MIL-PRF-38534 AND 38535 CERTIFIED FACILITY

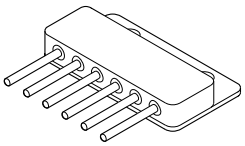
M.S KENNEDY CORP.

HIGH POWER OP-AMP

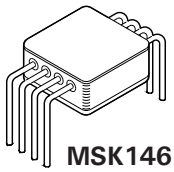
541 SERIES

FEATURES:

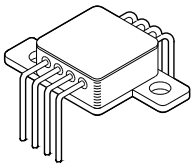
- Available to SMD #5962-88701
- High Output Current - 10 Amps Peak
- Wide Power Supply Range - ±10V to ±40V
- Programmable Current Limit
- FET Input
- Isolated Case
- Replacement for OMA 541SKB - MSK541
  OMA 541SDB - MSK146
  OMA 541SZB - MSK147



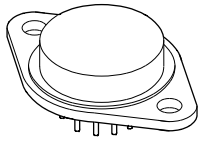
MSK145



MSK146



MSK147



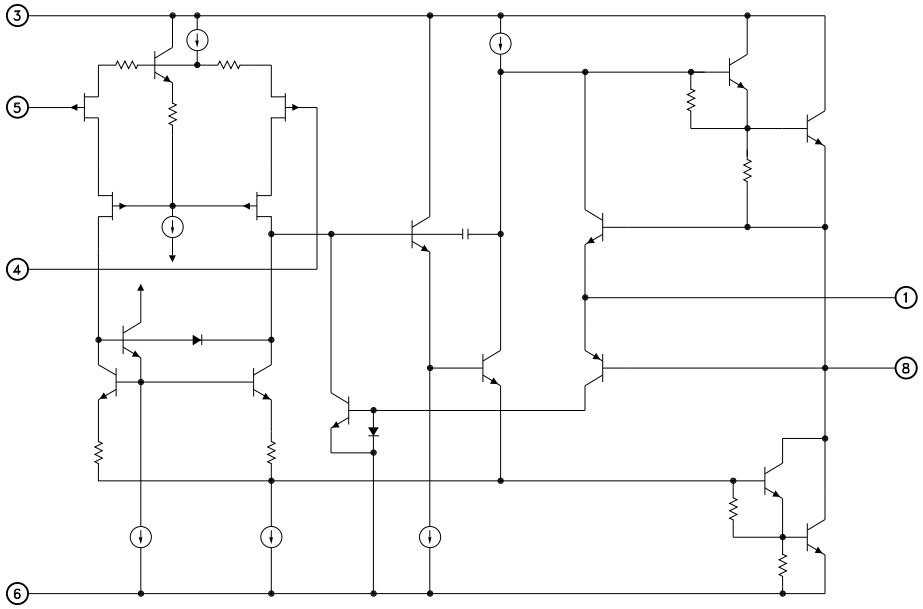
MSK541

DESCRIPTION:

The MSK541 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 MSK541 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 MSK541 is pin compatible with popular op-amps such as the Burr-Brown OPA501, OPA511, OPA512, OPA541 and 3573. The MSK541 is available in a hermetically sealed 8 pin TO-3 package. The MSK145 is available in a 6 pin SIP Package. The MSK146 is an 8 pin Power DIP Package and the MSK147 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

CASE = ISOLATED

The above pin out table is for the MSK541 (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	TST	Storage Temperature Range ⑪ . . . . . -65° to +150°C
IOUT	Peak Output Current . . . . . See S.O.A.	TLD	Lead Temperature Range
VIN	Differential Input Voltage . . . . . ±VCC		(10 Seconds) . . . . . 300°
VIN	Common Mode Input Voltage . . . . . ±VCC	TJ	Junction Temperature . . . . . 150°C
		TC	Case Operating Temperature Range
			Military Versions . . . . . -55°C to +125°C
			Industrial Versions . . . . . -40°C to +85°C

ELECTRICAL SPECIFICATIONS ⑨

Parameter	Test Conditions	Group A Subgroup	Military Min.	Military Typ.	Military 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	±150	-	±0.2	-	nA
Input Offset Current ④	VCM = 0V	1	-	2.0	30	-	2.0	30	pA
		2, 3	-	-	50	-	-	-	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:

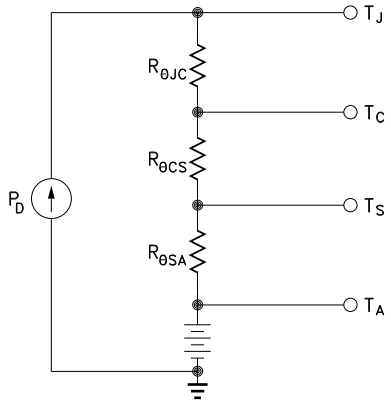
① Unless otherwise specified RCL = 0Ω, ±VCC = ±34 VDC
② Electrical specifications are derated for power supply voltages other than ±34 VDC.
③ AV = -1, measured in false summing junction circuit.
④ Devices shall be capable of meeting the parameter, but need not be tested. Typical parameters are for reference only.
⑤ Industrial 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.
⑪ Internal solder reflow temperature is 180°C, do not exceed.

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: (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.

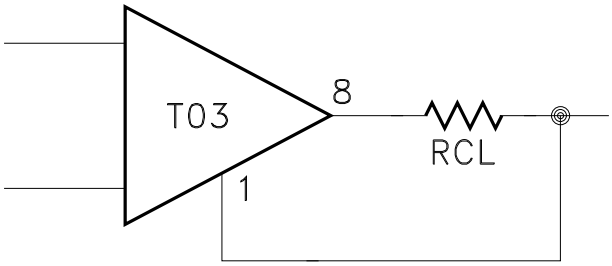
CURRENT LIMIT

The MSK541 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.

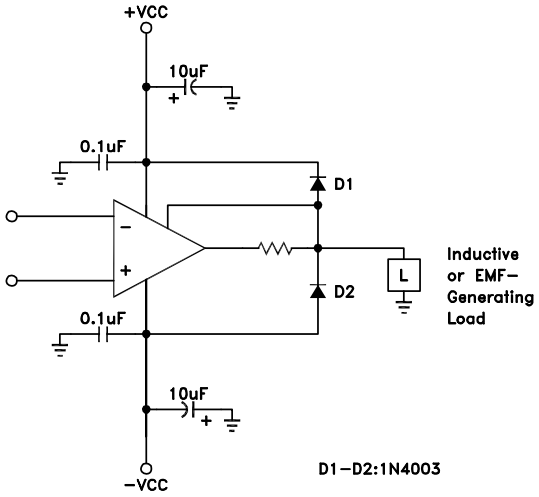
POWER SUPPLY BYPASSING

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 MSK541, 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 MSK541).

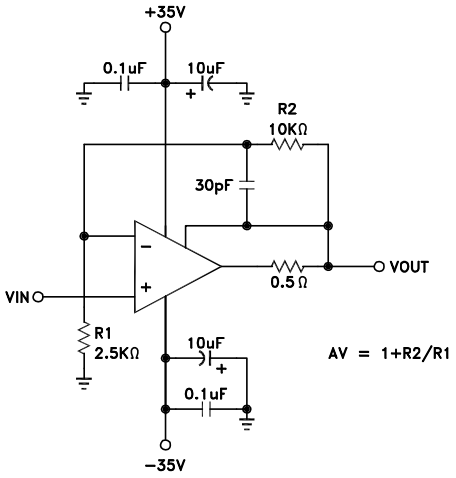
SAFE OPERATING AREA

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.

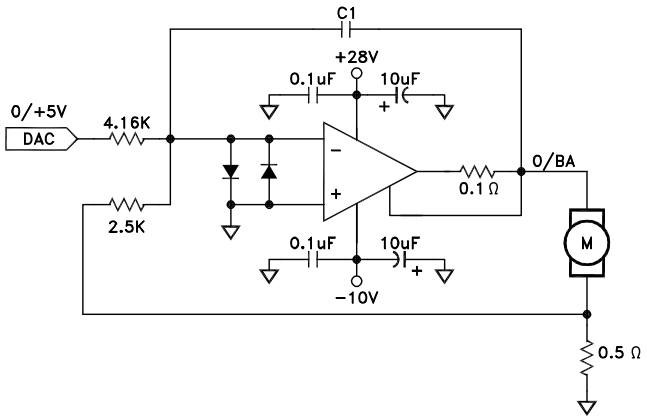
APPLICATION CIRCUITS



Clamping Output for EMF-Generating Loads

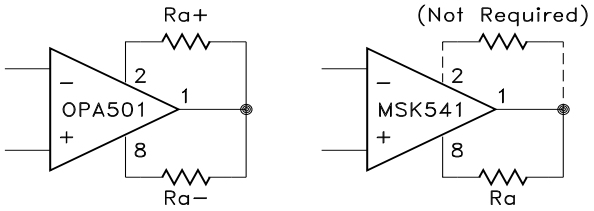


Isolating Capacitive Loads



Motor Current a Function of V_{IN}
Programmable Torque Circuit

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.

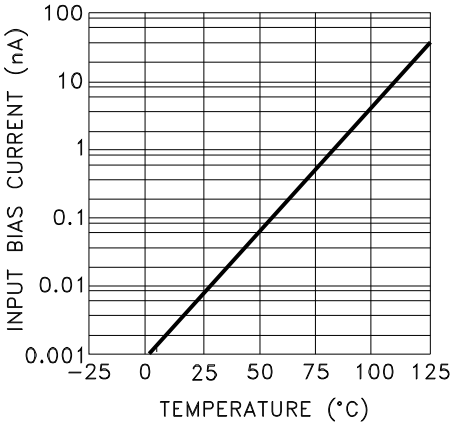


Replacing OPA501 with MSK541

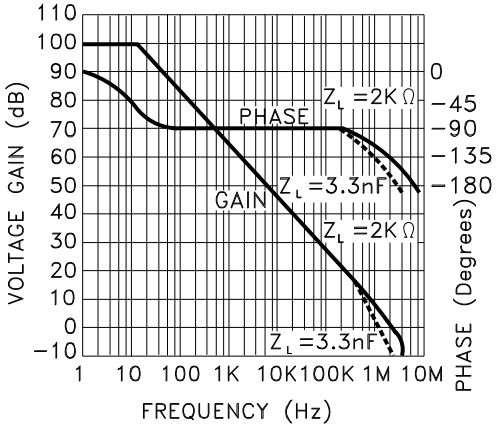
When replacing the OPA501, OPA511, OPA512 or 3573 with the MSK541, it is not necessary to make any changes in the current limit scheme. Since pin 2 is not connected in the MSK541, the current limit resistor connected from pin 1 to pin 2 can be left in the circuit or removed.

TYPICAL PERFORMANCE CURVES

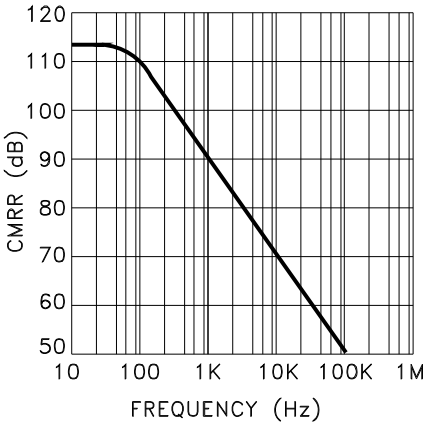
INPUT BIAS CURRENT vs TEMPERATURE



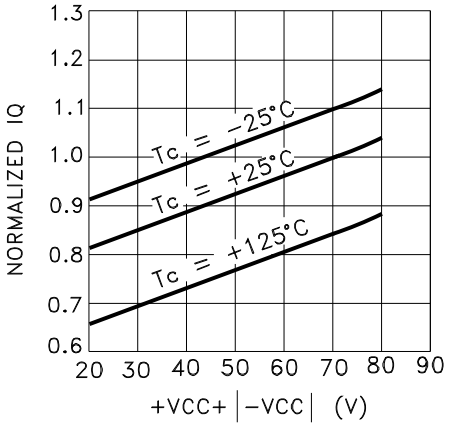
OPEN LOOP GAIN AND PHASE vs FREQUENCY



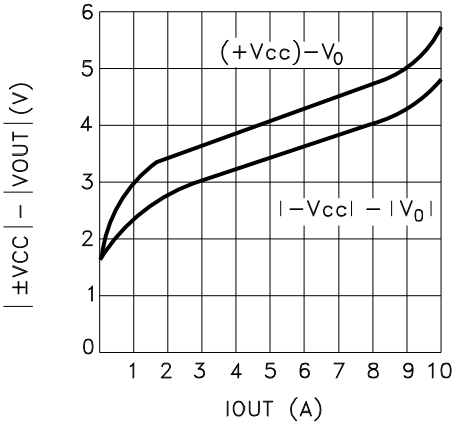
COMMON MODE REJECTION vs FREQUENCY



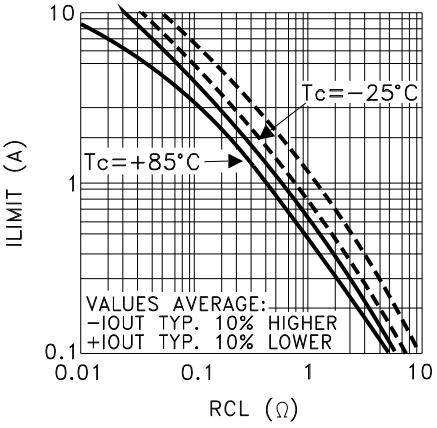
NORMALIZED QUIESCENT CURRENT vs TOTAL POWER SUPPLY VOLTAGE



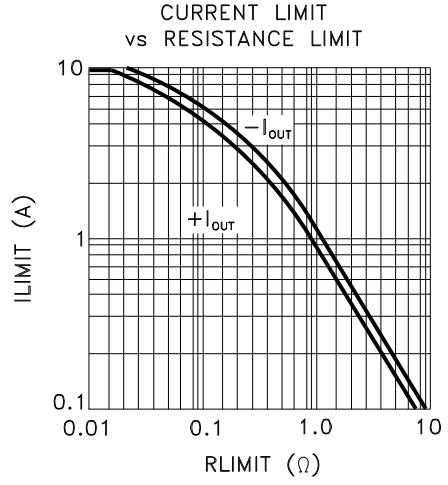
OUTPUT VOLTAGE SWING vs OUTPUT CURRENT



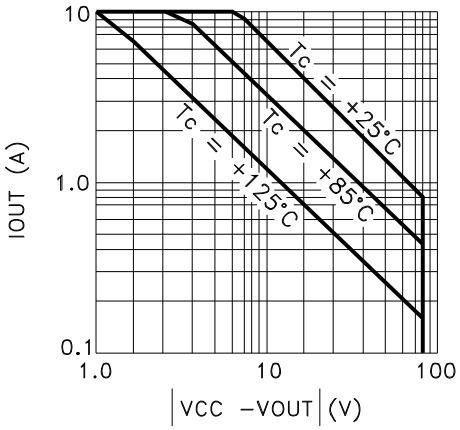
CURRENT LIMIT vs RESISTANCE LIMIT vs TEMPERATURE



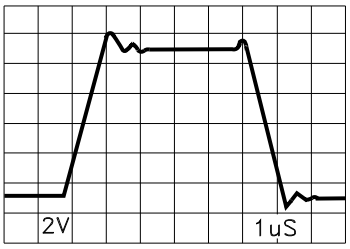
CURRENT LIMIT vs RESISTANCE LIMIT



SAFE OPERATING AREA (TO3)



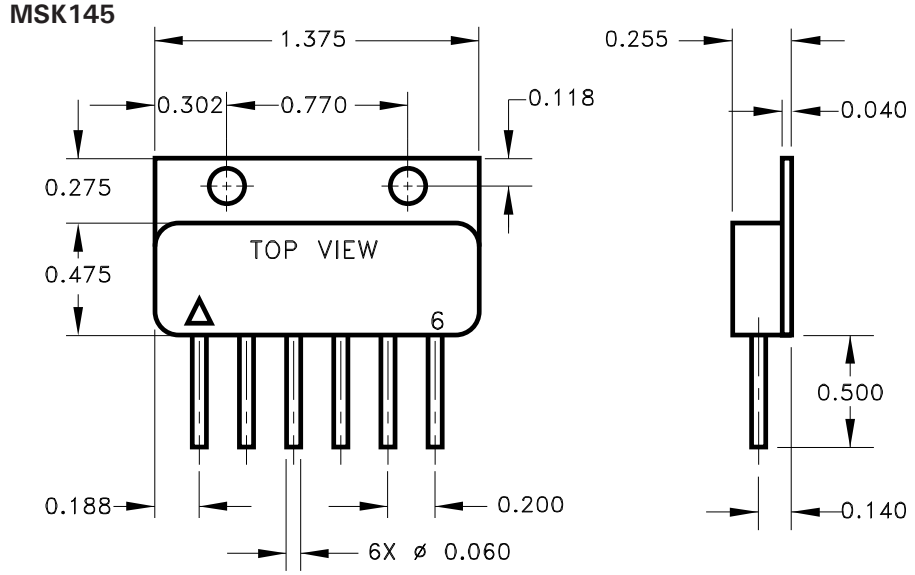
DYNAMIC RESPONSE



G = 1, CL =4.7nF

MECHANICAL SPECIFICATIONS

MSK145 — POWER SIP PACKAGE



ORDERING INFORMATION

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

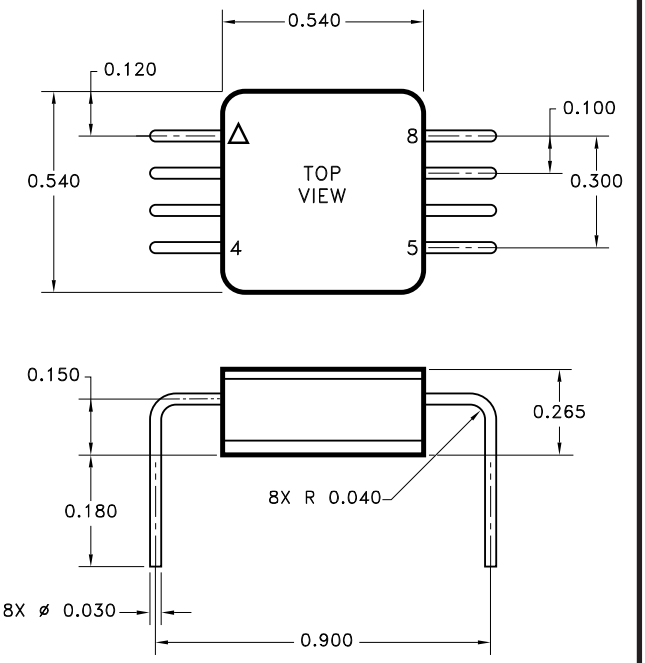
PIN NO.	FUNCTION
1	-VCC
2	OUTPUT DRIVE
3	CURRENT SENSE
4	+VCC
5	+INPUT
6	-INPUT

WEIGHT = 14.2 GRAMS TYPICAL

CASE = ISOLATED

ALL DIMENSIONS ARE SPECIFIED IN INCHES ESD TRIANGLE INDICATES PIN 1

MSK146 — POWER DIP PACKAGE



ORDERING INFORMATION

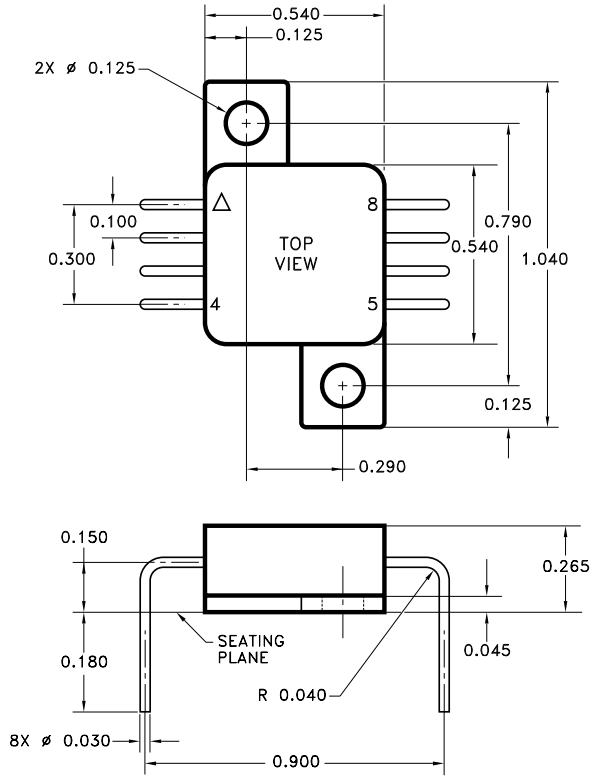
PART NO.	SCREENING LEVEL
MSK146	INDUSTRIAL
MSK146B	MIL-PRF-38534
5962-8870101Y	DSCC-SMD
5962-8870103Y	DSCC-SMD

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

WEIGHT = 5.9 GRAMS TYPICAL

CASE = ISOLATED

MSK147 — POWER Z-TAB PACKAGE



ORDERING INFORMATION

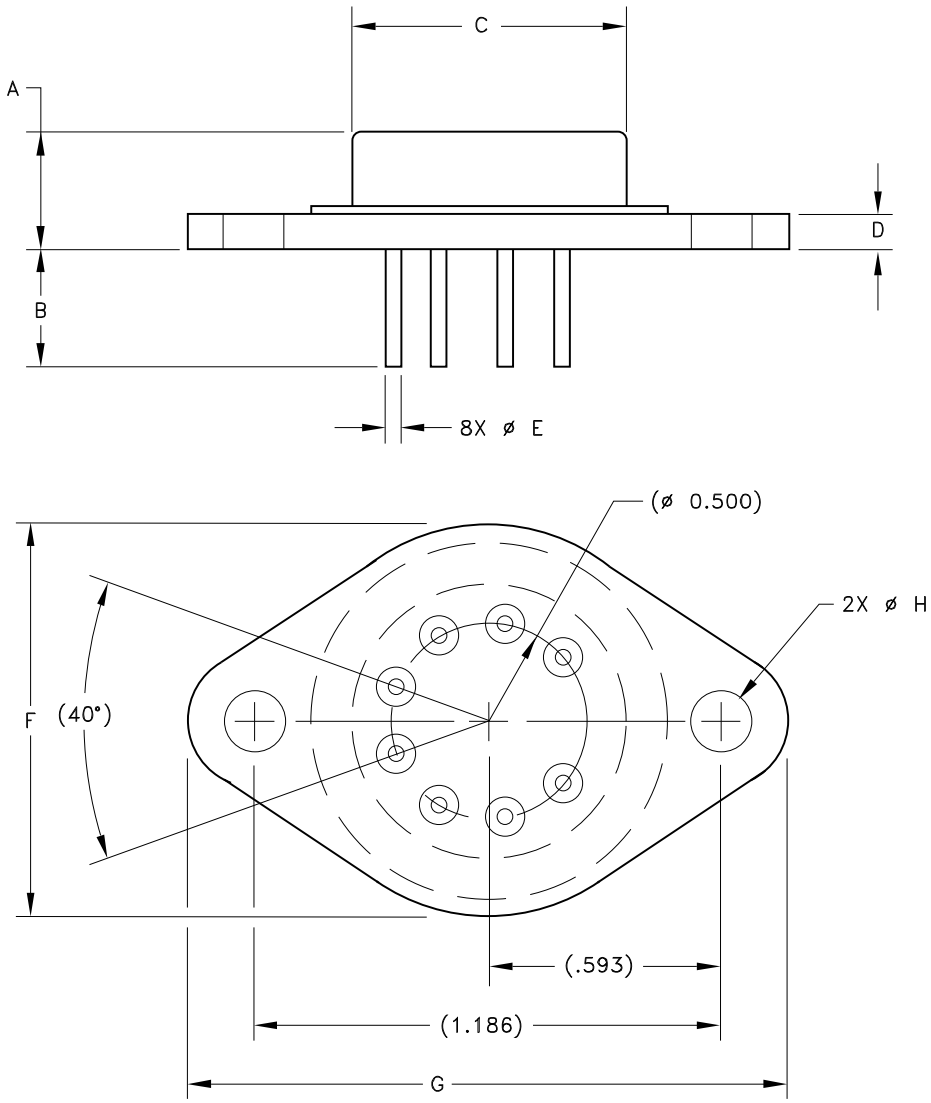
PART NO.	SCREENING LEVEL
MSK147	INDUSTRIAL
MSK147B	MIL-PRF-38534
5962-8870101U	DSCC-SMD
5962-8870103U	DSCC-SMD

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

WEIGHT = 6.5 GRAMS TYPICAL

CASE = ISOLATED

MECHANICAL SPECIFICATIONS CONTINUED



REF	MIN	MAX
A	0.260	0.340
B	0.400	0.500
C	0.745	0.770
D	0.080	0.105
E	0.038	0.042
F	0.980	1.020
G	1.510	1.550
H	0.151	0.161

WEIGHT = 15.2 GRAMS TYPICAL

ALL DIMENSIONS ARE SPECIFIED IN INCHES

ORDERING INFORMATION

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

REVISION HISTORY

REV	STATUS	DATE	DESCRIPTION
L	Released	06/14	Add new note for solder reflow and clarify mechanical outline.

M.S. Kennedy Corp.
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