Lecture 6 - Transistors

Resistors, capacitors, diodes are passive devices
- Apply a voltage, set a current
- Always some power dissipation

Most applications require active components
- Generate or amplify a signal
- Really, transfer power from a supply to a signal

Basic active building block: Transistor

Three terminals:

Collector

Base

Emitter.

Simple explanation of what it does:

Current amplifier: \( I_{CE} = \beta I_{BE} \)

\( \beta \approx 100 \) typically

Current from collector to emitter

Picture: transistor men adjusts potentiometer
to keep \( I_{CE} = \beta I_{BE} \)

- All he can control is pot setting

If \( V_C \leq V_E \), pot is at minimum resistance,
current at maximum.

Say transistor is saturated
Start saturating if \( V_C - V_E < \approx 1 \) \( V \)
Completely saturated if \( V_C - V_E \approx 0.2 \) \( V \)
So in typical circuit:

\[
\begin{align*}
15V & \quad \text{Vcc} \\
\frac{3}{2}R & \quad I_c \\
I_B & \quad I_e \\
\end{align*}
\]

Have \( V_c = 15V - I_c R \)

Starts to saturate at \( I_c R = 14V \)

Get

\[
\begin{align*}
I_c & \quad \text{vs} \quad 15V/R \\
14V/R & \quad \text{saturation} \\
I_c = \beta I_e & \quad \text{vs} \quad I_e \\
\end{align*}
\]

So you can't just count on \( I_c = \beta I_e \)

Some more details:

1) Looks like diode from B to E (arrow in symbol)

Get diode drop \( V_B = V_E + 0.6V \)

2) Value of \( \beta \) varies from device to device

With temperature

Better to use external components to set gain; see lab

3) Limits on \( I_c, I_e, V_{ce} \) & total power (or device breaks)

ZN3904

\[
\begin{align*}
I_c & < 200mA \\
I_e & < 100mA \\
V_{ce} & < 40V \\
P & < 500mW \\
\end{align*}
\]

Important to consider when designing circuit!
Physics:

Recall diode = pn junction

Transistor = two junctions

So B-C & B-E really are diodes

Wouldn't expect any current C→E

If $V_C > V_E$, set current B→E only

$\Rightarrow$ electrons from E→B

But, base region is very thin

Electrons that enter through E see positive attractive potential in C region. ~99% get diverted into C rather than exiting via B

$\Rightarrow$ current from C to E, $I_{CE} = 100I_{BE}$

Actually two types of transistor

npn as described

$pnp$:

Very similar, but currents reversed: $I_{EC} = \beta I_{EB}$

Need $V_C > V_L$

To remember:

npn: needs positive base

pnp: needs negative base

for current gain in normal operation