



T-51-09-08

# ZN558

## 8-BIT LATCHED INPUT MONOLITHIC D-A CONVERTER

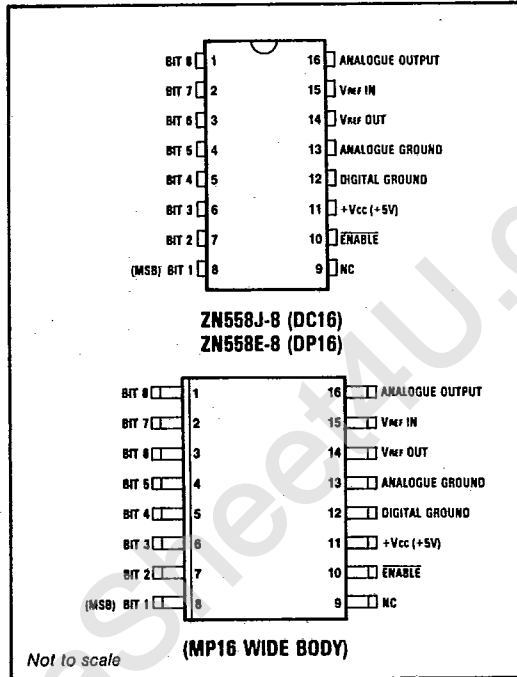
The ZN558 is a monolithic 8-bit D-A converter with input latches to facilitate updating from a data bus. The latch is transparent when enable is LOW and the data is held when enable is taken HIGH. The ZN558 also contains a 2.5V reference the use of which is pin optional to retain flexibility. An external fixed or varying reference may therefore be substituted.

### FEATURES

- Contains DAC with Data Latch and On-Chip Reference
- Guaranteed Monotonic over the Full Operating Temperature Range
- Single +5V Supply
- Microprocessor Compatible
- TTL and 5V CMOS Compatible
- 800ns Settling Time
- Complementary to ZN447 A-D Series
- Commercial and Military Temperature Ranges
- Available in Miniature Plastic Surface Mount Package (MP16)

### ORDERING INFORMATION

| Device type | Operating temperature | Package |
|-------------|-----------------------|---------|
| ZN558D      | 0°C to +70°C          | MP16    |
| ZN558E-8    | 0°C to +70°C          | DP16    |
| ZN558J-8    | -55°C to +125°C       | DC16    |



Pin connections - top view

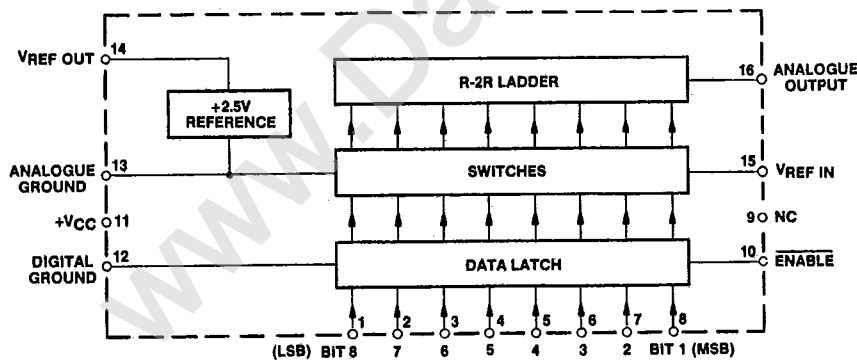


Fig.1 System diagram

**ABSOLUTE MAXIMUM RATINGS**

T-51-09-08

|   |   |
|---|---|
| Supply voltage $V_{CC}$                 | +7.0V   |
| Max. voltage, logic and $V_{REF}$ input | + $V_{CC}$  |
| Operating temperature range             | 0°C to +70°C (ZN558E-8, ZN558D)<br>-55°C to +125°C (ZN558J-8) |
| Storage temperature range               | -55°C to +125°C   |
| Analogue ground to digital ground       | ±200mV  |

**ELECTRICAL CHARACTERISTICS** ( $V_{CC} = +5V$ ,  $T_{amb} = 25^\circ C$  unless otherwise specified).

| Parameter                         | Min.  | Typ.  | Max.  | Units            | Conditions  |
|-----------------------------------|-------|-------|-------|------------------|---|
| <b>Internal voltage reference</b> |       |       |       |                  |   |
| Output voltage                    | 2.475 | 2.550 | 2.625 | V                | } $R_{REF} = 390\Omega$<br>$C_{REF} = 1\mu F$                                     |
| Slope resistance                  |       | 0.5   | 2     | $\Omega$         |   |
| $V_{REF OUT}$ T.C.                |       | 50    |       | ppm/°C           |   |
| Reference current                 | 4     |       | 15    | mA               | Note 1  |
| <b>D-A converter</b>              |       |       |       |                  |   |
| Linearity error                   |       |       | ±0.5  | LSB              | $2.0V \leq V_{REF IN} \leq 3.0V$  |
| Differential non-linearity        |       | ±0.5  |       | LSB              |   |
| Linearity error T.C.              |       | ±3    |       | ppm/°C           |   |
| Differential non-linearity T.C.   |       | ±6    |       | ppm/°C           |   |
| Offset voltage                    |       | 2     | 5     | mV               | All bits OFF  |
| Offset voltage                    |       | ±6    |       | $\mu V/^\circ C$ |   |
| Full scale output                 | 2.545 | 2.550 | 2.555 |                  | } External reference<br>$V_{REF IN} = 2.560V$ ,<br>all bits ON                    |
| Full scale output T.C.            |       | 2     |       | ppm/°C           |   |
| Analogue output resistance        |       | 4     |       | k $\Omega$       |   |
| External reference voltage        | 0     |       | 3.0   | V                |   |
| Settling time to 0.5 LSB          |       | 800   |       | ns               | 1 LSB major transition<br>(note 2)<br>All bits ON to OFF or<br>OFF to ON (note 2) |
|                                   |       | 1.25  |       | $\mu s$          |   |
| Operating temperature range:      |       |       |       |                  |   |
| ZN558E-8/D                        | 0     |       | 70    | C                |   |
| ZN558J-8                          | -55   |       | 125   | C                |   |
| Supply voltage ( $V_{CC}$ )       | 4.5   | 5.0   | 5.5   | V                |   |

Note 1 See REFERENCE, page 1-88.

Note 2  $R_L = 10M\Omega$ ,  $C_L = 10pF$ .

ELECTRICAL CHARACTERISTICS (Cont.)

| Parameter  | Min. | Typ. | Max.     | Units              | Conditions   |
|--|------|------|----------|--------------------|--|
| Supply current   |      | 20   | 30       | mA                 | Note 3   |
| Power consumption  |      | 100  |          | mW                 |  |
| <b>Logic</b><br>(over specified operating temperature range) |      |      |          |                    |  |
| High level input voltage                                     | 2.0  |      |          | V                  |  |
| Low level input voltage                                      |      |      | 0.8      | V                  |  |
| High level input current                                     |      |      | 60<br>20 | $\mu$ A<br>$\mu$ A | $V_{IN} = 5.5V, V_{CC} = Max.$<br>$V_{IN} = 2.4V, V_{CC} = Max.$ |
| Low level input current                                      |      |      | -5       | $\mu$ A            | $V_{IN} = 0.4V, V_{CC} = Max.$                                   |
| Input clamp diode voltage                                    |      | -1.5 |          | V                  | $I_{IN} = -8mA$  |
| Enable pulse width   | 100  |      |          | ns                 |  |
| Data set-up time   | 150  |      |          | ns                 | Note 4   |
| Data hold time   | 10   |      |          | ns                 | Note 5   |

Note 3 All inputs HIGH ( $V_{IH} = 3.5V$ ).

Note 4 Set up time before enable goes high.

Note 5 Hold time after enable goes high.

D-A CONVERTER

The converter is of the voltage switching type and uses an R-2R ladder network as shown in Fig. 2. Each 2R element is connected to 0V or  $V_{REF IN}$  by transistor voltage switches specially

designed for low offset voltage (<1mV). A binary weighted voltage is produced at the output of the R-2R ladder.

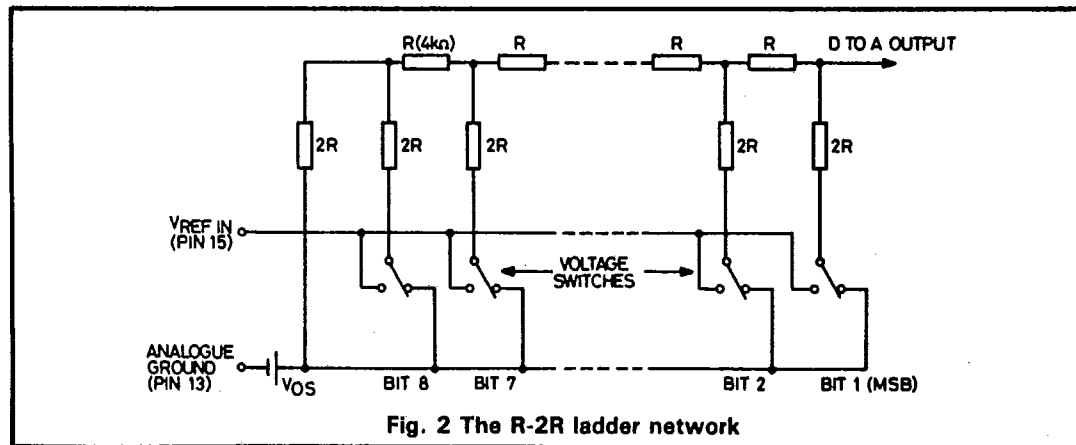


Fig. 2 The R-2R ladder network

$$\text{Analogue output} = \frac{n}{256}(V_{\text{REF IN}} - V_{\text{OS}}) + V_{\text{OS}}$$

where n is the digital input to the D-A from the data latch.

$V_{\text{OS}}$  is a small offset voltage produced by the D-A switch currents flowing through the

package lead resistance. The value of  $V_{\text{OS}}$  is typically 1mV. This offset will normally be removed by the setting up procedure (see APPLICATIONS section) and because the offset temperature coefficient is low ( $\pm 6\mu\text{V}/^\circ\text{C}$ ) the effect on accuracy is negligible.

T-51-09-08

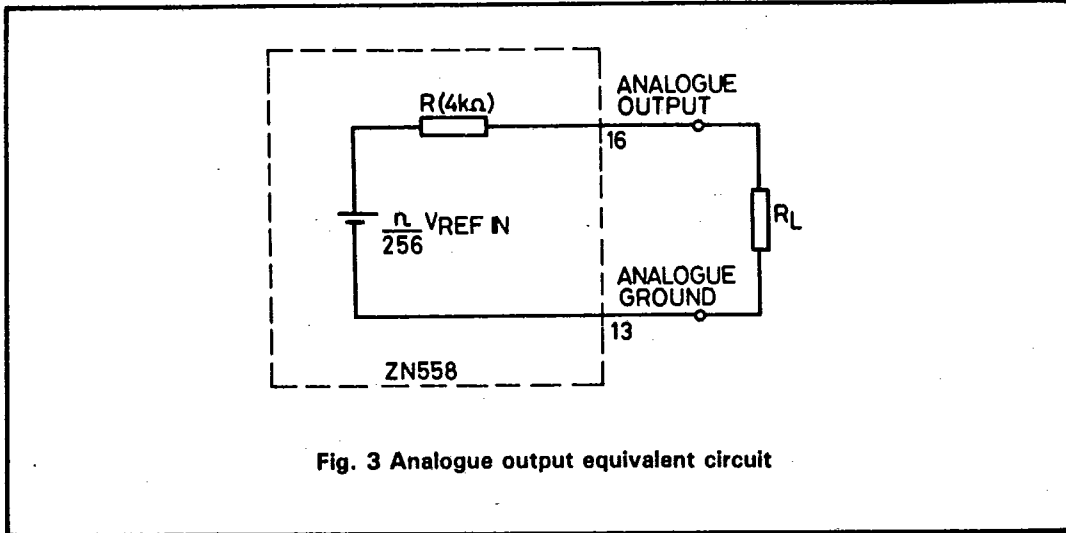


Fig. 3 Analogue output equivalent circuit

Fig. 3 shows an equivalent circuit of the output (ignoring  $V_{\text{OS}}$ ). The output resistance R has a temperature coefficient of +0.2% per °C.

The gain drift due to this is  $\frac{0.2R}{R + R_L}$  % per °C

$R_L$  should be chosen to be as large as possible to make the gain drift small. As an example if  $R_L = 400\text{k}\Omega$  then the gain drift due to the T.C. of R for a 100°C change in ambient temperature will be less than 0.2%. Alternatively the ZN558 can be buffered by an amplifier (see Operating Notes).

**REFERENCE**

**(a) Internal reference**

The internal reference is an active band gap circuit which is equivalent to a 2.5V Zener diode with a very low slope impedance (Fig. 4). A resistor ( $R_{\text{REF}}$ ), should be connected between + $V_{\text{CC}}$  (pin 11) and pin 14. The recommended value of 390Ω will supply a nominal reference current of  $(5.0 - 2.5)/0.39$

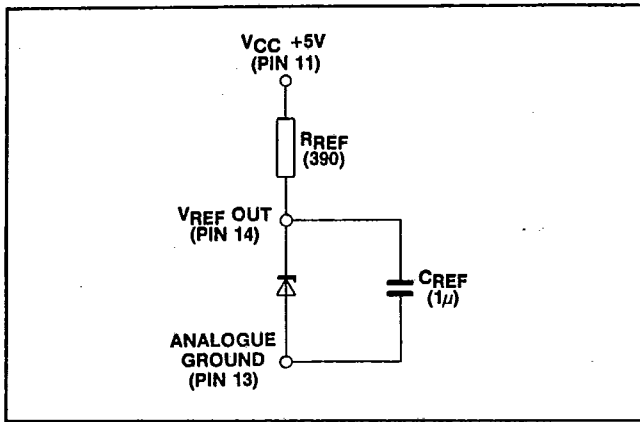
= 6.4mA. A stabilising/decoupling capacitor  $C_{\text{REF}} = 1\mu\text{F}$  is required between pins 14 and 13 for internal reference option,  $V_{\text{REF OUT}}$  (pin 14) being connected to  $V_{\text{REF IN}}$  (pin 15).

Up to five ZN558's may be driven from one internal reference (there is no need to reduce  $R_{\text{REF}}$ ). This useful feature saves power and gives excellent gain tracking between the converters.

**(b) External reference**

If required an external reference voltage may be connected to  $V_{\text{REF IN}}$ . The slope resistance of such a reference source should be less than  $\frac{2.5\Omega}{n}$ , where n is the number of converters supplied.

$V_{\text{REF IN}}$  can be varied from 0 to +3V for ratiometric operation. The ZN558 is guaranteed monotonic for  $V_{\text{REF IN}}$  above 2V.



T-51-09-08

Fig.4 Internal voltage reference

LOGIC

Input coding is binary for unipolar operation and offset binary for bipolar operation. When the enable input is low the data inputs drive the D-A directly. When enable goes high the input data word is held in the data latch.

inputs is shown in Fig.5.

The ZN558 is provided with separate analogue and digital ground connections. The circuit will operate correctly with as much as  $\pm 200\text{mV}$  between the two grounds.

The equivalent circuit for the data and clock

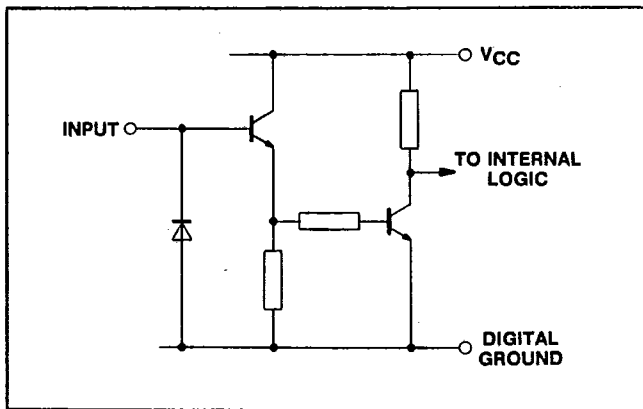


Fig. 5 Equivalent circuit of all inputs

T-51-09-08

**OPERATING NOTES**

**(1) Unipolar D-A converter**

The nominal output range of the ZN558 is 0 to  $V_{REF IN}$  through a  $4k\Omega$  resistance. Other output ranges can readily be obtained by using an external amplifier.

The general scheme (Fig. 6) is suitable for amplifiers with input bias currents less than  $1.5\mu A$ .

The resulting full scale range is given by

$$V_{OUT FS} = \left(1 + \frac{R_1}{R_2}\right) V_{REF IN} = G \cdot V_{REF IN}$$

The impedance at the inverting input is  $R_1//R_2$  and for low drift with temperature this parallel combination should be equal to the ladder resistance ( $4k\Omega$ ). The required nominal values of  $R_1$  and  $R_2$  are given by  $R_1 = 4Gk\Omega$  and  $R_2 = 4G/(G-1)k\Omega$ .

Using these relationships a table of nominal resistance values for  $R_1$  and  $R_2$  can be constructed for  $V_{REF IN} = 2.5V$ .

| Output range | G | $R_1$        | $R_2$          |
|--------------|---|--------------|----------------|
| +5V          | 2 | 8k $\Omega$  | 8k $\Omega$    |
| +10V         | 4 | 16k $\Omega$ | 5.33k $\Omega$ |

For gain setting  $R_1$  is adjusted about its nominal value. Practical circuit realisations (including amplifier stabilising components) for +5 and

+10V output ranges are given in Fig. 7. Settling time for a major transition is  $1.5\mu s$  typical.

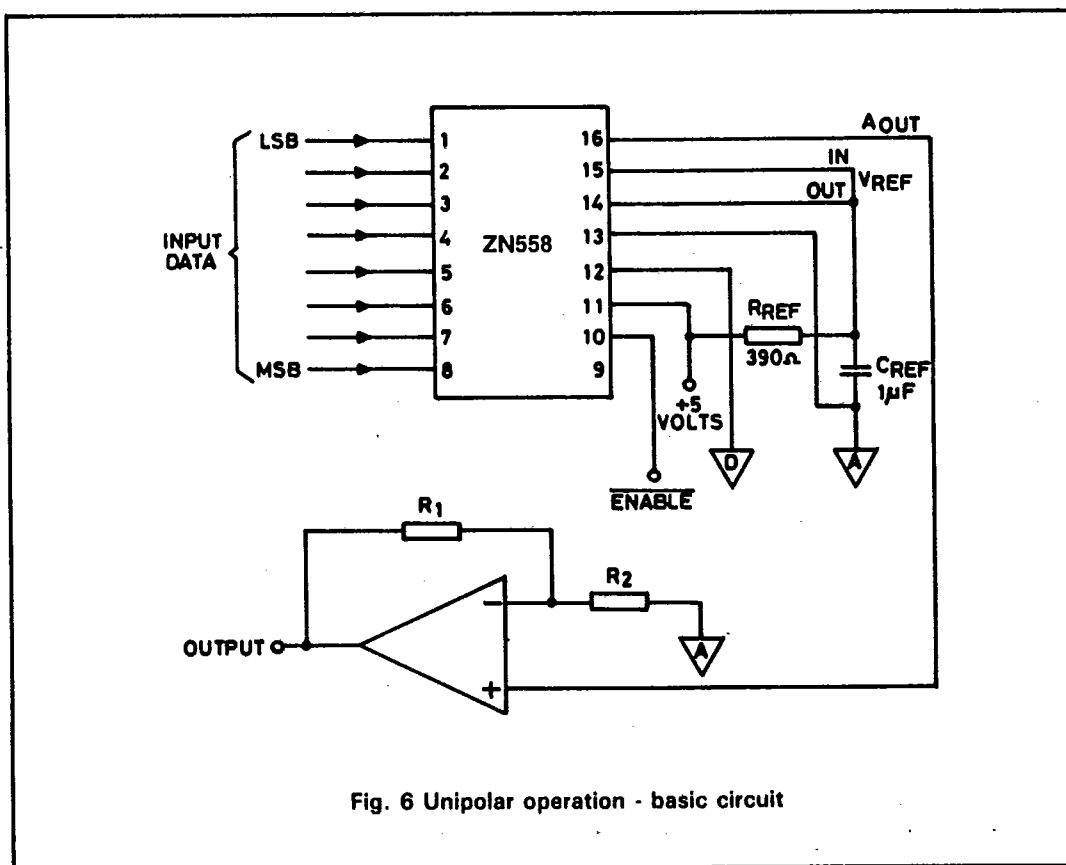


Fig. 6 Unipolar operation - basic circuit

T-51-09-08

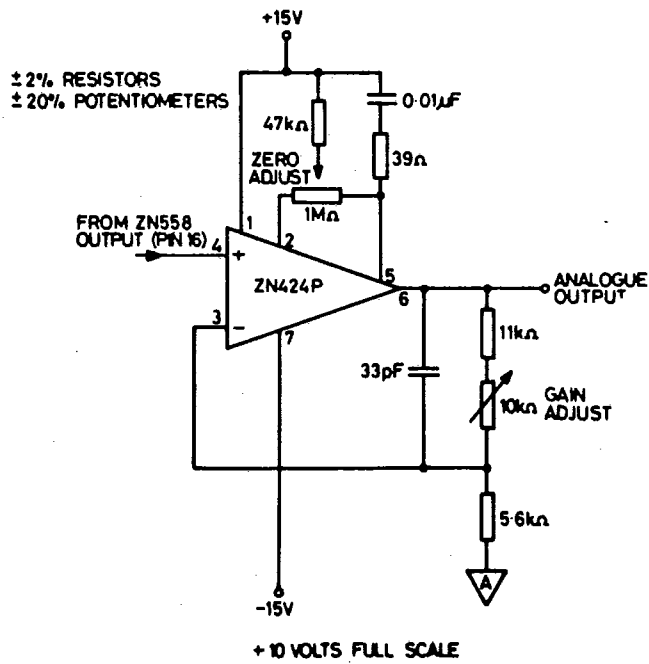
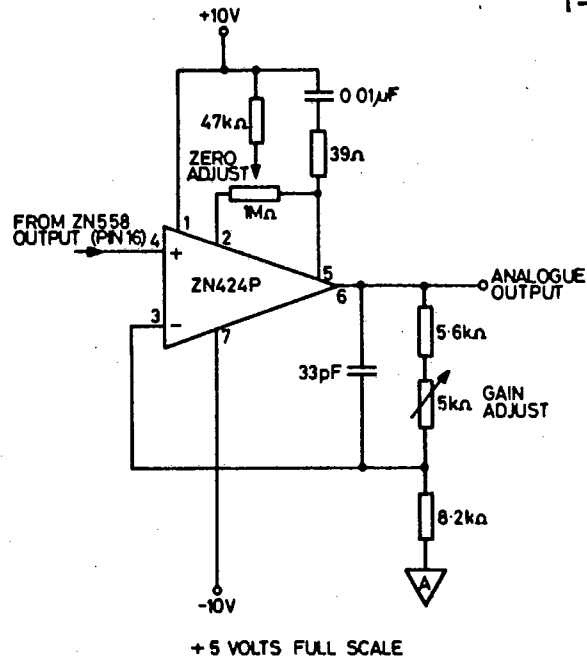


Fig. 7 Unipolar operation - component values

T-51-09-08

**UNIPOLAR ADJUSTMENT PROCEDURE**

- (i) Set all bits to OFF (low) with enable low and adjust zero until  $V_{OUT} = 0.0000V$ .
- (ii) Set all bits ON (high) and adjust gain until  $V_{OUT} = FS - 1LSB$ .

**UNIPOLAR SETTING UP POINTS**

| Output range, +FS | LSB    | FS - 1LSB |
|-------------------|--------|-----------|
| + 5V              | 19.5mV | 4.9805V   |
| + 10V             | 39.1mV | 9.9609V   |

$$1LSB = \frac{FS}{256}$$

**UNIPOLAR LOGIC CODING**

| Input code (Binary) | Analogue output (Nominal value) |
|---------------------|---------------------------------|
| 11111111            | FS - 1LSB                       |
| 11111110            | FS - 2LSB                       |
| 11000000            | $\frac{1}{4} FS$                |
| 10000001            | $\frac{1}{2} FS + 1LSB$         |
| 10000000            | $\frac{1}{2} FS$                |
| 01111111            | $\frac{1}{2} FS - 1LSB$         |
| 01000000            | $\frac{1}{4} FS$                |
| 00000001            | 1LSB                            |
| 00000000            | 0                               |



(2) Bipolar D-A converter

For bipolar operation the output from the ZN558 is offset by half full scale by connecting a resistor

$R_3$  between  $V_{REF IN}$  and the inverting input of the buffer amplifier (Fig. 8).

T-51-09-08

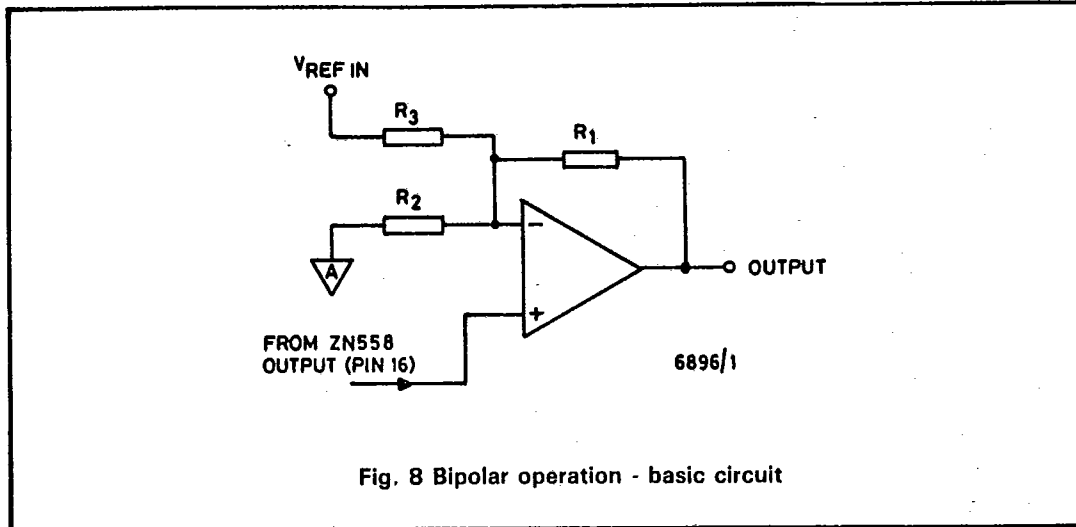


Fig. 8 Bipolar operation - basic circuit

When the digital input to the ZN558 is zero the analogue output is zero and the amplifier output should be - full scale. An input of all ones to the D-A will give a ZN558 output of  $V_{REF IN}$  and the amplifier output required is + full scale. Also, to match the ladder resistance the parallel combination of  $R_1$ ,  $R_2$  and  $R_3$  should be  $4k\Omega$ .

The nominal values of  $R_1$ ,  $R_2$  and  $R_3$  which meet these conditions are given by

$$R_1 = 8Gk\Omega, R_2 = 8G/(G-1)k\Omega \text{ and } R_3 = 8k\Omega$$

where the resultant output range is  $\pm G V_{REF IN}$ .

A bipolar output range of  $\pm V_{REF IN}$  (which corresponds to the basic unipolar range 0 to  $V_{REF IN}$ ) is obtained if  $R_1 = R_3 = 8k\Omega$  and  $R_2 = \infty$ .

Assuming that  $V_{REF IN} = 2.5V$  the nominal values of resistors for  $\pm 5$  and  $\pm 10V$  output ranges are given in the following table:

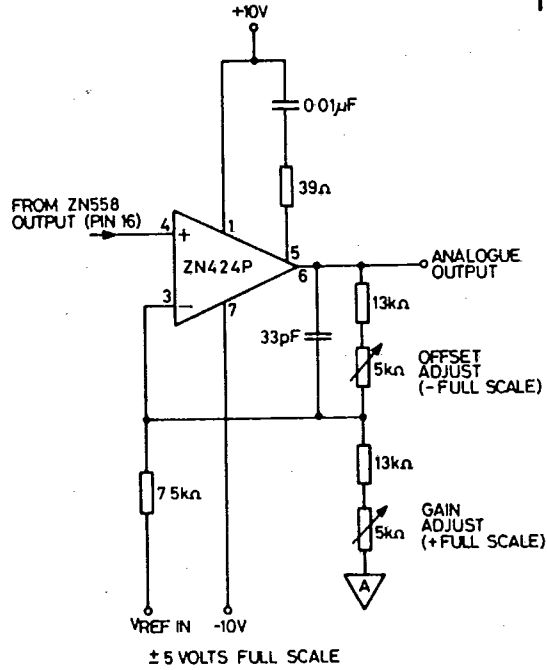
| Output range | G | $R_1$        | $R_2$           | $R_3$       |
|--------------|---|--------------|-----------------|-------------|
| $\pm 5V$     | 2 | 16k $\Omega$ | 16k $\Omega$    | 8k $\Omega$ |
| $\pm 10V$    | 4 | 32k $\Omega$ | 10.66k $\Omega$ | 8k $\Omega$ |

Minus full scale (offset) is set by adjusting  $R_1$  about its nominal value relative to  $R_3$ . Plus full scale (gain) is set by adjusting  $R_2$  relative to  $R_1$ .

Practical circuit realisations are given in Fig. 9.

Note that in the  $\pm 5V$  case  $R_3$  has been chosen as 7.5k $\Omega$  (instead of 8.2k $\Omega$ ) to get a more symmetrical range of adjustment using standard potentiometers. Settling time for a major transition is 1.5 $\mu s$  typical.

T-51-09-08



$\pm 2\%$  RESISTORS  
 $\pm 20\%$  POTENTIOMETERS

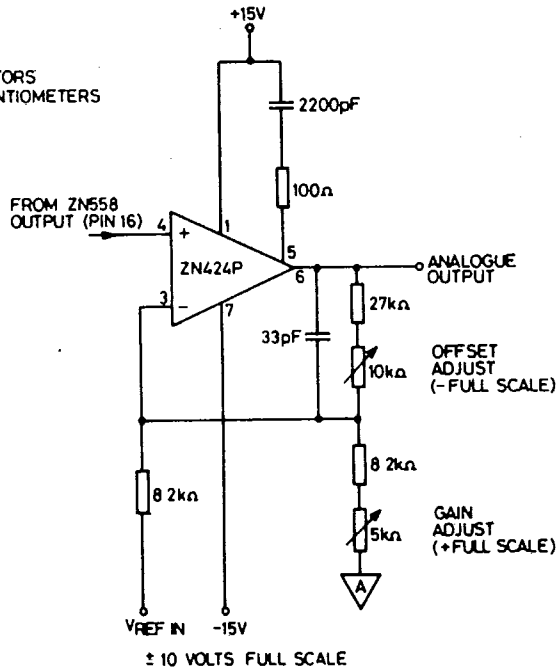


Fig. 9 Bipolar operation - component values

T-51-09-08

**Bipolar Adjustment Procedure**

- (1) Set all bits to OFF (low) with enable low and adjust offset until the amplifier output reads  $-$  full scale.
- (2) Set all bits ON (high) and adjust gain until the amplifier output reads  $+$  (full scale - 1LSB).

**BIPOLAR SETTING UP POINTS**

| Input range, $\pm$ FS | LSB    | $-$ FS       | $+$ (FS - 1LSB) |
|-----------------------|--------|--------------|-----------------|
| $\pm$ 5V              | 39.1mV | $-$ 5.0000V  | $+$ 4.9609V     |
| $\pm$ 10V             | 78.1mV | $-$ 10.0000V | $+$ 9.9219V     |

$$1\text{LSB} = \frac{2\text{FS}}{256}$$

**BIPOLAR LOGIC CODING**

| Input code<br>(Offset binary) | Analogue output<br>(Nominal value) |
|-------------------------------|------------------------------------|
| 11111111                      | $+$ (FS - 1LSB)                    |
| 11111110                      | $+$ (FS - 2LSB)                    |
| 11000000                      | $+$ $\frac{1}{2}$ FS               |
| 10000001                      | $+$ 1LSB                           |
| 10000000                      | 0                                  |
| 01111111                      | $-$ 1LSB                           |
| 01000000                      | $-$ $\frac{1}{2}$ FS               |
| 00000001                      | $-$ (FS - 1LSB)                    |
| 00000000                      | $-$ FS                             |