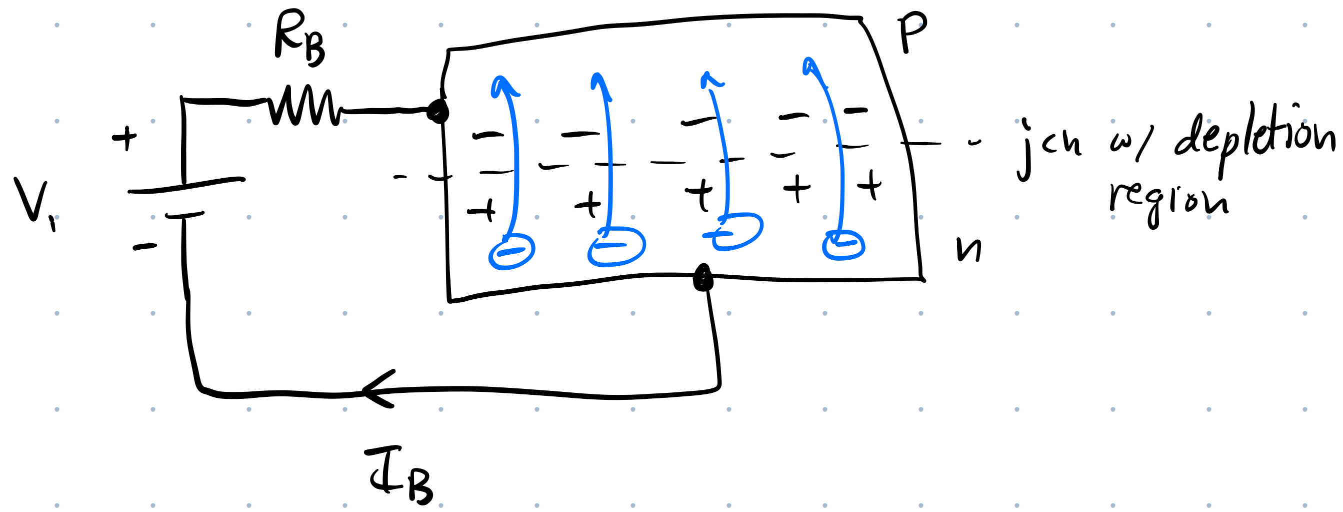
PHYS 231 Nov. 25, 2024

Bipolar Junction Transistor (BJT)

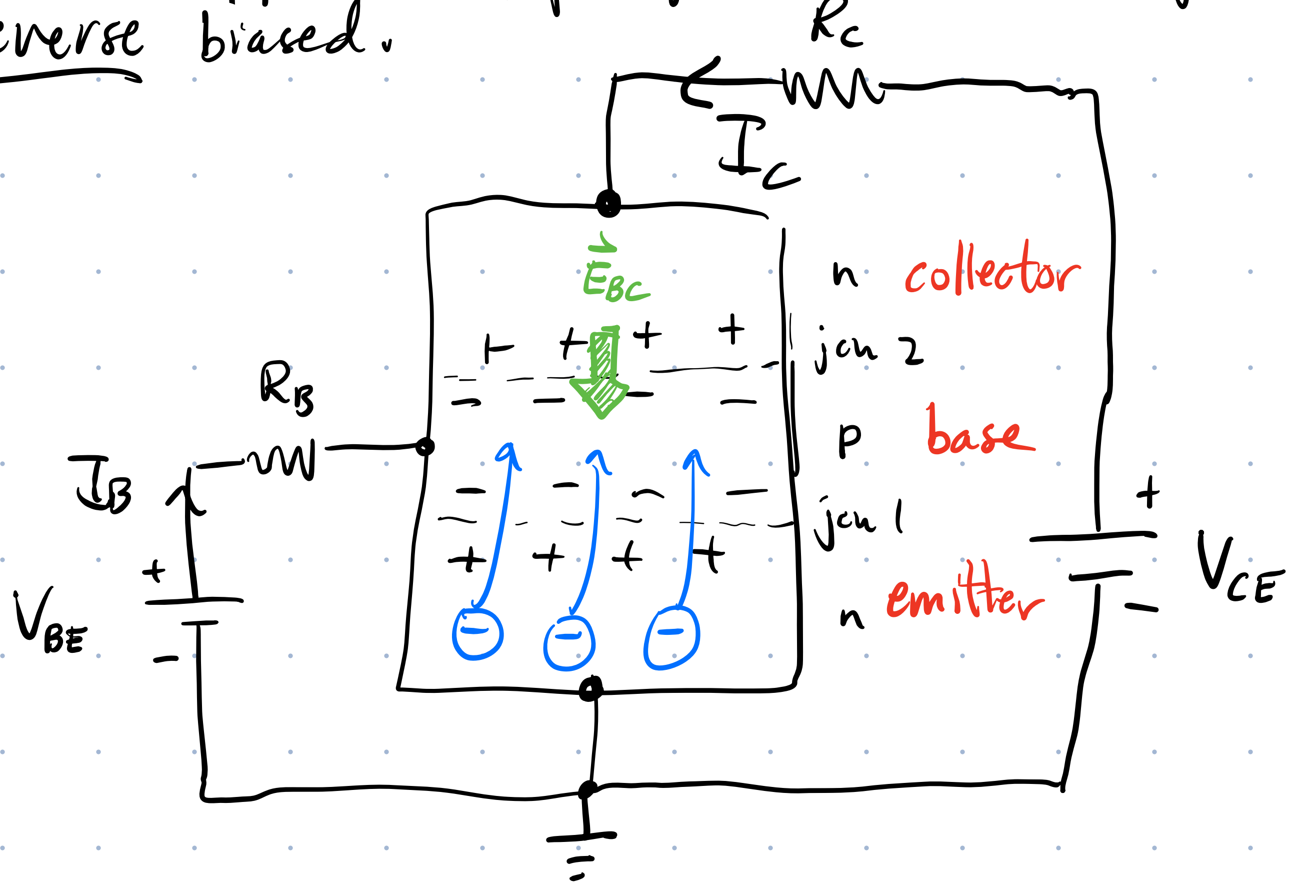
Start w/ a forward biased diode.



If $V_1 \geq V_D \approx 0.7\,V$, get large conduction across jcn.

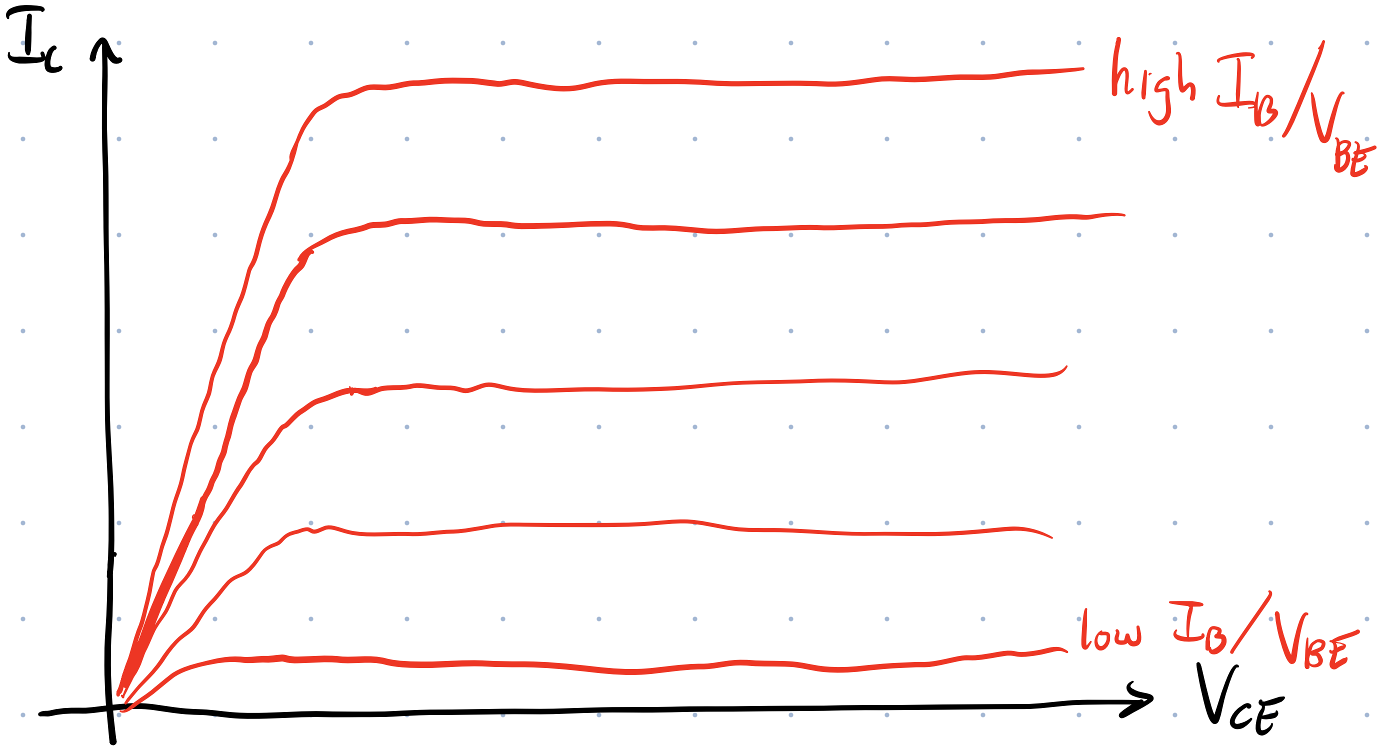
When making a transistor, n-region is much more heavily doped than p-region → most of current is due to flow of e^-.

To complete the BJT, a second p-n junction is created on opp. side of p-region. This second jcn is <u>reverse</u> biased.



Electrons from emitter injected into the base. Those that reach the depletion region of the base-collector are swept across the jcn by $\vec{E}_{BC}$. The base of the transistor is made thin to increase the prob. that e^- reach the base-collector jcn.

Increasing V_{CE} extends the depletion region at base-collector jcn which allows more e^- to be swept into the collector which increase I_C.

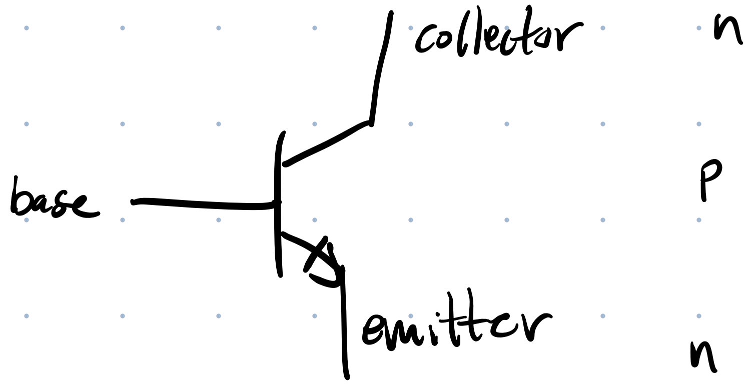


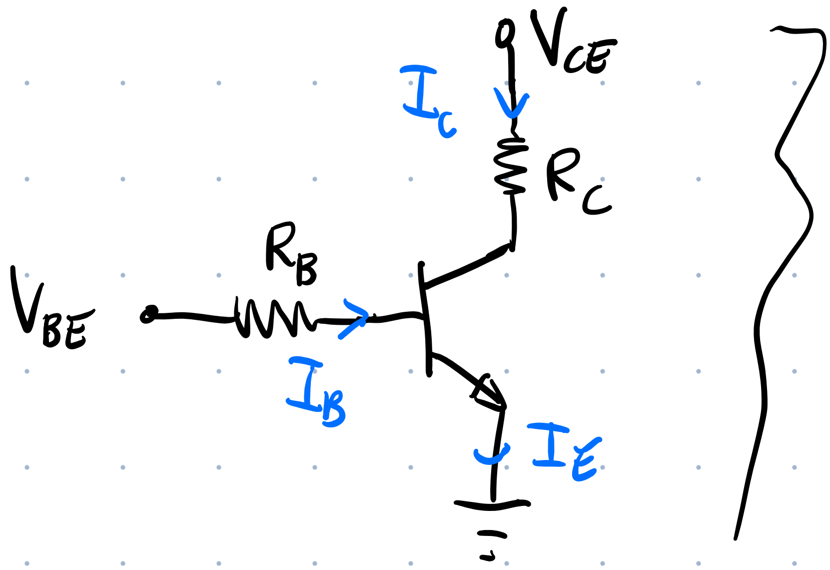
At some pt., essentially all e^- reach the collector & increasing V_{CE} no longer changes I_c.

Increasing $I_B = \frac{dq}{dt}$ (by increasing V_{BE})

increases the rate that e^- are injected into the emitter &, therefore, increases I_C for all values of V_{CE}.

Transistor circuit symbol (BJT, npn)





The circuit we've been analyzing above.

Because the base is thin, most e^- from emitter cross into the collector. ∴ I_B is always small.

By jcn rule: $I_B + I_C = I_E$

But since I_B is small, $I_C \approx I_E$ or $I_C = \alpha I_E$

where $\alpha \approx 0.99$ typically.

$$\therefore I_B = I_E - I_C = I_E(1-\alpha)$$

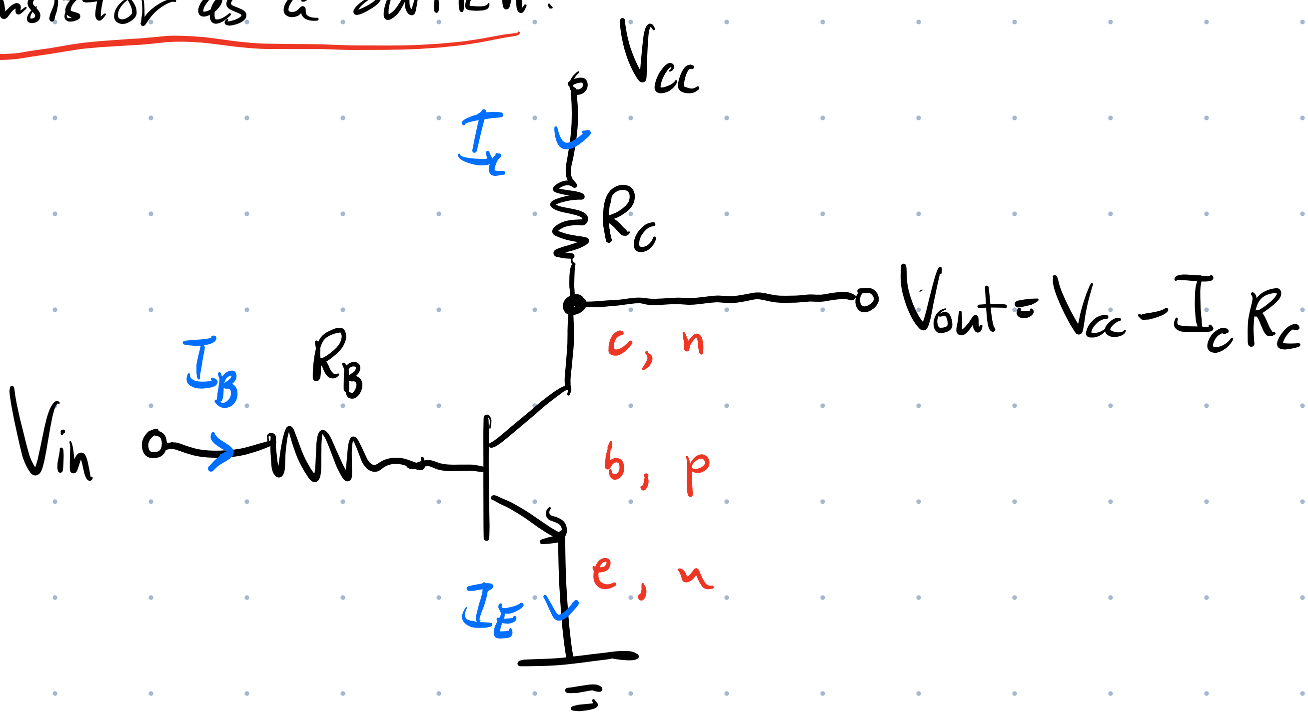
$$\therefore \frac{I_C}{I_B} = \frac{\alpha I_E}{(1-\alpha) I_E} = \frac{\alpha}{1-\alpha} \equiv \beta = 99$$

beta

Get a large current gain $(I_C = \beta I_B)$

In this way, transistor can be used as a current amplifier.

Transistor as a Switch.



Case ①: $V_{in} < 0.7V$

$\therefore$ B-E jcn is <u>reverse</u> biased

$\Rightarrow I_C = 0.$

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

case ② $V_{in} \gg 0.7V$ $\therefore I_B$ large

$\rightarrow I_C$ large.

$\therefore$ B-E jcn is forward biased.

$\Rightarrow I_C \neq 0.$

$\therefore V_{out} = V_{CC} - I_C R_C$ is small

Eventually, for sufficient I_C, both the B-E & B-C jcn become forward biased. $\Rightarrow V_{out} \approx 0.$

Truth Table

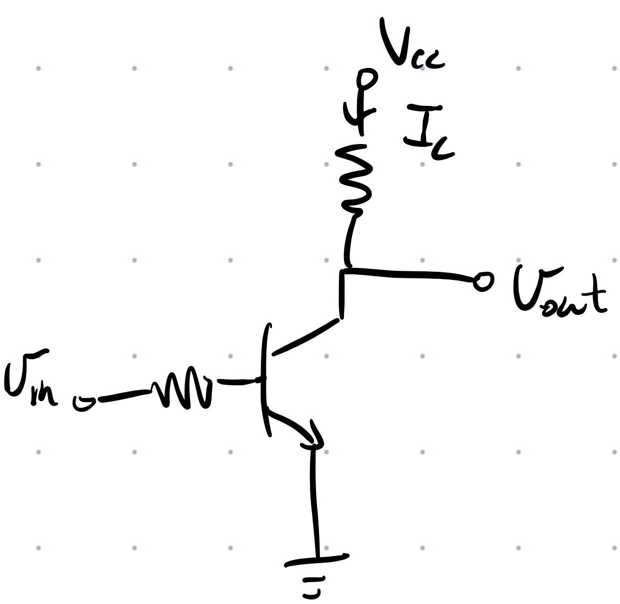
$V_{in} = V_B$	I_C	V_{out}
0 (LO)	0	V_{cc} (HI)
V_{cc} (HI)	$\neq 0$	0 (LO)

$\Rightarrow$

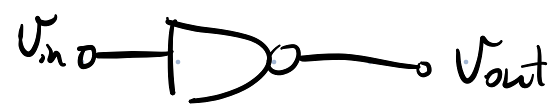
$V_{in} = V_B$	V_{out}
0	1
1	0

turn current through transistor off and on using $V_{in} \rightarrow$ switch

truth table is that of an inverter (NOT gate).

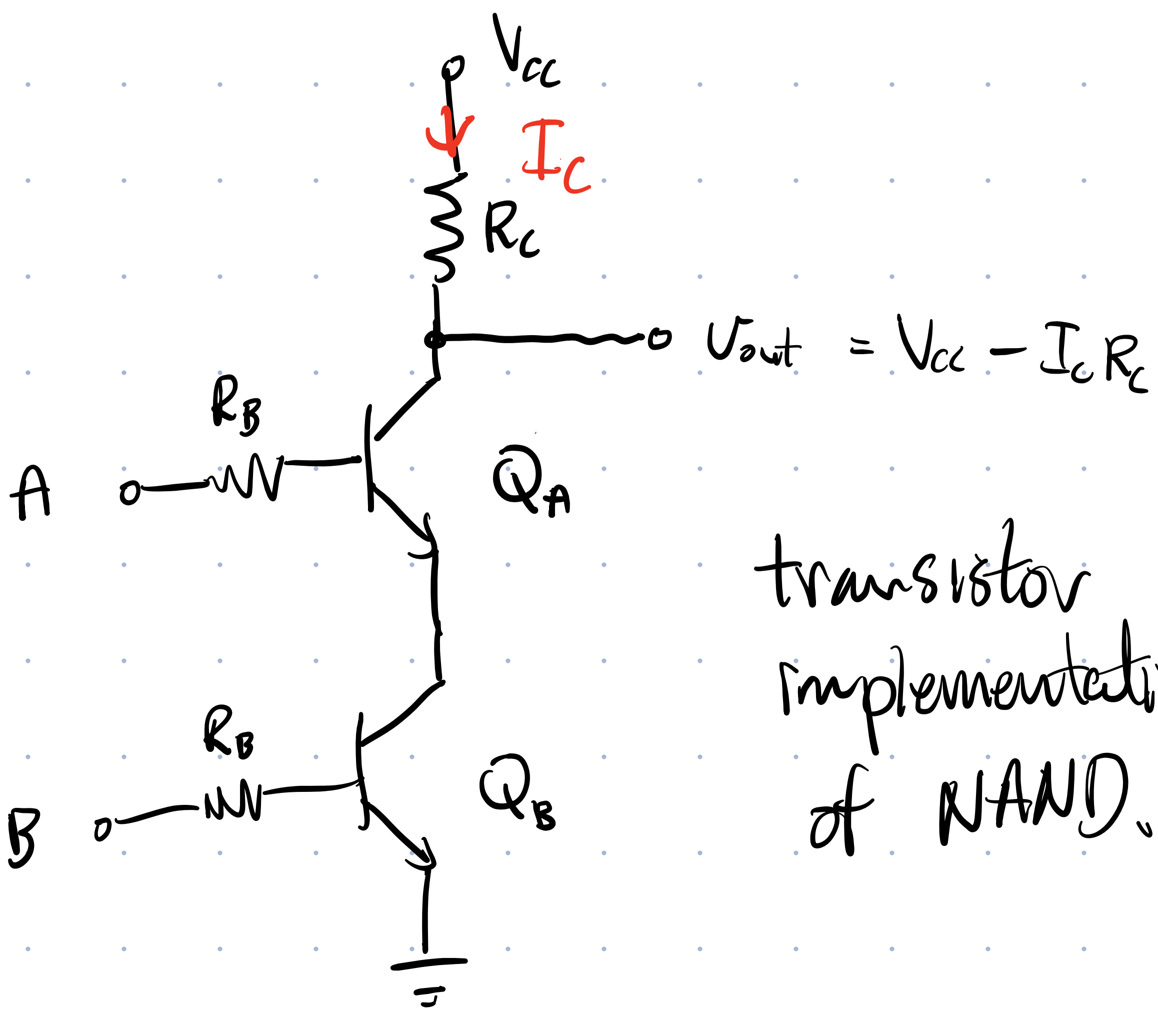


$\Rightarrow$



What about other logic gates?

Consider a series combination of two transistors.



transistor implementation of NAND.

A	B	Q_A	Q_B	I_c	V_{out}
0	0	OFF	OFF	0	1
0	1	OFF	ON	0	1
1	0	ON	OFF	0	1
1	1	ON	ON	$\neq 0$	0

A	B	Vout
0	0	1
0	1	1
1	0	1
1	1	0

NAND.