LIQUID CRYSTAL DISPLAY (LCD) :-

* A LCD is a low-cost, low-power device capable of displaying text and images. LCD's are extremely common in embeded systems, Since such system often do not have video monitors like those that come standard with desktop systems.
  LCD's can be found in numerous common device like watches, fax, copy machines and calculators.

Basic principle :-

The basic principle of one type of LCD, a reflective LCD, works as follows. First, incoming light passes through a polarizing plate. Next, that polarized light encounters liquid crystal material

If we excite a region of this material, we cause the material molecules to align, which in turn causes the polarized light to pass through the material. otherwise, the light doesnot pass through.

Finally, light that passed through hits a mirror and reflects back, so the excited region appears to light up.

Another type of LCD, an absorption LCD works similarly, but uses a black surface instead of a mirror. The surface below the excited region absorbs light, thus appearing darker than the other regions.

A dot-matrix LCD consists of a matrix of dots that can display alphanumeric characters (letters and digits) as well as other symbols. A common dot-matrix LCD has five columns and eight rows of dots for one character

An LCD driver converts input data into the appropriate electrical signals necessary to excite the appropriate LCD dots.}

* Each type of LCD may be able to display multiple characters. Each characters may be displayed in normal or inverted fashion.

The LCD may permit a character to be blinking or may permit display of a cursor indicating the 'current' character (blinking underscore). Such functionality would be difficult for us to implement using software.

Thus, we use an LCD controller to provide ~~up~~ us with a simple interface to an LCD having 8-data inputs (DB_0-DB_7) and one enable input.

* To send a byte to the LCD, we provide a value to the eight inputs and pulse the enable. This byte may be a control word, which instructs the LCD controller to initialize the LCD, clear the display, select the positions of the cursor, brighten the display.

* Alternately, this byte may be a data word, such as an ASCII characters, instructing the LCD to display the character at the currently-selected display position.

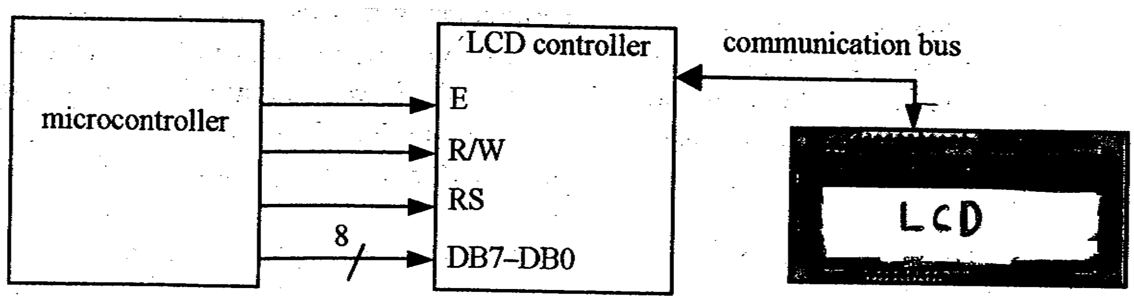

Fig ① a. LCD initialization Components

Codes	
I/D = 1 cursor moves left	DL = 1 8-bit
I/D = 0 cursor moves right	DL = 0 4-bit
S = 1 with display shift	N = 1 2 rows
S/C = 1 display shift	N = 0 1 row
S/C = 0 cursor movement	F = 1 5 × 10 dots
R/L = 1 shift to right	F = 0 5 × 7 dots
R/L = 0 shift to left	

```
void WriteChar(char c){
   /* indicate data being sent */
   RS = 1;
   /* send data to LCD */
   DATA_BUS = c;
   /* toggle LCD with delay */
   EnableLCD(45);
}
```

* In this example, a microprocessor is connected to an LCD controller, which in turn is connected to an LCD as shown in fig. 1 ⓐ. The LCD controller receives control words from the microcontroller, it decodes the control words and performs the corresponding action on the LCD

* once the initialization sequence is done, we can send control words or send actual data to be displayed.

* When RS is set to low to indicate that the data sent is control word.

* When RS is high, this indicates that the data sent over the communications bus corresponds to a character that is to be displayed.

* Everytime data is sent, whether it is a control word or data, the enable bit E must be toggled (ie ⎍)

* By using initialization code, the LCD has been set with an 8-bit interface. In addition, the display has been cleared, the cursor is in the home position, and the cursor moves to the right as data is displayed. The LCD is now ready to be written to.

* In order to write data, we set RS = 1. The actual data we want to write is on $DB_0 - DB_7$. The write char functions accepts a character which will be sent to the

LCD controller to display on the LCD.

The Enabled LCD(function toggles the enables bit and acts as a delay so that the command can be processed and executed.

KEYPAD CONTROLLERS :-

* A Keypad consist of a set of buttons that may be pressed to provide input to an embeded system. Again, keypads are extremely common in embeded system, since such systems may lack the keyboard that comes standard with desktop systems.

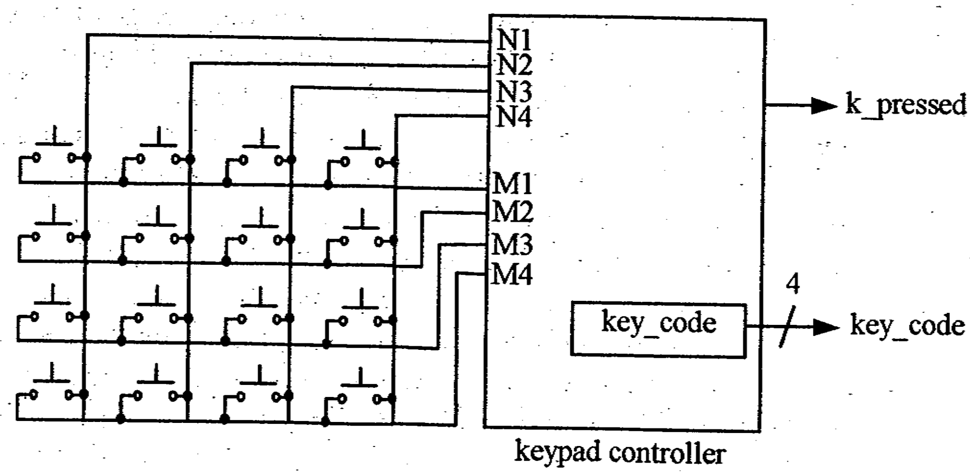

Figure ① Internal keypad structure, with $N = 4$ and $M = 4$.

Fig ① shows a simple keypad having buttons arranged in an N-coloumn by M-row grid.

The device has N outputs, each output corresponding to a coloumn, and another 'M' outputs, each output correspon-ds to a row.

When we press a button, one coloumn output and one row output go high, uniquely identifying the pressed button. To read such a keypad from software, we must scan the coloumn & row outputs. The scanning may be performed by a keypad controller. Such a device decodes rather than controls, but we will call it a "controller".

* Fig① shows the controller, which scans the coloumn and row outputs of the keypad. When the controller detects a button press, it stores a code corresponding to that button into a register, key-code, and sets an output high, k-pressed, indicating that a button has been pressed.

* The software may poll this o/p every 100 milliseconds or so and read the register when the o/p is high. Alternatively, this output can generate an interrupt on our general-purpose processor, eliminating the need for polling.

Analog to digital converter (ADC) :-

June-07,8M

❖ **Highlight the advantages of using data in digital form over its analog form. Explain the working of successive approximation types of analog to digital converter.**

* An analog-to-digital converter (ADC, A/D or A2D) converts an analog signal to a digital signal and a digital-to-analog converter (DAC, D/A or D2A) does the opposite.

* Analog refers to a continously valued signal, such as temperature or speed.

* Digital refers to discretely valued signals, such as integers. and these signals are encoded in binary.

For example, consider an analog input signals whose value could range from 0 to 7.5 volts. We want to represent each possible voltage inthis range using a 4 bit binary numbers. The 0000 would be the most obivious encoding for 0V and 1111 for 7.5V. The encodings between 0000 and 1111 would den be evenly distributed to the range between 0 and 7.5V. as shown in fig 1(a).

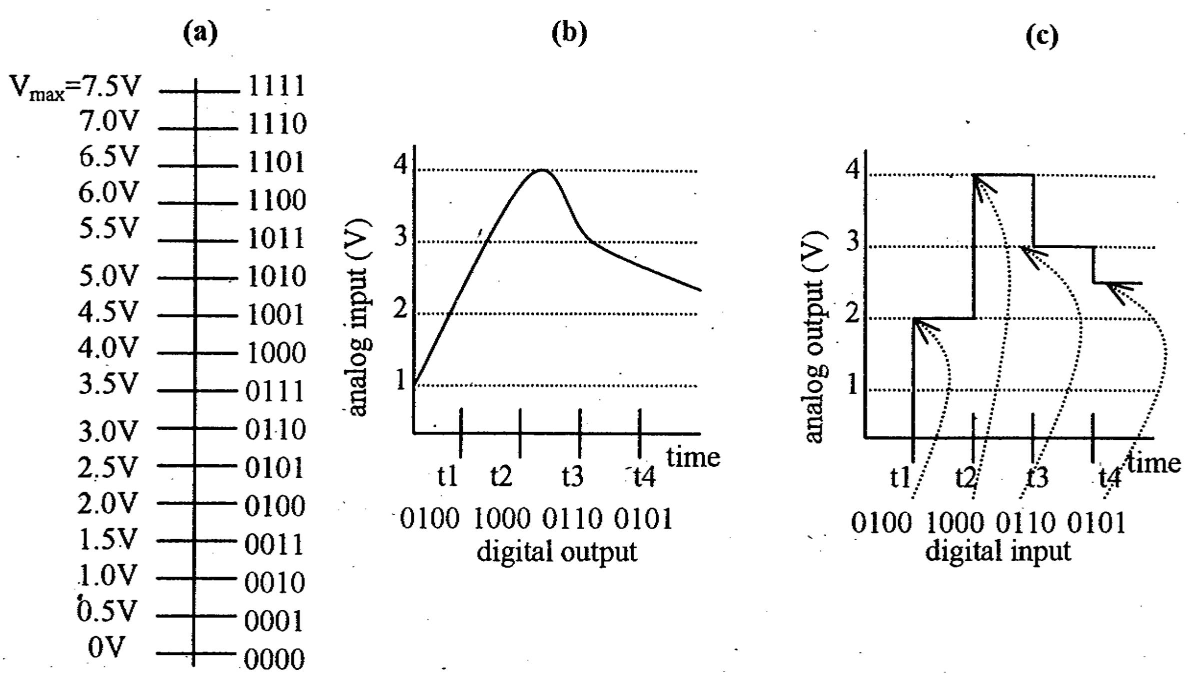

Figure 1 : Conversion: (a) proportionality, (b) analog-to-digital, (c) digital-to-analog.

Fig 1(b) ranging from 1V upto 4V and then down to just over 2V. The digital encoding of this signal, sampled at times t_1, t_2, t_3 and t_4, into four bits.

* We can compute the digital values from the analog values, and vice-versa using the following ratio:

$$\boxed{\frac{e}{V_{max}} = \frac{d}{(2^{n}-1)}}$$

Where

V_{max} is the maximum voltage that the analog signal can Assume n is the number of bits available for the digital encoding

d is the present digital encoding and

e is the present analog voltage.

For example: Suppose Vmax is 7.5V, Assume analog Voltage e = 3V, WKT it is a 4-bit converter ∴ n = 4

Then $$\frac{3V}{7.5V} = \frac{d}{2^4 - 1}$$

$$\frac{3 \times 15}{7.5V} = d$$

$$\therefore d = 6, \text{ or } 0110$$

* The resolution of ADC or DAC is $\frac{V_{max}}{2^n - 1}$. This represents the number of volts between "successive digital encoding"

$$\text{Resolution} = \frac{V_{max}}{(2^n - 1)} = \frac{7.5V}{2^4 - 1} = 0.5V.$$

∴ Resolution is 0.5V between successive encoding

---

1) Given an analog input signal whose voltage ranges from 0 to 15v and an 8-bit digital encoding is used. Calculate the correct encoding for 5v and then trace the successive approximation approach to find the correct encoding.

June-07,10M

Soln 1:- WKT the encoding should be

$$\frac{e}{V_{max}} = \frac{d}{2^n - 1}$$

When $V_{max} = V_{max} - V_{min}$

$$\frac{5}{15} = \frac{d}{2^8 - 1}$$

$$\frac{5}{15} \times (2^8 - 1) = d$$

$\boxed{d = 85}$ ← correct encoding.

$$\text{Resolution} = \frac{V_{max}}{2^n - 1} = \frac{15V}{2^8 - 1} = \frac{15}{255}$$

$\boxed{\text{Resolution} = 0.058823V}$

* Applying the successive approximation method we start by finding the halfway point between the maximum and minimum voltages.

Where $V_{max} = 15V$ & $V_{min} = 0V$

$$\therefore e' = \frac{V_{max} + V_{min}}{2} = \frac{15V + 0V}{2} = \underset{(e')}{7.5V}$$

* Since the above voltage is higher than the input voltage (5V). We insert a zero into the highest bit shown below.

∴

0	0	0	0	0	0	0	0

* Now $V_{max} = 7.5V$ and $V_{min} = 0V$

$$\therefore e' = \frac{V_{max} + V_{min}}{2} = \frac{7.5V + 0V}{2} = \underset{(e')}{3.75V}$$

Since $e' < e$ ie $3.75V < 5V$

$\therefore$ We insert a <u>one</u> into the next MSB as shown below

0	1	0	0	0	0	0	0

* Now $V_{max} = 7.5V$ & $V_{min} = 3.75V$

$$\therefore e' = \frac{V_{max} + V_{min}}{2} = \frac{7.5V + 3.5V}{2} = 5.63V$$

Since $e' > e$ ie $5.63V > 5V$

$\therefore$ We insert a <u>zero</u> into the next MSB as shown below.

0	1	0	0	0	0	0	0

* Now $V_{max} = 5.63V$ & $V_{min} = 3.75V$

$$\therefore e' = \frac{V_{max} + V_{min}}{2} = \frac{5.63V + 3.75V}{2} = 4.69V.$$

Since $e' < e$, we insert a <u>one</u> into next MSB as shown.

0	1	0	1	0	0	0	0

* Now $V_{max} = 5.63V$ & $V_{min} = 4.69V$

$$\therefore e' = \frac{V_{max} + V_{min}}{2} = \frac{5.63 + 4.69}{2} = 5.16V$$

Since $e' > e$, we insert a zero into next MSB as shown below.

0	1	0	1	0	1	0	0

* Now $V_{max} = 5.16V$ & $V_{min} = 4.93V$

$$\therefore e' = \frac{V_{max} + V_{min}}{2} = \frac{5.16V + 4.93V}{2} = 5.05V$$

Since $e' > e$, we insert a zero into the next MSB Bit as Shown Below.

0	1	0	1	0	1	0	0

* Now $V_{max} = 5.05V$ & $V_{min} = 4.93V$

$$\therefore e' = \frac{V_{max}+V_{min}}{2} = \frac{5.05V + 4.93V}{2} = 4.99V$$

Since $e' < e$, we insert a one into LSB as shown below.

0	1	0	1	0	1	0	1

$\therefore$ Resulting value $01010101 = 85d$

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2) Given an analog input signal whose voltage ranges from 0 to 5v and an 8-bit digital encoding. Calculate the correct encoding for 3.5v and then trace the successive approximation approach to find the correct encoding.

OR

Jan-11,8M

Determine the resolution of an 8-bit ADC with an analog input voltage range of 0 to 5V. Determine the digital encoding for 3.5 volts using a formula and trace the steps using successive approximation technique. Write successive approximation technique. Write the steps for this technique in the form of a table. With necessary columns/informations.

Jan-08,8M

Soln 2 :- Given $V_{max} = 5V$, $V_{min} = 0V$ $e = 3.5V$, $n = 8$-bit

WKT, The encoding should be

$$\frac{e}{V_{max}} = \frac{d}{(2^n - 1)}$$

$$\frac{3.5V}{5V} = \frac{d}{2^8 - 1}$$

$d = 178.5$

$d \approx 179 \rightarrow$ correct encoding

179 = 10110011

Using successive approximation approach.

1) $V_{max} = 5V$, $V_{min} = 0V$ $e = 3.5V$

$$e' = \frac{V_{max} + V_{min}}{2} = \frac{5V - 0V}{2} = 2.5V$$

Now $e' < e$ thus set MSB Bit 10000000

2) $V_{max} = 5V$ $V_{min} = 2.5V$

$$e' = \frac{V_{max} + V_{min}}{2} = \frac{5V + 2.5V}{2} = 3.75V$$

Now $e' > e$, thus clear the bit 10000000

3) $V_{max} = 3.75V$ $V_{min} = 2.5V$

$$e' = \frac{3.75V + 2.5V}{2} = 3.125V$$

Now $e' < e$ ie $3.125 < 3.5V$, thus set the bit

10100000

4) $V_{max} = 3.75V$, $V_{min} = 3.125V$

$$e' = \frac{3.75 + 3.125V}{2} = 3.437V$$

Now $e' < e$ ie $3.437V < 3.75V$, thus set the bit

10110000

5) $V_{max} = 3.75V$, $V_{min} = 3.43V$

$$e' = \frac{3.75V + 3.43V}{2} = 3.594V$$

Now $e' > e$, thus clear the bit 10110000.

6) $V_{max} = 3.594V$, $V_{min} = 3.437V$

$$e' = \frac{3.594 + 3.437}{2} = 3.515V$$

$e' > e$ thus clear the bit 10110000

7) $V_{max} = 3.515$ $V_{min} = 3.437$

$$e' = \frac{3.515 + 3.437}{2} = 3.476$$

$e' < e$, thus set the bit 10110010

8) $V_{max} = 3.515$ $V_{min} = 3.476$

$$e' = \frac{3.515 + 3.476}{2} = 3.4955$$

$e' < e$, thus set the bit 10110011.

$\therefore$ Resulting value 10110011 = 179 d.

❖ **Extend the ratio and resolution equations of analog to digital conversion to any voltage range between Vmin to Vmax rather than 0 to Vmax.**

* Ratio : $$\frac{(e - V_{min})}{(V_{max} - V_{min})} = \frac{d}{(2^n - 1)}$$

* Resolution : $$\frac{(V_{max} - V_{min})}{(2^n - 1)}$$

3) The analog input ranges for an 8-bit ADC is -5V to +5V. Determine the resolution of this ADC and also the digital output in binary when the input is 3.5V using formula. Also trace the successive approximation steps for verification. Write it in a tabular form with necessary columns.

June-09,8M

Given :- $V_{min} = -5V$, $V_{max} = +5V$, $n = 8$-bit & $e = 3.5V$

Soln :-

$$\frac{e - V_{min}}{(V_{max} - V_{min})} = \frac{d}{(2^n - 1)}$$

$$\frac{3.5 - (-5V)}{5V - (-5V)} = \frac{d}{(2^8 - 1)}$$

$$\frac{(3.5 + 5V)}{10V} = \frac{d}{(2^8 - 1)}$$

$$216.75 = d$$

$$\therefore \boxed{d = 217} \Rightarrow \boxed{11011001}$$

Using successive approximation approach :-

1) $V_{max} = 5V$, $V_{min} = -5V$, $e = 3.5V$

$$e' = \frac{V_{max} + V_{min}}{2} = \frac{5 - 5}{2} = 0V$$

Now $e' < e$, thus set the bit 1000 0000

2) $V_{max} = 5V$, $V_{min} = 0V$

$e' = \frac{5 + 0}{2} = 2.5V$ Now $e' < e$, thus set the bit

11000000.

3) $V_{max} = 5V$ $V_{min} = 2.5V$

$e' = \frac{5 + 2.5V}{2} = 3.75V$. Now $e' < e$, thus clear the bit

11 0 0 0 0 0 0

4) $V_{max} = 3.75V$, $V_{min} = 2.5V$

$$e' = \frac{3.75 + 2.5V}{2} = 3.125V.$$

Now e'<e, set the bit 1101 0000.

5) $V_{max} = 3.75V$, $V_{min} = 3.125V$

$$e' = \frac{3.75V + 3.125V}{2} = 3.4375V.$$

Now e'<e, thus set the bit 1101 1000

6) $V_{max} = 3.75V$, $V_{min} = 3.4375V$

$$e' = \frac{3.75 + 3.4375}{2} = 3.59375V$$

Now else. Thus clear the bit 11011000

7) $V_{max} = 3.59375V$ $V_{min} = 3.4375V$

$$e' = \frac{3.59375 + 3.4375}{2} = 3.515625V.$$

Now else, Thus clear the bit 11011000.

8) $V_{max} = 3.515625V$, $V_{min} = 3.4375V$

$$e' = \frac{3.515625 + 3.4375}{2} = 3.4765625V$$

Now e'<e. Thus set the bit 11011001

∴ Resulting value 11011001 = 217 d.

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4) Assume 8-bit encoding of input voltage in the range -5V to +5V. Calculate the encoding for 1.2V and trace the successive approximation approach to find the correct encoding. What is the resolution of the conversion? Extend the ratio and resolution equations to any voltage in the range V_{min} to V_{max}.

Given :- $V_{max} = 5V$, $V_{min} = -5V$ $n = 8$ bit $e = 1.2V$

Soln :-

$$\frac{e - (V_{min})}{V_{max} - V_{min}} = \frac{d}{2^n - 1}$$

$$\frac{1.2V - (-5V)}{5 - (-5V)} = \frac{d}{2^8 - 1}$$

$$\frac{1.2V + 5V}{10V} = \frac{d}{255}$$

$d = 158.1$

$\therefore$ Correct encoding $\boxed{d = 158 = 10011110}$.

1) $V_{max} = 5V$, $V_{min} = -5V$

$$e' = \frac{5 - 5}{2} = 0V$$

Now $e' < e$. Thus set the bit $\underline{1}0000000$.

2) $V_{max} = 5V$ $V_{min} = 0V$

$$e' = \frac{5 + 0}{2} = 2.5V$$

Now $e' > e$. Thus clear the bit $1\underline{0}000000$

3) $V_{max} = 2.5V$, $V_{min} = 0V$

$$e' = \frac{2.5 + 0}{2} = 1.25V$$

Now $e' > e$. Thus clear the bit $10\underline{0}00000$

4) $V_{max} = 1.25V$, $V_{min} = 0$

$$e' = \frac{1.25 + 0}{2} = 0.625V$$

Now $e' < e$. Thus set the bit $100\underline{1}0000$.

5) $V_{max} = 1.25V$, $V_{min} = 0.625V$

$$e' = \frac{1.25 + 0.625}{2} = 0.9375V$$

Now $e' < e$. Thus set the bit 10011000

6) $V_{max} = 1.25V$, $V_{min} = 0.9375V$

$$e' = \frac{1.25 + 0.9375V}{2} = 1.09375V$$

Now $e' < e$. Thus set the bit 10011100

7) $V_{max} = 1.25V$, $V_{min} = 1.09375V$

$$e' = \frac{1.25 + 1.09375}{2} = 1.171$$

Now $e' < e$. Thus set the bit 10011110

8) $V_{max} = 1.25V$, $V_{min} = 1.171$

$$e' = \frac{1.25 + 1.171}{2} = 1.2109V.$$

Now $e' > e$. Thus clear the bit 10011110

$\therefore$ Resulting value 10011110 = 158d

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5) In successive approximation ADC, calculate the correct encoding of 5V given an analog signal whose voltage ranges from 0 to 5V and an 8-bit digital encoding. Also determine the resolution of this ADC.

Jan-07,8M

Given :- $V_{max} = 5V$, $V_{min} = 0V$ $e = 5V$ $n = 8$-bits.

Soln :-

$$\frac{e}{(V_{max} - V_{min})} = \frac{d}{(2^n - 1)}$$

$$\frac{5}{(5-0)} = \frac{d}{(2^8-1)}$$

$$255 = d$$

$\therefore$ correct encoding $\boxed{d = 255 = 11111111}$

Using successive approximation Approach.

1) $V_{max} = 5V$, $V_{min} = 0V$

$$e' = \frac{V_{max} + V_{min}}{2} = \frac{5+0}{2} = 2.5V$$

Now $e < e$. Thus, set the bit $\underline{1}000\ 0000$

2) $V_{max} = 5V$, $V_{min} = 2.5V$

$$e' = \frac{+5V + 2.5}{2} = 3.75V$$

Now $e < e$. Thus, set the bit $1\underline{1}00\ 0000$

3) $V_{max} = 5V$, $V_{min} = 3.75V$

$$e' = \frac{5V + 3.75V}{2} = 4.375V$$

Now $e' < e$. Thus, set the bit $11\underline{1}0\ 0000$

4) $V_{max} = 5V$, $V_{min} = 4.375V$

$$e' = \frac{5V + 4.375V}{2} = 4.6875V$$

Now $e' < e$. Thus, set the bit $111\underline{1}\ 0000$

5) $V_{max} = 5V$, $V_{min} = 4.6875V$

$$e' = \frac{5V + 4.6875V}{2} = 4.84375V$$

Now $e < e$. Thus set the bit $1111\ \underline{1}000$.

6) $V_{max} = 5V$, $V_{min} = 4.84375V$

$$e' = \frac{5V + 4.84375}{2} = 4.921875V$$

Now e'<e. Thus, set the bit 11111100

7> $V_{max} = 5V$, V_{min} 4.921875V

$$e' = \frac{5V + 0.921875V}{2} = 4.9609375V$$

Now e'<e. Thus, set the bit 11111110

8> $V_{max} = 5V$, $V_{min} = 4.9609375V$

$$e' = \frac{5V + 4.9609375V}{2} = 4.98046875V$$

Now e'<e. Thus, set the bit 11111111

∴ Resulting value 11111111 = 255d.

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6) Given an analog output signal whose voltage should range from 0 to 10V and an 8-bit digital encoding provide the encodings for the following desired voltages.

a) 0v b) 1V c) 5.33v d) 10V

e) What is the resolution of our conversion?

Given :- $n = 8$, $2^n - 1 = 2^8 - 1 = 255$ $V_{max} = 10V$, $V_{min} = 0V$

a) $e = 0V$,

$$\frac{e}{(V_{max} - V_{min})} = \frac{d}{(2^8 - 1)}$$

$$\frac{0}{10V} = \frac{d}{255}$$

$$\boxed{d = 0 = 00000000}$$

b) $e = 1V$

$$\frac{1V}{10V} = \frac{d}{255}$$

$d = 25.5$ $\boxed{d = 25 \quad 00011001}$

c) $e = 5.33V$

$$\frac{5.33V}{10} = \frac{d}{255}$$

$d = 135.9$

$$\boxed{d = 136 = 10001000}$$

d) $e = 10V$

$$\frac{10}{10} = \frac{d}{255}$$

$$\boxed{d = 255 = 11111111}$$

e) $$\text{Resolution} = \frac{V_{max} - V_{min}}{2^n - 1} = \frac{10V - 0V}{2^8 - 1}$$

$$\boxed{\text{Resolution} = 0.039V}$$