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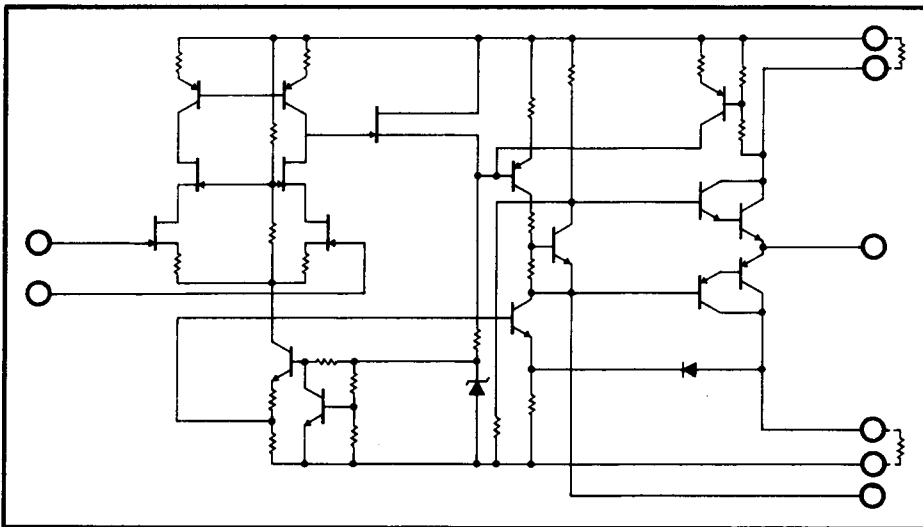
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## High Current — High Power OPERATIONAL AMPLIFIERS

### FEATURES

- **HIGH CURRENT**  
Up to 5A Peak, 2A Continuous
- **EASY TO USE**  
Adjustable Current Limits  
Electrically Isolated Case  
Small Size — 8-Pin TO-3 Package
- **HIGH VOLTAGE**  
Up to 70V p-p Output
- **SELF-PROTECTED**  
Self-Contained Automatic Thermal  
Sensing and Shutdown
- **HIGH POWER**  
Delivers up to 70W to Load



OPERATIONAL AMPLIFIERS

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PDS-334C

## DESCRIPTION

The 3571AM and 3572AM are high output current integrated circuit operational amplifiers. Their performance, ease of use and compact size make them ideal to use in a variety of high current applications. They are especially well suited for driving permanent magnet DC servo and torque motors.

The equivalent circuit for the 3571AM and 3572AM is shown in Figure 1. The design uses a monolithic FET input stage for high input impedance, low bias current, and low voltage drift versus temperature. The high input impedance provides negligible source impedance loading errors when the noninverting circuit configuration is used. The low bias currents minimize offset errors when large values of source and feedback resistors are used.

The input offset voltage at 25°C and the input offset voltage drift versus temperature are compensated by state-of-the-art laser trimming techniques. The offset voltage is low enough so that trimming will not be required in most applications. The excellent input characteristics and the high gain available mean that the use of a preamplifier, sometimes required with other servo type amplifiers, will not be necessary with the 3571AM and 3572AM.

The output stage is a class AB design which provides low distortion and minimizes quiescent current drain. The output circuitry provides for external current limiting resistors for both positive and negative output currents. This allows the user to select the current limit value suited to his particular application. This is especially desirable for driving permanent magnet motors where the high current seen during direction reversal (plugging) can demagnetize the motor.

The 3571AM and 3572AM have been designed to operate over a relatively wide supply range ( $\pm 15\text{VDC}$  to  $\pm 40\text{VDC}$ ) while still maintaining the high output current capability. This allows the user a wide range for the selection of the proper output voltage and current and makes the ampli-

fiers useful for many different types of loads.

The output circuit has a unique protection feature which is practical only in integrated circuit amplifiers - self-contained automatic thermal-sensing and shut-off circuitry which automatically turns the amplifier off when the internal temperature reaches approximately 150°C. This is accomplished by sensing the substrate temperature and deactivating the amplifiers biasing network when the temperature reaches 150°C. As this happens, the output load current limits at a safe value and the amplifier's quiescent current decreases. The output current may remain at a low value or oscillate between two values depending on the amount of power being dissipated and the heat sink conditions seen by the amplifier. In either case, the amplifier will not sustain internal damage and will return to normal operation within a few seconds after the abnormal load condition is removed.

Internal thermal protection removes some of the constraints of power derating for abnormal operating conditions. The amplifier will protect itself for many conditions of excess power dissipation (see Power Derating Curve). This allows the use of a smaller heat sink to protect against abnormal output conditions since the amplifier has its own internal protection for many conditions of excess power dissipation. The output constraints of the Safe Operating Area Curves must still be observed.

The 3571AM and 3572AM have several other features that improve their utility. For instance, the metal case of the units is completely electrically isolated. (This can be contrasted to most power semiconductors where the case is connected to the collector of the device.) This simplifies mounting and reduces cost because the need for insulating spacers and bushings is eliminated. The hermetically sealed package improves reliability and will withstand severe environments better than discrete component amplifiers. The small package size makes mounting more convenient.

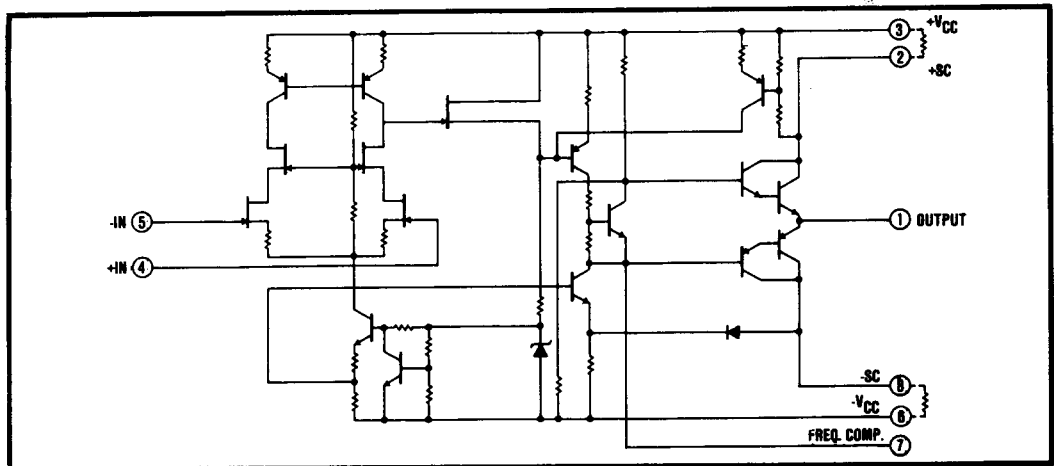


FIGURE 1. Equivalent Circuit

# SPECIFICATIONS

## ELECTRICAL

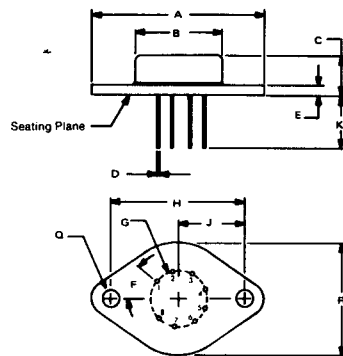
Typical at  $T_{case} = 25^{\circ}C$  and  $\pm V_{CC} = \pm 35VDC$  max unless otherwise noted.

MODELS	3571AM	3572AM
<b>RATED OUTPUT (to load)</b>		
Power to Load		
Continuous, min(1)	30W	60W
Peak, min(1)	60W	150W
Output Voltage, $\pm(V_{CC} - 5)V$		
Continuous, min(1)	$\pm 30V$ at $\pm 1A$	$\pm 30V$ at $\pm 2A$
Peak, min(1)	$\pm 30V$ at 2A	$\pm 30A$ at 5A
Load Capacitance, min. $C_c = 0$		3300pF
		15 $\mu$ F
<b>DISSIPATION RATING</b>		
At 25°C Case Temperature	33W	50W
Derating Above 25°C	See Typical Performance Curves	
Thermal Resistance, Case to Free Air	30°C/W	
Thermal Time Constant (no heat sink)	2 minutes	
Thermal Resistance, Junction to Case	2.5°C/W	
<b>POWER SUPPLY</b>		
Voltage, $\pm V_{CC}$	$\pm 15VDC$ to $\pm 40VDC$	
Quiescent Current, max	$\pm 35mA$	
<b>OPEN LOOP</b>		
Gain min, at $R_{load} = 30\Omega$ (3572AM)	94dB	
	$R_{load} = 60\Omega$ (3571AM)	
Output Impedance	2.5 $\Omega$	
<b>FREQUENCY RESPONSE</b>		
Unity Gain Bandwidth, Small Signal	500kHz	
Full Power Bandwidth	16kHz at $V_{pk} = 30V$	
Slew Rate, $C_c = 1000pF$	3V/ $\mu$ sec	
<b>INPUT OFFSET VOLTAGE</b>		
Initial at 25°C, max	$\pm 2mV$	
Drift vs. Temp., max	$\pm 40\mu V/^{\circ}C$	
Drift vs. Supply Voltage	$\pm 100\mu V/V$	
Drift vs. Time	50 $\mu V/mo$	
Drift vs. Power Dissipation ( $T_c$ constant)	20 $\mu V/W$	
<b>INPUT BIAS CURRENT</b>		
Initial at 25°C, max	-100pA	
Drift vs. Temp.	doubles every 10°C	
Drift vs. Supply Voltage	0.5pA/V	
<b>INPUT OFFSET CURRENT</b>		
Initial at 25°C	$\pm 50pA$	
Drift vs. Temp.	doubles every 10°C	
Drift vs. Supply Voltage	0.5pA/V	
<b>INPUT IMPEDANCE</b>		
Differential	10 <sup>11</sup> $\Omega$    10pF	
Common-mode	10 <sup>11</sup> $\Omega$	
<b>INPUT NOISE</b>		
Voltage 0.01Hz to 10Hz, p-p	4 $\mu V$	
10Hz to 1kHz, rms	3 $\mu V$	
Current 0.01Hz to 10Hz, p-p	1pA	
10Hz to 1kHz, rms	0.1pA	
<b>INPUT VOLTAGE RANGE</b>		
Max Safe Differential Voltage	$(+V_{CC} + 1 - V_{CC})$	
Max Safe Common-mode Voltage	$+V_{CC} - V_{CC}$	
Common-mode Voltage, Linear Operation	$\pm(V_{CC} - 10)V$	
Common-mode Rejection	80dB min., 90dB, typ.	
<b>TEMPERATURE RANGE (Case)</b>		
Specification	-25°C to +85°C	
Operating	-55°C to +125°C	
Storage	-55°C to +125°C	

**NOTE:**

1. Safe Operating Area and Power Derating limitations must be observed.

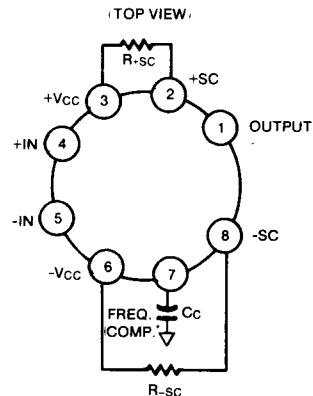
## MECHANICAL



**NOTE:**  
Leads in true position within 0.010"  
0.25mm - R at MMC at seating plane.  
Pin numbers shown for reference only.  
Numbers may not be marked on package.

DIM	INCHES		MILLIMETERS	
	MIN	MAX	MIN	MAX
A	1.510	1.650	38.35	39.37
B	.745	.770	18.92	19.56
C	.300	.400	7.62	10.16
D	.038	.042	0.97	1.07
E	.080	.105	2.03	2.67
F	40° BASIC		40° BASIC	
G	.500 BASIC		12.7 BASIC	
H	1.186 BASIC		30.12 BASIC	
J	.593 BASIC		15.06 BASIC	
K	.400	.500	10.16	12.70
Q	.151	.161	3.84	4.09
R	.980	1.020	24.89	25.91

## CONNECTION DIAGRAM



The case is electrically isolated. It is recommended that the case be grounded during use.

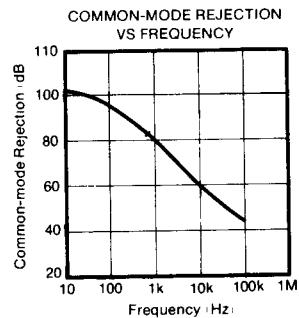
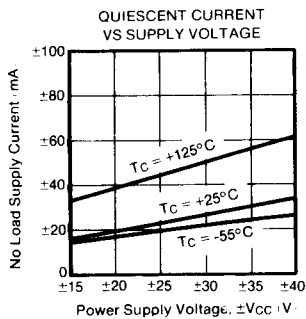
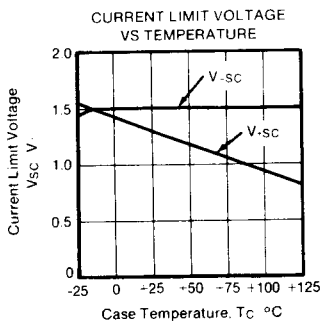
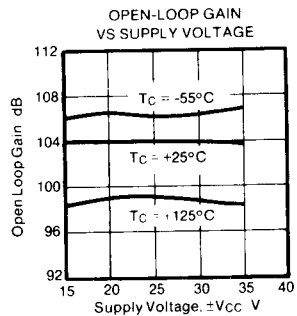
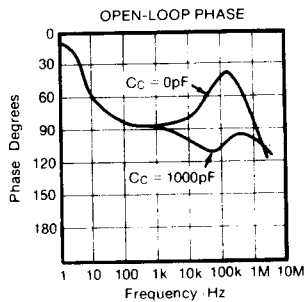
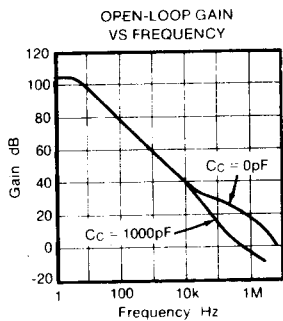
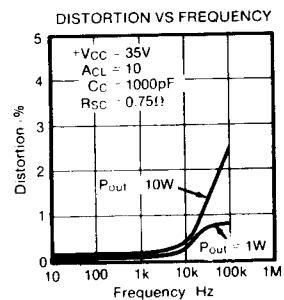
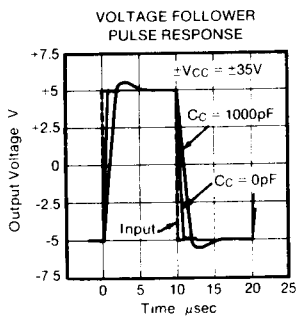
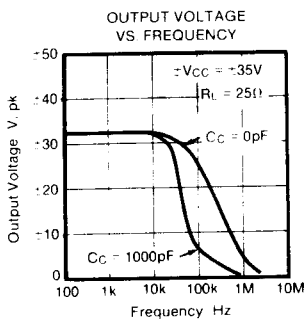
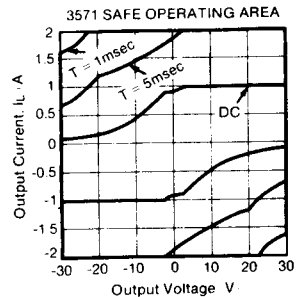
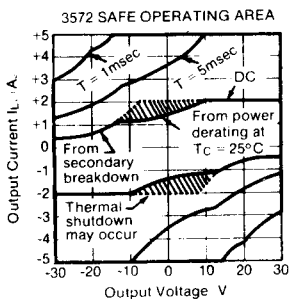
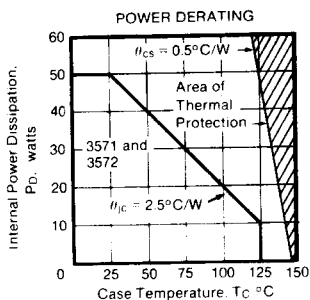
\*A 1000pF  $\pm 20\%$  ceramic capacitor is recommended for all circuit configurations and at all amplifier gains. The capacitor's lead lengths should be short. For gains above 10V/V,  $C_c$  is not absolutely required but is recommended.

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OPERATIONAL AMPLIFIERS

# TYPICAL PERFORMANCE CURVES

Typical  $T_{case} = 25^{\circ}C$  and  $\pm V_{CC} = \pm 35VDC$  unless otherwise noted.



# INSTALLATION AND OPERATING INSTRUCTIONS

## GENERAL PRECAUTIONS

### Current Limiting

It is recommended that during initial amplifier setup, particularly in breadboarding and when a lack of familiarity with the amplifier exists, that the current limit be set at about 250mA ( $R_{SC} \cong 5.6\Omega$ ). This will allow verification of the circuit and will minimize the possibility of damaging the amplifier. Later, when the circuit configuration and connections have been proven, the current limits can be raised to the desired value.

### Minimum Heat Sink

The 3571AM and 3572AM require a minimum heat sink of 16°C/W or lower in order to insure thermal stability (mounting on a 3" x 3" x 0.06" piece of 80% copper-clad printed circuit board material will be sufficient). Normally, this will not be a consideration since a larger heat sink will be used to provide the proper power dissipation as described in the Thermal Considerations section which follows.

### Proper Grounding and Power Supply Bypassing

Particular attention should be given to proper grounding practices because the large output currents can cause significant grounding-loop errors. Proper connections are shown in Figure 2.

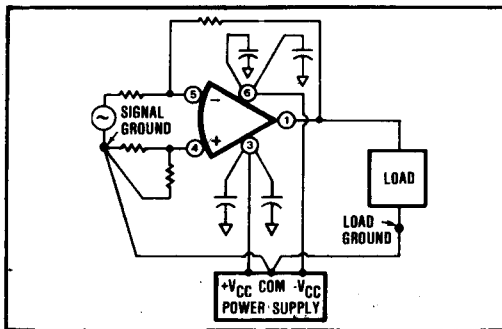


FIGURE 2. Proper Power Supply Connections.

Note that the connections are such that the load current does not flow through the wire connecting the signal ground point to the power supply common. Also, power supply and load leads should be physically separated from the amplifier input and signal leads.

The amplifier power supply should be bypassed with 50μF tantalum capacitors connected in parallel with 0.01μF ceramic capacitors connected as close to pins 3 and 6 as possible. The capacitors should be connected to the load ground rather than the signal ground.

### CURRENT LIMITS

The amplifiers are designed so that both the positive and negative load current limits can be adjusted with external resistors,  $R_{+SC}$  and  $R_{-SC}$  respectively. The value of the resistors are given by the following equations:

$$R_{+SC} = \frac{1.3 \text{ (volts)}}{I_{+limit} \text{ (amps)}}, \quad R_{-SC} = \frac{1.5 \text{ (volts)}}{I_{-limit} \text{ (amps)}}$$

$I_{limit}$  is the desired maximum current. The maximum power dissipation of the resistors is  $P_{max} = R_{SC} (I_{limit})^2$ . The current limits determined by the equations above are accurate to about ±10%. The variation of  $I_{limit}$  versus temperature is shown in the Typical Performance Curves. Both +V<sub>CC</sub> and -V<sub>CC</sub> must be on for the current limits to function.

To avoid introducing unwanted inductance into the current limit circuitry, which may introduce oscillations and permanent damage, both current limit resistors must be noninductive. Do not use wire wound resistors. Carbon composition resistors are preferred and paralleling them can provide a wide current limit range at the wattage needed.

The maximum value of the negative current limit resistor is 15Ω (100mA, min). Exceeding this value, or an open circuit, could permanently damage the internal 75Ω, thin-film resistor which parallel  $R_{-SC}$ .

The amplifier should be used with as low a current limit as possible for the particular application. This will minimize the chance of damaging the amplifier under abnormal load conditions and increase reliability by limiting the internal power dissipation of the amplifier.

### THERMAL CONSIDERATIONS

The 3571AM and 3572AM are rated for 150°C maximum junction temperature. The thermal resistance from junction to case ( $\theta_{jc}$ ) is 2.5°C/W. The corresponding Power Derating Curve is given in the Typical Performance Curves.

The internal power dissipation of the amplifier is given by the equation  $P_D = P_{DQ} + P_{DL}$ , where  $P_{DQ}$  is the quiescent power dissipation and  $P_{DL}$  is the power dissipated in the output stage due to the load. (For ±V<sub>CC</sub> = ±40V,  $P_{DQ} = 80 \times 0.035 = 2.8W$ , max). For the case where the amplifier is driving a grounded load ( $R_L$ ) with a DC voltage (±V<sub>out</sub>) the maximum value of  $P_{DL}$  occurs at ±V<sub>out</sub> = ±V<sub>CC}/2 and is equal to  $P_{DL, max} = (\pm V_{CC})^2 / 4R_L$ . Figure 3 shows  $P_D$  as function of the output voltage with the load resistance as a running parameter.</sub>

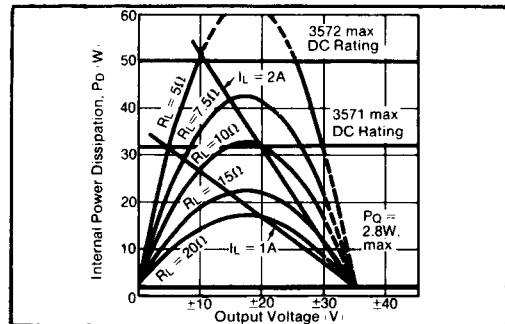


FIGURE 3. Internal Power Dissipation vs. Output Voltage.

$P_{DI}$  for any other value of  $V_{out}$  can be computed from

$$P_{DI} = (\pm V_{CC} - \pm V_{out}) \cdot I_L = (\pm V_{CC} - \pm V_{out}) \left( \frac{\pm V_{out}}{R_L} \right)$$

The use of an adequate heat sink is mandatory and thermal resistance of the heat sink ( $\theta_{hs}$ ) can be determined from the equation:

$$\theta_{hs} = (T_J - T_A / P_D) - \theta_{jc}$$

where  $T_J$  is the desired amplifier junction temperature (+150°C. max),  $T_A$  is the ambient temperature,  $P_D$  is the amplifiers dissipation,  $P_D = P_{DO} + P_{DI}$ , and  $\theta_{jc}$  is the junction to case thermal resistance of the amplifier. Burr-Brown Application Note AN-83 entitled, "How to Determine What Heat Sink to Use", is available for additional information.

The electrically isolated case of the 3571AM and 3572AM simplifies mounting the amplifiers to the heat sink (and the heat sink to any other assemblies) since there is no need for electrical insulation. Thermal joint compound and lock washers should be used to prevent mechanical relaxation due to thermal stresses.

## Safe Operating Area

There are additional constraints on the output voltage and current other than those just due to the maximum internal power dissipation of the amplifiers. These are related to the prevention of secondary breakdown in the output stage transistors. These restrictions are shown in the Safe Operating Area Curves in the Typical Performance Curves.

## Application Constraint

Because of the possibility of damaging the output stage if frequency instability (oscillations) occurs, applications with an inductive load which will activate the current limit of the amplifier, are limited to a load impedance phase angle of less than 60°C leading, over the frequency band of 10kHz to 100kHz. Increasing the load's series resistance will decrease the angle, if necessary. Larger inductive loads may be applied if current limit is not activated.

## Frequency Compensation

The optimum value of the compensation capacitor is 1000pF. A  $\pm 20\%$  tolerance ceramic capacitor is recommended. The compensation capacitor should be used with all circuit configurations and at all amplifier gains (see note on Connection Diagram).

## TYPICAL APPLICATIONS

