1) In the cutoff region

$I_B = 0$ ; $I_C = 0$, and $I_E = 0$

2) In the active region

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

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

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

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

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

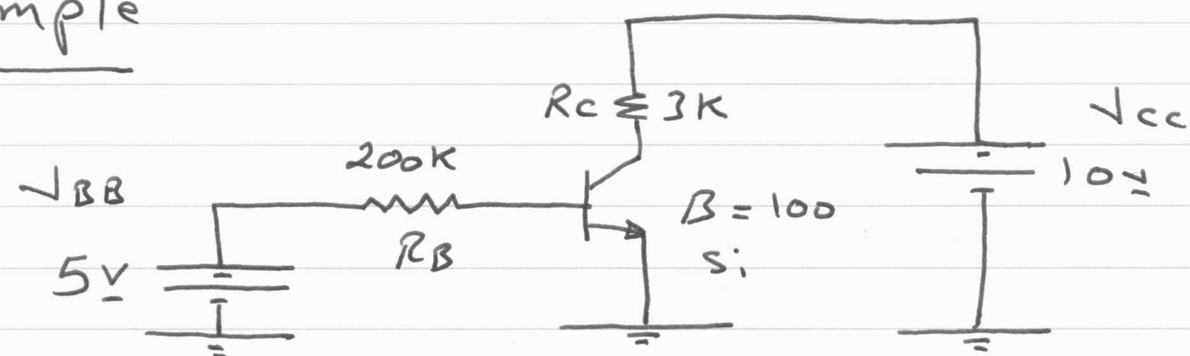
3) In the saturation region

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

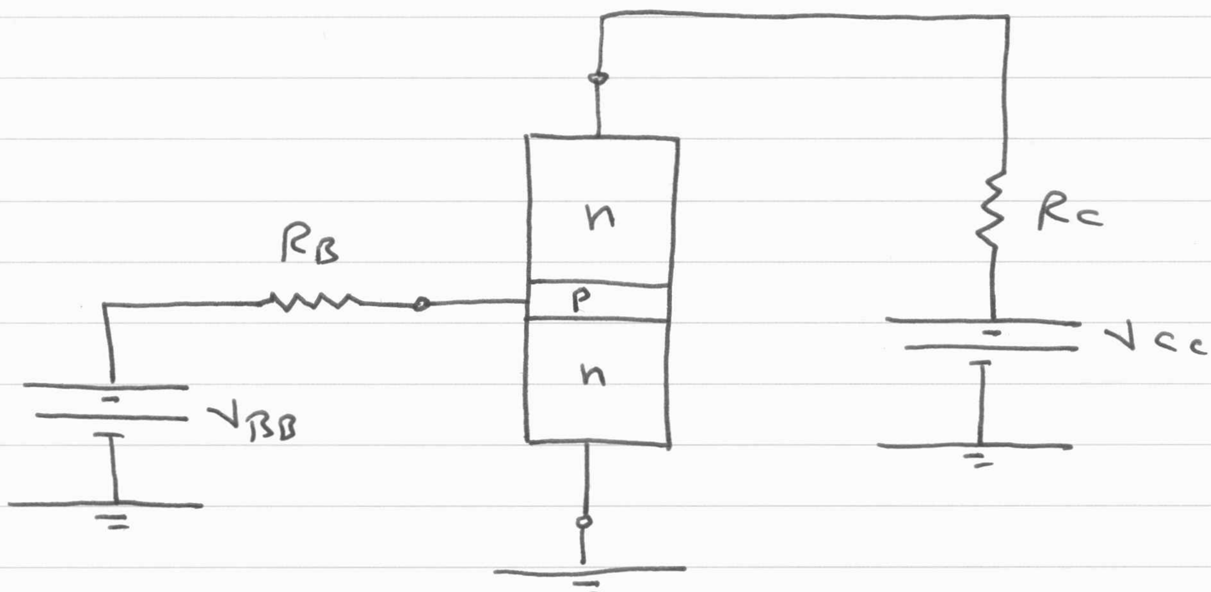
$V_{BE} = 0.8\,V$ , Si, npn

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

## Example

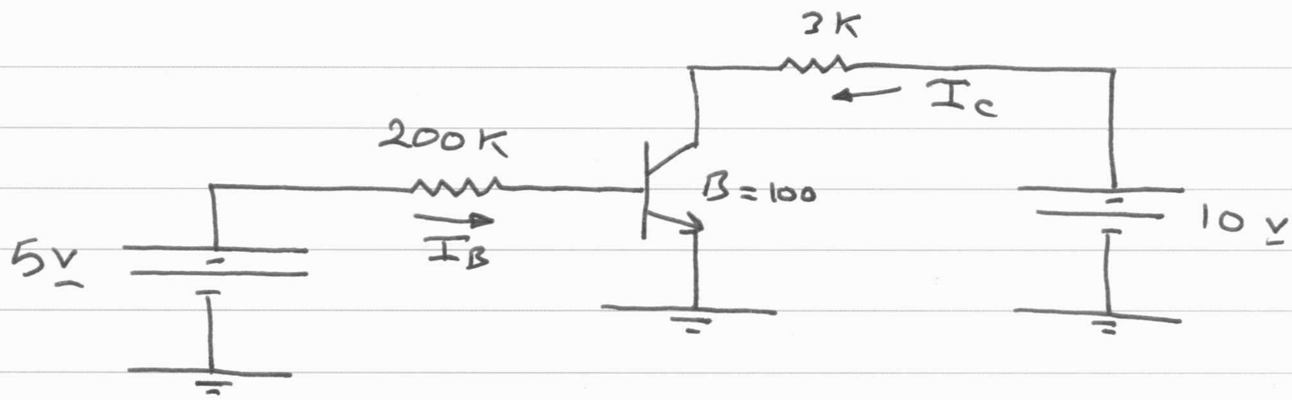



Find Q point ($I_{CQ}$, $V_{CEQ}$).




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

∴ Assume that the Transistor is in the active region.




KVL : $5 = 200K\, I_B + V_{BE}$

$\therefore I_B = \dfrac{5 - 0.7}{200K} = 0.0215\, mA$

$\therefore I_C = \beta I_B = 2.15\, mA$

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

$10 = 3K\, I_C + V_{CE}$

$\therefore V_{CE} = 10 - (3K)(2.15m\, A)$

$V_{CE} = 3.55\, V$

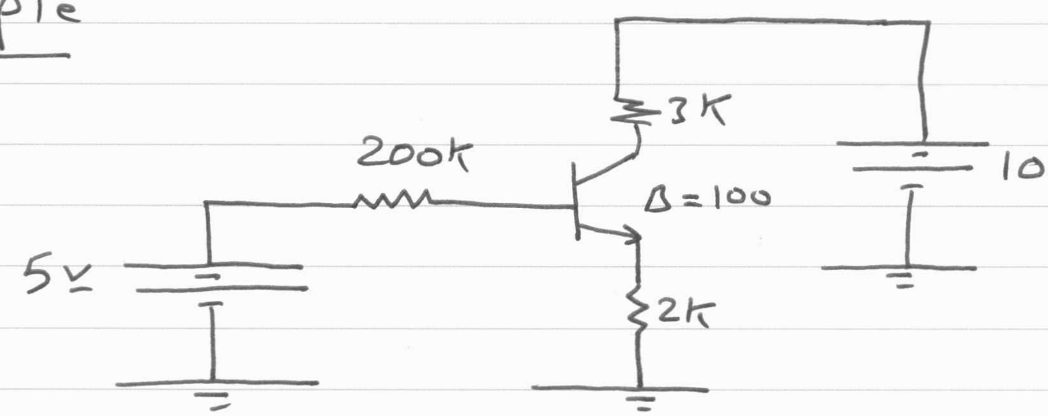
Since $V_{CE} > V_{CE,sat}$

$\therefore$ Transistor is in the active region

$I_{CQ} = 2.15\, mA$

$V_{CEQ} = 3.55\, V$

## 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.

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

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

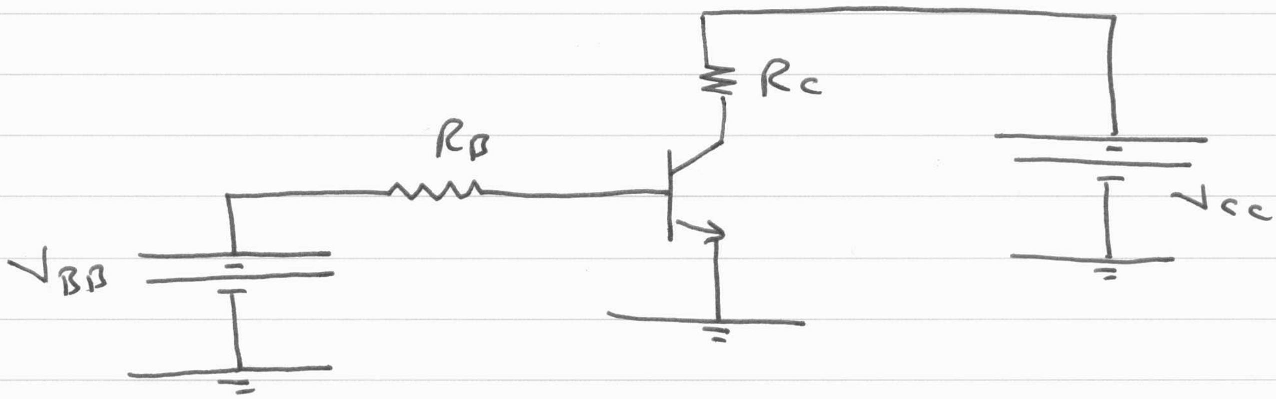
$$\therefore I_B = \frac{5 - 0.7}{200k + (101)\, 2k} = 0.0107 mA$$

$$\therefore I_C = \beta I_B = 1.07\ mA$$

KVL : $10 = 3K\, I_C + V_{CE} + 2K\, I_E$

$$\therefore V_{CE} = 4.63 V > V_{CE,sat}$$ ✓

## Second method




1) In the active region

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

$$I_C = \beta I_B$$

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

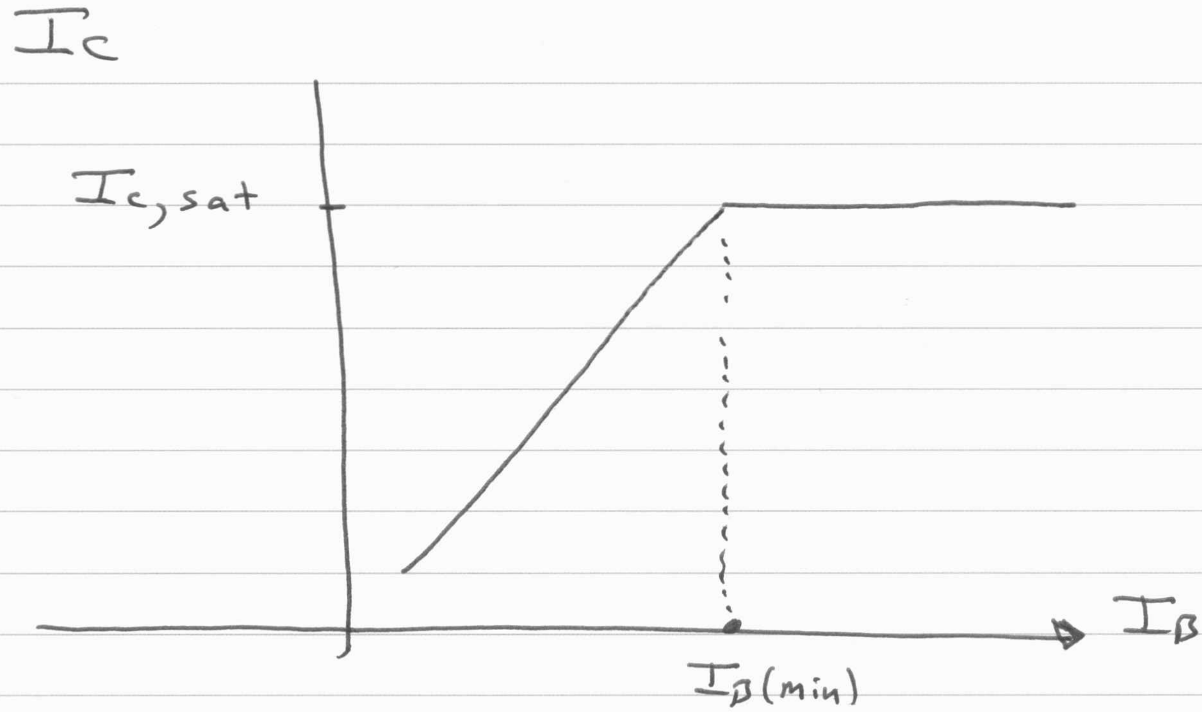
as $R_B \downarrow$, $I_B \uparrow$, $I_C \uparrow$, $V_{CE} \downarrow$

2) In saturation

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

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

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

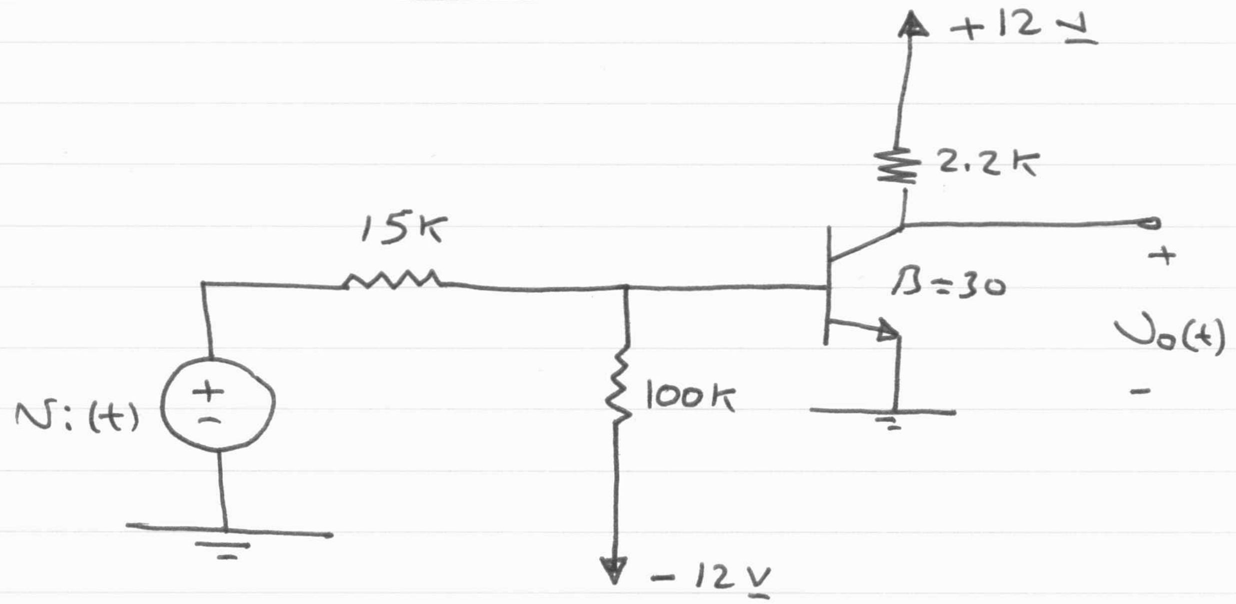



$$I_B(min) = \frac{I_{C,sat}}{\beta}$$

if $I_B > I_B(min)$, the transistor is in saturation

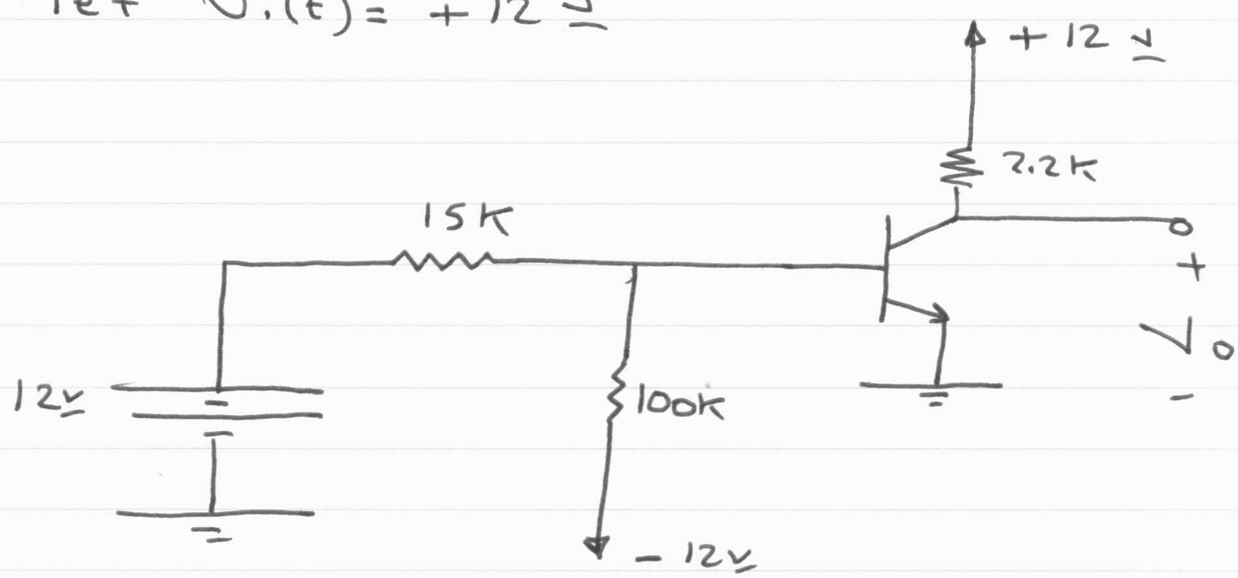
if $I_B < I_B(min)$; the transistor is in the active region

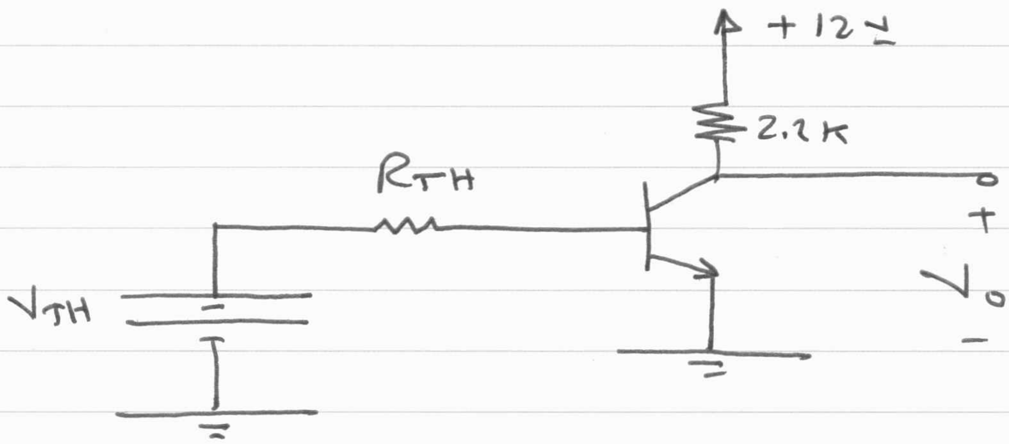
# BJT as a Switch





1) let $v_i(t) = +12\,V$






$R_{TH} = 15K \| 100K = 13K$

$V_{TH} = 8.9\ V$ 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

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

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

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

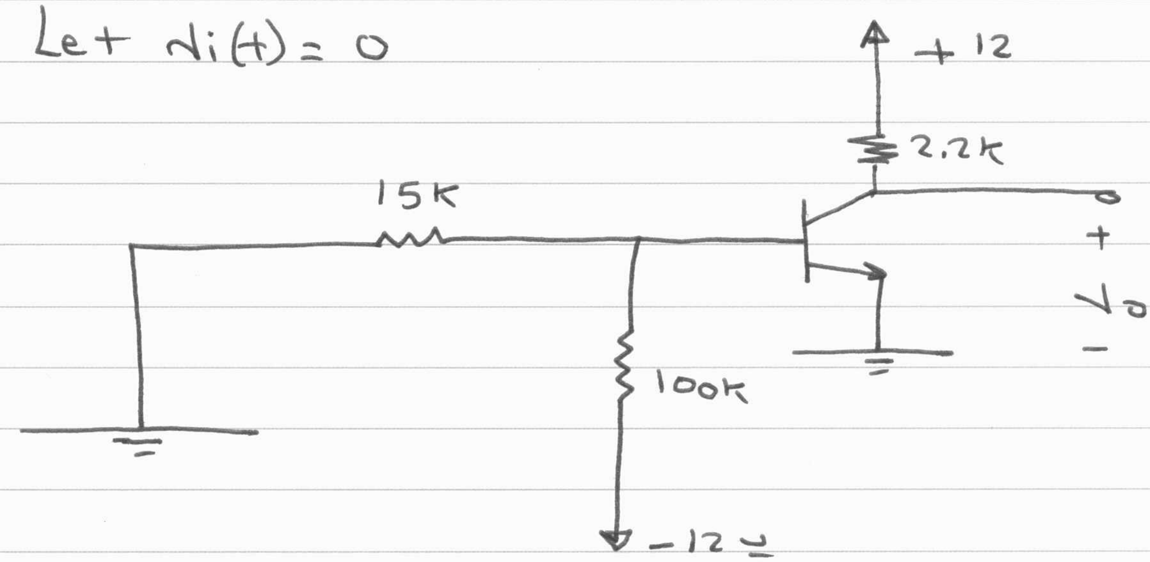
Since $I_B > I_B(min)$

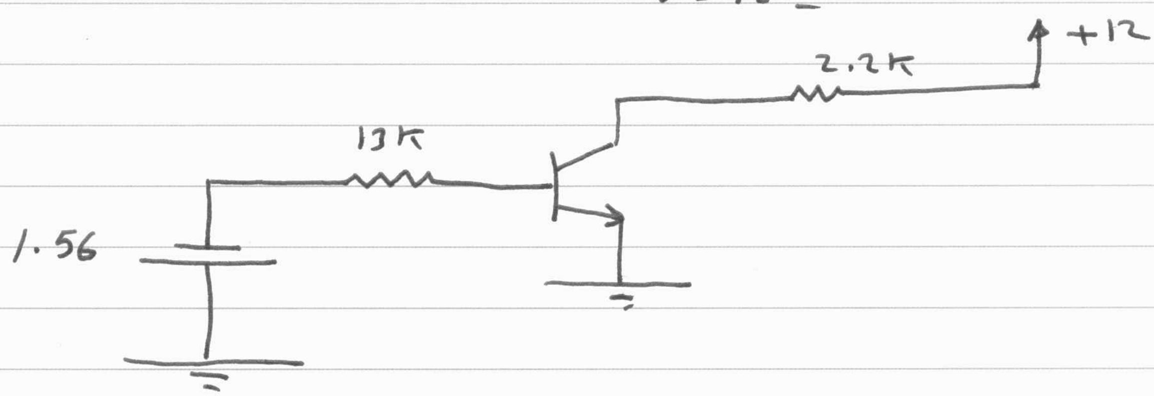
$\therefore$ Transistor is in saturation

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

$I_C = I_{C,sat} = 5.36 \; mA$

2) Let $v_i(t) = 0$



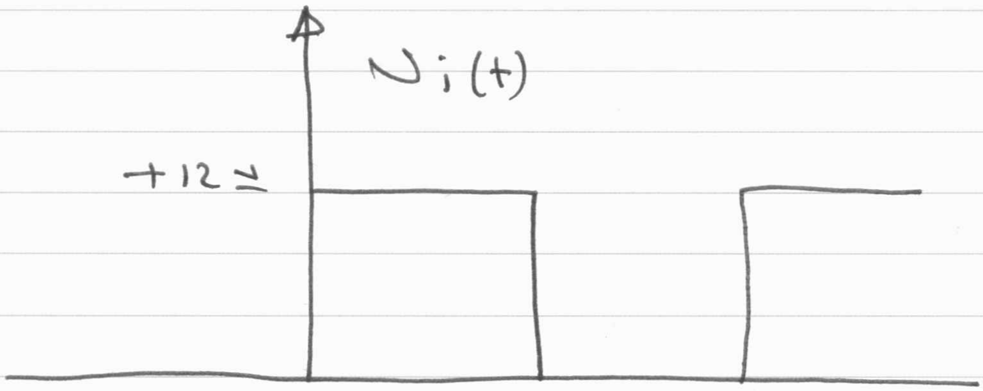

Since $V_{TH} = -1.56 \; V$

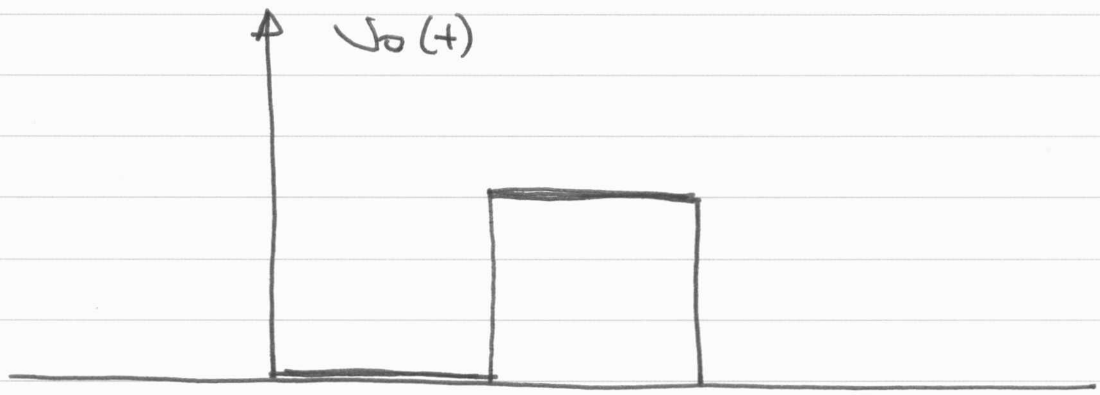
$\therefore$ base emitter junction is reverse biased

$\therefore$ The transistor is in Cutoff

$\therefore \; I_C = 0$

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




The circuit acts as an inverter or not gate.