

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?



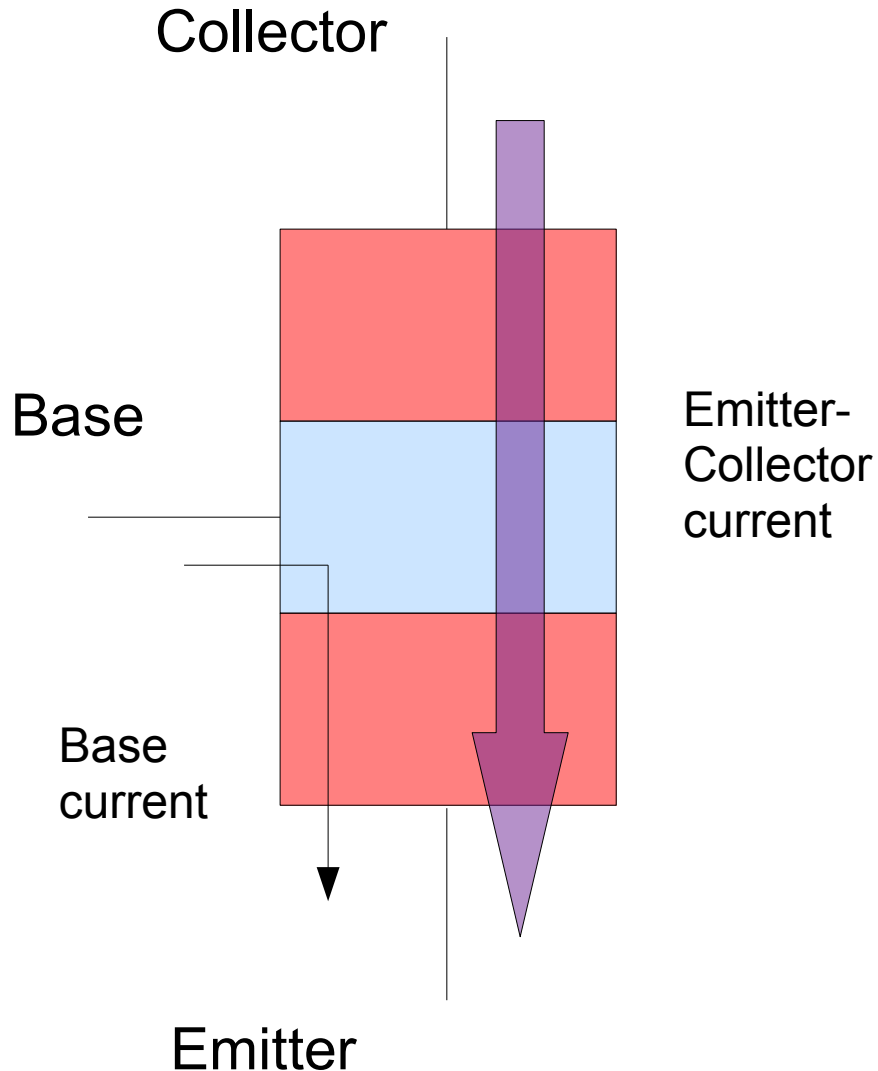
What are transistors (really)?



The semiconductor sandwich



BJTs



Used in:

- Very common as discrete components
- Control current
- Low voltage amplifiers
- Cheap, easy switches

BJT

NPN

Q1
2N3904



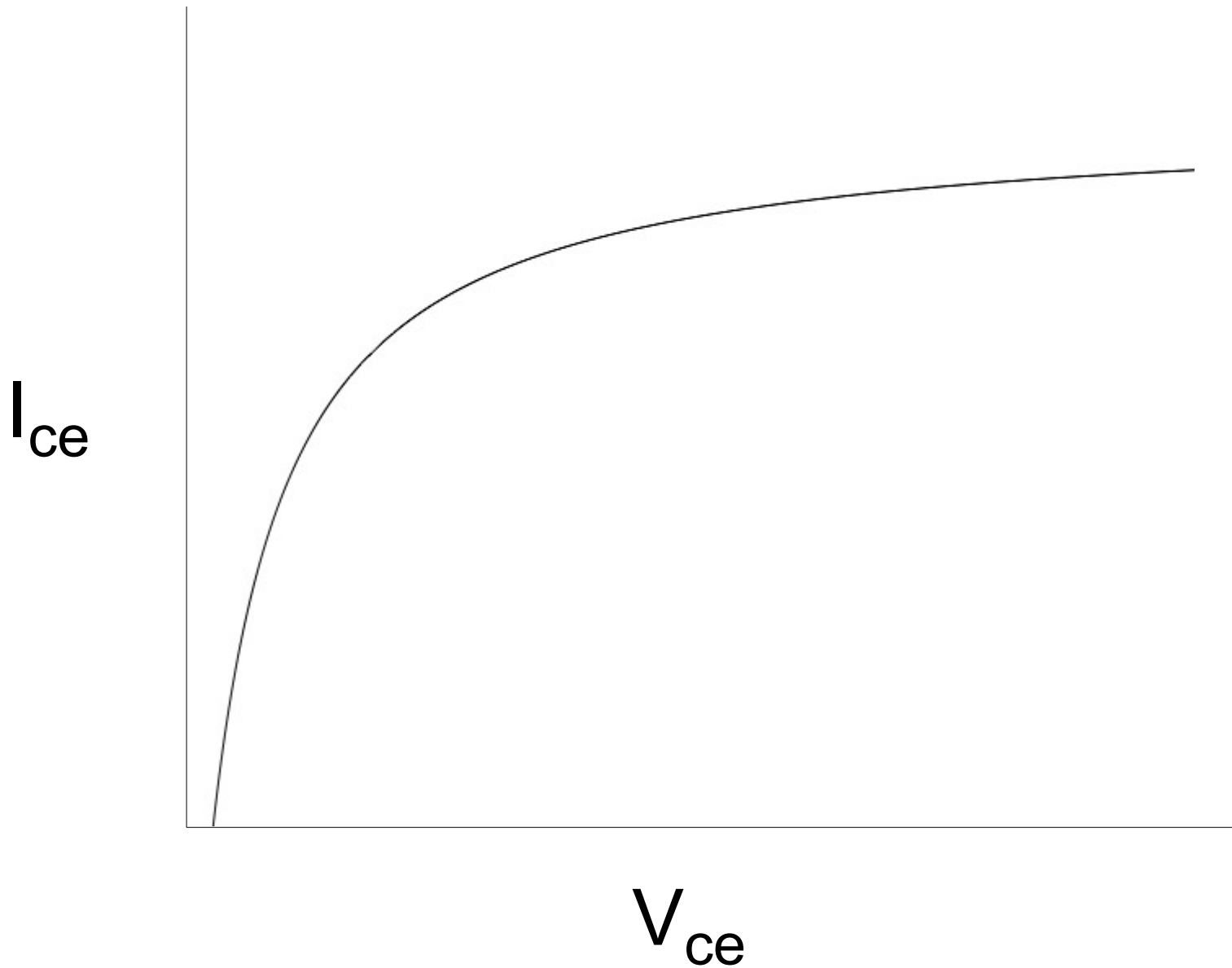
PNP

Q1
2N3906

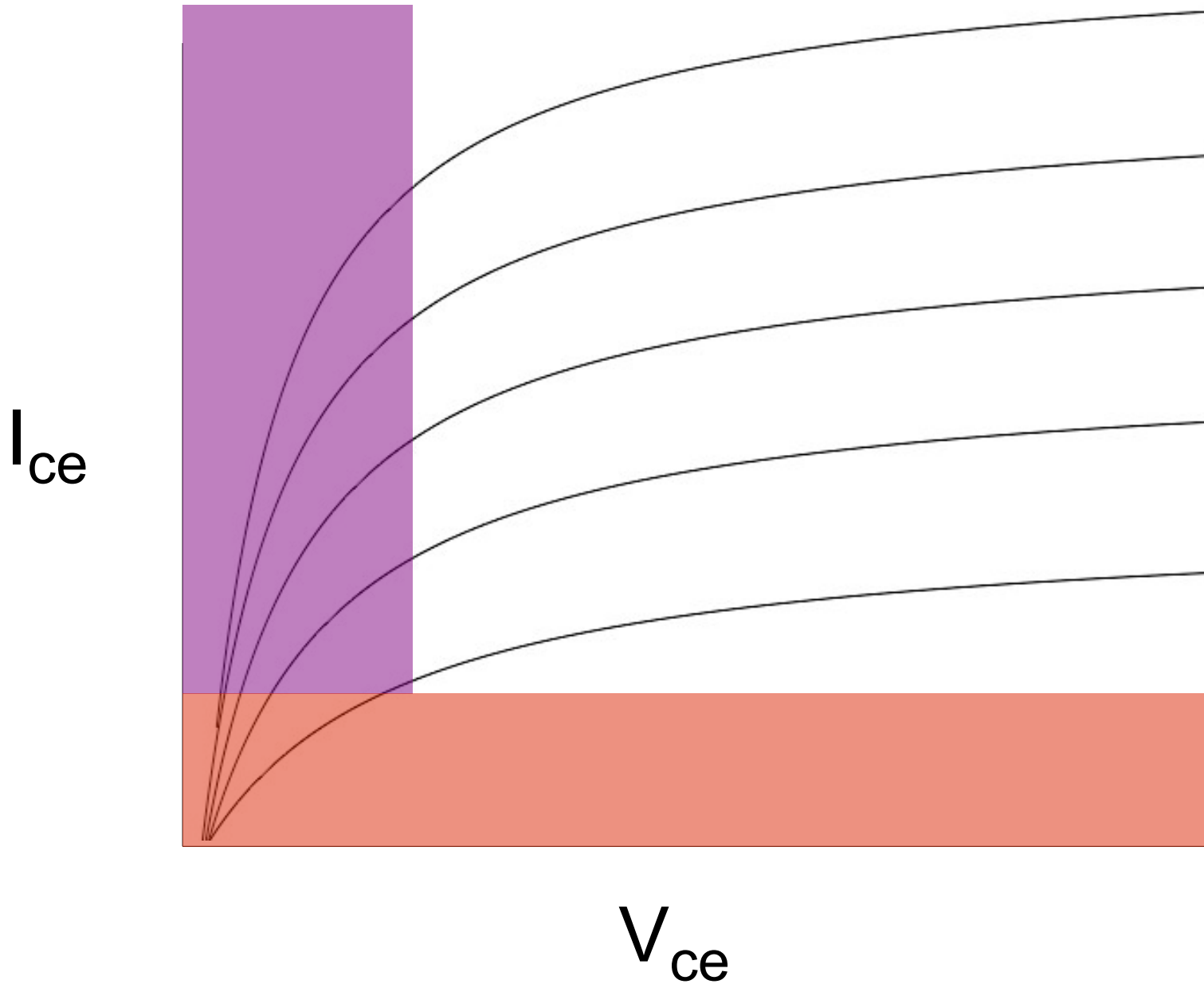


- Current controlled current amplifier
- Three main regions of operation
- Has current gain parameter β

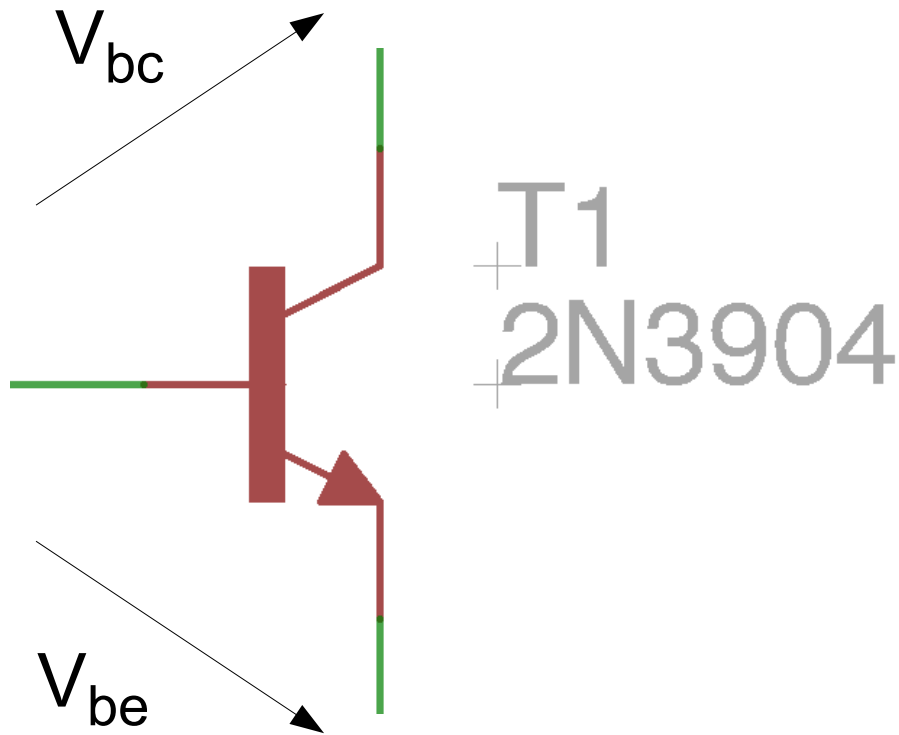
Basic I-V curve



Changing I_{be} changes I-V curve

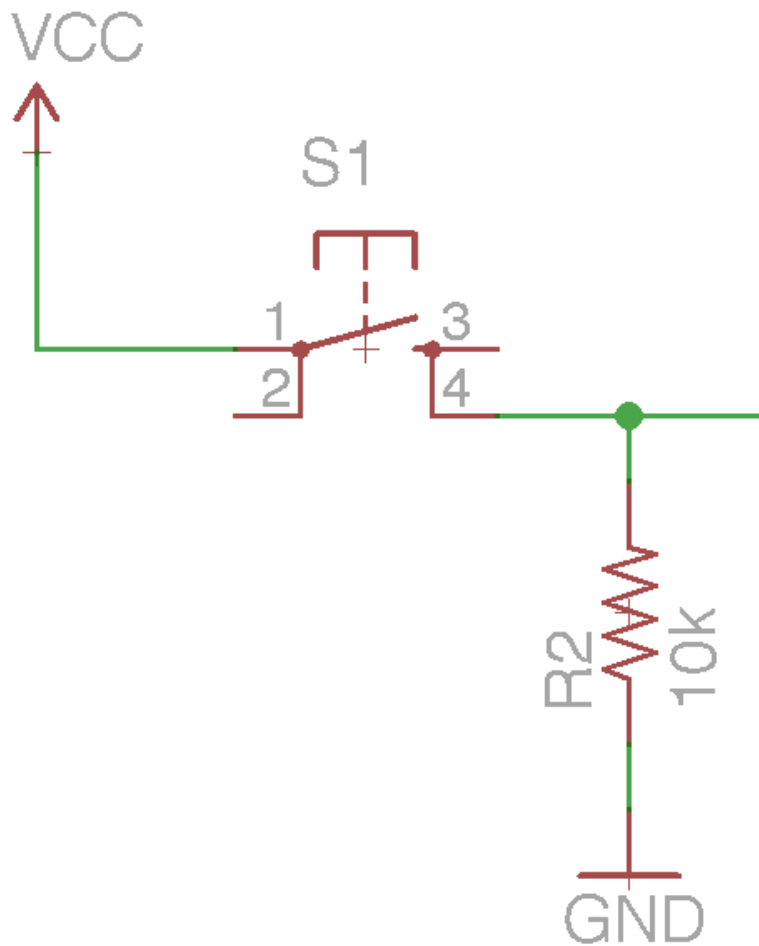


BJT NPN regions of operation



- 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



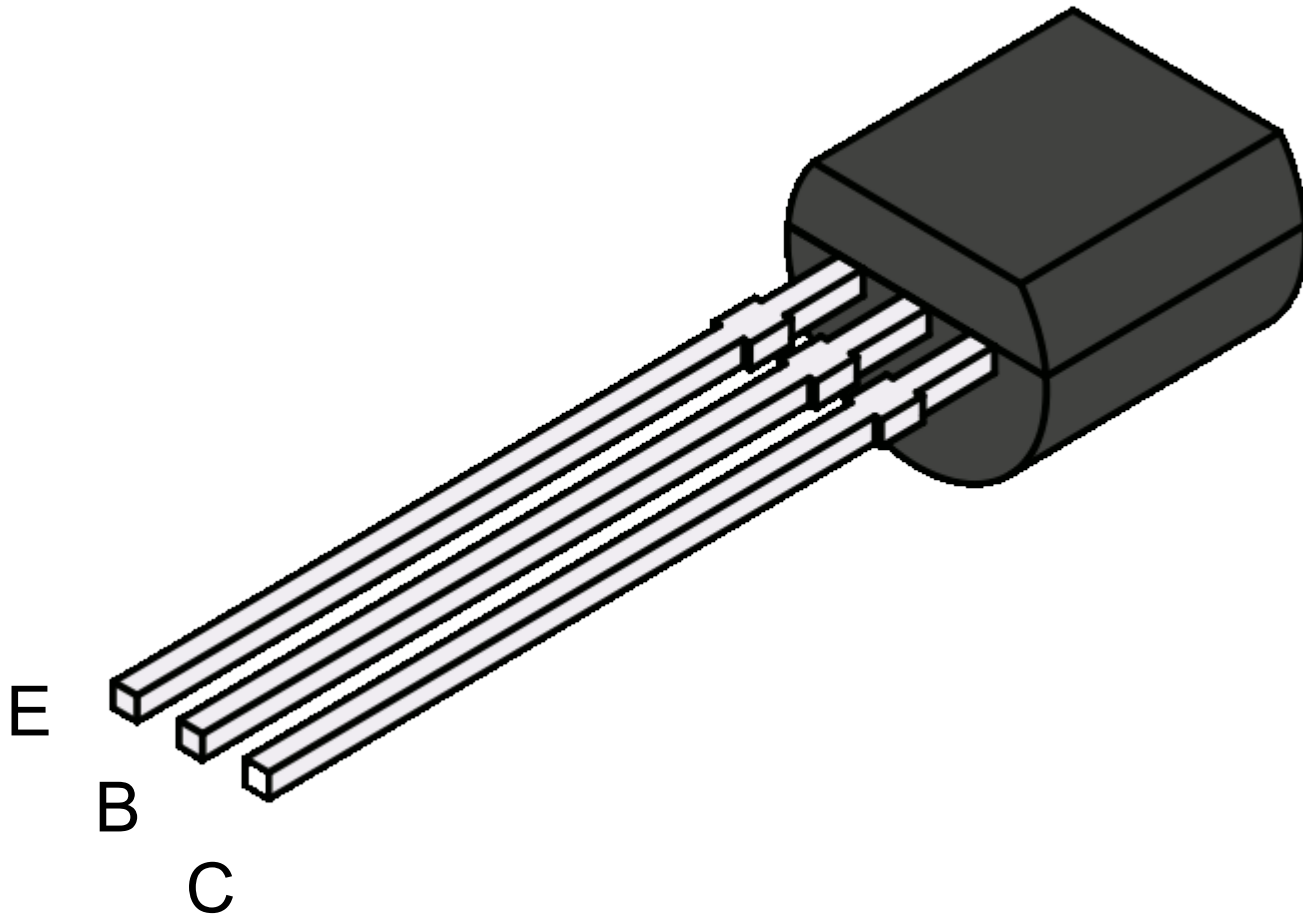
- Ensures that the input sees a certain voltage at all times
- Resistance is arbitrary
- Larger resistances are better (smaller current)

Current limiting resistors

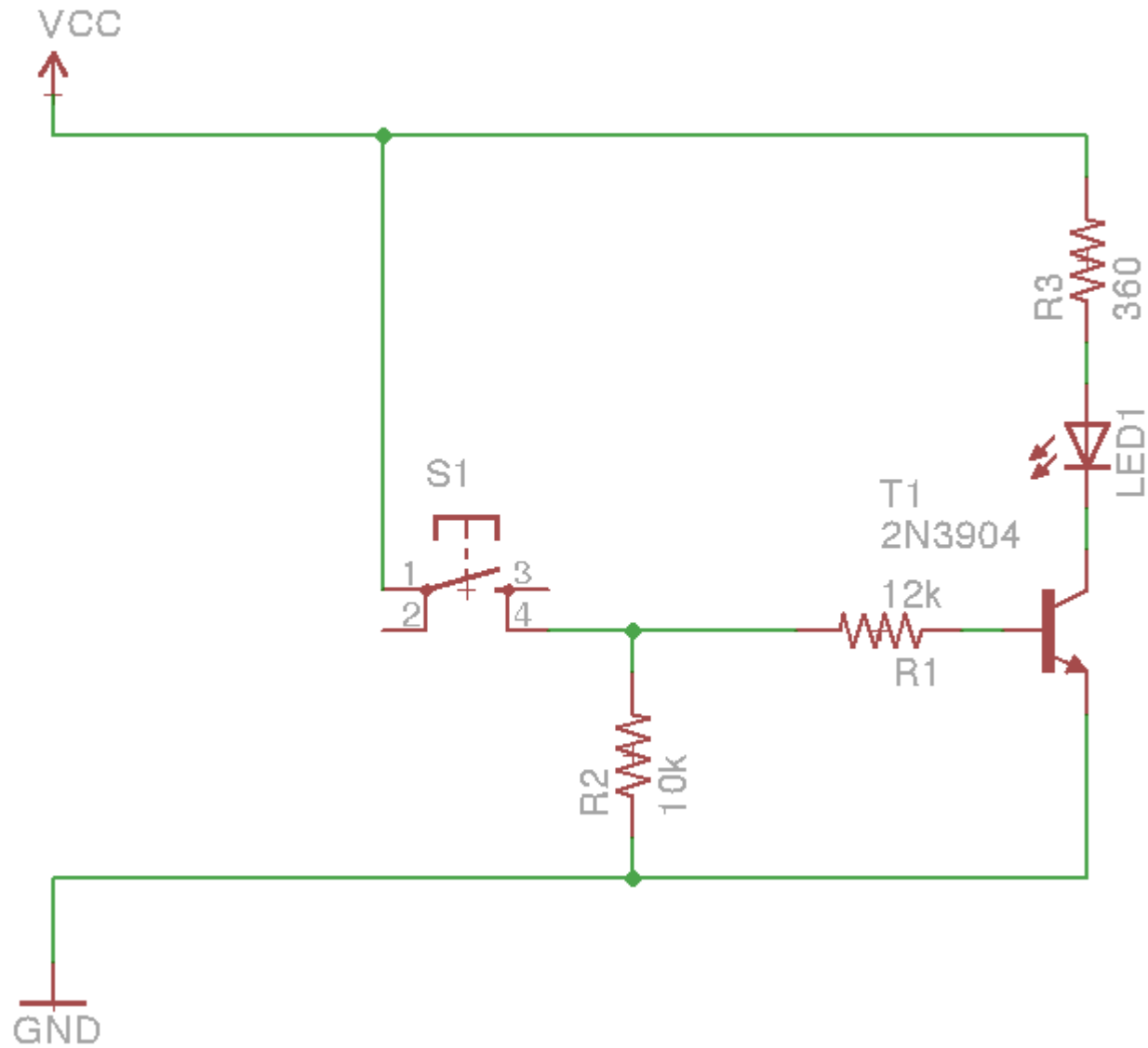


- Sets I_{be} (and thus I_{ce})
- We know desired I_{ce}
 - $I_{be} = I_{ce} / \beta$
- Calculate R via Ohm's Law
 - $R = V / I_{be}$
 - $V = V_{total} - V_{be}$

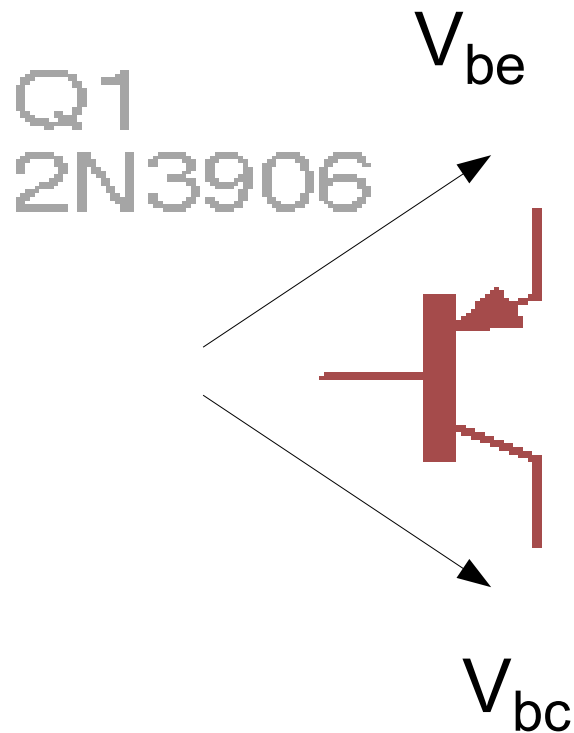
The TO-92 package



NPN Switch

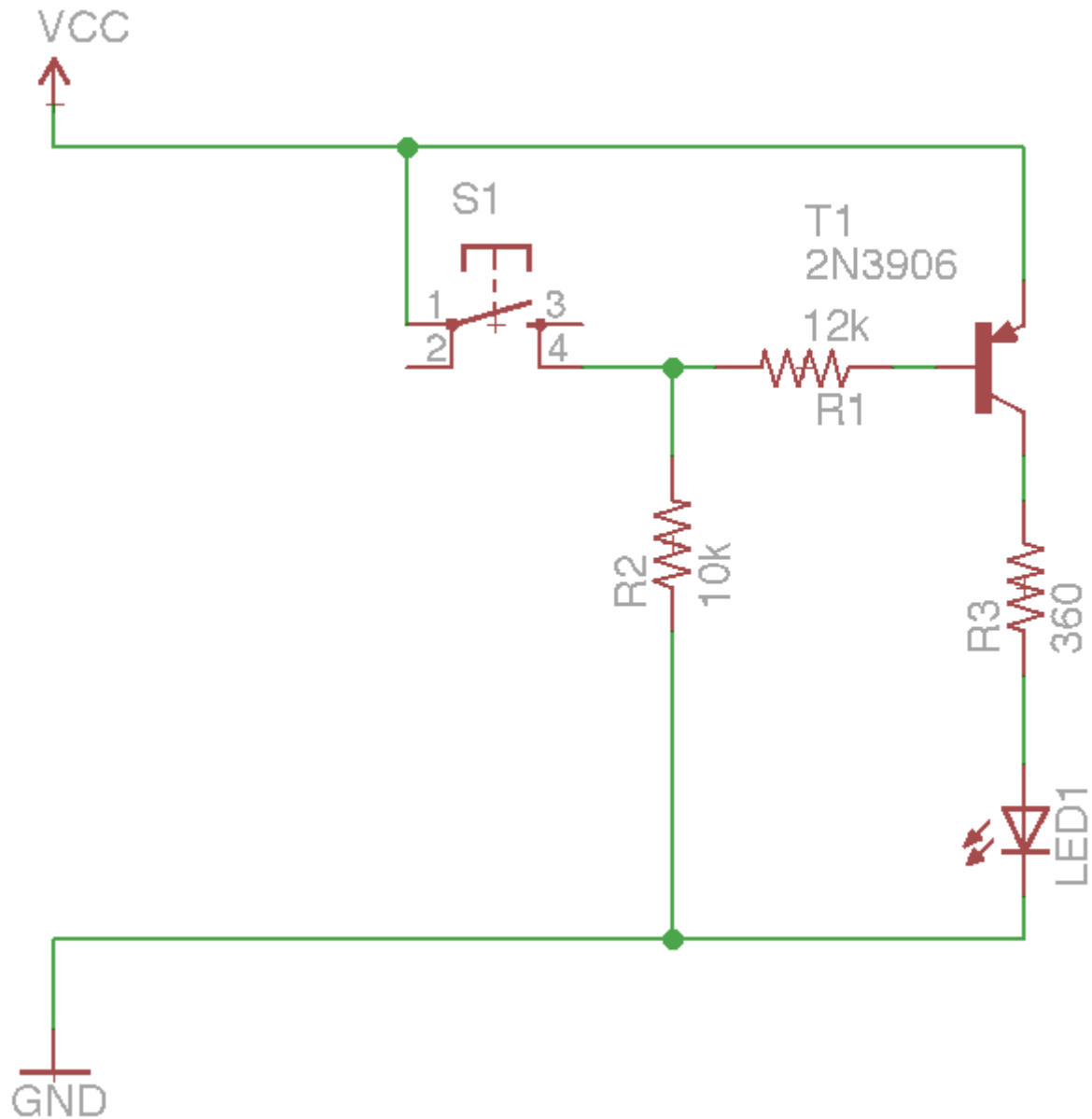


BJT PNP regions of operation



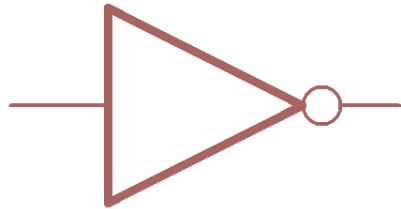
- Cut-off
 - $V_{be} > -V_{th}$, $V_{bc} < 0$
 - $I_{ce} = 0$
- Forward Active
 - $V_{be} < -V_{th}$, $V_{bc} > 0$
 - $I_{ce} = \beta_F I_{be}$
- Saturation
 - $V_{be} < -V_{th}$, $V_{bc} > 0$
 - I_{ce} depends on load

PNP Switch

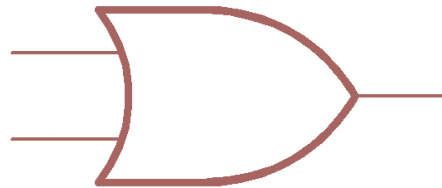


Logic Gates

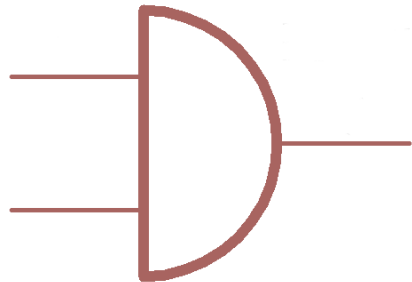
not



or

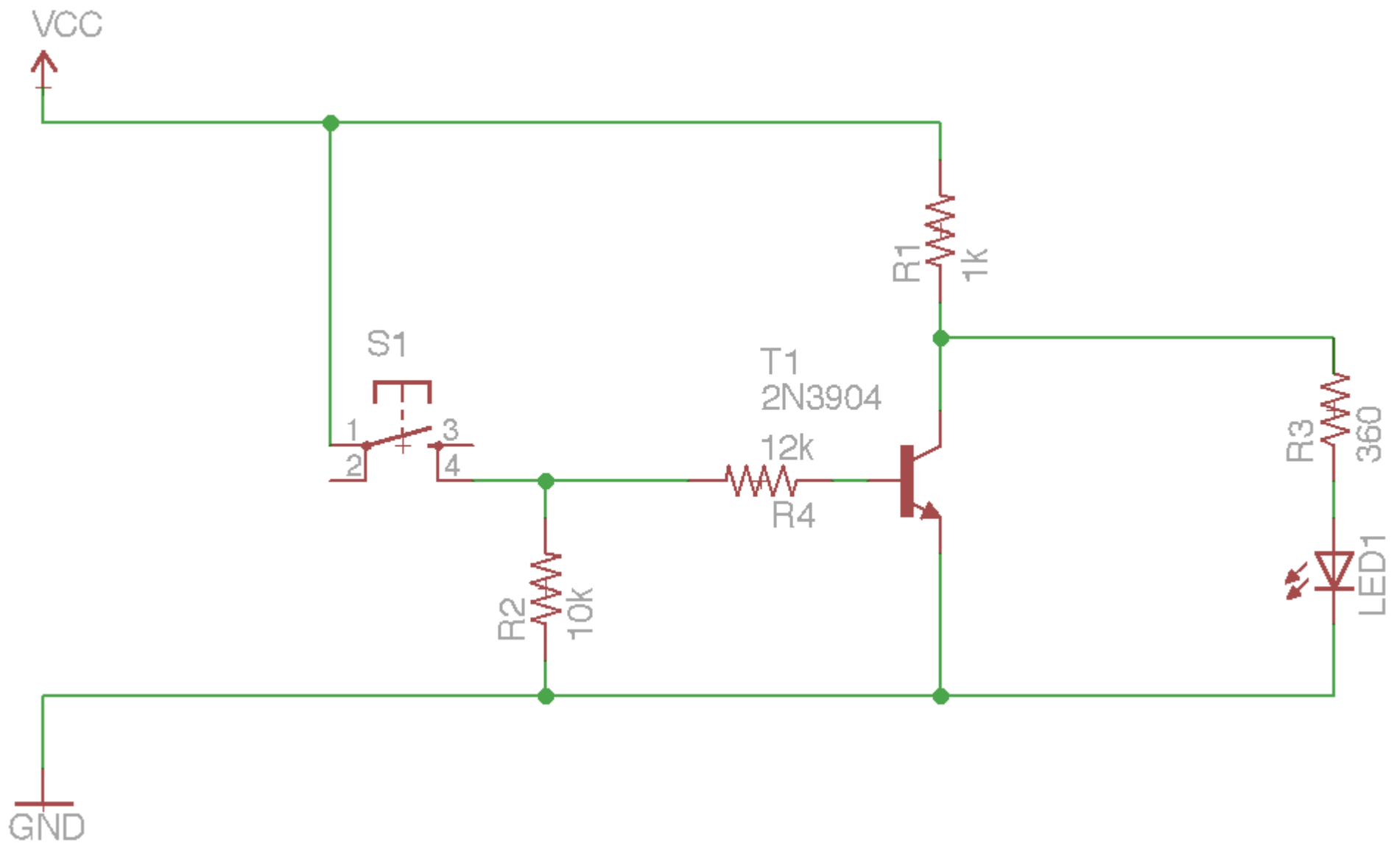


and

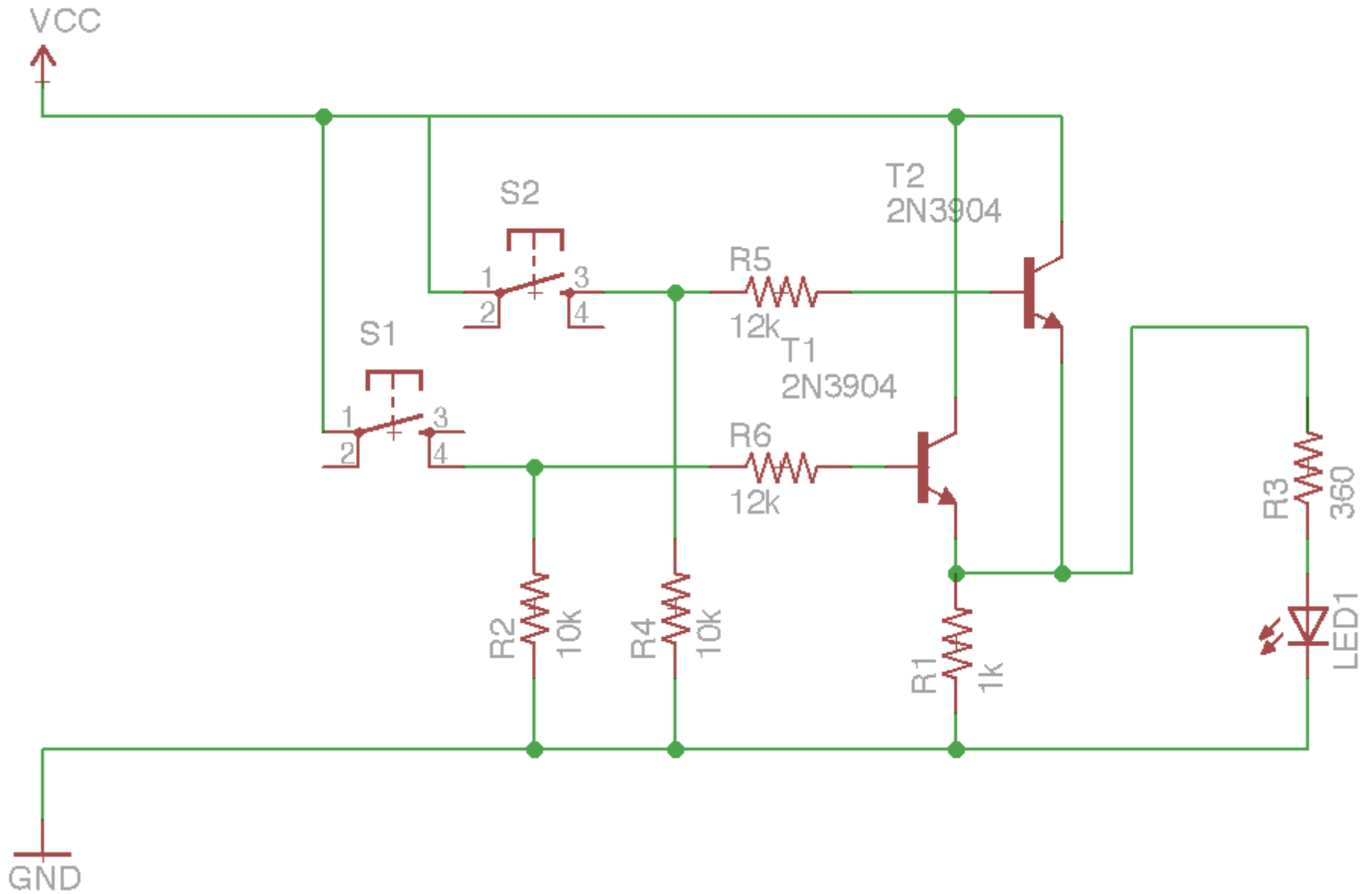


- Generate binary output from binary inputs
- Can be chained together to create complex systems
- BJT logic gates operate in the saturation and cut-off regions

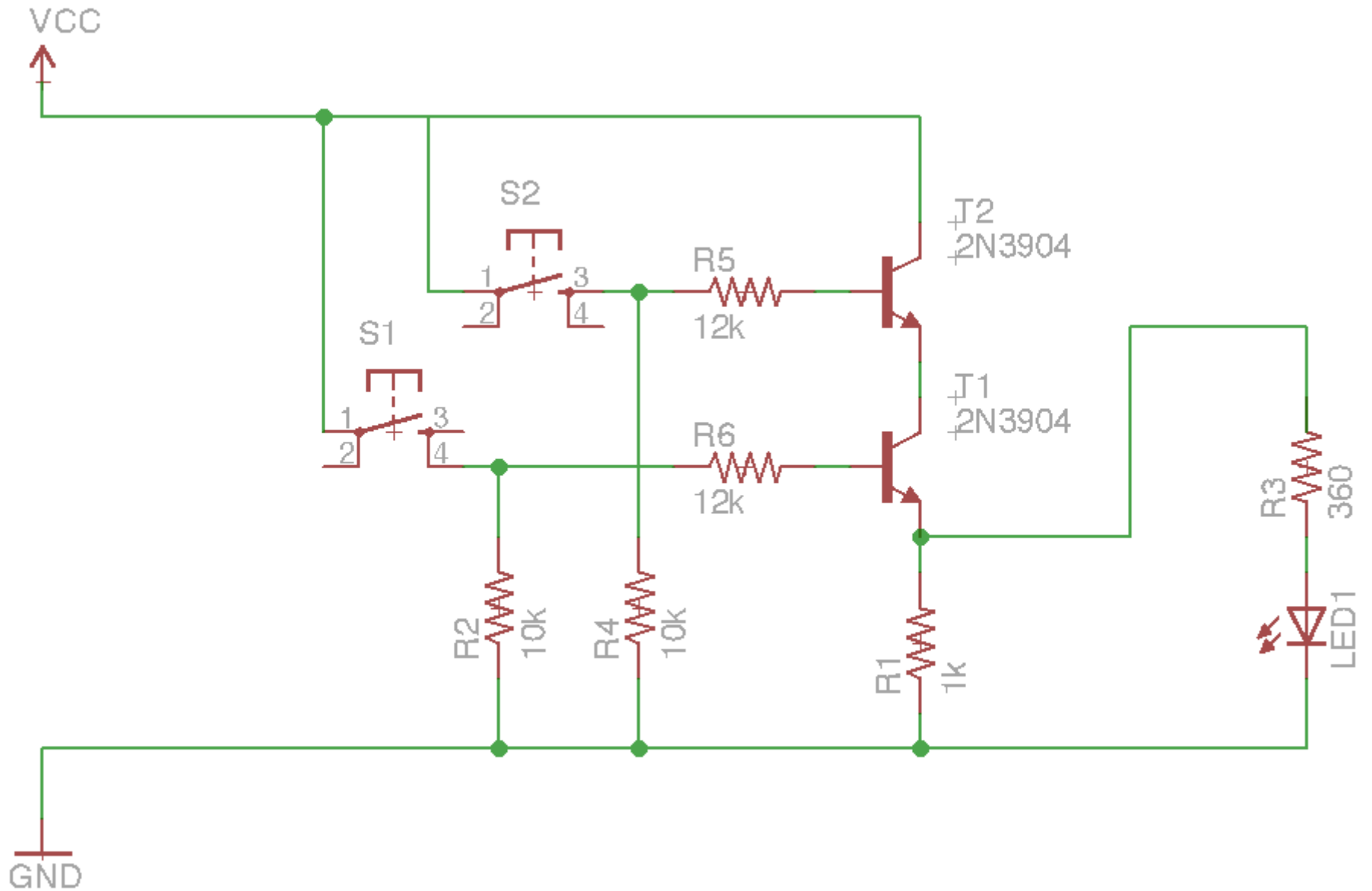
Not Gate



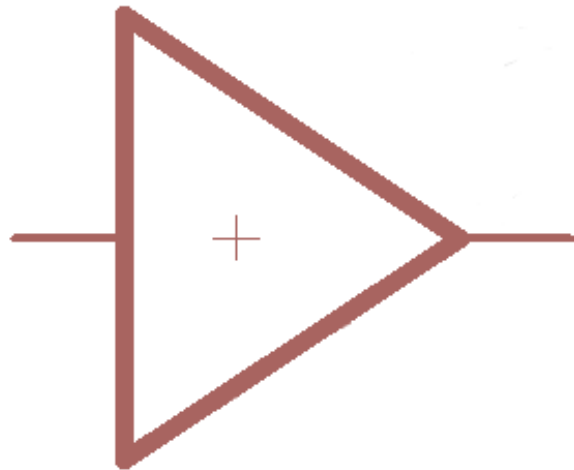
Or Gate



And Gate

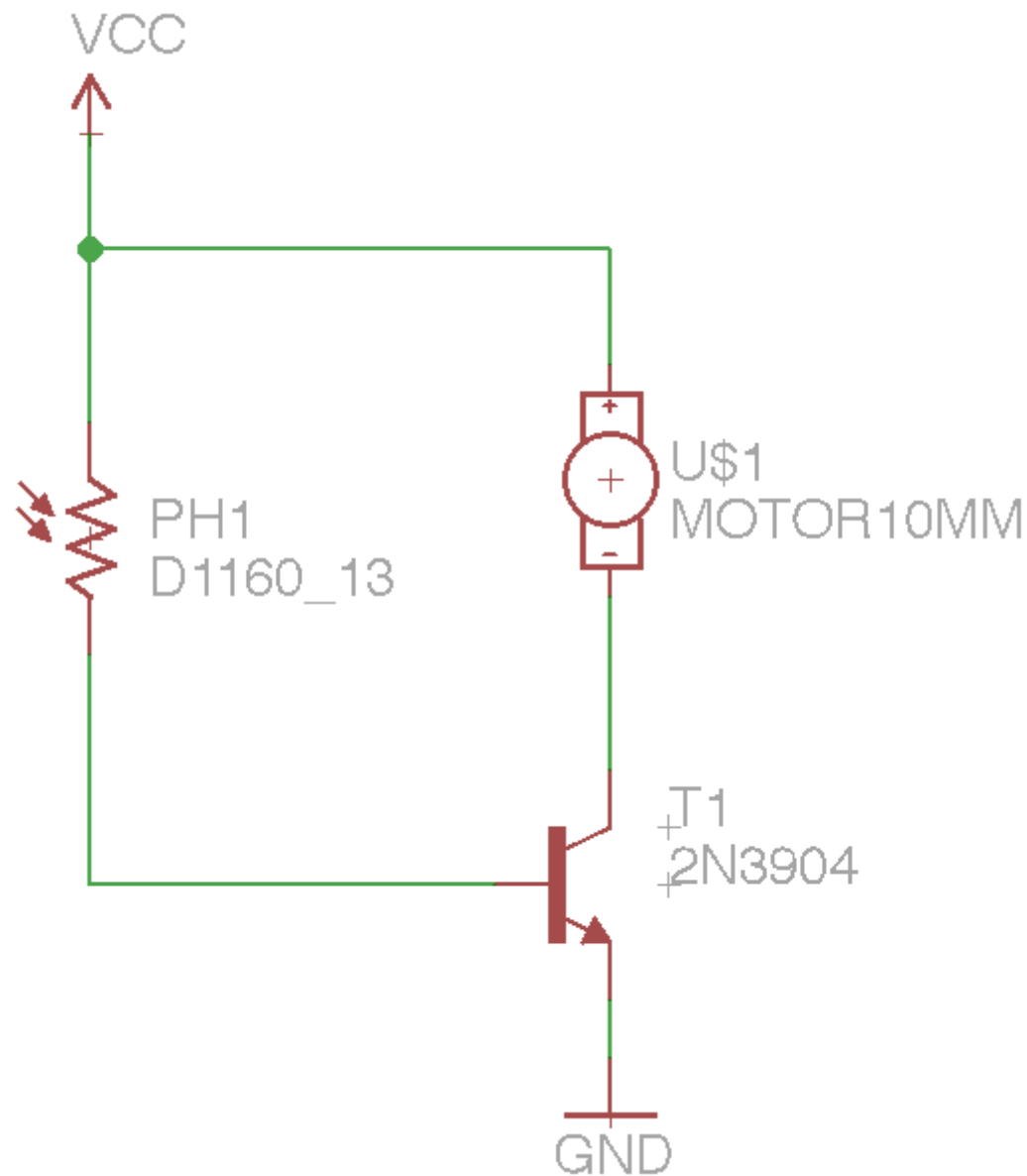


Amplifiers

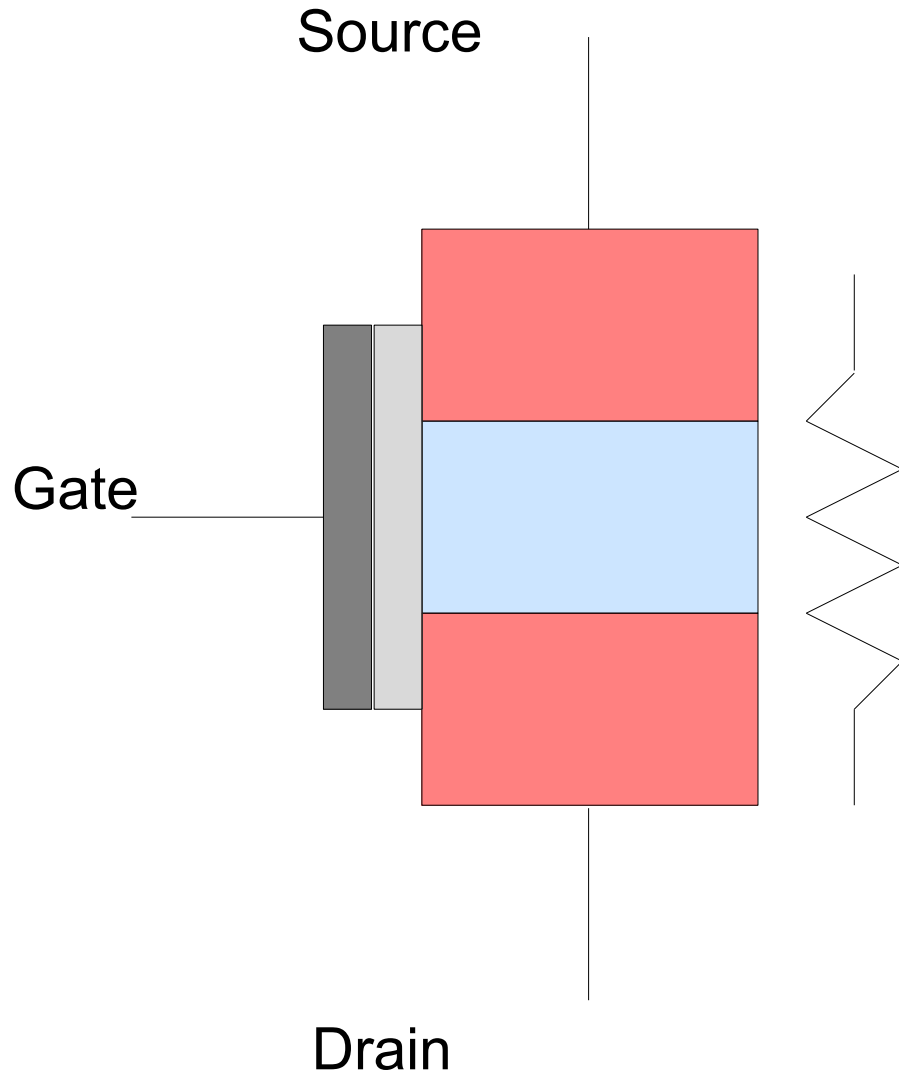


- Take a small signal and make it bigger
- Not a passive component (needs external power)
- Often used in audio, sensing, and communications

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