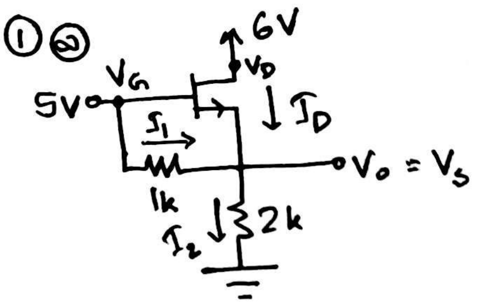
Set 01

① ⓐ



$V_G = 5V$
$V_D = 6V$ $\Big\} \longrightarrow$ For saturation, $V_{DS} \geq V_{ov}$

$\Rightarrow V_D - V_S \geq V_G - V_S - V_T$

$\Rightarrow 6 - V_S \geq 5 - V_S - 1$

$\Rightarrow 6 - V_S \geq 4 - V_S$

$\downarrow$

condition is always TRUE

• KCL at Source terminal -

$I_D + I_1 = I_2$

$\Rightarrow I_D = I_2 - I_1$

ⓑ MOSFET operates in saturation -

$I_D = \frac{1}{2} k V_{ov}^2 = I_2 - I_1$

$\Rightarrow \frac{1}{2} \times 1 \times (4 - V_S)^2 = \frac{V_S}{2} - \frac{(V_G - V_S)}{1}$

$\Rightarrow 8 - 4V_S + \frac{V_S^2}{2} = \frac{V_S}{2} - 5 + V_S$

$\Rightarrow \frac{V_S^2}{2} - \frac{11}{2} V_S + 13 = 0$

$V_S = 7.56 \;,\; 3.43$

For $V_S = 7.56$, $V_{DS} = 6 - 7.56$
$= \underline{\underline{-1.56}}$

does not satisfy condn for saturation

For $V_S = 3.43$,

$V_{DS} = 6 - 3.43 = 2.57$

$V_{GS} = 5 - 3.43 = 1.57$

$V_{ov} = V_{GS} - V_T = 0.57$

verification $[V_{DS} > V_{ov}]$

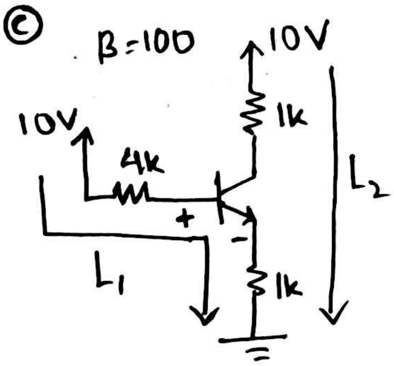
$V_o = V_S = 3.43V$

$I_1 = \frac{V_G - V_S}{1k} = 1.57 \, mA$

$I_2 = \frac{V_S}{2k} = 1.72 \, mA$

$I_D = I_2 - I_1 = 0.15 \, mA$

ⓒ



V_{CC} and V_{BB} values are comparable - Assume saturation.

$V_{BE(sat)} = 0.8V$

$V_{CE(sat)} = 0.2V$

$(L_1) \rightarrow 10 = 4I_B + V_{BE} + 1I_E$

$\Rightarrow 4I_B + I_E = 9.2$ — ⓘ

$(L_2) \rightarrow 10 = 1I_C + V_{CE} + 1I_E$

$\Rightarrow I_C + I_E = 9.8$ — ⓘⓘ

(KCL) $I_B + I_C - I_E = 0$ — ⓘⓘⓘ

solving, $I_B = 0.96 \, mA$, $I_E = 5.38 \, mA$

$I_C = 4.42 \, mA$

verification $\left[\frac{I_C}{I_B} = 4.6 < \beta \right]$

$V_E = I_E \times 1k = 5.38V$

$\therefore V_C = 0.2 + 5.38 = 5.58V$

ⓓ $T = 1.25 - 0.25 = 1 \, ms$

$\therefore f = \frac{1}{T} = 1 \, kHz = f_{out}$

$V_{avg} = V_P - \frac{V_r}{2}$

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

$= 7.5V$

② (a) $V_{in} = 10 \sin(\underline{200\pi t})$

$\hookrightarrow 200\pi = 2\pi f_{in}$

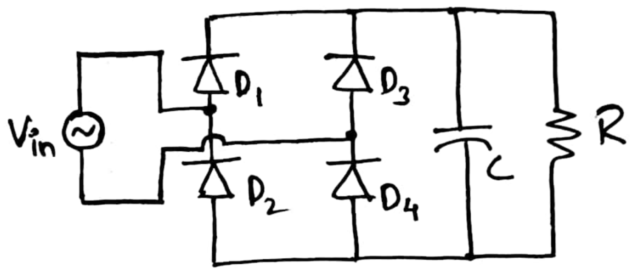
$f_{in} = 100Hz$

$V_p = V_m - 2V_{D_0}$
$= 10 - 2\times 0.7$
$= 8.6V$

given that $f_{out} = 200Hz$, required design is that of a full-wave rectifier.

$[f_{out} = 2\times f_{in}]$

ckt :



now, $V_{r(p-p)} = 5\%$ of $V_{out(max)}$

$= \frac{5}{100} \times V_p$

$= 0.43\ V$

also, $V_{r(p-p)} = \frac{V_p}{2f_{in}RC} = \frac{8.6}{200\times RC} = 0.43$

$\Rightarrow C = \frac{8.6}{0.43\times 200\times R} = \frac{100\,\mu F}{1k}, \frac{50\,\mu F}{2k}, \frac{25\,\mu F}{4k}, \frac{20\,\mu F}{5k}, \ldots$

(b) $f = \bar{A}B + \bar{B}C + \bar{C}A$

Any combination that is correct.

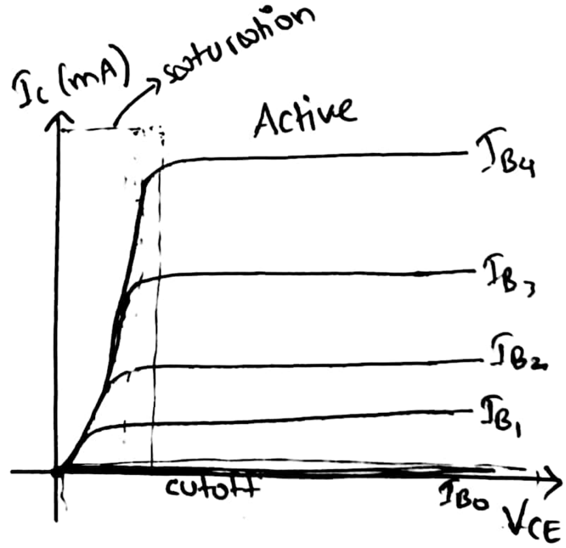
③ (a) $V_{out} = V_{in} - 2V_{D_0}$ $(V_{in} > 2V_{D_0})$

(b) MOSFET is a three terminal device, where it is either turned 'ON' or 'OFF' ~~via~~ at its output terminals via a control terminal. (output → D-S, control → G)

→ Let V_T be a threshold voltage. If $V_G > V_T$ → 'ON'/short ckt

If $V_G < V_T$ → 'OFF'/open ckt.

(c)



$I_{B4} > \ldots > I_{B1}$ (in μA)

Set 02

① ⓐ Same as set-01.

ⓑ $I_D = \frac{1}{2} k V_{ov}^2 = I_2 - I_1$ [same equation and condition as set 01]

$$= \frac{1}{2} \times \frac{1}{2} \times (4 - V_s)^2 = \frac{V_s}{4} - \frac{(V_G - V_s)}{2}$$

$$= \frac{1}{4} (4 - V_s)^2 = \frac{V_s - 2(V_G - V_s)}{4}$$

$$\Rightarrow 16 - 8V_s + V_s^2 = V_s - 10 + 2V_s$$

$$\Rightarrow V_s^2 - 11V_s + 26 = 0$$

$V_s = \underline{\underline{7.56}}, \underbrace{3.43} \longrightarrow$ $V_{DS} = 2.57$

$\times$ (see set 01)

$V_{GS} = 1.57$

$V_{ov} = 0.57$

$[V_{DS} > V_{ov}]$

$V_o = V_s = 3.43V$

$I_1 = \frac{V_G - V_S}{2} = 0.785mA$

$I_2 = \frac{V_s}{4} = 0.86mA$

$I_D = 0.073mA$

ⓒ same condition as set 01;

$(L_1) \rightarrow 10 = 2I_B + V_{BE} + I_E$

$\Rightarrow 2I_B + I_E = 9.2$ — (i)

$(L_2) \rightarrow 10 = I_C + V_{CE} + I_E$

$\Rightarrow I_C + I_E = 9.8$ — (ii)

(KCL) $I_B + I_C - I_E = 0$ — (iii)

solving, $I_B = 1.72mA$, $I_E = 5.76mA$, $I_C = 4.04mA$ $\Big\}$ $\frac{I_C}{I_B} = 2.34 < \beta$.

$V_E = I_E R_E = 5.76V$

$V_C = V_{CE} + V_E$

$= 5.96V$

ⓓ $T = 1.25 - 0.25 = 1ms$

$f = \frac{1}{T} = 1kHz = f_{out}$

$V_{avg} = V_p - \frac{V_P}{2}$

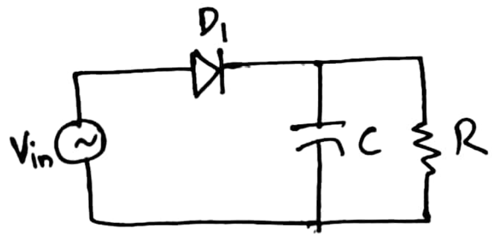
$= 20 - \frac{10}{2}$

$= 15V$

(2) (a) $V_{in} = 10\sin(\underline{200\pi}t)$

$\hookrightarrow 200\pi = 2\pi f_{in}$

$f_{in} = 100\text{Hz}$



$f_{out} = 100\text{Hz}$;

$f_{out} = f_{in} \longrightarrow$ Half-wave rectifier $\Big\} \rightarrow V_p = V_m - V_{D_0}$

$= 10 - 0.7$

$= 9.3\text{ V}$

$V_{r(p-p)} = 10\%$ of $V_{out(max)}$

$= \frac{10}{100} \times V_p$

$= 0.93\text{ V}$

$V_{r(p-p)} = \frac{V_p}{f_{in}RC}$

$\Rightarrow \quad C = \frac{9.3}{0.93 \times R \times 100}$

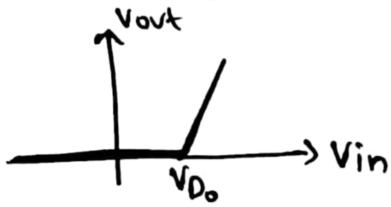
$= \underset{1k}{\underline{100\,\mu F}}, \underset{2k}{\underline{50\,\mu F}}, \ldots$

(b) $f = \bar{C}A + \bar{A}B + \bar{B}C$

Any correct combination.

(3) (a) $V_{out} = V_{in} - V_{D_0}$ $[V_{in} > V_{D_0}]$

(0 otherwise)

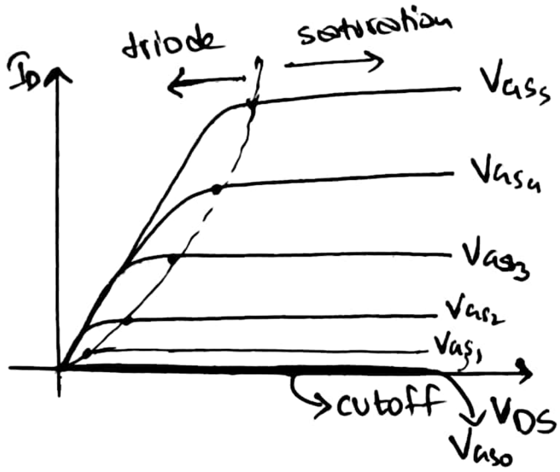


(b) similar to MOSFET, but conditions are -

$I_B > I_{th} \rightarrow$ ON/short ckt

$I_B < I_{th} \longrightarrow$ OFF/open ckt

(c)



$V_{GS_5} > \ldots > V_{GS_1}$