Active circuit elements: the transistor (`transfer resistor')
And some useful circuits with transistors
A quick interlude on diodes...

- Note: 0.6V "diode drop:"

100V "reverse breakdown:"

\[ I = \frac{V - 0.6V}{R} \]

Devised: Rectifier:

\[ V_{in} \]

\[ V_{out} \]

\[ V_{out} \]

Clamps:

\[ V_{clump} \]

\[ V_{-0.6V} \]
Onward with transistors: We’ll work with BJTs (bipolar junction transistors)

Think of it like a valve:
Some ground rules and two views of the transistor:

A relatively simple view: current amplifier

A simpler view: just assume $\beta$ (aka $h_{FE}$) is at work

Current flows on transistor:

\[ V_{BE} = 0.6 \text{ V} \]

\[ I_C \approx I_E \]

\[ \beta = \frac{I_C}{I_E} \]

Ground rules:

1. $V_C > V_E$ by at least $\sim 0.1 \text{ V}$
2. $V_B - V_E \approx 0.6 \text{ V}$
Understanding transistor behavior through example circuits: *a current source*

\[ V_T = 20V \]

\[ V_E = 5V, b_v 0m: S = I_E \cdot 5.1k \]

\[ \Rightarrow I_E = \frac{S}{5.1k} \approx 1mA \]

\[ \Rightarrow I_C = I_E \]

1. Let's say \( R_L \) is very small; \( R_L = 1k \):
   \[ V_C = 19V(?) \quad V_C > V_E, \text{Okay.} \]

2. \( R_L \) gets large; \( 100k \):
   \[ V_T = V_C \approx 1mA \cdot 100k = 100V (!) \]

   \[ V_C > V_E \Rightarrow \text{transistor behavior changes.} \]

   Effect is \( I_C \) is reduced.
Understanding transistor behavior through example circuits: *an emitter amplifier*

1. Let $|V_m| = \Delta V_b$. \[ \Delta V_b \rightarrow \Delta V_e \]
2. $\Delta V_e \rightarrow \Delta I_e \rightarrow \Delta I_c$.
3. If $R_e$ is small, we get $\Delta I_c$.

Alternatively,

$$\Delta V_{out} = \Delta I_c R_c$$

*Note: gain of emitter amp comes from $R_c > R_e$.***
Understanding transistor behavior through example circuits: *a follower*

- $V_E \approx V_m \ (= V_m - 0.6)$.
- Why would we do this?
- Incredible behavior of the transistor in changing impedances.
Understanding transistor behavior through example circuits: a push-pull – npn - pnp device
$\beta$ is a poorly constrained parameter, around 100 but varies by 50-100%!!!

$\beta$ – *do not* use it as a design parameter
Transistor impedance: *not* the V-divider view; `rose-colored lens` effect

A second look at the follower:

\[ \Delta V_{in} = \Delta V_{out} \]

Small \( \Delta I_b \)

\[ \Delta V_{out} = \Delta V_e \sim \Delta V_{base} \]

Large \( \Delta I_e \sim \Delta I_c \)

\[ \Delta I_s \]

\[ \frac{1}{Z_{out}} \]

Looking into base of the transistor, I see a very large impedance.

Looking into the emitter from output, we see a very low impedance.

- Step 1: Measure \( V_{be} \) with a short load, with a 33kΩ resistor on the base.
- Step 2: Connect a 1kΩ load to ground, measure \( V_{be} \) again.
Asymmetry introduces clipping*
(can also be seen for a single-supply follower driven with a symmetric input)

Reach or bridging:
$V_{in}$ $\approx 5V$. 

"A/L coupling"

Output impedance:
looks like $R_e || R_{source} \approx 50\Omega \approx 50\Omega \Rightarrow R_{out} \approx \frac{R_L}{20}$

Again, no dropout.

At $V_{in}$ as low as possible, transistor shuts off $\Rightarrow 3.3k \approx 7k \approx 2k$

This can be addressed with the push-pull introduced earlier.
An anomalous transistor circuit: the switch

- Transistor is in one of two states:
  1. Totally on — current passes through lamp, lights up.
  2. Totally off — no current passes through lamp, no light.

\[ V = I_0 \times R > 0.6V \]

\[ I_C \neq I_{CQ} \text{; } V_{CE} \text{ is low reducing power consumed by transistor.} \]
A summary of our transistor circuits: