

1) In the cutoff region

$$I_B = 0 ; I_C = 0, \text{ and } I_E = 0$$

2) In the active region

$$I_C = \beta I_B$$

$$I_C = \alpha I_E$$

$$I_E = (\beta + 1) I_B$$

$$V_{BE} = 0.7 \text{ V} , \text{ Si, npn}$$

$$V_{BE} = -0.7 \text{ V} , \text{ Si, pnp}$$

$$V_{CE} > V_{CE, \text{sat}} = 0.2 \text{ V} , \text{ Si, npn}$$

$$V_{CE} < V_{CE, \text{sat}} = -0.2 \text{ V} , \text{ Si, pnp}$$

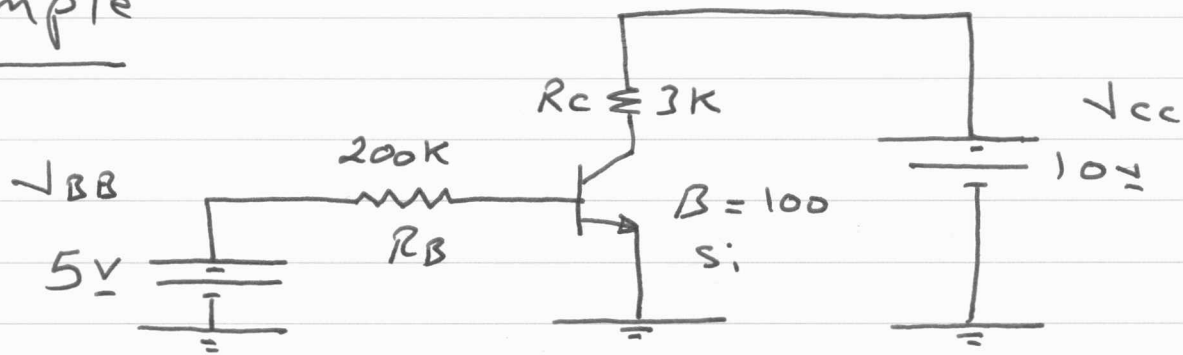
3) In the Saturation region

$$V_{CE} = V_{CE, \text{sat}}$$

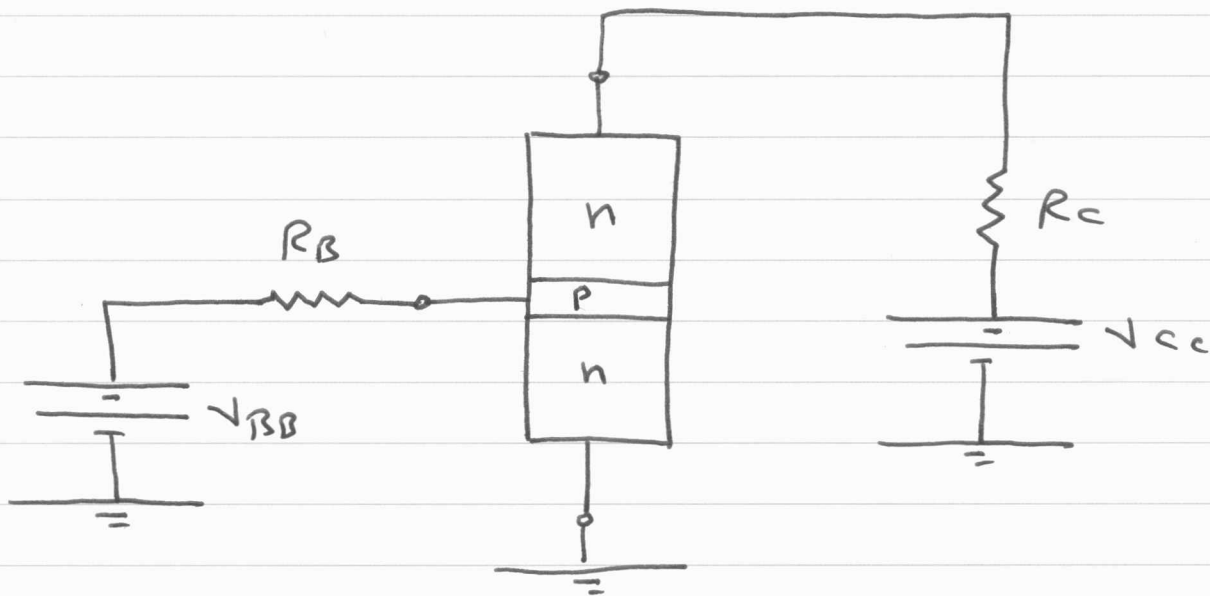
$$V_{BE} = 0.8 \text{ V} , \text{ Si, npn}$$

$$V_{BE} = -0.8 \text{ V} , \text{ Si, pnp}$$

Example

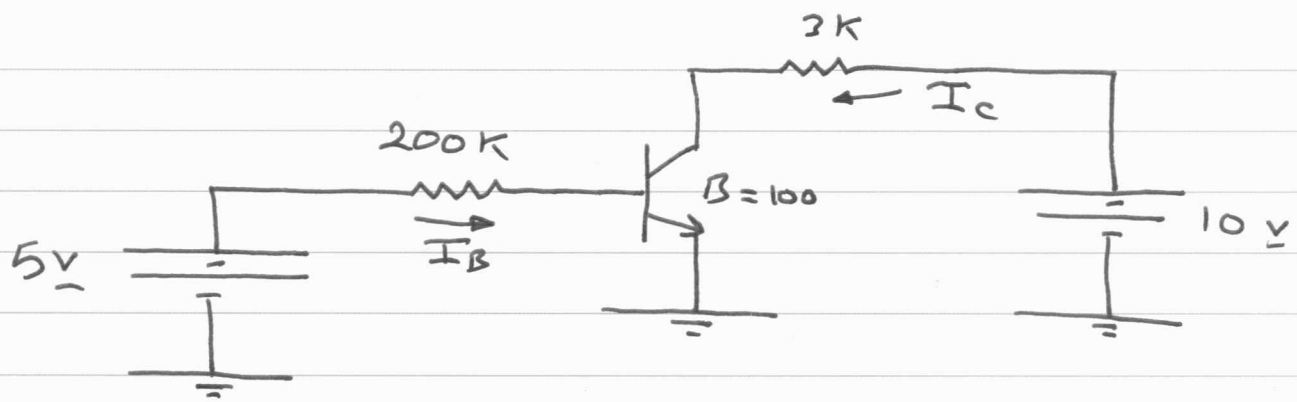


Find Q point (I_{CQ} , V_{CEQ}).



Since the base emitter junction is forward bias; the transistor could be either in the active or the saturation region

$\therefore$ Assume that the Transistor is in the active region.



$$\text{KVL : } 5 = 200\text{k} I_B + V_{BE}$$

$$\therefore I_B = \frac{5 - 0.7}{200\text{k}} = 0.0215\text{mA}$$

$$\therefore I_C = \beta I_B = 2.15\text{mA}$$

$$\text{KVL : } 10 = R_C I_C + V_{CE}$$

$$10 = 3\text{k} I_C + V_{CE}$$

$$\therefore V_{CE} = 10 - (3\text{k})(2.15\text{mA})$$

$$V_{CE} = 3.55\text{V}$$

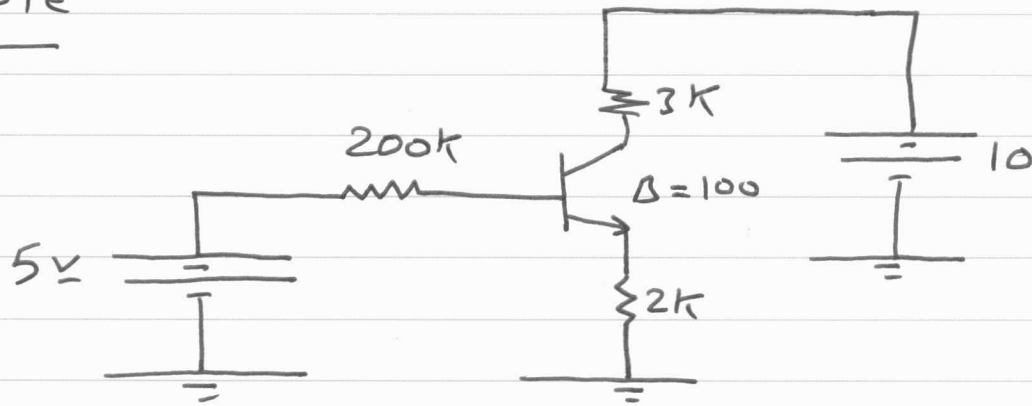
Since $V_{CE} > V_{CE, \text{sat}}$

$\therefore$ Transistor is in the active region

$$I_{CQ} = 2.15\text{mA}$$

$$V_{CEQ} = 3.55\text{V}$$

Example



Find Q point .

Since the base emitter junction is forward biased, the transistor could be either in the active or saturation region

Assume that the transistor is in the active region.

$$\text{KVL : } 5 = 200k I_B + V_{BE} + 2k I_E$$

$$I_E = (\beta + 1) I_B$$

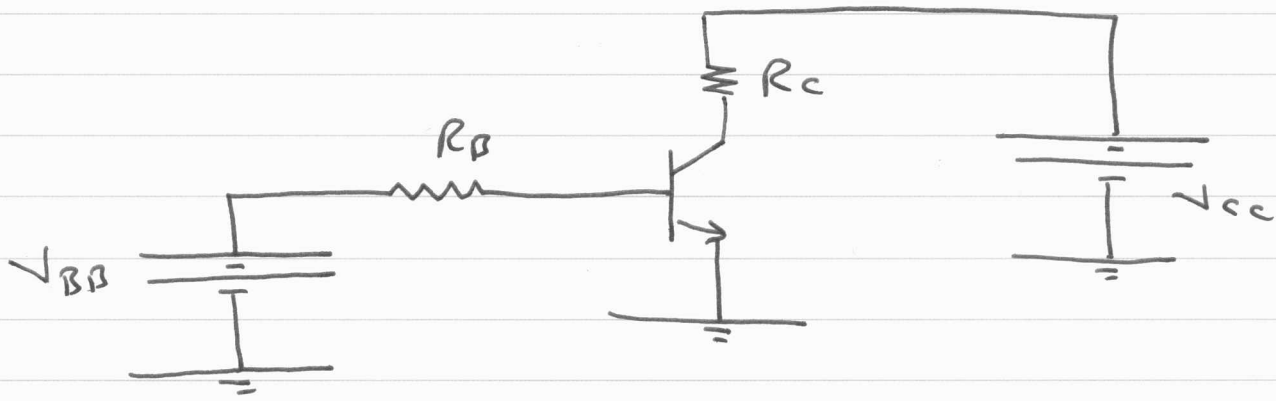
$$\therefore I_B = \frac{5 - 0.7}{200k + (101) 2k} = 0.0107 \text{ mA}$$

$$\therefore I_C = \beta I_B = 1.07 \text{ mA}$$

$$\text{KVL : } 10 = 3k I_C + V_{CE} + 2k I_E$$

$$\therefore V_{CE} = 4.63 \text{ V} > V_{CE, \text{sat}} \quad \checkmark$$

Second method



1) In the active region

$$I_B = \frac{V_{BB} - V_{BE}}{R_B}$$

$$I_C = \beta I_B$$

$$V_{CE} = V_{CC} - R_C I_C$$

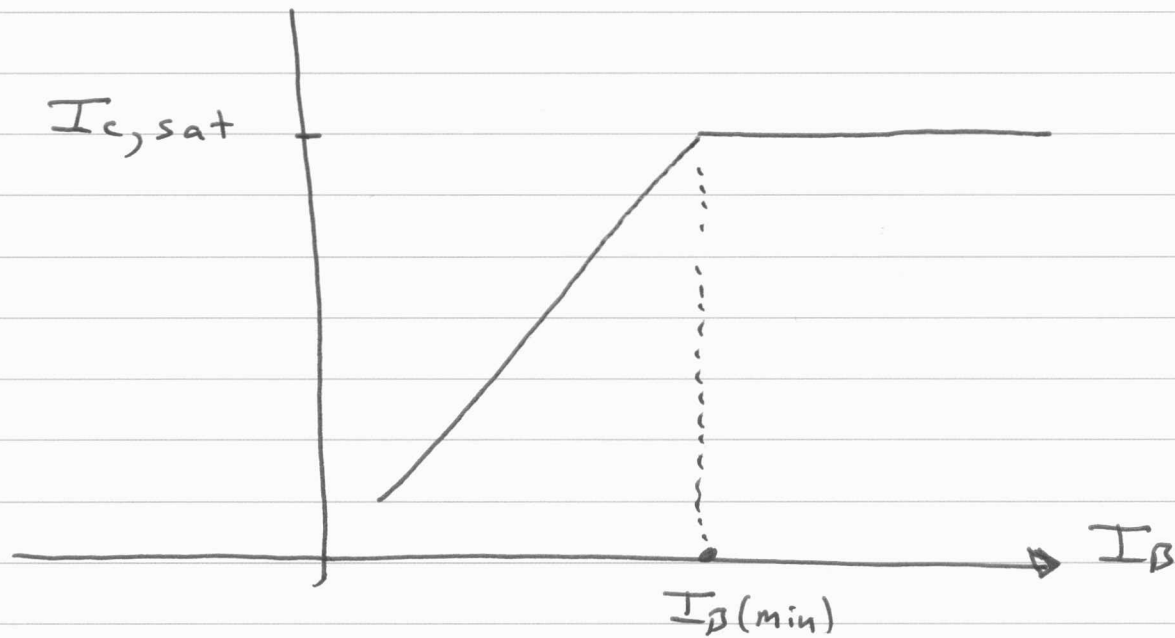
as $R_B \downarrow$, $I_B \uparrow$, $I_C \uparrow$, $V_{CE} \downarrow$

2) In Saturation

$$V_{CE} = V_{CE, \text{sat}} = 0.2 \text{ V, Si, npn}$$

$$\therefore I_C = I_{C, \text{sat}} = \frac{V_{CC} - V_{CE, \text{sat}}}{R_C}$$

$$\text{let define } I_B(\text{min}) = \frac{I_{C, \text{sat}}}{\beta}$$

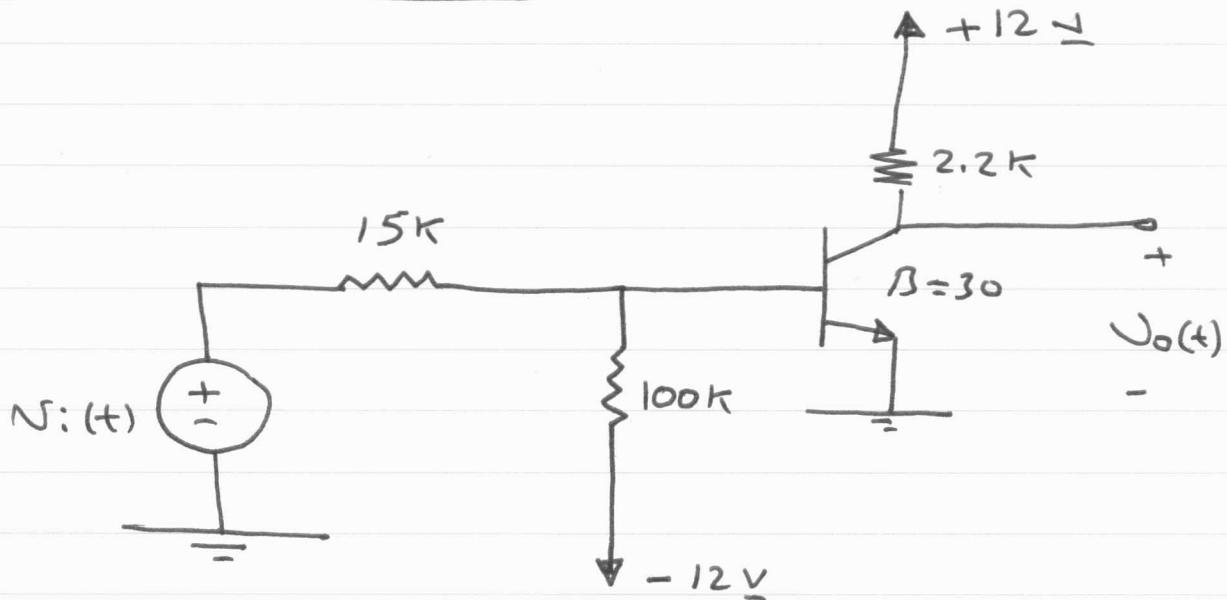
I_C 

$$I_{B(min)} = \frac{I_{C,sat}}{\beta}$$

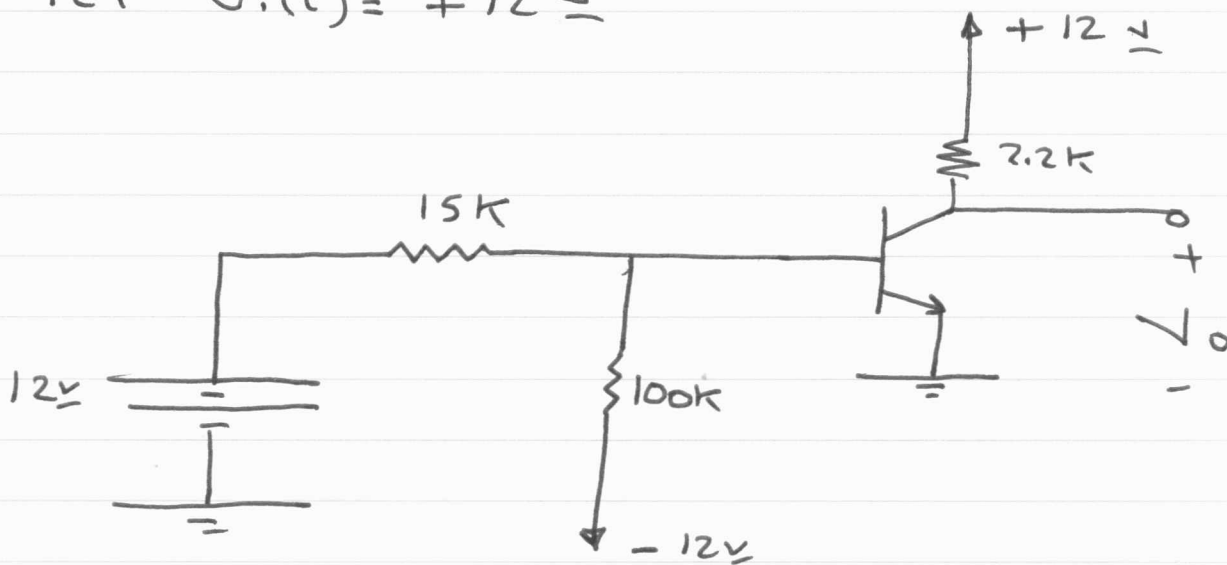
if $I_B > I_{B(min)}$, the transistor is
in saturation

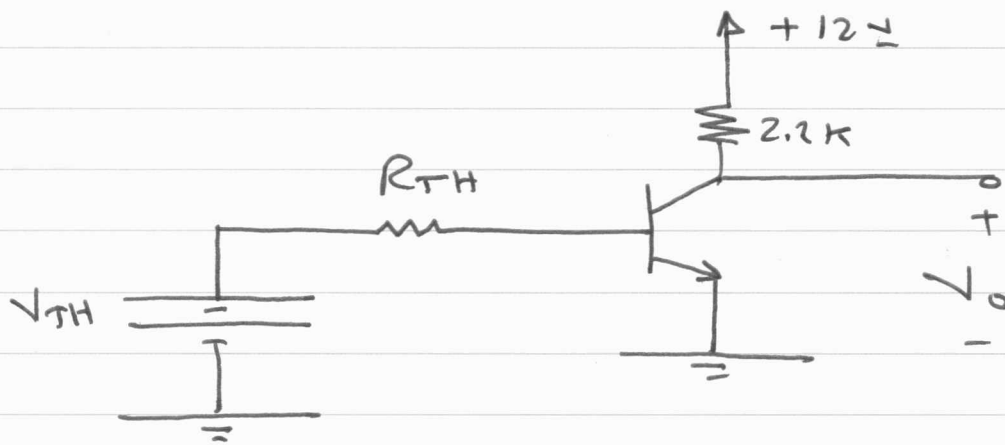
if $I_B < I_{B(min)}$; the transistor
is in the active region

BJT as a Switch



1) let $V_i(t) = +12\text{V}$





$$R_{TH} = 15k \parallel 100k = 13k$$

$$V_{TH} = 8.9 \text{ V} \quad \text{Proof!}$$

Since the base-emitter junction is forward biased, the transistor could be either in the active or the saturation region.

Assume that the transistor is in the saturation region.

$$I_{C, \text{sat}} = \frac{12 - 0.2}{2.2k} = 5.36 \text{ mA}$$

$$I_B(\text{min}) = \frac{I_{C, \text{sat}}}{\beta} = 0.18 \text{ mA}$$

$$\text{KVL: } I_B = \frac{V_{TH} - 0.8}{R_{TH}} = 0.62 \text{ mA}$$

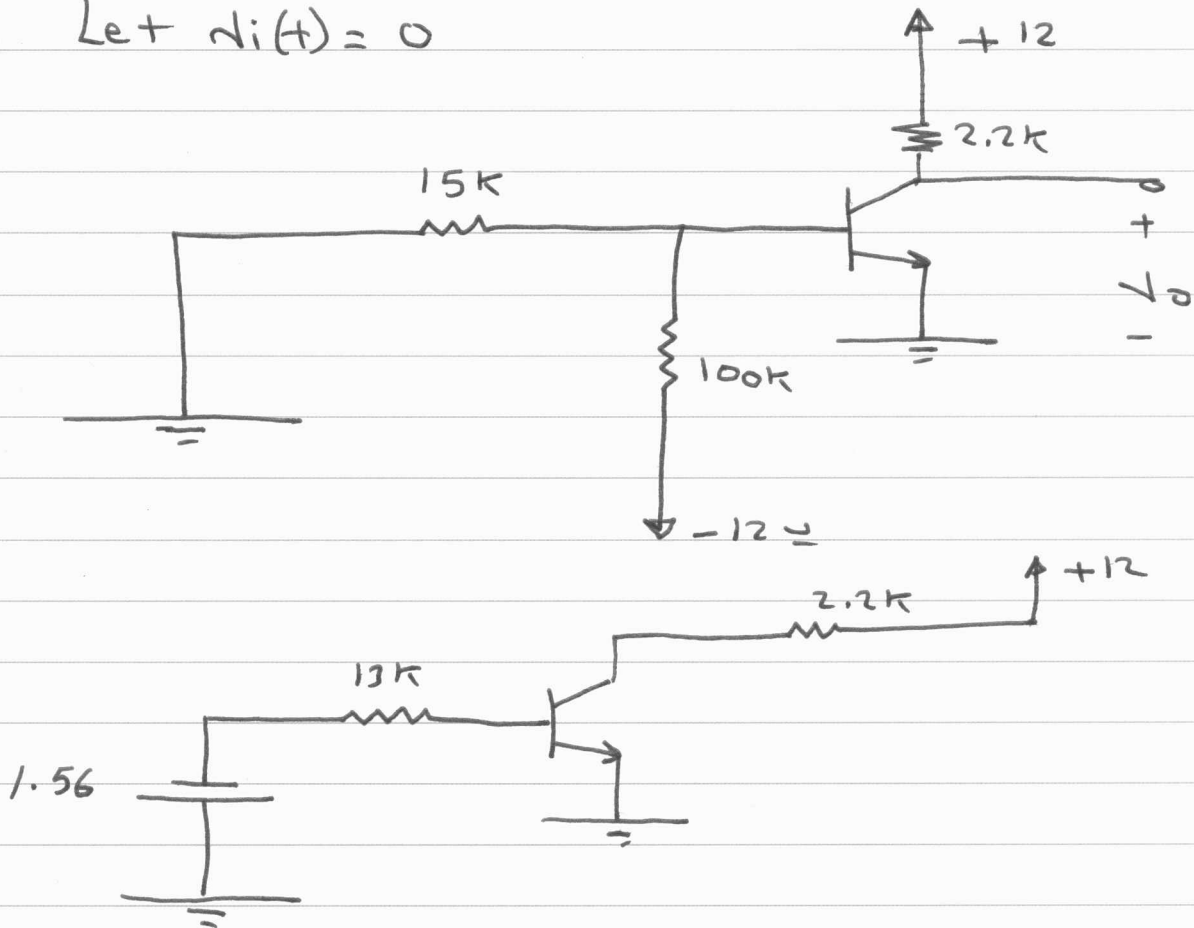
Since $I_B > I_B(\text{min})$

$\therefore$ Transistor is in saturation

$$\therefore V_o = V_{CE, \text{sat}} = 0.2 \text{ V}$$

$$I_c = I_{c, \text{sat}} = 5.36 \text{ mA}$$

2) Let $i_i(t) = 0$



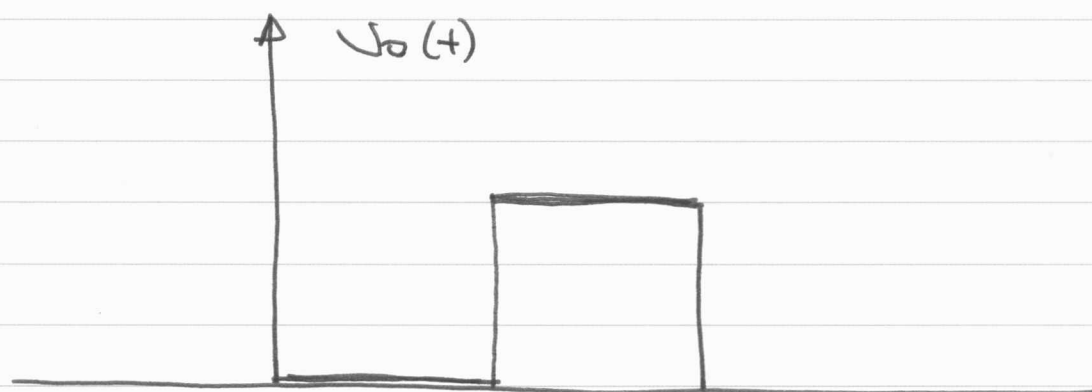
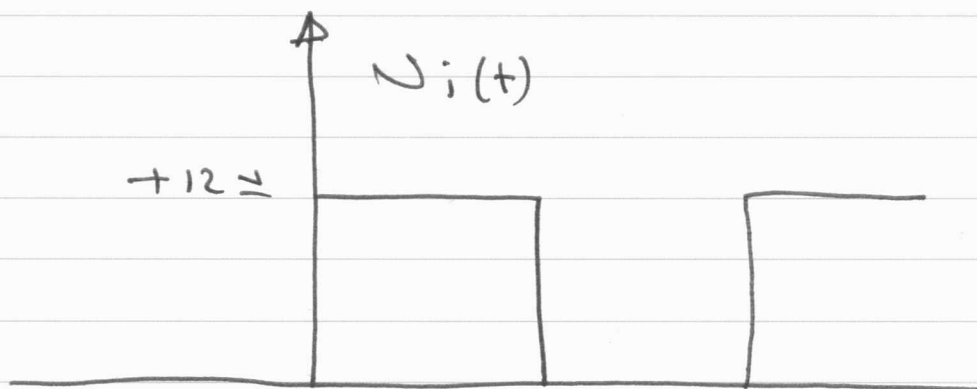
Since $V_{TH} = -1.56 \text{ V}$

$\therefore$ base emitter junction is reverse biased

$\therefore$ The transistor is in Cut off

$$\therefore I_c = 0$$

$$\therefore V_o = V_{CE} = +12 \text{ V}$$



The circuit acts as an inverter or not gate.