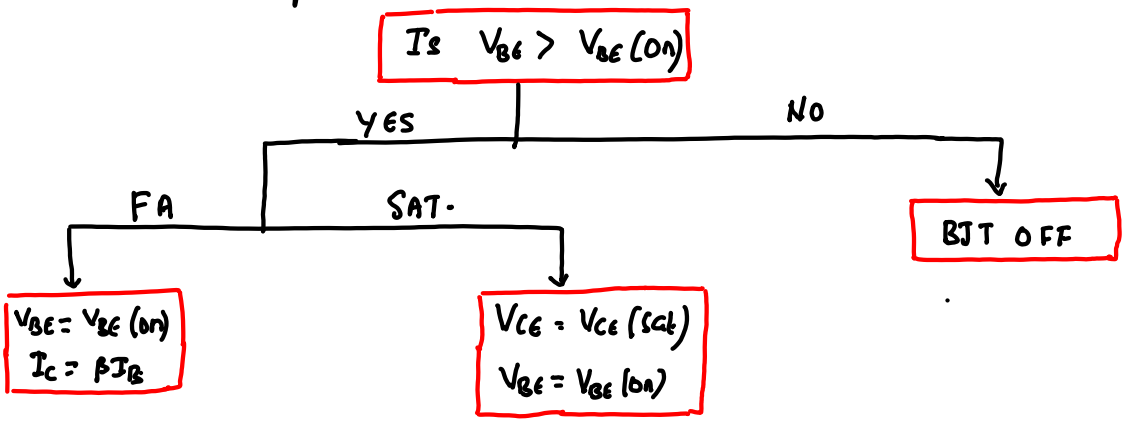
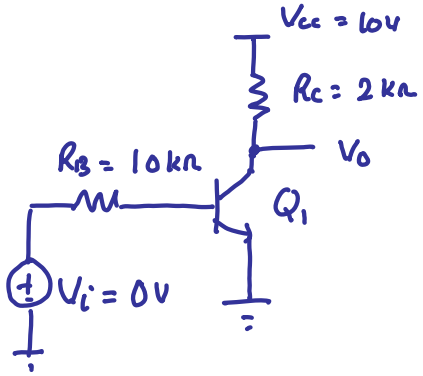
Logic gates using BJT

Recall: BJT operation

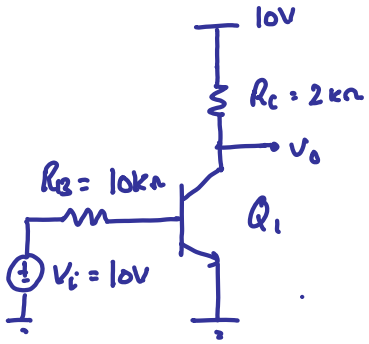


Consider the following two circuits:

$V_{BE(on)} = 0.7\ V$ $\quad$ $V_{CE(sat)} = 0.2\ V$



Q_1 OFF



$$I_B = \frac{10 - 0.7}{10k\Omega} = 0.93\ mA$$

$I_C = \beta I_C$ (Assuming FA)

$= 9.3\ mA$

$V_o = V_{cc} - I_C R_C = -8.6\ V$

$\Rightarrow$ Q_1 SATURATION

Hence:

1. $V_i = 0\ V \Rightarrow$ BJT OFF
2. V_i = Large Voltage $\Rightarrow$ BJT SATURATION (FOR THE CORRECT CHOICE OF V_{cc}, R_B, R_C)

Logic Gates Using BJT:

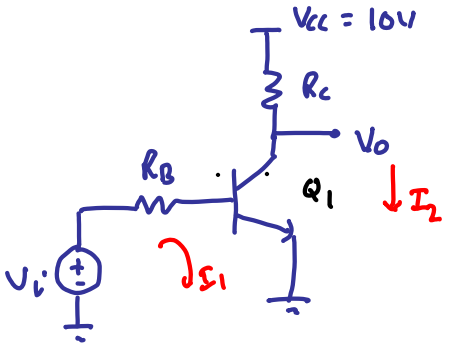
We will now use the BJT to design logic gates.

For logic gate design the BJT has the following two states of operation:

① ..Saturation OR ② OFF

i.e the voltages and resistors are picked so that the above conditions hold. The transistor now behaves as a Switch

Consider the following circuit:



$R_C = 1\,k\Omega$

$R_B = 1\,k\Omega$

$V_{BE}(on) = 0.7\,V$

Let:

Voltage		Logic level
10 V	→	1
0 V	→	0

V_i	logic state i/p	Q_1 State	V_o	V_o State
0 V	0	OFF	10V	1
10V	1	SAT	0.2 V	0

∴ the circuit performs the NOT function

NOTG: $I_1 = \frac{10 - 0.7}{1k\Omega} = 9.3\,mA$

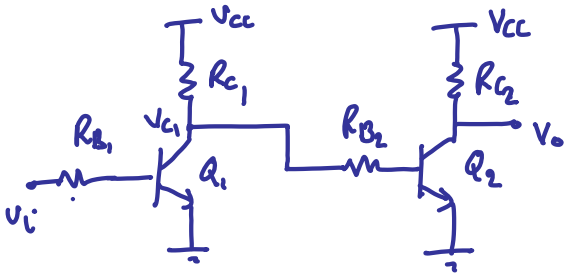
if we assume Q_1 is FA:

$I_2 = \beta I_1 = 930\,mA \Rightarrow V_o = 10 - 930 \times 1 = -920\,V$

∴ $Q_1 \rightarrow$ Saturated

$I_2 = \frac{10 - 0.2}{1k\Omega} \Rightarrow I_2 = 9.8\,mA$

(2)



$V_{CC} = 10V$

$R_{C_1} = R_{C_2} = R_{B1} = R_{B2} = 1k\Omega$

$V_{BE}(on) = 0.7\ V$

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

$\beta = 100$

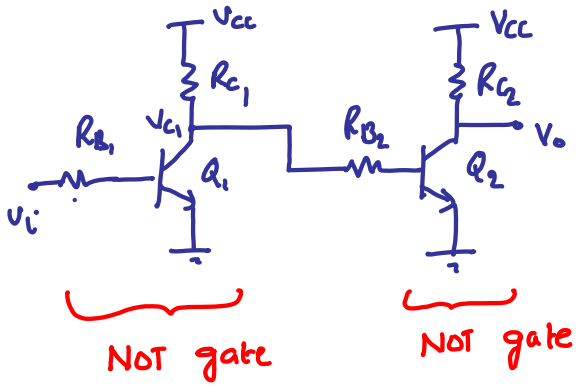
V_i	Q_1	V_{C_1}	Q_2	V_o
0 V	OFF	10V	Sat	0.2 V
10 V	Sat	0.2V	OFF	10 V

Assume : High : 8V – 10V

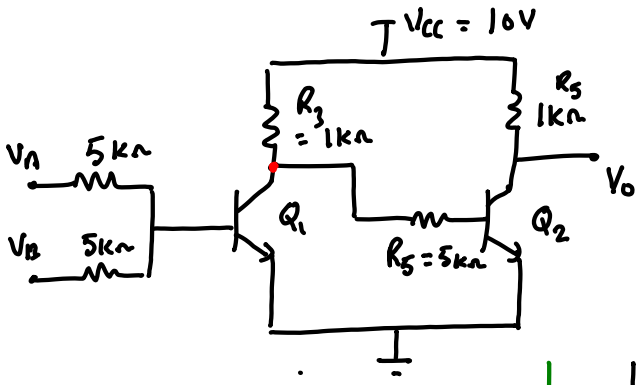
Low : 0 – 1V

Input	output
0	0
1	1

NOTE :



②



$V_{BE}(on) =$

$\beta = 100$

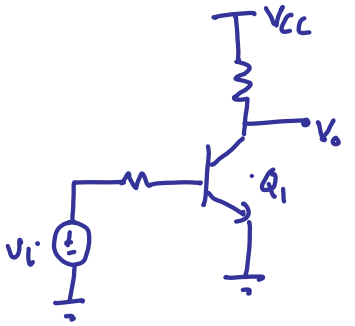
V_A	V_B	Q_1	Q_2	V_o
0 V	0 V	OFF	SAT	0·2
0 V	10V	SAT	OFF	10 V
10V	0 V	SAT	OFF	10V
10V	10V	SAT	OFF	10

LOGIC FUNCTION :

A	B	Z
0	0	0
0	1	1
1	0	1
1	1	1.

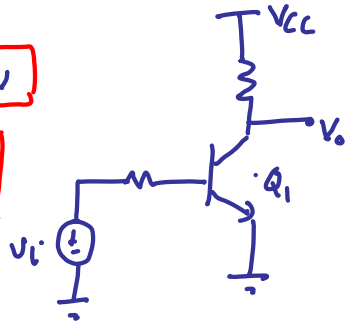
⇒ OR GATE

Transistor as a Switch :



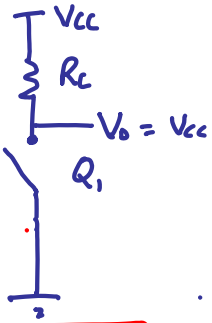
$V_{CC} = 10V$

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

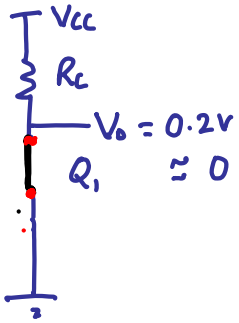


$V_i = 0 \Rightarrow Q_1$. OFF

$V_i = 10V \Rightarrow Q_1$. SAT (ON)

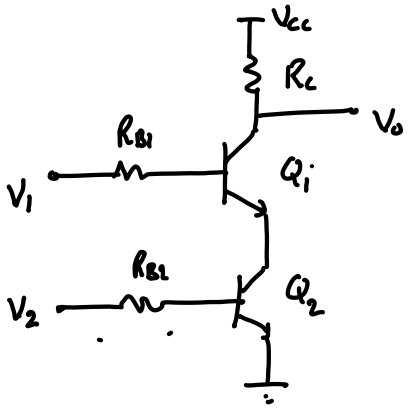


$\therefore$ $V_o = V_{CC}$



$V_o = 0.2V \simeq 0V$

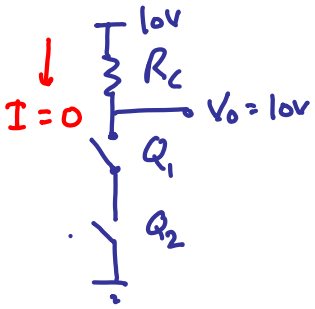
Consider two transistor in series



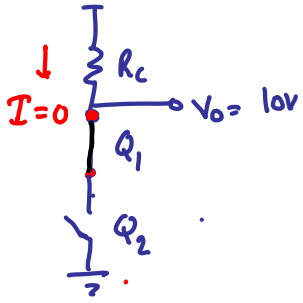
$V_{cc} = 10V$

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

① $V_1 = V_2 = 0\,V$



② $V_1 = 10V$ $V_2 = 0V$



③ $V_1 = 0V$ $V_2 = 10V$