Transistors

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2-4 PM
Today we'll be covering

- What are transistors
- BJTs, a very common transistor
- Basic Switches
- Logic Gates
- Amplifiers
- MOSFETs, another very common transistor
What we won't cover

- Why transistors do what they do
- How transistors are made
What are transistors?
What are transistors (really)?
The semiconductor sandwich
BJTs

Used in:
- Very common as discrete components
- Control current
- Low voltage amplifiers
- Cheap, easy switches
BJT

NPN
Q1
2N3904

PnP
Q1
2N3906

- Current controlled current amplifier
- Three main regions of operation
- Has current gain parameter $\beta$
Basic I-V curve
Changing $I_{be}$ changes $I-V$ curve
BJT NPN regions of operation

- **Cut-off**
  - $V_{be} < V_{th}$
  - $I_{ce} = 0$

- **Forward Active**
  - $V_{be} > V_{th}, V_{bc} < 0$
  - $I_{ce} = \beta_F I_{be}$

- **Saturation**
  - $V_{be} > V_{th}, V_{bc} > 0$
  - $I_{ce}$ depends on load
Pull-down resistors

- Ensures that the input sees a certain voltage at all times
- Resistance is arbitrary
- Larger resistances are better (smaller current)
Current limiting resistors

- Sets $I_{be}$ (and thus $I_{ce}$)
- We know desired $I_{ce}$
  - $I_{be} = I_{ce} / \beta$
- Calculate $R$ via Ohm's Law
  - $R = V / I_{be}$
  - $V = V_{total} - V_{be}$
The TO-92 package
NPN Switch

VCC

S1

R2 10k

T1 2N3904

R3 360

LED1

GND
BJT PNP regions of operation

- Cut-off
  - $V_{be} > -V_{th}$, $V_{bc} < 0$
  - $I_{ce} = 0$

- Forward Active
  - $V_{be} < -V_{th}$, $V_{bc} > 0$
  - $I_{ce} = \beta_F I_{be}$

- Saturation
  - $V_{be} < -V_{th}$, $V_{bc} > 0$
  - $I_{ce}$ depends on load
PNP Switch

VCC

S1

T1 2N3906

12k

R1

R2 10k

R3 360

LED1

GND
Logic Gates

- **not**
  - Generate binary output from binary inputs

- **or**
  - Can be chained together to create complex systems

- **and**
  - BJT logic gates operate in the saturation and cut-off regions
Not Gate

Diagram of a NOT gate circuit with components such as VCC, GND, S1, T1 (2N3904), R1 (1k), R2 (10k), R3 (360), and LED1.
Or Gate
Amplifiers

- Take a small signal and make it bigger
- Not a passive component (needs external power)
- Often used in audio, sensing, and communications
The simplest amplifier
MOSFETs

Used in:
- IC logic gates
- Very low current amplifiers
- High current or high voltage switches
- High frequency applications
MOSFETs

voltage controlled resistors

N-Channel

- Gate voltage determines Source-Drain resistance
- No current through the gate

P-Channel

- Has three regions
  - Cut-off
  - Linear
  - Saturation
Where do you go next?

- PSPICE
- Code, by Charles Petzold
- AC amps
Thanks to

- Jason Zack for the switch photo on slide 4
- Matthew Bowden for the faucet photo on slide 5
- Michael Frey for the TO-92 graphic on slide 14