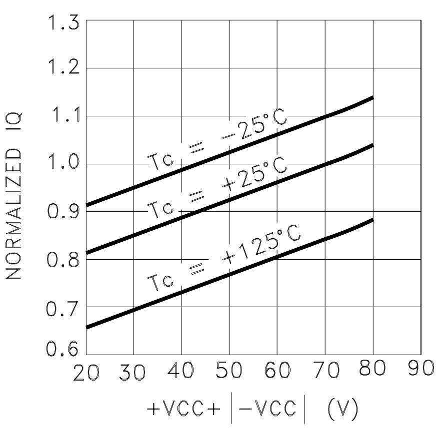
OPEN LOOP GAIN AND
PHASE vs FREQUENCY



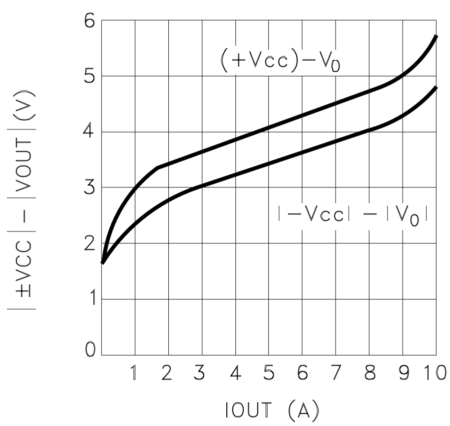
COMMON MODE REJECTION
vs FREQUENCY



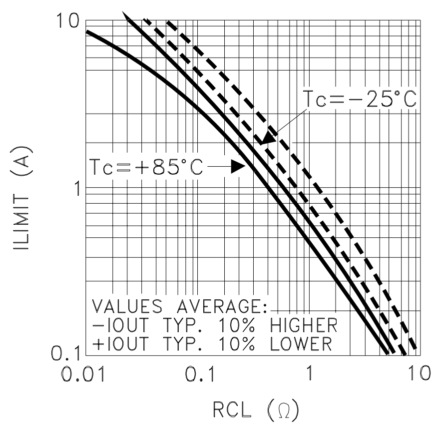
NORMALIZED QUIESCENT CURRENT
vs TOTAL POWER SUPPLY VOLTAGE



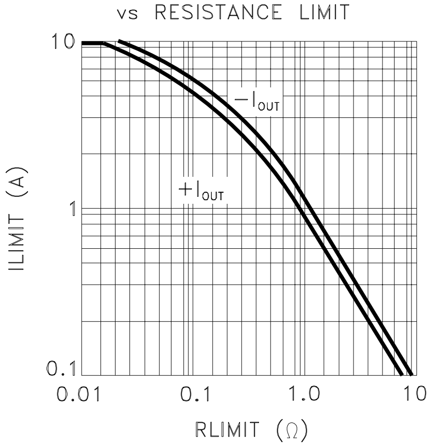
OUTPUT VOLTAGE SWING
vs OUTPUT CURRENT



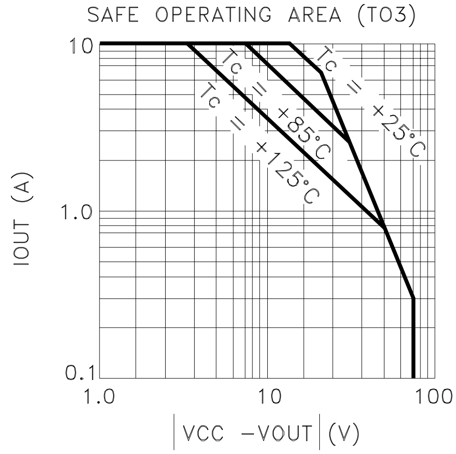
CURRENT LIMIT vs RESISTANCE
LIMIT vs TEMPERATURE



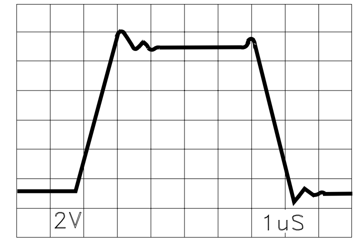
CURRENT LIMIT
vs RESISTANCE LIMIT



SAFE OPERATING AREA (TO3)



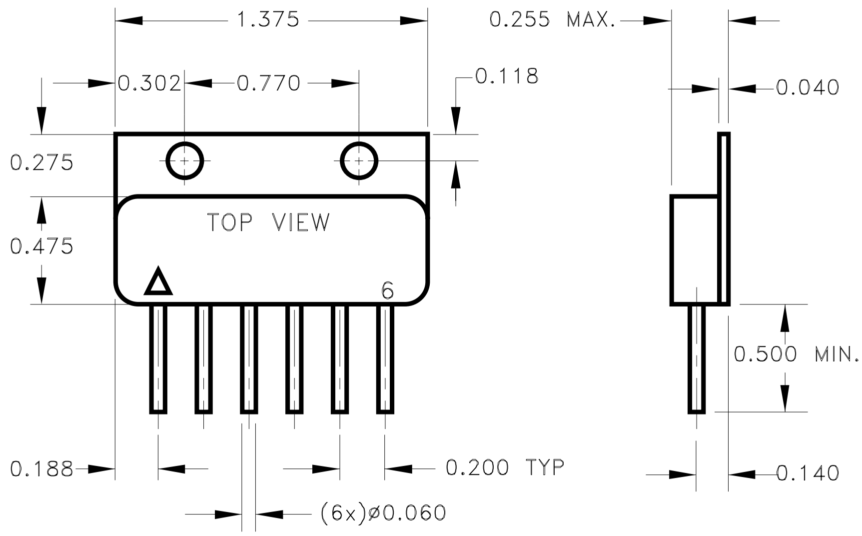
DYNAMIC RESPONSE



G = 1, CL =4.7nF

MECHANICAL SPECIFICATIONS

MSK145 — POWER SIP PACKAGE



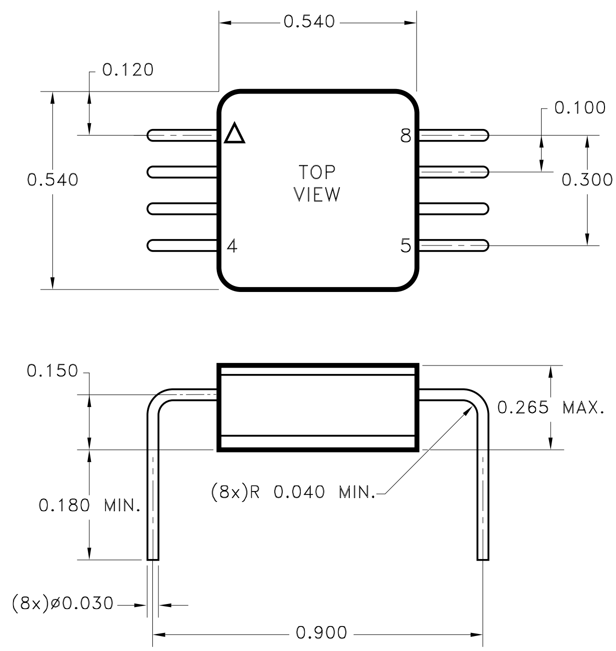
ORDERING INFORMATION

PART NO.	SCREENING LEVEL
MSK145	INDUSTRIAL
MSK145E	EXTENDED RELIABILITY
MSK145B	MIL-PRF-38534
5962-8870101Z	DSCC-SMD
5962-8870103Z	DSCC-SMD

PIN NO.	FUNCTION
1	-VCC
2	OUTPUT DRIVE
3	CURRENT SENSE
4	+VCC
5	+INPUT
6	-INPUT

ALL DIMENSIONS ARE ±0.01 INCHES UNLESS OTHERWISE SPECIFIED   ESD TRIANGLE INDICATES PIN 1

MSK146 — POWER DIP PACKAGE

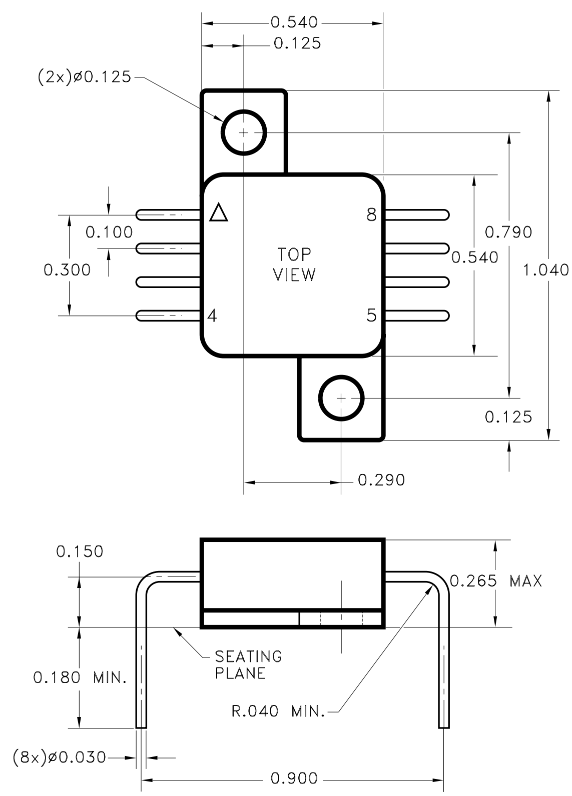


ORDERING INFORMATION

PART NO.	SCREENING LEVEL
MSK146	INDUSTRIAL
MSK146E	EXTENDED RELIABILITY
MSK146B	MIL-PRF-38534
5962-8870101Y	DSCC-SMD
5962-8870103Y	DSCC-SMD

PIN NO.	FUNCTION
1	-VCC
2	N/C
3	OUTPUT DRIVE
4	CURRENT SENSE
5	+VCC
6	N/C
7	+INPUT
8	-INPUT

MSK147 — POWER Z-TAB PACKAGE

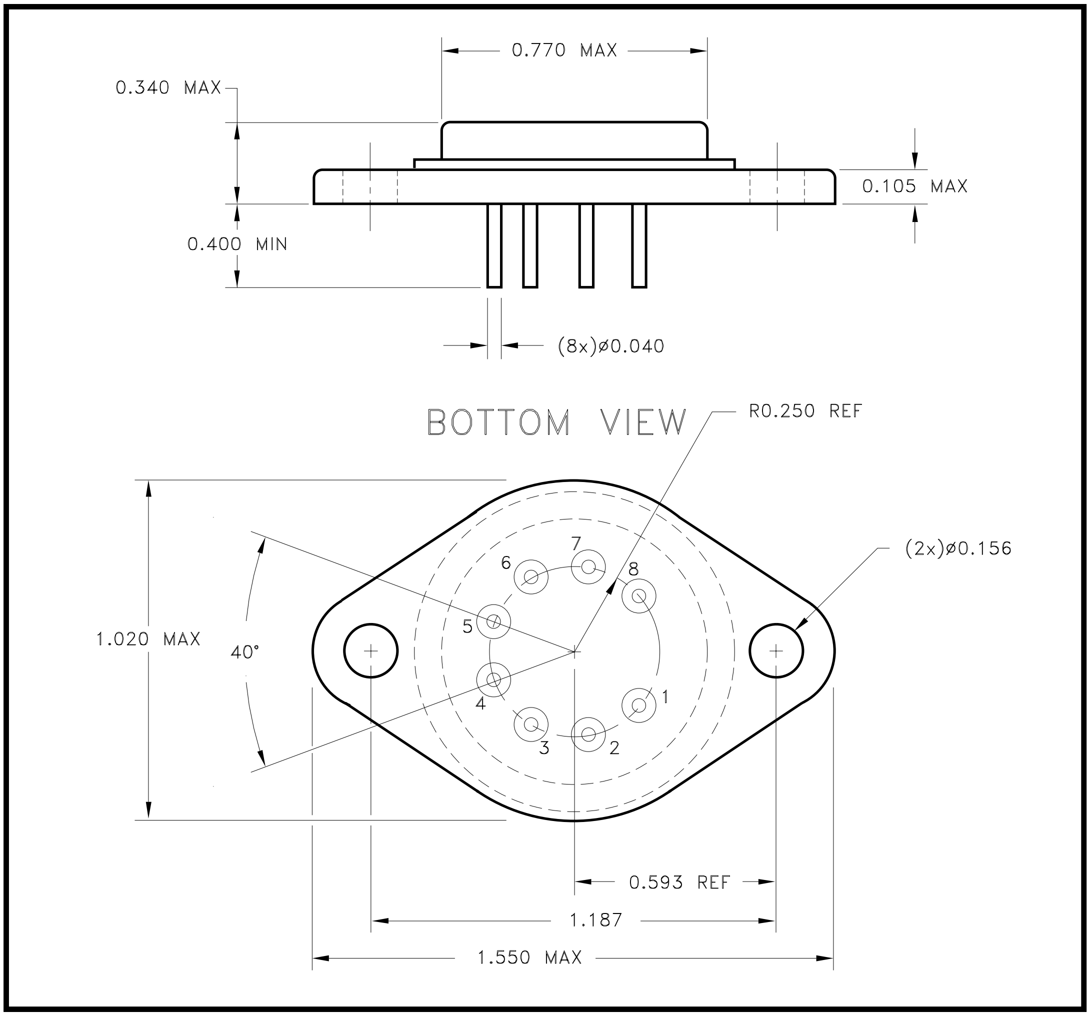


ORDERING INFORMATION

PART NO.	SCREENING LEVEL
MSK147	INDUSTRIAL
MSK147E	EXTENDED RELIABILITY
MSK147B	MIL-PRF-38534
5962-8870101U	DSCC-SMD
5962-8870103U	DSCC-SMD

PIN NO.	FUNCTION
1	-VCC
2	N/C
3	OUTPUT DRIVE
4	CURRENT SENSE
5	+VCC
6	N/C
7	+INPUT
8	-INPUT

MECHANICAL SPECIFICATIONS CONTINUED



ALL DIMENSIONS ARE ±0.010 INCHES UNLESS OTHERWISE SPECIFIED

ORDERING INFORMATION

Part Number	Screening Level
MSK541	Industrial
MSK541E	Extended Reliability
MSK541B	MIL-PRF-38534, Class H
5962-887010101X	DSCC-SMD
5962-887010103X	DSCC-SMD

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