AM-7650
Low Cost
Operational Amplifier

PRODUCT DATA SHEET

FEATURES

- **±5 Microvolt maximum input offset**
- **0.05 Microvolt/°C maximum offset drift**
- **Low cost**
- **110 dB Minimum CMRR**
- **10 pA Maximum input bias**

GENERAL DESCRIPTION

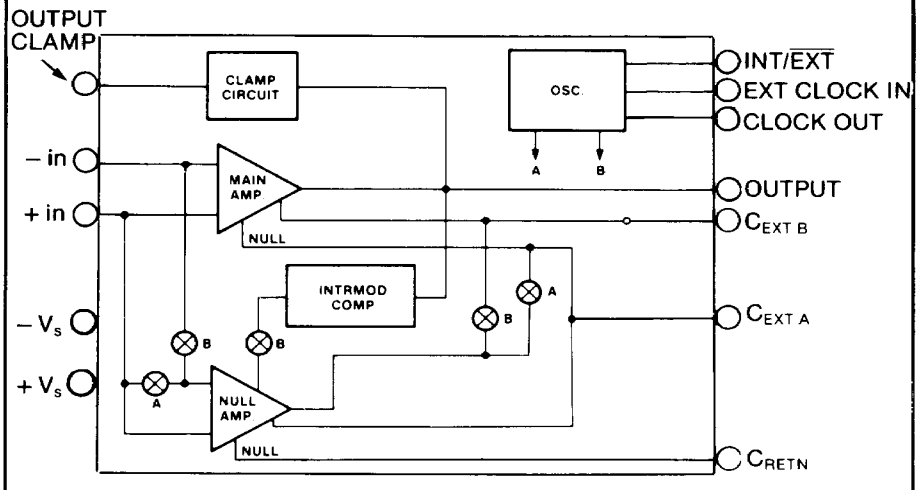
The AM-7650 is a low cost, monolithic chopper-stabilized operational amplifier fabricated using CMOS technology. The amplifier consists of a main dc amplifier, nulling amplifier, output clamp, compensation circuit, and switches controlled by a two-phase oscillator. The extremely low offset voltage drift, 0.05 microvolt/°C maximum, and the initial input offset voltage of only ±5 microvolt maximum eliminate the requirement for external zero adjustment in most applications.

The amplifier achieves its low offset by comparing the input voltages to a nulling amplifier that spends alternate clock phases nulling itself and the main amplifier. Two external capacitors, the only external components necessary, are required to store the correcting potentials on the two amplifier nulling inputs. The compensation circuit minimizes the intermodulation between the applied signal and the chopping frequency. The output clamp circuit reduces the over-load recovery time of the amplifier.

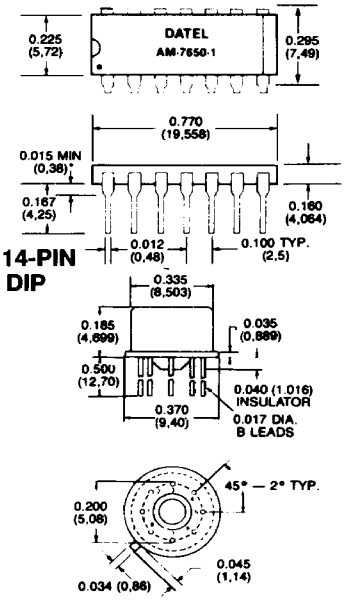
Besides providing virtually glitch-free output and very fast recovery from overloads, the AM-7650 offers differential inputs, maximum input bias current of 10 pA, input noise voltage of only 2 microvolt peak-to-peak, and an input resistance of $10^{12}\Omega$. Unity gain bandwidth product is 2 MHz, CMRR is 110 dB minimum and the open loop gain is a minimum of 120 dB. Long term stability is typically 100 nV/ $\sqrt{mnth}$.

The clock oscillator and all the other circuitry is entirely self-contained, however, the AM-7650-1 includes a provision for the use of an external clock, if required for a particular application. In addition, the AM-7650 is internally compensated for unity gain operation.

Applications would include inverting or non-inverting amplifier configurations, strain gauge pre-amplifiers, nulling amplifiers, and low offset comparator circuits.



MECHANICAL DIMENSIONS
inches (mm)



INPUT/OUTPUT CONNECTIONS

AM-7650-1

PIN	FUNCTION	PIN	FUNCTION
1	C EXT B	8	C RETURN
2	C EXT A	9	OUTPUT CLAMP
3	NC (GUARD)	10	OUTPUT
4	– IN	11	+ Vs
5	+ IN	12	INT CLOCK OUT
6	NC (GUARD)	13	EXT CLOCK IN
7	– Vs	14	INT/EXT

AM-7650-2

PIN	FUNCTION	PIN	FUNCTION
1	C EXT A	5	OUTPUT CLAMP
2	– IN	6	OUTPUT
3	+ IN	7	+ Vs
4	– Vs	8	C EXT B

ABSOLUTE MAXIMUM RATINGS	AM-7650-1	AM-7650-2
Power Supply Voltage ($+V_s$ to $-V_s$)	18V	
Input Voltage	($+V_s$ +0.3) to ($-V_s$ −0.3)	
Lead Temperature (soldering, 10 seconds)	300°C	
Oscillator Control Voltage (Pins, 12, 14)[1]	$\pm V_s$	
Current into any Pin	10 mA	
Current into any Pin while operating[2]	100 µA	
Total Power Dissipation	375 mW	250 mW

FUNCTIONAL SPECIFICATIONS

Typical at 25°C, ±5V supplies unless otherwise noted.

INPUT CHARACTERISTICS	
Input Resistance	$10^{12}\Omega$
Input Offset Voltage, maximum[3]	±5 µV
Input Bias Current, maximum[4]	10 pA
Input Offset Current	8 pA
OUTPUT CHARACTERISTICS	
Output Voltage Swing, minimum[5]	±4.7V
Output Short Circuit Duration	Indefinite
PERFORMANCE	
Large Signal Voltage Gain, minimum[6]	10^6V/V
Input Offset Voltage Drift, maximum	0.05 µV/°C
Long Term Stability	100 nV/$\sqrt{\text{month}}$
Common Mode Voltage Range, minimum	−5.0V
maximum	+3.5V
Common Mode Rejection Ratio, minimum	120 dB
Power Supply Rejection Ratio, minimum	120 dB
Input Noise Voltage[7]	2 µV peak-to-peak
Input Noise Current, 10 Hz	0.01 pA/Hz
Unity Gain Bandwidth	2.0 MHz
Slew Rate[8]	2.5V/µsec
Rise Time	0.2 µsec
Overshoot	20%
Internal Chopping frequency,[9] minimum	120 Hz
maximum	375 Hz
Clamp ON Current[10], minimum	25 µA
Clamp OFF Current[10]	1 pA
POWER REQUIREMENTS	
Power Supply Range ($+V_s$ to $-V_s$), minimum	4.5V
maximum	16V
Power Supply Current (no load), maximum	3.2 mA

PHYSICAL/ENVIRONMENTAL		
Operating Temperature Range	0°C to +70°C	
Storage Temperature Range	−55°C to +150°C	
Package	14 Pin Plastic DIP	8 Pin TO-99

FOOTNOTES:

1. AM-7650-1 only. Voltage on EXT CLOCK IN = ($+V_s$ +0.3V) to (V_s −6.0V)
2. Limiting input current to 100 µA is recommended to avoid latch-up problems. Typically 1 mA is safe, however, it is not guaranteed.
3. Specified at 25°C. Typically ±1.0 microvolts over temperature (0°C to +70°C).
4. Specified at 25°C. Typically 35 pA over temperature (0°C to +70°C). Doubles every 10°C.
5. OUTPUT CLAMP not connected. R_L = 10 kΩ. With R_L = 100 kΩ, the output voltage swing is typically ±4.95V.
6. R_L = 10 kΩ.
7. R_S = 100Ω. 0 to 10 Hz.
8. C_L = 50 pF, R_L = 10 kΩ.
9. Pins 12 and 14 open (DIP).
10. See Technical Note 2.

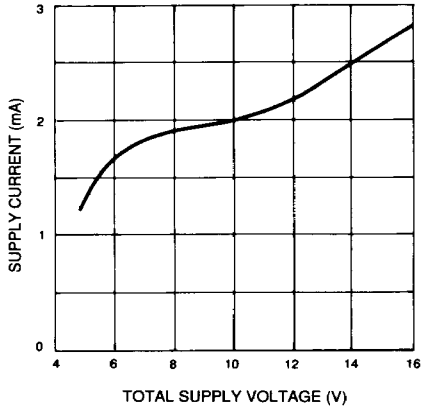
TECHNICAL NOTES

1. Null-storage capacitors should be connected to the C_{EXTA} and C_{EXTB} pins, with a common connection to the C_{RETN} pin (for the AM-7650-1) or the $-V_S$ pin (for the AM-7650-2). This connection should be made directly by either a separate wire or PC trace to avoid injecting load current IR drops into the capacitive circuitry. The outside foil, where available, should be connected to C_{RETN} (or $-V_S$ for TO-99). C_{EXTA} and C_{EXTB} have optimum values which depend on the clock or chopping frequency. For the preset internal clock, the correct value is 0.1 µF. If an external clock is used, the value of C_{EXTA} and C_{EXTB} should be scaled approximately in proportion in order to maintain the same relationship between the chopping freqency and the nulling time constant. A high quality film-type capacitor such as mylar is preferred, however, a ceramic or other lower-grade capacitor may be suitable for many applications. For the quickest settling on initial turn-on, low dielectric absorption capacitors (such as polypropylene) are recommended.
2. To reduce overload recovery time which is inherent with chopper-stabilized amplifiers, tie the OUTPUT CLAMP to the inverting input pin or summing junction. A current path between this point and the output pin occurs just before the device output saturates. Thus, uncontrolled differential inputs are avoided, along with the consequent charge build-up on the correction-storage capacitors. The output swing is slightly reduced.
3. To avoid latch-up, no voltage greater than 0.3V beyond the supply rails should be applied to any pin. In general, the amplifier supplies must be established either at the same time or before any input signals are applied. If this is not possible, the drive circuits must limit input current flow to under 1 mA to avoid latch-up, even under fault conditions.
4. All of the AM-7650's inputs are static-protected by the use of input diodes. However, strong static fields and discharges should be avoided as this can cause degraded diode junction characteristics, which may result in increased input-leakage currents.

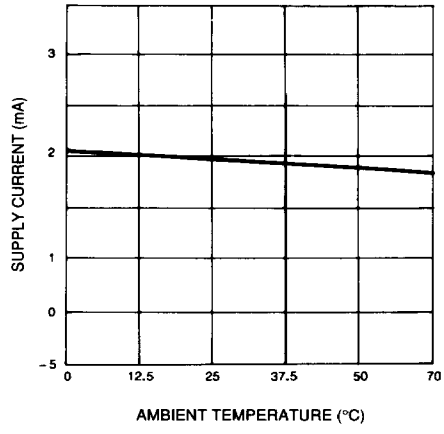
5. The open loop gain of this amplifier will be 17 dB 8 lower with a 1 kΩ load than with a 10 kΩ load. If the device is used strictly for dc applications, the lower gain is of little consequence since the dc gain of this device is greater than 120 dB with loads down to 1 kΩ. For wideband applications, the best frequency response will be achieved with a load resistor of 10 kΩ or greater. This will result in a smooth 6 dB/octave response from 0.1 Hz to 2 MHz, with phase shifts of less than 10° in the transition region where the main amplifier takes over from the null amplifier.
6. Due to thermo-electric or Peltier effects arising in the thermocouple junctions of dissimilar metals, alloys, silicon, etc., special precautions should be made to avoid temperature gradients. All components should be enclosed to eliminate air movement, especially that caused by power-dissipating elements in the system. Low thermoelectric-coefficient connections should be used where possible and power supply voltages and power dissipation should be kept to a minimum. High impedance loads are preferable, and good separation from surrounding head-dissipation elements is recommended.
7. Care must be taken in the assembly of printed circuit boards to take full advantage of the AM-7650's low input currents. The boards should be thoroughly cleaned with TCE or alcohol and blown dry with compressed air. After cleaning, the boards should be coated with epoxy or silicone rubber to prevent contamination. Even with properly cleaned and coated boards, leakage currents may cause trouble, particularly since the input pins are adjacent to pins that are at supply potentials. This leakage can be significantly reduced by using guarding to lower the voltage difference between the inputs and the adjacent metal runs. Input guarding of the 8-pin TO-99 package can be accomplished by using a 10 lead pin circle, with the leads of the device formed so that the holes adjacent to the inputs are empty when the device is inserted into the board. The guard which is a conductive ring surrounding the inputs, is connected to a low impedance point that is approximately the same voltage as the inputs. Leakage currents from high-voltage pins are then absorbed by the guard. The pin configuration of the 14-pin DIP version is designed to facilitate guarding since the pins adjacent to the inputs are not used.

PERFORMANCE

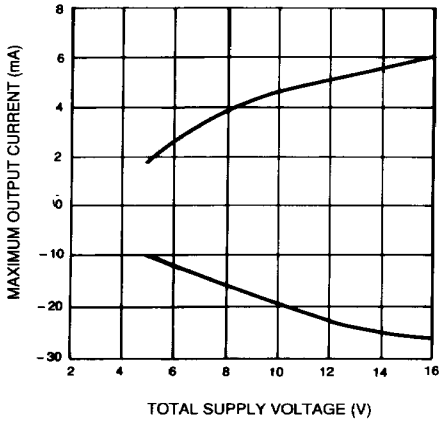
SUPPLY CURRENT VS. SUPPLY VOLTAGE



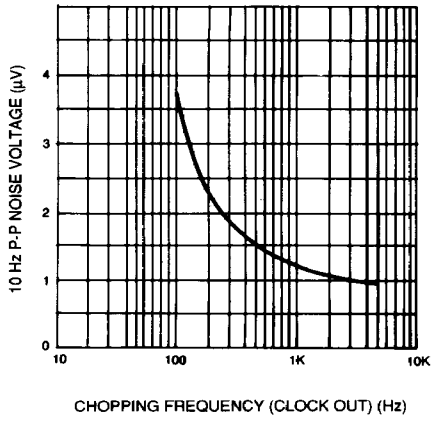
SUPPLY CURRENT VS. AMBIENT TEMPERATURE



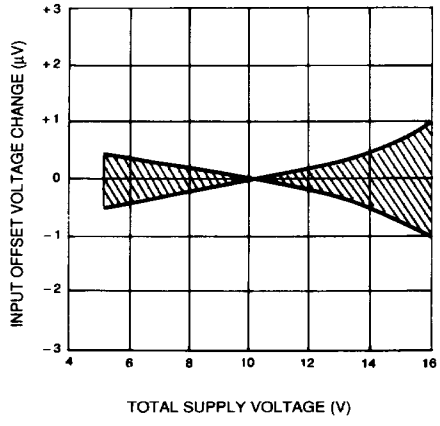
MAXIMUM OUTPUT CURRENT VS. SUPPLY VOLTAGE



10 Hz P-P NOISE VOLTAGE VS. CHOPPING FREQUENCY

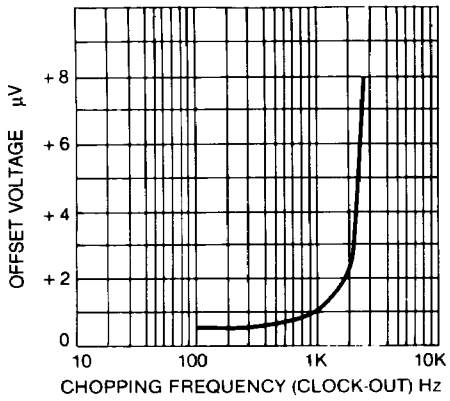


INPUT OFFSET VOLTAGE CHANGE VS. SUPPLY VOLTAGE

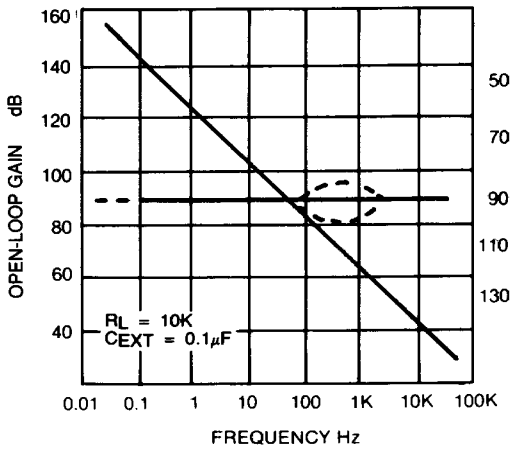


PERFORMANCE

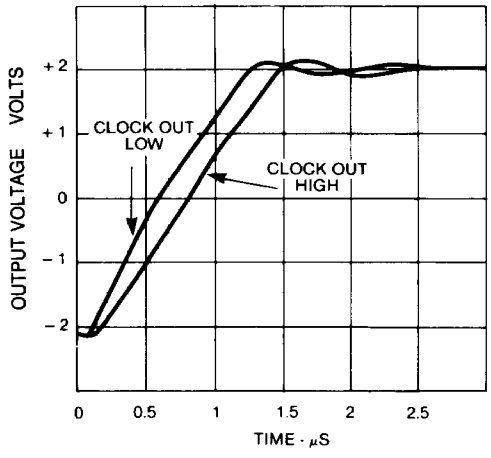
INPUT OFFSET VOLTAGE vs. CHOPPING FREQUENCY



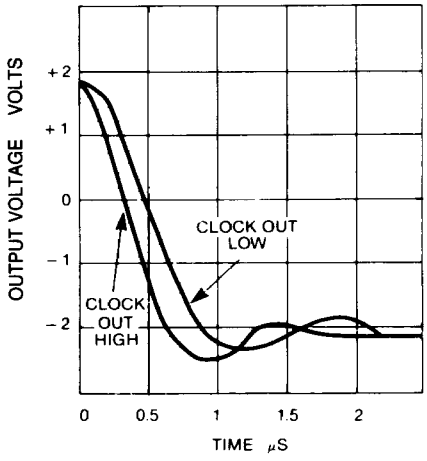
OPEN LOOP GAIN AND PHASE SHIFT vs. FREQUENCY



VOLTAGE FOLLOWER LARGE SIGNAL PULSE RESPONSE

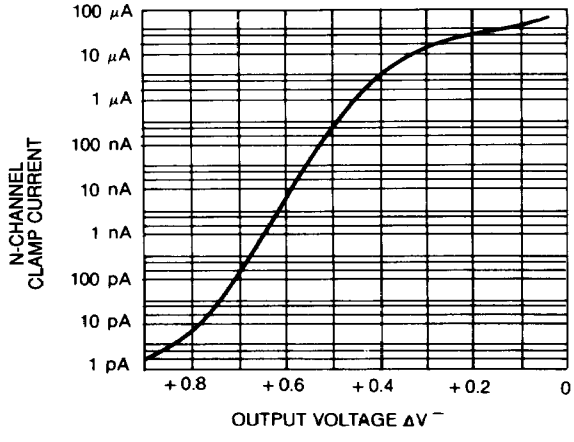


VOLTAGE FOLLOWER LARGE SIGNAL PULSE RESPONSE

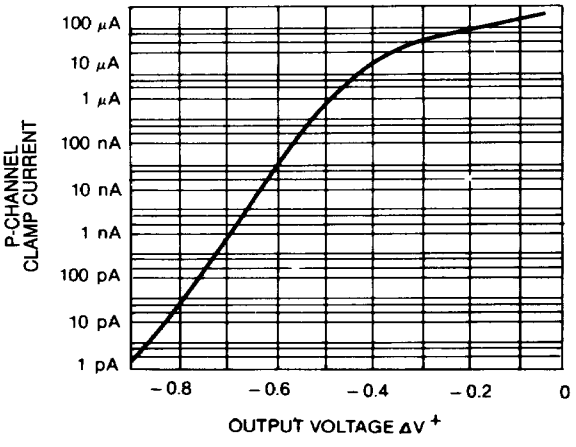


THE TWO DIFFERENT RESPONSES CORRESPOND TO THE TWO PHASES OF THE CLOCK

N-CHANNEL CLAMP CURRENT vs. OUTPUT VOLTAGE



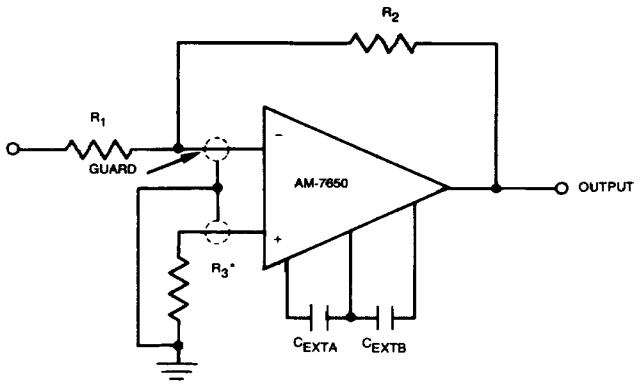
P-CHANNEL CLAMP CURRENT vs. OUTPUT VOLTAGE



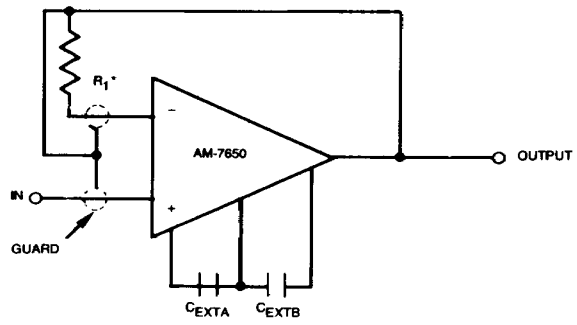
CONNECTION

INPUT GUARD CONNECTION

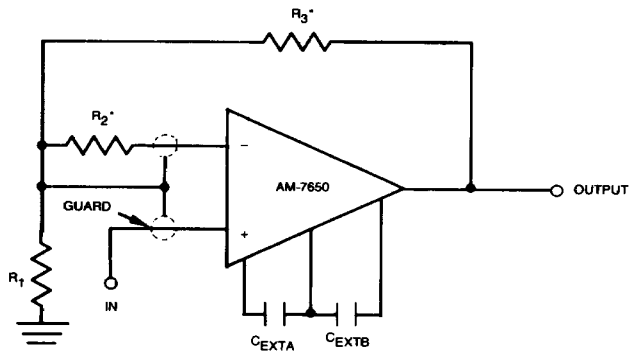
INVERTING AMPLIFIER



VOLTAGE FOLLOWER



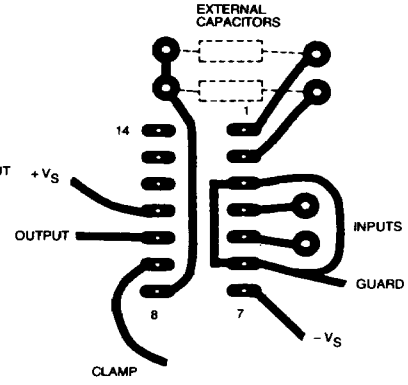
NON-INVERTING AMPLIFIER



R_1/R_2 COMBINATION $\left(\frac{R_1R_2}{R_1+R_2}\right)$ MUST BE LOW IMPEDANCE

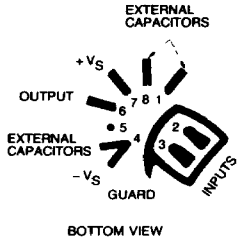
*COMPENSATES FOR LARGE SOURCE RESISTANCE

SUGGESTED BOARD LAYOUT AM-7650-1



BOTTOM VIEW

SUGGESTED BOARD LAYOUT AM-7650-2

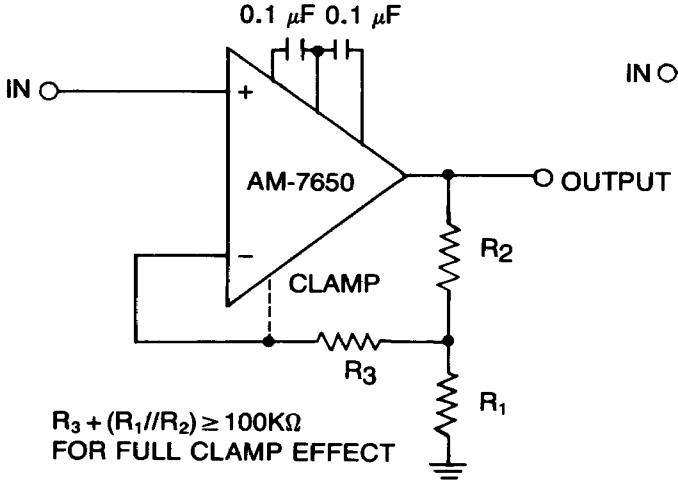


BOTTOM VIEW

THIS LAYOUT REQUIRES A 10-PIN LEAD CIRCLE.

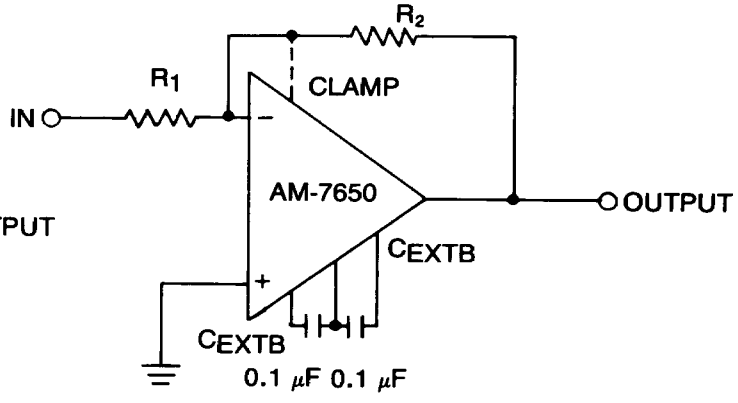
TYPICAL CONNECTION

NON-INVERTING AMPLIFIER WITH OPTIONAL CLAMP



$R_3 + (R_1//R_2) \geq 100K\Omega$
FOR FULL CLAMP EFFECT

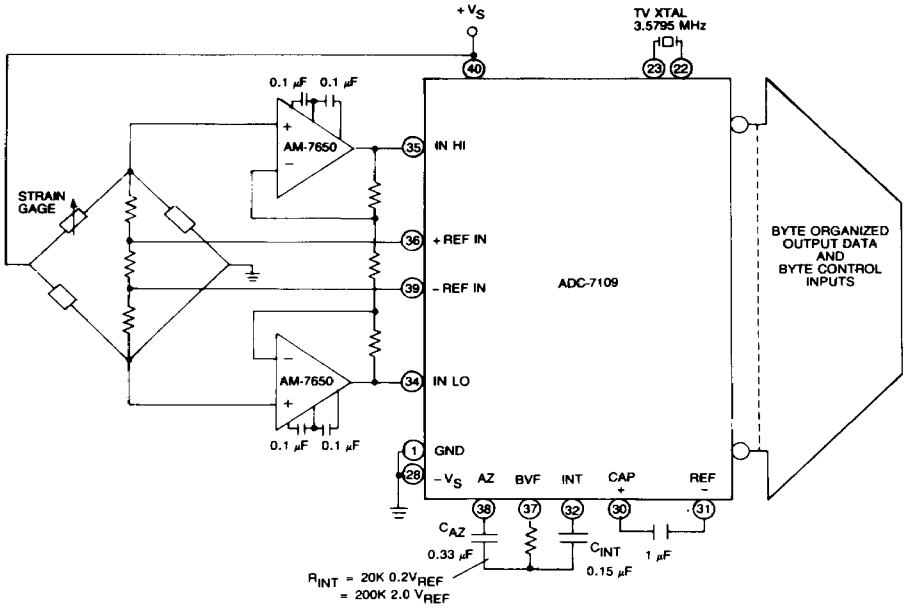
INVERTING AMPLIFIER WITH OPTIONAL CLAMP



$(R_1//R_2) \geq 100K\Omega$
FOR FULL CLAMP EFFECT

The AM-7650 can be used in any application where the performance of a circuit can be significantly upgraded by improved input offset voltage and bias current. This application shows the basic connection for inverting and non-inverting configurations of the AM-7650. The "Output Clamp" function is used to improve the overload recovery performance.

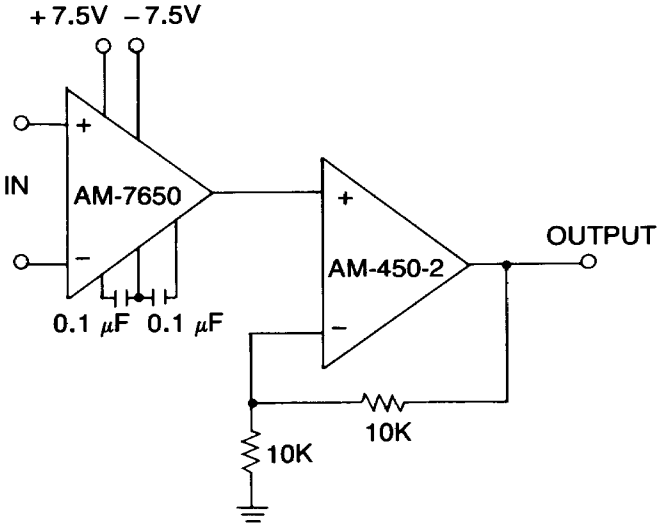
APPLICATION
DIFFERENTIAL PRE-AMP FOR ADC-7109



Two AM-7650s may be used with Datel's ADC-7109, 12-bit integrating A/D converter to construct a preamplifier for signals from bridge type transducers such as strain gages. The circuit will maintain high differential gain without any common-mode gain.

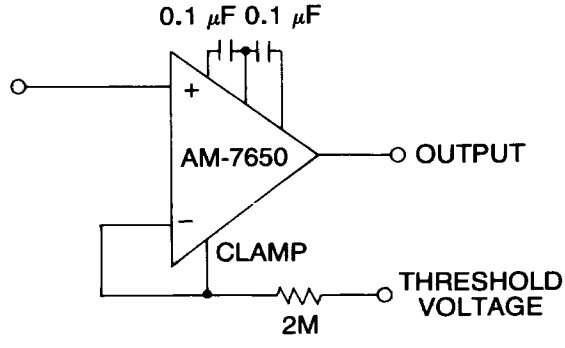
This circuit also works well with thermocouples in noisy environments where shielding is grounded at the sensing end.

BOOSTING OUTPUT DRIVE CAPABILITY



The AM-7650 is an ideal replacement for any operational amplifier with the only limitations being the supply voltage (±8V max) and the output drive capability, (10 kΩ load for a full output swing). These limitations can be overcome by using a booster amplifier as shown.

LOW OFFSET COMPARATOR



The AM-7650 will operate well as a low offset comparator. Other chopper amplifiers perform poorly under overload conditions. However, the optional overload avoidance feature (output clamp) allows the AM-7650 to be used in many of these applications.

ORDERING INFORMATION

MODEL NO.	OPERATING TEMP. RANGE	PACKAGE
AM-7650-1	0 to +70°C	Plastic DIP
AM-7650-2	0 to +70°C	TO-99

DATEL, Inc. 11 CABOT BOULEVARD, MANSFIELD, MA 02048 TEL. (508) 339-3000 / TELEX 951340 FAX (508) 339-6356
• Santa Ana, CA (714) 835-2751 • San Jose, CA (408) 297-7944
• OVERSEAS: DATEL (UNITED KINGDOM) Tel. Basingstoke (256) 469-085 • DATEL (FRANCE) Tel. (1) 460-25711
• DATEL (GERMANY) Tel. (89) 53-0741 • DATEL(JAPAN) Tokyo Tel. (3) 779-1031 • Osaka Tel. (6) 354-2025