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Sec: 11

350
HW 4

Question 01:

Here, $QE = \frac{\Delta Q}{V_{max} - V_{min}}$

$\Delta Q = \frac{1}{2} \times \frac{V_{max} - V_{min}}{2^n}$ [n = number of bits]

So, $QE = \frac{1}{2} \times \frac{V_{max} - V_{min}}{2^n} \times \frac{1}{V_{max} - V_{min}}$

$\rightarrow QE = \frac{1}{2^{n+1}}$

$\rightarrow 1.562 \times \frac{1}{100} = \frac{1}{2^{n+1}}$

$\rightarrow 2^{n+1} = \frac{100}{1.562}$

$\rightarrow n+1 = \log_2 \left(\frac{100}{1.562}\right)$

$\rightarrow n+1 = 6.00$

$\therefore \boxed{n = 5}$ (Ans:)

Question 02:

Here.

S_1 S_2 S_3 S_4

MSB ← LSB

2 (a) $V_o = \left(-\frac{R_F}{R_4} \times V_{S4}\right) + \left(-\frac{R_F}{R_3} \times V_{S3}\right) + \left(\frac{-R_F}{R_2} \times V_{S2}\right) + \left(-\frac{R_F}{R_1} \times V_{S1}\right)$

For the given binary input 0101-

$V_o = \left(-\frac{10}{160} \times (-5)\right) + \left(\frac{-10}{80} \times 0\right) + \left(\frac{-10}{40} \times 5\right) + \left(\frac{-10}{20} \times 0\right)$

$V_o = 1.562V$

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(b) 1 LSB $= \left(-\frac{Rf}{R_4} \times V_{S4}\right) = \left(\frac{-10}{160} \times (-5)\right)$

$= 0.3125\ V$

$\therefore \frac{1}{2}\ LSB = \frac{0.3125}{2} = 0.15625$

$\therefore 1\ MSB = \left(-\frac{Rf}{R1} \times V_{S1}\right) = \left(\frac{-10}{20} \times -5\right) = 2.5\ V$

S_1 is ON $\rightarrow 2.5 \pm 0.15625$

$\therefore \left(-\frac{10}{R1} \times -5\right) = (2.5 + 0.15625)$

$\therefore R_1 = 18.8235\ K\Omega$

$\therefore max\ error = \frac{20 - 18.8235}{20} \times 100$

$= 5.8823\ \%$ Ans:)

Question 03:

(a) Here, $I = \frac{V_{ref}}{R_{total}}$.

$$\therefore I = \frac{13}{\frac{3R}{2} + 6R + \frac{R}{2}} = \frac{13}{8R}$$

$$\therefore V_1 = I \times \frac{R}{2} = \frac{13}{8R} \times \frac{R}{2} = 0.8125\,V$$

$$V_2 = I \times \left(\frac{R}{2} + R\right) = \frac{13}{8R} \times \frac{3R}{2} = 2.4375\,V$$

$$V_3 = I \times \left(\frac{R}{2} + 2R\right) = \frac{13}{8R} \times \frac{5R}{2} = 4.0625\,V$$

$$V_4 = I \times \left(\frac{R}{2} + 3R\right) = \frac{13}{8R} \times \frac{7R}{2} = 5.6875\,V$$

$$V_5 = I \times \left(\frac{R}{2} + 4R\right) = \frac{13}{8R} \times \frac{9R}{2} = 7.3125\,V$$

$$V_6 = I \times \left(\frac{R}{2} + 5R\right) = \frac{13}{8R} \times \frac{11R}{2} = 8.9375\,V$$

$$V_7 = I \times \left(\frac{R}{2} + 6R\right) = \frac{13}{8R} \times \frac{13R}{2} = 10.5625\,V$$

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Now,

V_7	V_6	V_5	V_4	V_3	V_2	V_1	OUTPUT
OFF	OFF	OFF	OFF	OFF	OFF	OFF	000
OFF	OFF	OFF	OFF	OFF	OFF	ON	001
OFF	OFF	OFF	OFF	OFF	ON	ON	010
OFF	OFF	OFF	OFF	ON	ON	ON	011
OFF	OFF	OFF	ON	ON	ON	ON	100
OFF	OFF	ON	ON	ON	ON	ON	101
OFF	ON	ON	ON	ON	ON	ON	110
ON	ON	ON	ON	ON	ON	ON	111

For output, 110
up to V_5 is ON.
min value of $V_A = V_5 = 7.3125V$
max " " $V_A = V_6 =$ ~~to 5.625V~~ $8.0375V$ (Ans)

(b) Resistor required $= 2^n = 2^6 = 64$

comparators need $= 2^6 - 1 = 63$

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Question 04:

for 6 bit,

$$V_o = (-V_{ref})\left(b_1 + \frac{b_2}{2} + \frac{b_3}{4} + \frac{b_4}{8} + \frac{b_5}{16} + \frac{b_6}{32}\right)$$

for output, $b_1 \rightarrow 010110 \rightarrow b_6$

$$V_o' = (-(-7))\left(0 + \frac{1}{2} + \frac{0}{4} + \frac{1}{8} + \frac{1}{16} + \frac{0}{32}\right)$$

$$= 7 \times \frac{11}{16} = 4.8125\ V$$

for output, 110010,

$$V_o'' = (-(-7))\left(1 + \frac{1}{2} + \frac{0}{4} + \frac{0}{8} + \frac{1}{16} + \frac{0}{32}\right)$$

$$= 7 \times 1.5625$$

$$= 10.9375\ V$$

$\therefore$ changes, $\Delta V_o = V_o'' - V_o'$

$$= |10.9375 - 4.8125|$$

$$= 6.125\ V \quad \text{Ans}$$

Question 5:

(a) upper threshold voltage $V_{TU} = +V_{sat} \times \frac{R_2}{R_1+R_2}$

$= 20 \times \frac{172}{372}$

$= 9.2473\,V$

lower threshold voltage, $V_{TL} = -V_{sat} \times \frac{R_2}{R_1+R_2}$

$= -20 \times \frac{172}{372}$

$= -9.2473\,V$

(b) $T_1 = \tau \ln\left(\frac{+V_{sat} - V_{TL}}{+V_{sat} - V_{TU}}\right)$

$= R_f C \ln\left(\frac{+V_{sat} - V_{TL}}{+V_{sat} - V_{TU}}\right)$

$= 10ms \times \ln\left(\frac{20 + 9.2473}{20 - 9.2473}\right) = 10.006ms$

$T_2 = \tau \ln\left(\frac{-V_{sat} - V_{TU}}{-V_{sat} - V_{TL}}\right)$

$= R_f C \ln\left(\frac{-V_{sat} - V_{TU}}{-V_{sat} - V_{TL}}\right)$

$= 10ms \times \ln\left(\frac{-20 - 9.2473}{-20 + 9.2473}\right)$

$= 10.006ms$

$\therefore$ Total time $= t_1 + t_2 = 20.012\,6\ ms$

Question 6:

$f = 500Hz = 0.5\,kHz$

$T = \frac{1}{f} = \frac{1}{0.5} = 2ms \;;\; V_{UT} \cong 5V$

$\therefore V_{UT} = -\left(\frac{-V_{SAT}}{P}\right) = -\left(\frac{-13.8}{P}\right)$

$\Rightarrow P = \frac{13.8}{5} = 2.76$

$\therefore PR = 2.76 \times 10 = \boxed{27.6\,k\Omega}$

$f = \frac{P}{4RiC} = \frac{2.76}{4 \times 14 \times C}$

$\therefore C = \frac{2.76}{4 \times 14 \times 500} = \boxed{0.1\,\mu F}$

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$V_H = +V_{SAT}$
$V_L = -V_{SAT}$

Question 7:-

hysteresis width $= V_{TH} - V_{TL}$

$$= \left(V_H \times \frac{R_1}{R_1+R_2}\right) - \left(V_L \times \frac{R_1}{R_1+R_2}\right)$$

$$\Rightarrow 100 \times 10^{-3} = (V_H - V_L) \times \frac{R_1}{R_1+R_2}$$

$$\Rightarrow 100 \times 10^{-3} = (15+5) \times \frac{1}{1+\frac{R_1}{R_2}}$$

$$\Rightarrow \frac{R_2}{R_1} = \frac{20}{100\times10^{-3}} - 1 = 199 \quad 200-1=199$$

So, $\boxed{R_1 = 1k\Omega}$, $\boxed{R_2 = 199k\Omega}$

$$V_{Tref} = V_s \times \frac{R_1+R_2}{R_2} = 1.5 \times \frac{1+199}{199}$$

$$= 1.5 \times 1.0050$$

$$\therefore \boxed{V_{Tref} = 1.5075}$$

Now,

$V_H = 300 \times 10^{-6} \times 110 = 0.033V$

$V_y = V_H + 0.7 = 0.733$

$$\therefore R = \frac{V_H - V_y - 0.7}{300\times10^{-6}} = \frac{15 - 0.733 - 0.7}{300\times10^{-6}}$$

$$= \boxed{95.223k\Omega}$$

(Ans:)