Low cost 8-bit monolithic D-A converter
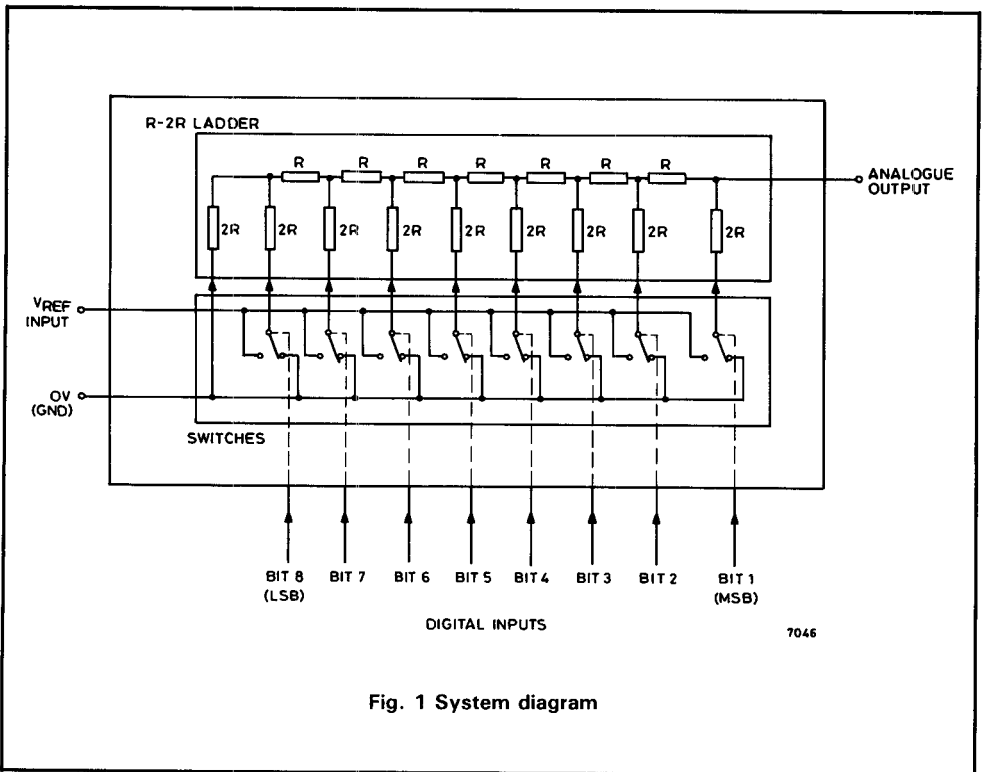
ZN429E-8
ZN429J-8
ZN429D

FEATURES

- ZN429E-8 and ZN429D (SO-14) Commercial temperature range O to 70°C
- ZN429J-8 Military temperature range − 55 to + 125°C
- Linearity error ± ½ LSB
- Single + 5V supply
- Low power consumption : 25mW typ.
- Settling time : 1μs typ.
- TTL and 5V CMOS compatible
- Designed for low-cost applications

DESCRIPTION

The ZN429 is a monolithic 8-bit D-A converter, containing an R-2R ladder network of diffused resistors with precision bipolar switches.

The recent introduction of the miniature SO-14 package allows a combination of reduced size and surface mountability which enables smaller and simpler P.C.B's. to be constructed.

Fig. 1 System diagram

ZN429E-8 ZN429J-8 ZN429D

INTRODUCTION

The ZN429 is an 8-bit D-A converter. It contains an advanced design of R-2R ladder network and an array of precision bipolar switches on a single monolithic chip.

The special design of ladder network results in full 8-bit accuracy using normal diffused resistors.

The converter is of the voltage switching type and uses an R-2R resistor ladder network as shown in Fig. 2.
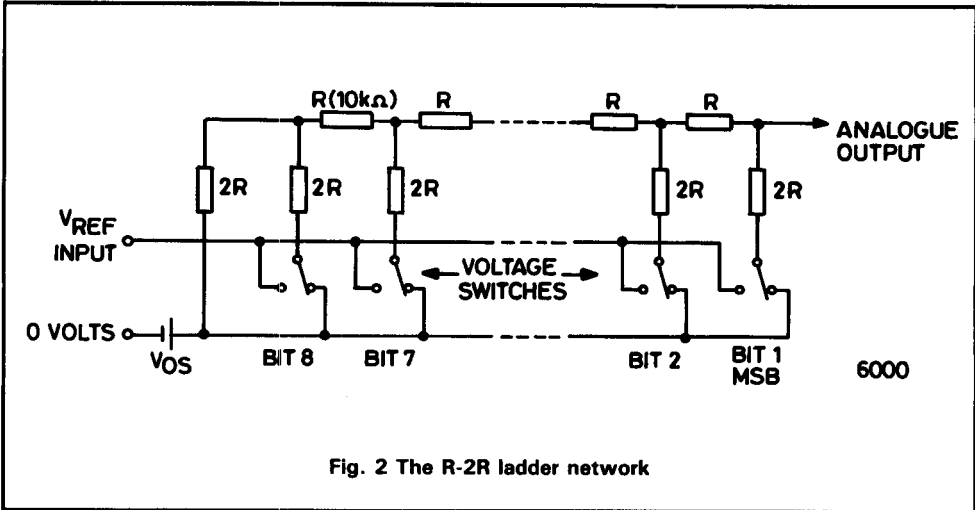

Fig. 2 The R-2R ladder network

Each 2R element is connected either to 0V or V_{REF} by transistor switches specially designed for low offset voltage (typically 1mV).

Binary weighted voltages are produced at the output of the R-2R ladder, the value depending on the digital number applied to the bit inputs.

An external fixed or varying reference is required which should have a slope resistance less than 2Ω.

Suggested external reference sources are the ZN404 or one of the ZN458 range. Each ZN404 is capable of supplying up to five ZN429 circuits and this is increased to ten for the ZN458 range.

ORDERING INFORMATION

Device type	Operating temperature	Package
ZN429E-8	0 to +70°C	Plastic D.I.L.
ZN429J-8	−55 to +125°C	Ceramic D.I.L.
ZN429D	0 to +70°C	Plastic SO-14

ABSOLUTE MAXIMUM RATINGS

Supply voltage, V_{CC} .. .. +7V

Max. voltage, logic and V_{REF} inputs .. .. .. +5.5V

Storage temperature range .. .. −55 to +125°C

ZN429E-8 ZN429J-8 ZN429D

ELECTRICAL CHARACTERISTICS (at $T_{amb} = 25°C$ and $V_{CC} = +5V$ unless otherwise specified).

Parameter	Symbol	Min.	Typ.	Max.	Units	Conditions
Converter						
Resolution		8	–	–	Bits	
Accuracy		8	–	–	Bits	
Non-linearity		–	–	± 0.5	LSB	Note 1
Differential non-linearity		–	± 0.5	–	LSB	Note 2
Settling time to 0.5LSB		–	1.0	–	μs	1 LSB step
Settling time to 0.5LSB		–	2.0	–	μs	All bits ON to OFF or OFF to ON

Offset voltage
  ZN429J-8
  ZN429E-8, ZN429D
	V_{OS}	–	5.0
			3.0
				8.0
				5.0
					mV
					mV
						All bits OFF note 1

V_{OS} temperature co-efficient		–	5	–	$\mu V/°C$	
Full-scale output		2.545	2.550	2.555	V	All bits ON Ext. $V_{REF} = 2.56V$
Full-scale temperature coefficient		–	3	–	ppm/°C	Ext. $V_{REF} = 2.560V$
Non-linearity temp. co-efficient		–	7.5	–	ppm/°C	Relative to F.S.R.
Analogue output resistance	R_O	–	10	–	$k\Omega$	
External reference voltage		0	–	3.0	V	
Supply voltage	V_{CC}	4.5	–	5.5	V	
Supply current	I_S	–	5	9	mA	
High level input voltage	V_{IH}	2.0	–	–	V	
Low level input voltage	V_{IL}	–	–	0.7	V	
High level input current	I_{IH}	– –	– –	10 100	μA μA	$V_{CC} = $ max, $V_I = 2.4V$ $V_{CC} = $ max, $V_I = 5.5V$
Low level input current	I_{IL}	–	–	–0.18	mA	$V_{CC} = $ max, $V_I = 0.3V$

Notes:

1. The ZN429J-8 differs from the ZN429E-8 and the ZN429D in the following respects:

   (a) For the ZN429J-8, the maximum linearity error may increase to $\pm 0.4\%$ FSR i.e. ± 1LSB over the temperature ranges -55 to 0°C and $+70$ to $+125°C$.

   (b) Offset voltage. The difference is due to package lead resistance. This offset will normally be removed by the setting up procedure, and because the offset temperature coefficient is low, the specified accuracy will be maintained.

2. Monotonic over full temperature range.

ZN429E-8 ZN429J-8 ZN429D

APPLICATIONS

(1) Unipolar D-A converter

The nominal output range of the ZN429 is 0 to $V_{REF\ IN}$ through a 10kΩ resistance. Other output ranges can readily be obtained using an external amplifier.

The resulting full-scale range is given by

$$V_{OUT\ FS} = \left(1 + \frac{R1}{R2} \right) V_{REF\ IN} = G.\ V_{REF\ IN}$$

The impedance at the inverting input is R1//R2

and for low drift with temperature this parallel combination should be equal to the ladder resistance (10kΩ). The required nominal values of R1 and R2 are given by

$$R1\ =\ 10G k\Omega\ \text{and}\ R2\ =\ 10G/(G-1)\ k\Omega$$

Using these relationships a table of nominal resistance values for R1 and R2 can be constructed for $V_{REF\ IN}\ =\ 2.5V$.

Output range	G	R1	R2
+ 5V	2	20kΩ	20kΩ
+ 10V	4	40kΩ	13.33kΩ

For gain setting R1 is adjusted about its nominal value. Practical circuit realisations (including amplifier stabilising components) for + 5 and + 10V output ranges are given in Fig. 4. Settling time for a major transition is 2.5µs typical.

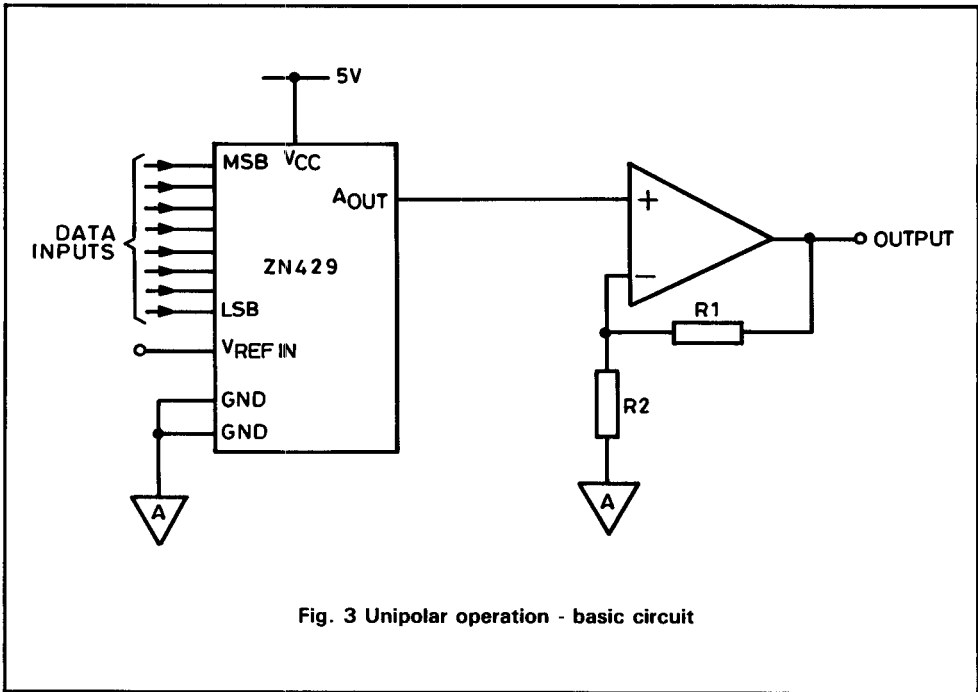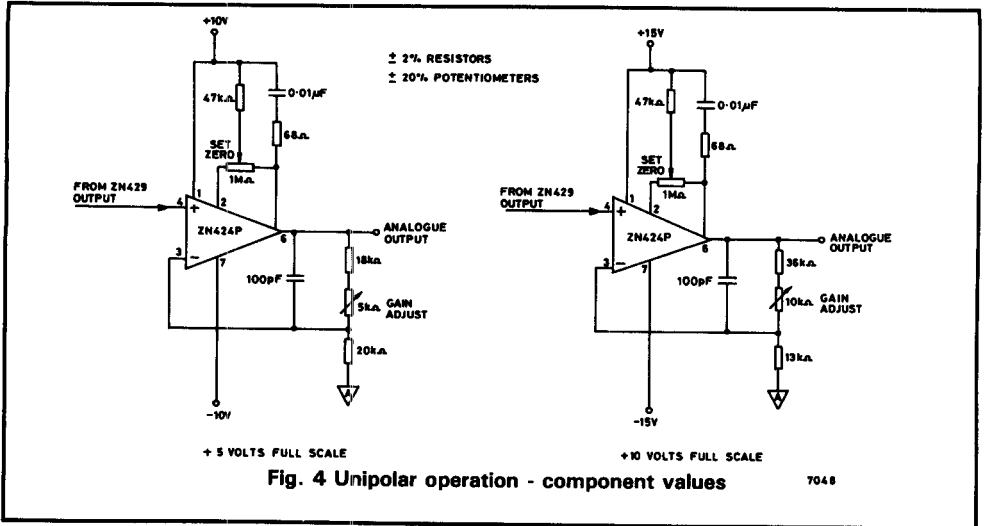Fig. 3 Unipolar operation - basic circuit

Fig. 4 Unipolar operation - component values 7048

UNIPOLAR ADJUSTMENT PROCEDURE

(i) Set all bits to OFF (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

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

UNIPOLAR LOGIC CODING

Input code (Binary)	Analogue output (Nominal value)
11111111	FS − 1LSB
11111110	FS − 2LSB
11000000	¾FS
10000001	½FS + 1LSB
10000000	½FS
01111111	½FS − 1LSB
01000000	¼FS
00000001	1LSB
00000000	0

ZN429E-8 ZN429J-8 ZN429D

(2) Bipolar D-A converter

For bipolar operation the output from the ZN429 is offset by half full-scale by connecting a resistor R3 between $V_{REF\ IN}$ and the inverting input of the buffer amplifier (Fig. 5).
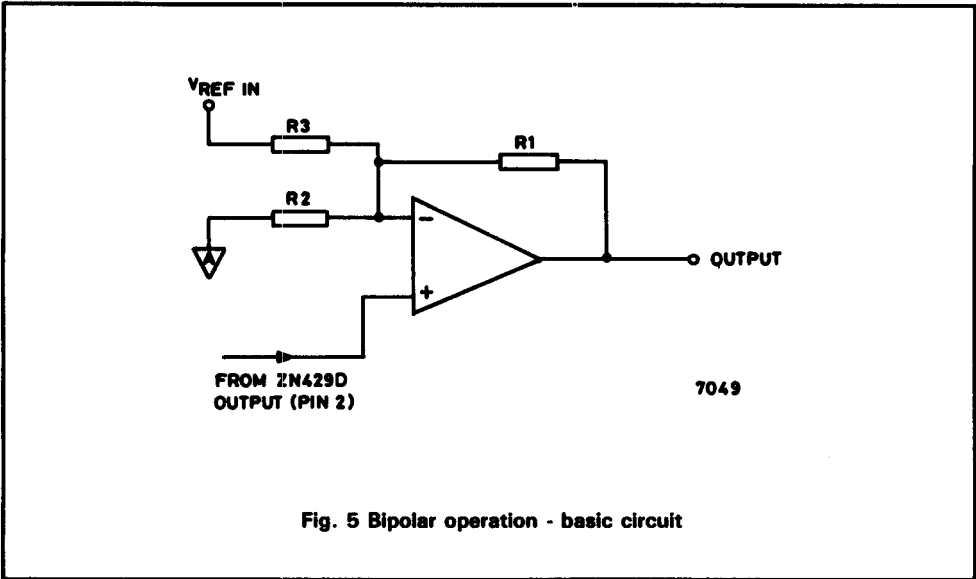

Fig. 5 Bipolar operation - basic circuit

When the digital input of the ZN429 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 ZN429 output of $\simeq V_{REF\ IN}$ and the amplifier output required is + full-scale. Also, to match the ladder resistance, the parallel combination of R1, R2 and R3 should be 10kΩ.

The nominal values of R1, R2 and R3 which meet these conditions are given by

$R1 = 20G k\Omega$, $R2 = 20G/(G-1)k\Omega$ and $R3 = 20k\Omega$

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

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

Output range	G	R1	R2	R3
± 5V	2	40kΩ	40kΩ	20kΩ
± 10V	4	80kΩ	26.67kΩ	20kΩ

Minus full-scale (OFFSET) is set by adjusting R1 about its nominal value relative to R3. Plus full-scale (GAIN) is set by adjusting R2 relative to R1

Settling time for a major transition is 2.5μs typical.

Fig. 6 Bipolar operation component values

7050
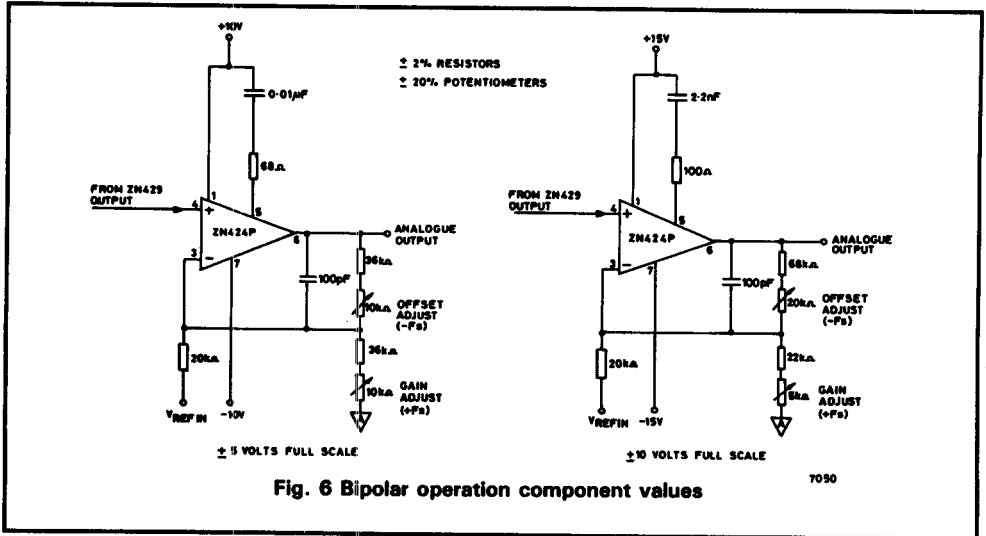
BIPOLAR ADJUSTMENT PROCEDURE

(i)   Set all bits to OFF (LOW) and adjust OFFSET until the amplifier output reads – FULL-SCALE.

(ii) Set all bits ON (HIGH) and adjust gain until the amplifier reads + (FULL-SCALE - 1LSB).

BIPOLAR SETTING UP POINTS

Input range, ±FS	LSB	– FS	+ (FS - 1LSB)	
± 5V	39.1mV	– 5.0000V	+ 4.9609V	$1LSB = \dfrac{2FS}{256}$
± 10V	78.1mV	– 10.0000V	+ 9.9219V	

BIPOLAR LOGIC CODING

Input code (Offset binary)	Analogue output (Nominal value)
11111111	+ (FS − 1LSB)
11111110	+ (FS − 2LSB)
11000000	+ ½ FS
10000001	+ 1LSB
10000000	0
01111111	− 1LSB
01000000	− ½ FS
00000001	− (FS - 1LSB)
00000000	− FS

ZN429E-8 ZN429J-8 ZN429D

For both unipolar and bipolar operation, an alternative output buffer, employing the 741 operational amplifier, or any other suitable op-amp, may be used.

The feedback resistors chosen are as indicated in the relevant sections.

The following circuit shows the use of the 741 in the unipolar operation mode for a voltage output range of 0→5V with a 2.5V reference.
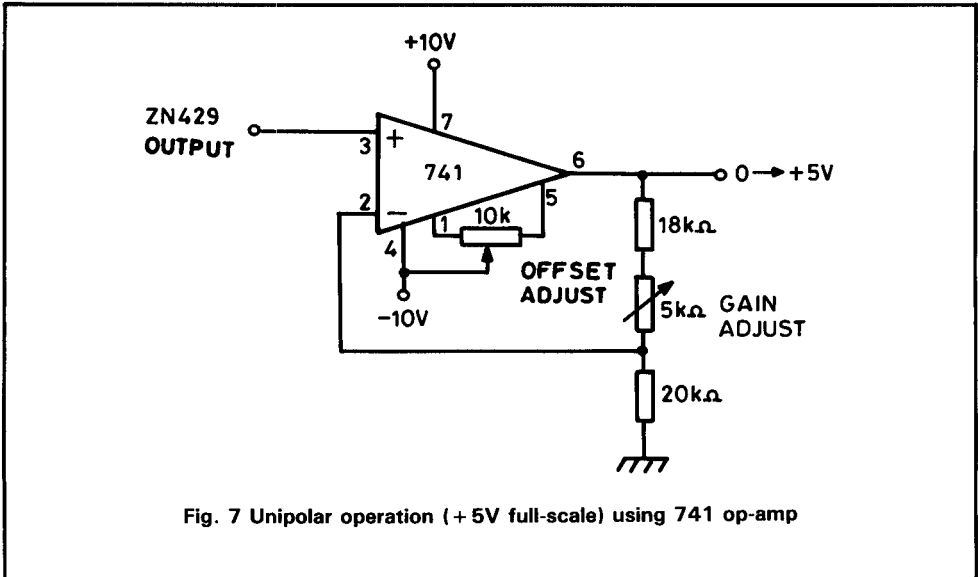
Fig. 7 Unipolar operation (+5V full-scale) using 741 op-amp

PIN CONNECTIONS

	ZN429D	
N.C. 1		14 BIT 1
ANALOGUE OUTPUT 2		13 BIT 2
VREF IN 3		12 BIT 3
GND 4		11 +Vcc
BIT 8 5		10 BIT 4
BIT 7 6		9 BIT 5
GND 7		8 BIT 6

7051

	ZN429E / J8	
BIT 3 1		14 +Vcc (+5 VOLTS)
BIT 2 2		13 BIT 4
(MSB) BIT 1 3		12 BIT 5
ANALOGUE OUTPUT 4		11 BIT 6
VREF IN 5		10 BIT 7
N.C. 6		9 BIT 8 (LSB)
OV 7		8 N.C.

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