DIGITAL TO ANALOG CONVERTORS

(DACS)

$$\boxed{V_{OUT} = V_R \left[b_1 2^{-1} + b_2 2^{-2} + \cdots + b_n 2^{-n} \right]}$$

BINARY

V_{OUT} = ANALOG OUTPUT VOLTAGE

V_R = REFERENCE VOLTAGE

$b_1, b_2 \cdots b_n$ = n BIT BINARY WORD

$$\boxed{V_{OUT} = \frac{N}{2^n} \times V_{REF}}$$

HEX

ph WHAT IS THE OUTPUT VOLTAGE OF A 10 BIT ADC WITH A 10.0 V REFERENCE IF THE INPUT IS

(a) 001 0110 101 = 0B5H

(b) 20 FH ?

WHAT INPUT IS NEEDED TO GET A 6.5V OUTPUT?

(a) 001 0110 101

10 9 8 7 6 5 4 3 2 1

b_{10} b_9 b_8 b_7 b_6 b_5 b_4 b_3 b_2 b_1

$$V_{OUT} = V_R \left[b_1 2^{-1} + b_2 2^{-2} + --- b_n 2^{-n} \right]$$

$$= 10 \left[1 \times 2^{-1} + 0 \times 2^{-2} + 1 \times 2^{-3} + 0 \times 2^{-4} + 1 \times 2^{-5} + 1 \times 2^{-6} + 0 \times 2^{-7} + 1 \times 2^{-8} + 0 \times 2^{-9} + 0 \times 2^{-10} \right]$$

$$= 10 \times 0.1767528$$

$$= 1.762528 \text{ V}$$

(b) $20FH$

$$\begin{array}{ccc} 2 & 0 & F\,H \\ \uparrow & \uparrow & \uparrow \\ 2 & 1 & 0 \end{array}$$

$$2 \times 16^{2} + 0 \times 16^{1} + 15 \times 16^{0} = 527_{10}$$

$$V_{OUT} = \frac{N}{2^{n}} V_{REF}$$

$$= \frac{527}{2^{10}} \times 10 = 5.164\cancel{8}\,V$$

FOR 6.5 V OUTPUT

$$V_{OUT} = \frac{N}{2^{n}} \times V_{REF}$$

$$6.5 = \frac{N}{2^{10}} \times 10 \rightarrow N = \frac{6.5 \times 2^{10}}{10} = 665.6\,V$$

$\Delta V_{OUT} = V_r \times 2^{-n}$

ΔV_{OUT} = SMALLEST OUTPUT CHANGE

V_r = REFERENCE VOLTAGE

n = NUMBER OF BITS IN THE WORD

Pb CALCULATE ΔV_{OUT} FOR 5 BIT D/A CONVERTER WITH 10V REFERENCE.

$$\Delta V_{OUT} = V_r \times 2^{-n}$$

$$= 10 \times 2^{-5}$$

$$= \frac{10}{2^5}$$

$$= \frac{10}{32}$$

$$= 0.3125 \text{ V/BIT}$$

Pb DETERMINE HOW MANY BITS A D/A CONVERTER MUST HAVE TO PROVIDE OUTPUT INCREMENT OF 0.04 VOLT (OR) LESS. THE REFERENCE IS 10V.

$$\Delta V = \text{INCREMENT VOLTAGE} = V_r \times 2^{-n}$$

$$0.04 = 10 \times 2^{-n}$$

$$\log 0.04 = \log 10 \times 2^{-n}$$

$$\log 0.04 = \log 10 + \log 2^{-n}$$

$$\log 0.04 = \log 10 + (-n) \log 2$$

$$\log 0.04 = 1 - n \log 2$$

$$n \log 2 = 1 - \log 0.04$$

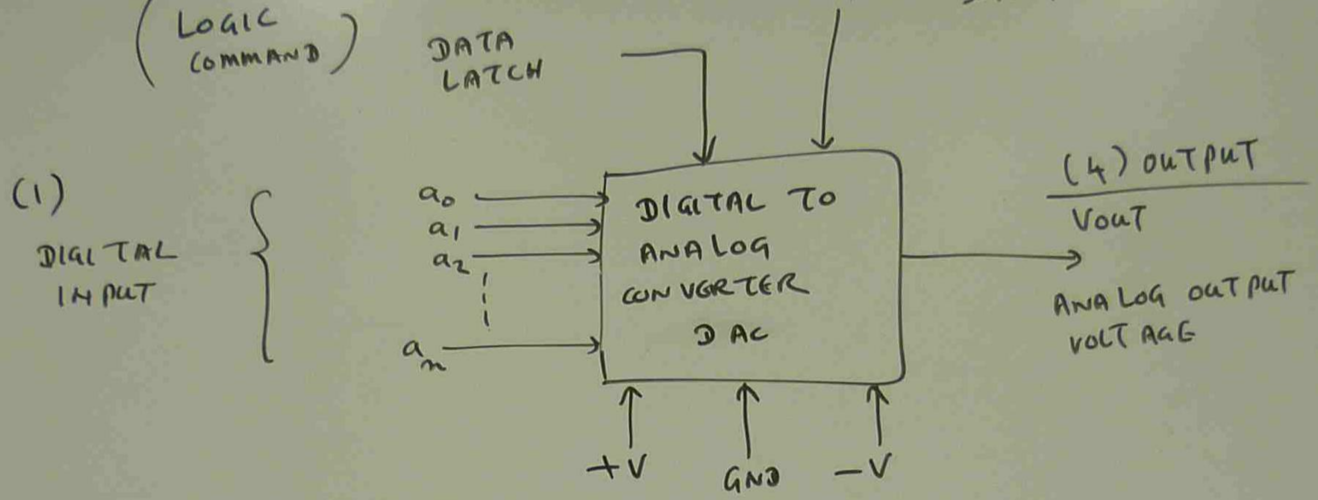
$$n = \frac{1 - \log 0.04}{\log 2} = 7.966 \simeq 8$$

BIT = 8 BIT

$$\Delta V_{OUT} = V_r \times 2^{-n} \rightarrow = 10 \times 2^{-8} = 0.03906\text{V}$$

DAC CHARACTERISTICS

(3) V_R = REFERENCE SUPPLY VOLTAGE (low RIPPLE SOURCE)



(2) POWER SUPPLY

$\pm 12V \longrightarrow \pm 18V$

OFFSET

THE DAC IS USUALLY IMPLEMENTED WITH OP-AMP.

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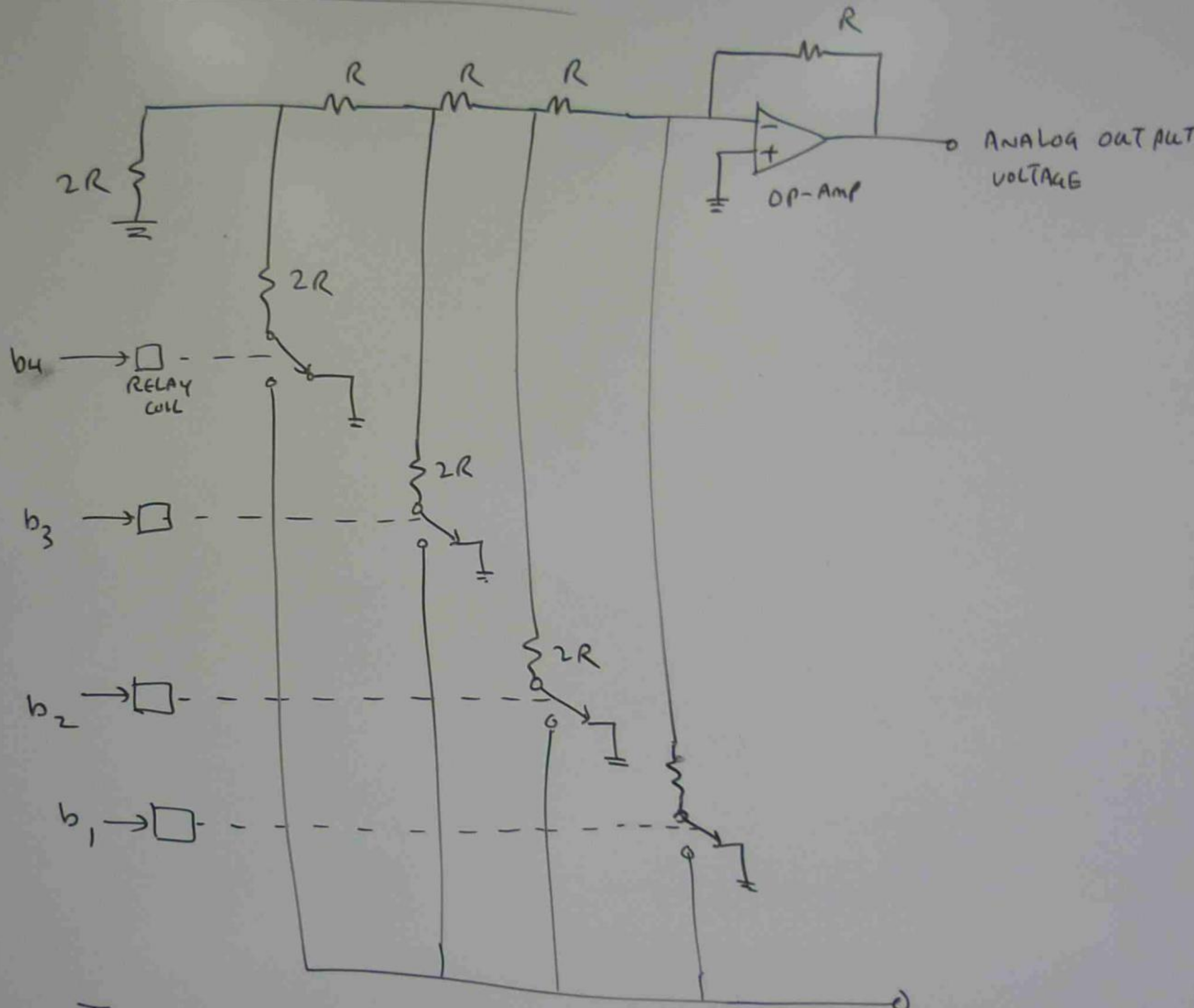
THERE MAY BE TYPICAL OUTPUT OFFSET VOLTAGE WITH ZERO INPUT.

THE LADDER NETWORK



THE LADDER NETWORK IS OFTEN USED TO IMPLEMENT THE DAC FUNCTIONS.

pb A CONTROL VALVE HAS A LINEAR VARIATION OF OPENING AS THE INPUT VOLTAGE VARIES FROM 0 TO 10V.

A MICRO COMPUTER OUTPUTS AN 8 BIT WORD TO CONTROL VALVE OPENING USING AN 8 BIT DAC TO GENERATE THE VALVE VOLTAGE (a) FIND THE REFERENCE VOLTAGE REQUIRED TO OBTAIN A FULL OPEN VALVE (10V) (b) FIND THE PERCENTAGE OF VALVE OPENING FOR 1 BIT CHANGE IN THE INPUT WORD.

(a) FULL OPENING OF VALVE, ALL 8 BITS ARE ONES.

$$V_{OUT} = V_{REF}\left[2^{-1} + 2^{-2} + 2^{-3} + \cdots 2^{-8}\right]$$

$$= 10\left[\frac{1}{2} + \frac{1}{2^2} + \frac{1}{2^3} + \cdots \frac{1}{2^8}\right]$$

$$= 10\left[\frac{1}{2} + \frac{1}{4} + \frac{1}{8} + \cdots + \frac{1}{256}\right]$$

$$= 10.039\,V$$

IT NEEDS LARGER REF: VOLTAGE

(b) $\Delta V_{out} = V_r \times 2^{-n}$

1 BIT CHANGE

$$\Delta V_{out} = 10.039 \times 2^{-8} = 0.0392V$$

$$\% \text{ CHANGE} = \frac{\Delta V_{out}}{V_r} \times 100 = \frac{0.0392}{10} \times 100 = 0.392\%$$

MICROPROCESSOR COMPATIBLE DAC

DATA OUTPUT BOARDS

ADDRESS DECODING, BUS INTERFACE, C, BASIC, ASSEMBLY.

ANALOG TO DIGITAL CONVERTER (ADC)

$$\boxed{\text{PROCESS}} \xrightarrow{\text{ANALOG}} \boxed{\text{ADC}} \xrightarrow{\text{DIGITAL}} \boxed{\text{COMPUTER}}$$

$$\Delta v = V_r \, 2^{-n}$$

$$V_{IN} = V_R \left[b_1 2^{-1} + b_2 2^{-2} + \cdots b_n 2^{-n} \right]$$

V_{IN} = ANALOG VOLTAGE INPUT

V_r = REFERENCE VOLTAGE

$b_1 \, b_2 \cdots b_n$ = N BIT.

Pb TEMPERATURE IS MEASURED BY A SENSOR WITH AN OUTPUT OF $0.02 \; V/°C$. DETERMINE THE REQUIRED ADC REFERENCE AND WORD SIZE TO TO MEASURE $0 \rightarrow 100°C$ WITH $0.1°C$ RESOLUTION.

V_r = MAXIMUM TEMPERATURE °C × V/°C

$V_r = 100 \times 0.02 = 2V \leftarrow$

ΔV = RESOLUTION × V/°C

$= 0.1 \times 0.02 = 0.002\,V \leftarrow$

WORD SIZE = BIT = n = ?

$$\Delta V = V_r \times 2^{-n}$$

$$0.002 = 2 \times 2^{-n}$$

$$0.001 = 2^{-n}$$

$$\log 0.001 = \log 2^{-n}$$

$$\log 10^{-3} = -n \log 2$$

$$-3 \log 10 = -n \log 2$$

$$n = \frac{\cancel{-}3 \log 10}{\cancel{-} \log 2} = \frac{3 \times 1}{0.3010} \simeq 9.996 \simeq 10$$

10 BIT WORD IS REQUIRED FOR RESOLUTION.

$$\Delta V = V_r \times 2^{-n}$$
$$= 2 \times 2^{-10}$$
$$= 2^{-9} = \frac{1}{2^9} \simeq 0.00195V$$

Pb FIND THE DIGITAL WORD THAT RESULTS FROM A 3.127 V INPUT TO A 5 BIT ADC WITH A 5 VOLT REFERENCE.

THE RELATIONSHIP BETWEEN INPUT & OUTPUT

$$V_{IN} = V_r \left[a_1 2^{-1} + a_2 2^{-2} + a_3 2^{-3} + a_4 2^{-4} + a_5 2^{-5}\right]$$

$$3.127 = 5 \left[a_1 2^{-1} + a_2 2^{-2} + a_3 2^{-3} + a_4 2^{-4} + a_5 2^{-5}\right]$$

$$\frac{3.127}{5} = a_1 2^{-1} + a_2 2^{-2} + a_3 2^{-3} + a_4 2^{-4} + a_5 2^{-5}$$

$$0.6254 = a_1 2^{-1} + a_2 2^{-2} + a_3 2^{-3} + a_4 2^{-4} + a_5 2^{-5}$$

DIGITAL

$0.6254 \times 2 = 1.2508 \longrightarrow a_1 = 1$

$0.2508 \times 2 = 0.5016 \longrightarrow a_2 = 0$

$0.5016 \times 2 = 1.0032 \longrightarrow a_3 = 1$

$0.0032 \times 2 = 0.0064 \longrightarrow a_4 = 0$

$0.0064 \times 2 = 0.0128 \longrightarrow a_5 = 0$

$(a_1 a_2 a_3 a_4 a_5)_2$

OUTPUT 10100_2

Pb THE INPUT TO A 10BIT ADC WITH A 2.5V REFERENCE IS 1.45V. WHAT IS THE HEX OUTPUT? SUPPOSE THE OUTPUT IS FOUND TO BE 1B4H. WHAT IS THE VOLTAGE INPUT?

1.45V

$$\boxed{\text{INTEGER PART OF ACTUAL OUTPUT (N BIT)} = \frac{V_{IN}}{V_r} \times 2^n}$$

$$= \frac{1.45}{2.5} \times 2^{10}$$

$$= 593$$

16	593	1
16	37	5
	2	

$\longrightarrow$ 251H

1B4H

$\uparrow \uparrow \uparrow$

2 1 0

$$1 \times 16^2 + 11 \times 16^1 + 4 \times 16^0$$

$$= 436\ V$$

$$INT(N) = \frac{V_{IN}}{V_r} \times 2^n$$

$$436 = \frac{V_{IN}}{2.5} \times 2^{10}$$

$$V_{IN} = \frac{436 \times 2.5}{2^{10}}$$

$$= 1.06445V$$

BIPOLAR OPERATION

A BIPOLAR ADC IS THE ONE WHICH ACCEPTS INPUT BIPOLAR VOLTAGE FOR CONVERSION INTO AN APPROPRIATE DIGITAL OUTPUT.

THE NORMAL OUTPUT IS SHIFTED BY HALF, THE SCALE SO THAT ALL ZEROS CORRESPOND TO THE NEGATIVE MAXIMUM INPUT VOLTAGE INSTEAD OF ZERO

$$INT(N) = \frac{1}{V_R}\left[V_{IN} + \frac{V_R}{2}\right] \times 2^n$$

BY INCREASING ONE DIGITAL STEP, DECIMAL IS REPRESENTED.

pb REFERENCE VOLTAGE = 10 V, 8 BITS

IF −5 V IS REPRESENTED AT ALL BITS ZERO CONDITION, (REF)

DETERMINE THE ONE STEP INCREMENT OF BIT.

$$\Delta V_{IN} = \frac{V_{REF}}{2^n} = \frac{10}{2^8} = 0.039V$$

$$-5V \longrightarrow 00000000_2$$

$$(1)\,STEP \rightarrow -5V + 0.039 = -4.961 \rightarrow 00000001_2$$

ONE WHICH ACCEPTS INPUT BIPOLAR
TO AN APPROPRIATE DIGITAL OUTPUT.

FTED BY HALF, THE SCALE SO
D TO THE NEGATIVE MAXIMUM
OF ZERO

$$\left[V_{IN} + \frac{V_R}{2} \right] \times 2^n$$

E= 10 V, 8 BITS

PRESENTED AT ALL BITS ZERO CONDITION, (REF)
NE STEP INCREMENT OF BIT.

$$= \frac{10}{2^8} = 0.039V$$

$\longrightarrow 00000000$

$-4.961 \rightarrow 00000001_2$

2

BY INCREASING
ONE DIGITAL STEP,
DECIMAL IS
REPRESENTED.

$-5 + 0.039 \times 2 \rightarrow 00000010$

$-5 + 0.039 \times 3 \rightarrow 00000011$

$-5 + 0.039 \times 4 \rightarrow 00000100$

ph — WHAT IS THE HEX AND BINARY OUTPUT OF A BIPOLAR 8 BIT ADC WITH A 5 V REFERENCE FOR INPUTS OF −0.85 V AND +1.5 V? WHAT INPUT VOLTAGE WOULD CAUSE AN OUTPUT 72 H?

$V_R = 5V$, $n = 8$

$$INT(N) = \frac{1}{V_R}\left(V_{IN} + \frac{V_R}{2}\right)2^n$$

$$= \frac{1}{5}\left(-0.85 + \frac{5}{2}\right)2^8$$

$$= 84\,V$$

HEX

$84_{10} \rightarrow$ HEX

16 | 84 | 4

| 5

54H

$84_{10} \rightarrow$ BINARY

2	84	0
2	42	0
2	21	1
2	10	0
2	5	1
2	2	0
	1	

8 BIT

$1010100 \rightarrow 01010100_2$

← 7 BIT →

← COMPARISON

OUTPUT 72 H

7 2 H →

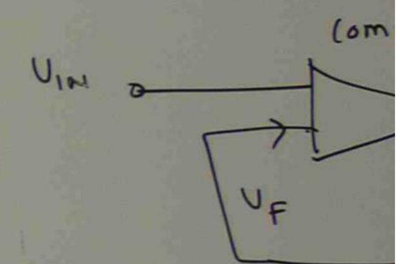
1 0 =

$INT(N) = V_{IN} = \frac{1}{V_R}$

$114 = \frac{1}{5}$

$V_{IN} = -$

PARALLEL FEED



COMPARATOR COMP

INPUT VOLTAGE V

TO FEEDBACK

POLAR

of

USE

$0\,1\,0\,1\,0\,0_2$

OUTPUT 72 H

$72\,H \rightarrow 7\times16^1 + 2\times16^0$

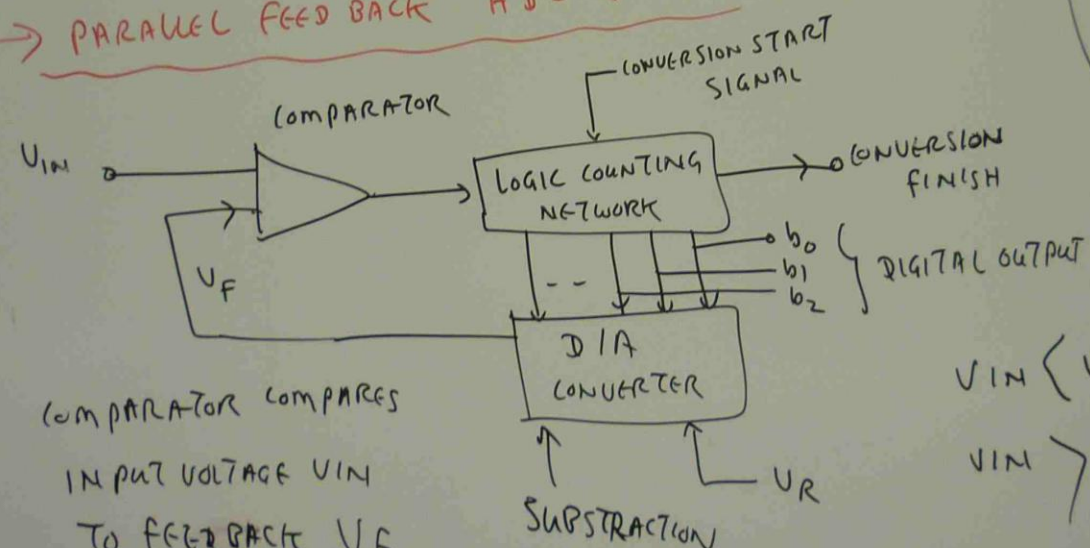
$= 114\ \underline{\underline{V}}$

$$INT(N) = V_{IN} = \frac{1}{V_R}\left(V_{IN} + \frac{V_R}{2}\right)2^n$$

$$114 = \frac{1}{5}\left(V_{IN} + \frac{5}{2}\right)2^8$$

$$V_{IN} = -0.2734\ V$$

PARALLEL FEED BACK ADC SYSTEM



COMPARATOR COMPARES INPUT VOLTAGE VIN TO FEEDBACK V_F.

b_1

$V_{IN} < V_R 2^{-1} \rightarrow$ ZERO

$V_{IN} > V_R 2^{-2} \rightarrow b_2 = 1$