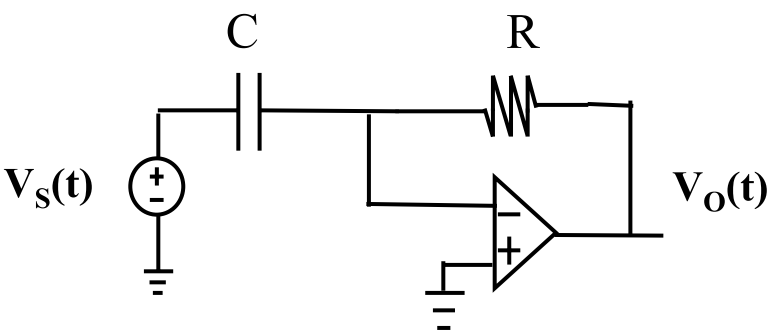
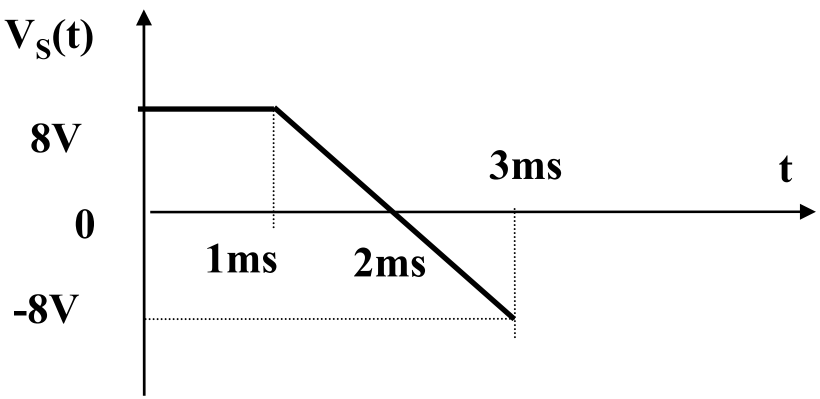
(300) **(15)**

1

Find Vo(t) in terms of C, R, and Vs(t).
If C = 1µF and R = 1kΩ, find and plot Vo(t) . Assume the op amp is ideal.

(15)



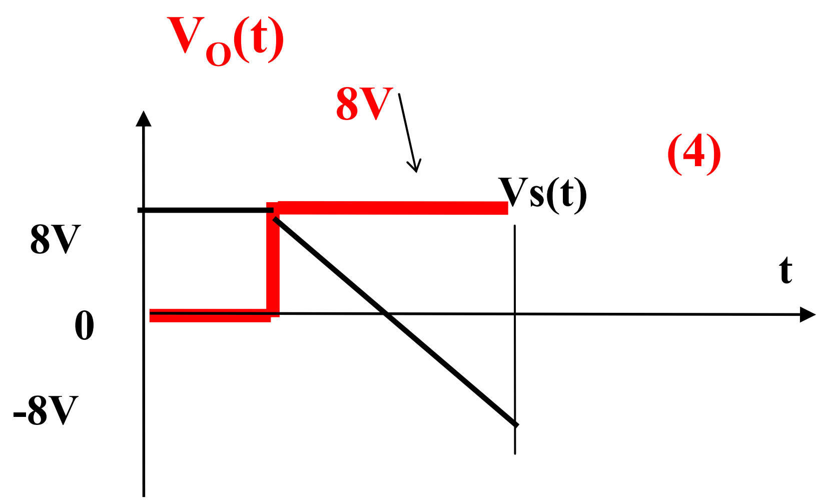


$$\text{apply KCL} \Rightarrow C\frac{dV_s}{dt} \cong \frac{-V_o}{R} \qquad \textbf{(5)}$$

$$CR = 1\mu F * 1k\Omega = 1ms$$

$$\therefore V_o \cong -CR\frac{dV_s}{dt} = -1ms * \frac{-8V-8V}{2ms} = 8V$$

(6)



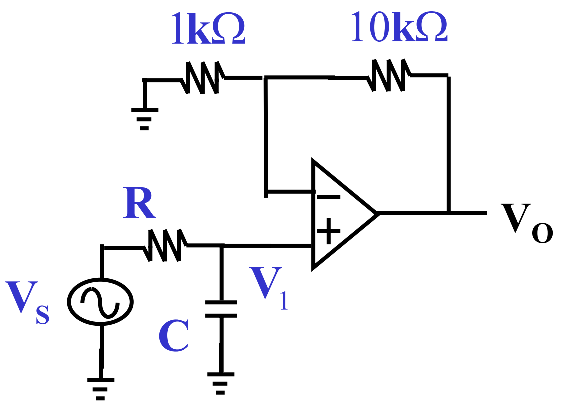
(4)

(13)

2

Given that $V_O / V_1 = 11$, find V_1 / V_S in terms of R, C and jw. If C = 1μF and R = 1kΩ, find the complex transfer function G (= V_O / V_S). Is the op amp circuit a low pass filter? Assume the op amp is ideal.

(13)



$$V = V_S * \frac{\frac{1}{j\omega C}}{R + \frac{1}{j\omega C}} = V_S * \frac{1}{1 + j\omega CR}$$

$$V_O = 11V = 11 * V_S \frac{1}{1 + j\omega CR}$$

$$= \frac{11V_S}{1 + j\omega(1\mu F * 1k\Omega)}$$

$$G = \frac{V_O}{V_S} = \frac{11}{1 + j\omega * 1ms}$$ (10)

Circuit is a low pass filter (3)

(22)

3

In an ideal op amp filter circuit, the complex transfer function G (= V_O / V_S) is given as $\dfrac{-10}{1 - j/\omega CR}$

C = 1nF and R = 10kΩ.

(a) Show that the cut off frequency ω_O is 100k rad/s.

(b) Plot the magnitude of G ($|G|$) versus ω. Show clearly the value of $|G|$ when $\omega = \infty$ and $\omega = \omega_O$ in your plot.

(c) If $V_S(t) = 1\cos 100kt$ V, find $V_O(t)$.

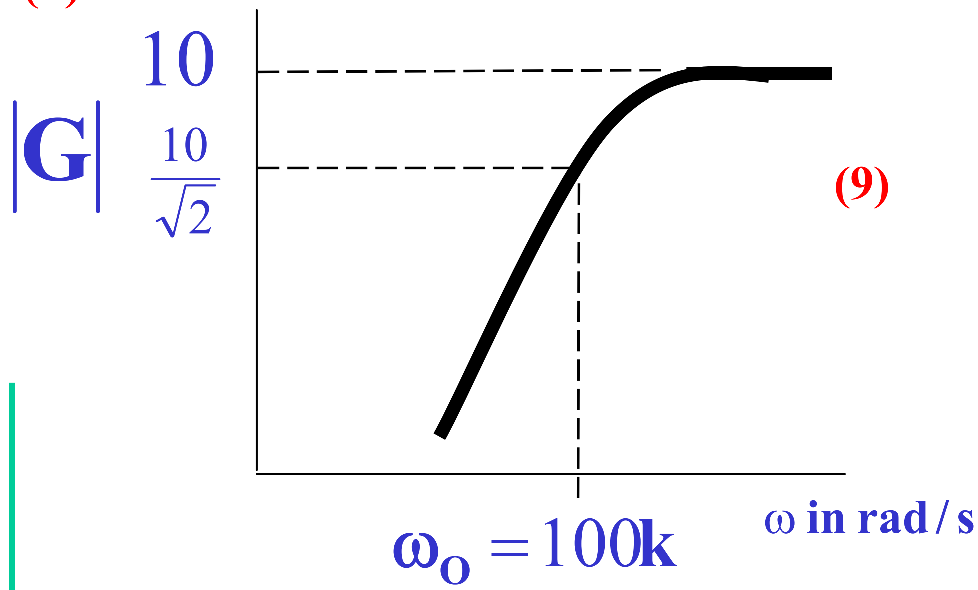
(22)

(a)

$$\omega_O = \frac{1}{CR} = \frac{1}{1nF * 10k\Omega} = 100krad/s$$

(5)

(b)



(9)

(c)

$$V_o = 1\angle 0 * \frac{-10}{1-j} = \frac{-10}{\sqrt{2}\angle -45^o}$$

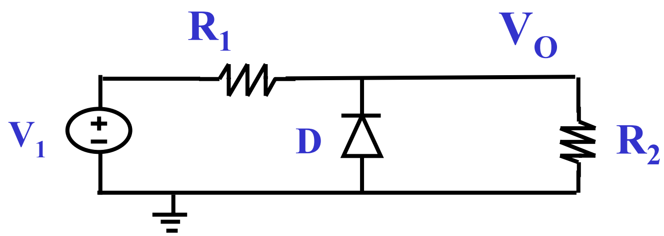
(8)

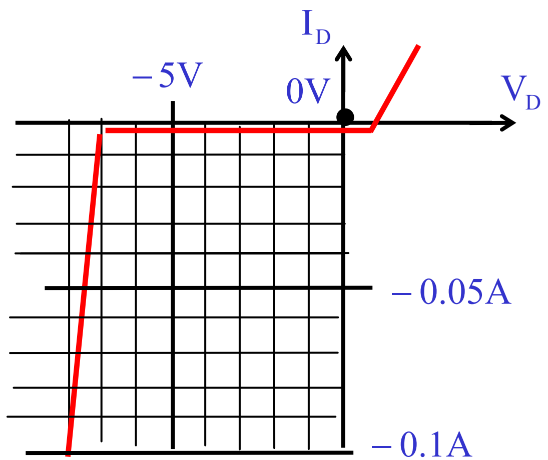
$$V_o(t) = -\frac{10}{\sqrt{2}}\cos(100kt + 45^o)V$$

(17)

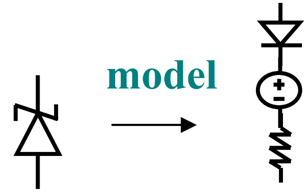
4

In the diode circuit, the diode has the forward, reverse and breakdown characteristics as shown.
(a) Draw the circuit model of the diode at breakdown.
(b) If $V_1 = 16V$, $R_1 = 2k\Omega$, $R_2 = 2k\Omega$, find V_O.
Show clearly your reasons. (17)





a



$V_{ZK} = 7V$

$r_Z = 10\Omega$

(6)

b

$$V_O = V_1 * \frac{R_2}{R_1 + R_2} = 16V * \frac{2k\Omega}{2k\Omega + 2k\Omega} = 8V$$

diode is BREAKDOWN

(2)

$$\frac{16V - V_O}{2k\Omega} = \frac{V_O - 7V}{10\Omega} + \frac{V_O}{2k\Omega}$$

$$16V - V_O = 200(V_O - 7V) + V_O$$

$$V_O = \frac{1400V + 16V}{202} \cong 7.08V$$

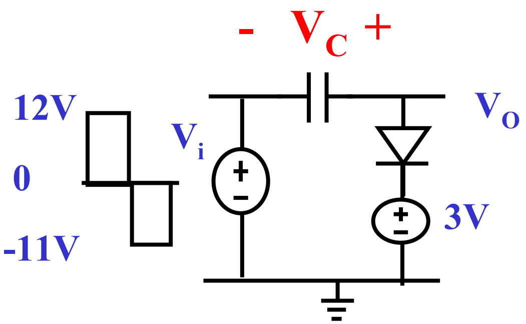
(9)

(12)

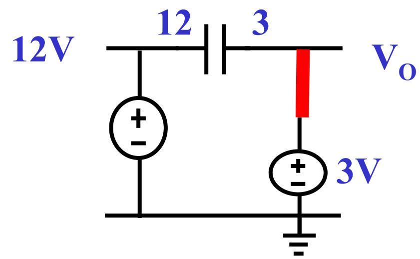
5

(a) In the ideal diode circuit, find Vc and sketch Vo(t).

Show clearly the voltages in your sketch. Assume the diode is ideal. (12)

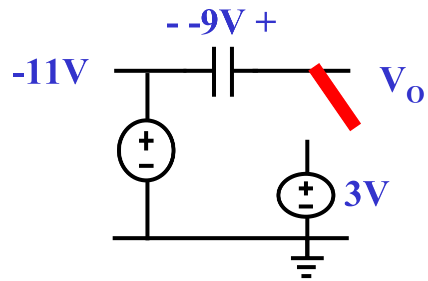


when T = T/2, V_i = 4 V, D is OFF

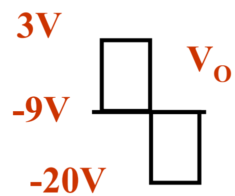


Vc = - 9V

(8)

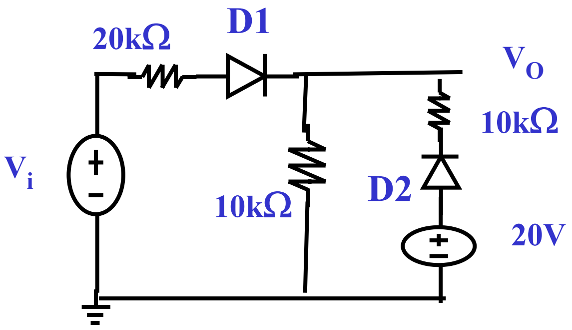


$V_O = Vi + Vc$
$= -11 - 9$
$= -20\ V$



(4)

(b) In the ideal diode circuit, find Vo when Vi = 15V. (15)



$\boxed{\text{Vi = 15V, D1 and D2 ON,}}$ **(4)**

$$\therefore \frac{Vi - Vo}{20k\Omega} + \frac{20 - Vo}{10k\Omega} = \frac{Vo}{10k\Omega}$$

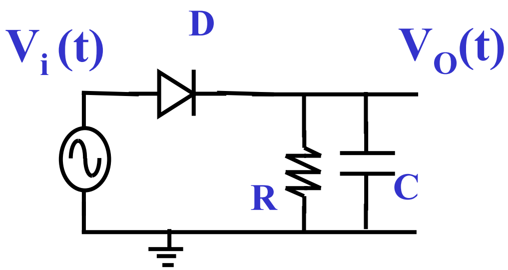
$$\therefore Vi - Vo + 40 - 2Vo = 2Vo$$

$$\therefore Vo = \frac{Vi + 40}{5} = \frac{15V + 40}{5} = 11V$$ **(11)**

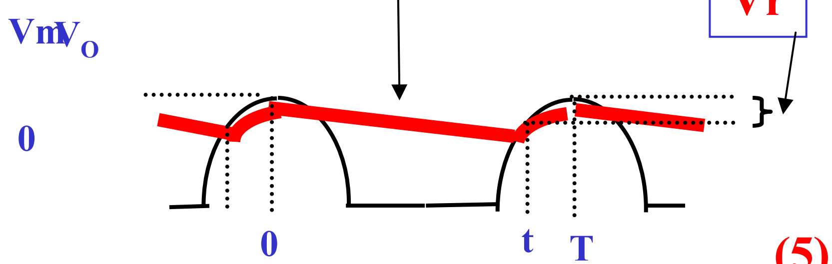
(16)

6

. Vi = 6 cos 2π1kt V. Plot the waveform of $V_O(t)$. Show also that the ripple voltage Vr of $V_O(t)$ is about 0.2V. Given that R = 30kΩ, C = 1μF and diode is an <u>offset diode</u> where $V_F = 0.7V$. (16)



$$V_O(t) = V_m\, e^{-t/CR}$$



(5)

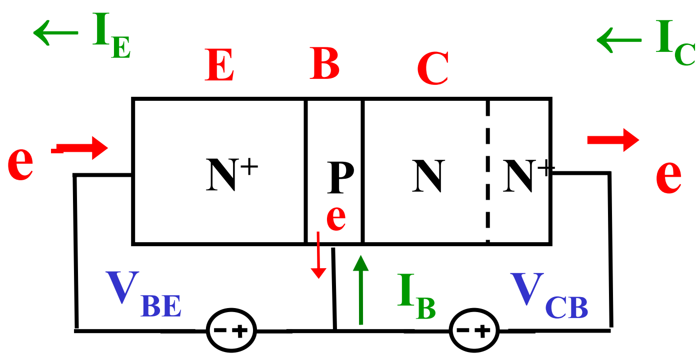
$$V_r = V_m(1 - e^{-t/RC}) \cong V_m(T/CR)$$
$$= (7V - 0.7V)(1ms/30ms) = 0.21V$$

(11)

(15)

7

Draw the cross sectional structure of a NPN BJT transistor operated in the active mode, describe the movement of electrons, and explain briefly why $I_C \cong \alpha I_E$.
If $I_C \cong \beta I_B$, find α in terms of β. Show clearly your explanations and steps. (15)



1. EB Junction is a forward bias (on) diode and BC is reverse bias (off) diode

2. E is very heavily doped (N$^+$ for NPN). E has many electrons,

3. B is very thin. So most electrons injected from E (to B) are attracted to C and

$$I_C \cong \alpha I_E$$

(9)

$$I_E \cong \frac{I_C}{\alpha} = I_B + I_C = \frac{I_C}{\beta} + I_C$$

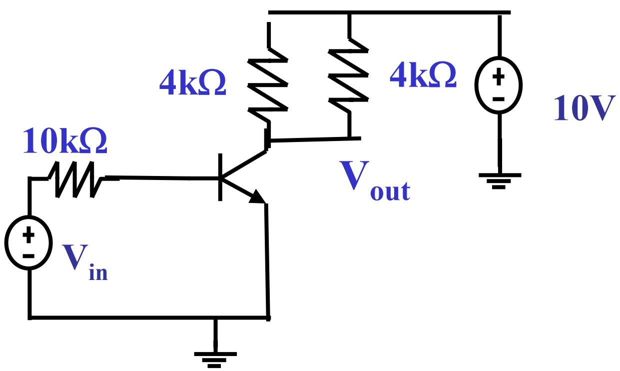
$$\text{hence } \frac{1}{\alpha} = \frac{1}{\beta} + 1$$

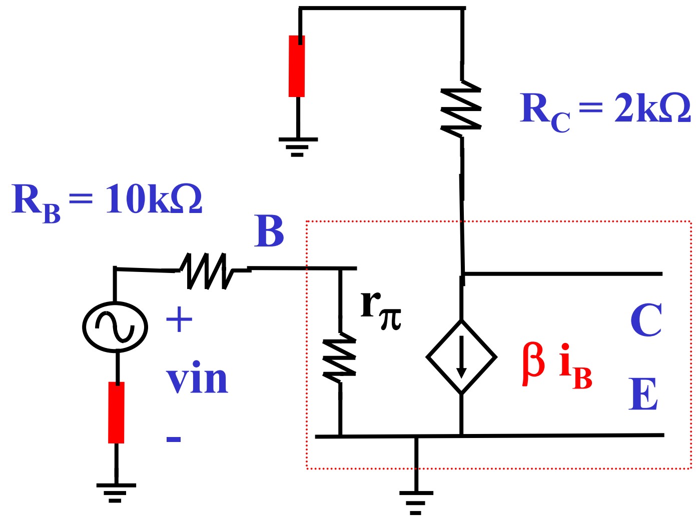
$$\alpha = \frac{\beta}{\beta + 1}$$

(6)

8

.
Draw the small signal (AC) equivalent circuit of the BJT amplifier and find the voltage gain Av (= V_{out} / V_{in}). Given $\beta = 100$, and $V_{CESAT} = 0.2V$, $V_{BE(ON)} = 0.7V$, $r\pi = 0\Omega$. (16)





(8)

$$\therefore Av = \frac{VOUT}{Vin} = \frac{-\beta\, i_B R_C}{i_B(R_B + r_\pi)}$$

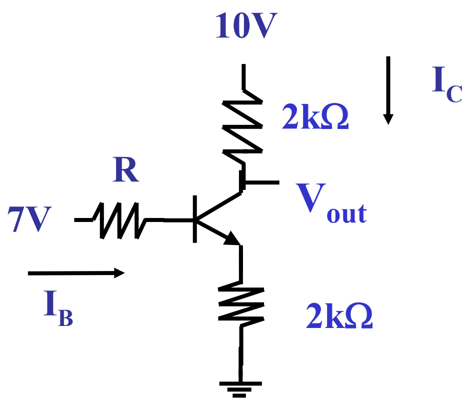
$$= \frac{-\beta R_C}{R_B + r_\pi} = \frac{-(100)(2k\Omega)}{10k\Omega + 0\Omega} = -20$$ (8)

(14)

9

.

(a) If R = 0, find Ic, and Vout. Show clearly your reasons. Given $\beta = 100$, and $V_{CESAT} = 0.2V$, $V_{BE(ON)} = 0.7V$. (14)



(a)

BJT is not OFF since V_{BE} can be 0.7V

Assume BJT is in active mode

$$\therefore I_E = \frac{V_E}{R_E} = \frac{7V - 0.7V}{2k\Omega} = 3.15mA$$

but max I_C is ~ 10V/4kΩ = 2.5mA

Hence BJT is in saturation mode (6)

$$\therefore V_{out} = V_E + V_{CESAT} = 6.3V + 0.2V = 6.5V$$

(5)

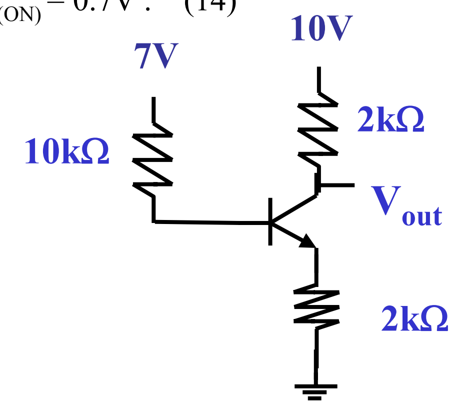
$$\therefore I_C = \frac{10V - 6.5V}{2k\Omega} = 1.85mA$$

(3)

(14)

.

(b) If R = 10kΩ, show that forced beta is about 18.8. Hence find Vout and IB. Show clearly your reasons. Given $\beta = 100$, and $V_{CESAT} = 0.2V$, $V_{BE(ON)} = 0.7V$. (14)



(b) $I_B \cong 0.13mA$

$$I_C \cong \beta I_B \cong 100 * 0.13mA = 13mA$$

$$>> \max I_C (= 2.5mA)$$

Hence BJT is in saturation mode

$$\therefore V_E \cong 7V - 0.13mA * 10k\Omega - 0.7V = 5V$$

$$\therefore V_{out} \cong V_E + 0.2V = 5.2V$$

(14)

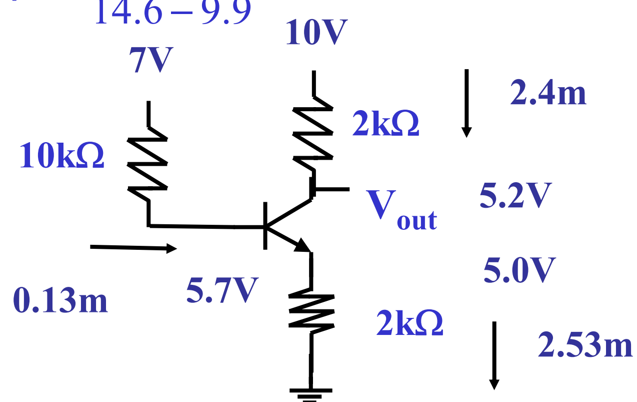
$$\therefore I_B = \frac{V_B - V_{BE}}{R_B + (1+\beta^*)R_E} = \frac{V_{CC} - V_{CESAT}}{\beta^* R_C + (1+\beta^*)R_E}$$

$$\therefore I_B = \frac{8-0.7}{1k + (1+\beta^*)1k} = \frac{10-0.1}{1k(1+2\beta^*)}$$

$$\therefore 7.3(1+2\beta^*) = 9.9(2+\beta^*)$$

$$\therefore 14.6\beta^* + 7.3 = 9.9\beta^* + 19.8$$

$$\therefore \beta^* = \frac{19.8-7.3}{14.6-9.9} \cong 2.66$$



$$\therefore\ I_B = \frac{V_B - V_{BE}}{R_B + (1+\beta^*)R_E} = \frac{V_{CC} - V_{CESAT}}{\beta^* R_C + (1+\beta^*)R_E}$$

$$\therefore\ I_B = \frac{7-0.7}{10k + (1+\beta^*)2k} = \frac{10-0.2}{2k(1+2\beta^*)}$$

$$\therefore 6.3(1+2\beta^*) = 9.8(6+\beta^*)$$

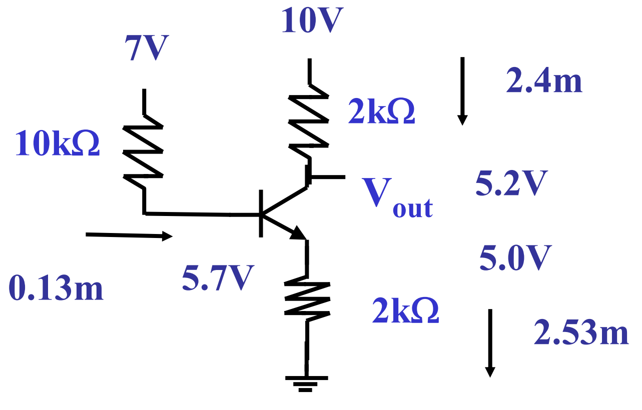
$$\therefore 12.6\beta^* + 6.3 = 9.8\beta^* + 58.8$$

$$\therefore \beta^* = \frac{58.8-6.3}{12.6-9.8} \cong 18.75$$

$$\therefore V_E \cong 7V - 0.13mA * 10k\Omega - 0.7V = 5V$$

$$\therefore V_{out} \cong V_E + 0.2V = 5.2V$$

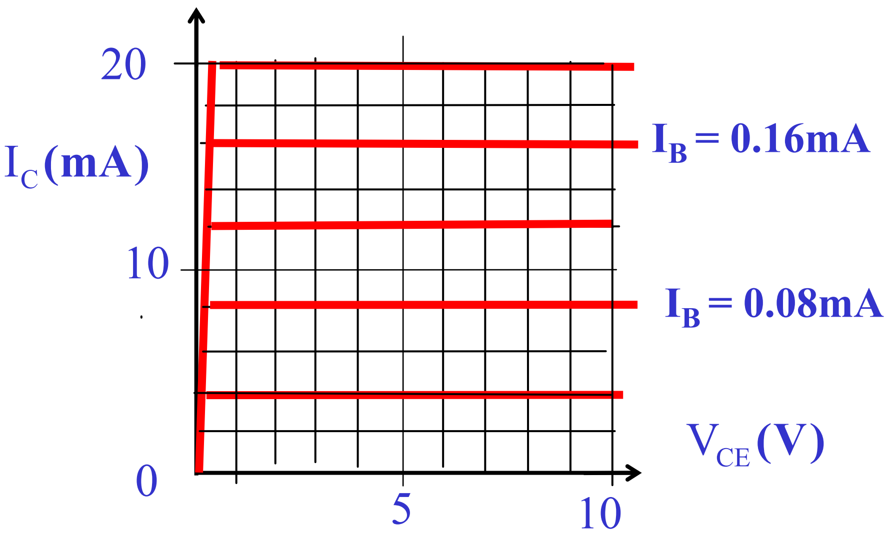
(14)

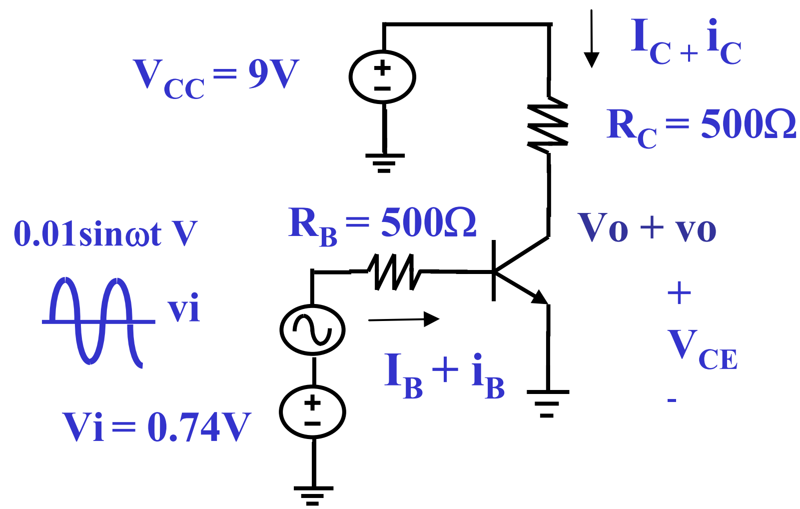


10

Given the BJT circuit below and the I_C-V_{CE} curve of the BJT. (a) Draw the load line $V_{CE} = V_{CC} - I_C R_C$ and locate the Q point on the I-V curve. (b) Estimate also from the I-V curve the voltage gain v_O / v_i, (21)

For the BJT, given $\beta = 100$, $V_{BE(ON)} = 0.7V$, $V_{CESAT} = 0.2V$, $r\pi = 0\Omega$

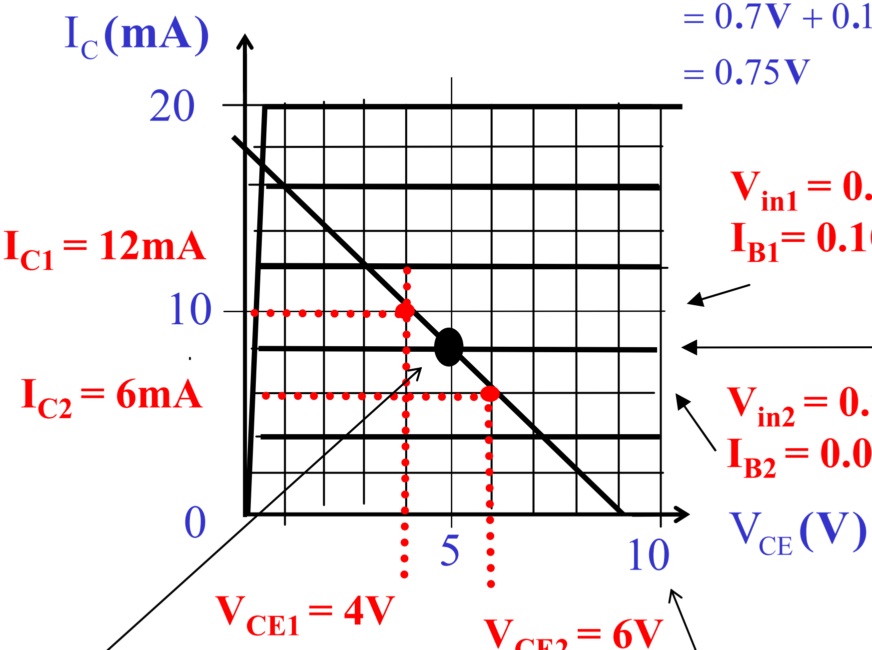




Draw load line, Q point,

(a)

$$V_{in2} = V_{BE(ON)} + I_B R_B = 0.7V + 0.1mA * 500\,\Omega = 0.75V$$



$$I_B = \frac{Vi - V_{BE(ON)}}{R_B} = \frac{0.74V - 0.7V}{500\Omega} = 0.08mA$$

(6)

(6)

(b) **and find voltage gain**

$$\text{voltage gain } A_v = \frac{dV_{CE}}{dV_{in}} = \frac{V_{CE2} - V_{CE1}}{V_{in2} - V_{in1}}$$

$$\cong \frac{6V - 4V}{0.73V - 0.75V} = -100$$

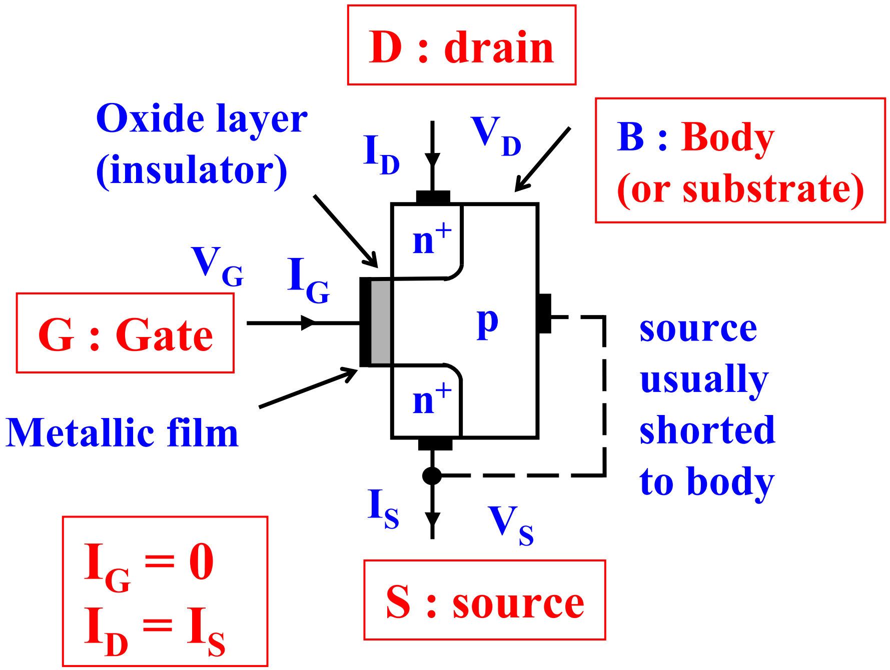
(9)

14

(a) Name two advantages of MOSFET. (b) Draw the cross sectional diagram for an enhancement NMOSFET and describe very briefly the structure.
(22)

small size (scaled down easily) and low power consumption.

(5)



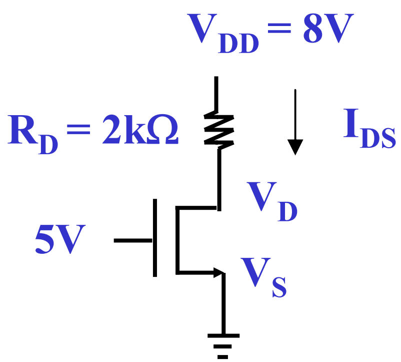
An NMOSFET consists of a metal gate insulated from a p-type semiconductor substrate (or body) by an insulating layer of silicon dioxide. On either side of the gate there are n type regions forming the drain and source.

(10)

(c) If $I_{DS} = 3mA$, find the mode of the MOSFET.

Given $V_T = 1V$

(c)



$$V_{GS} = V_G - V_S = 5V - 0V = 5V$$

$$V_{GS} > V_T$$

$$\therefore V_{DS} = 8V - I_{DS}R_D = 8V - 3mA * 2k\Omega = 2V$$

$$V_{GS} - V_T > V_{DS}$$

(7)

NMOSFET is in triode mode