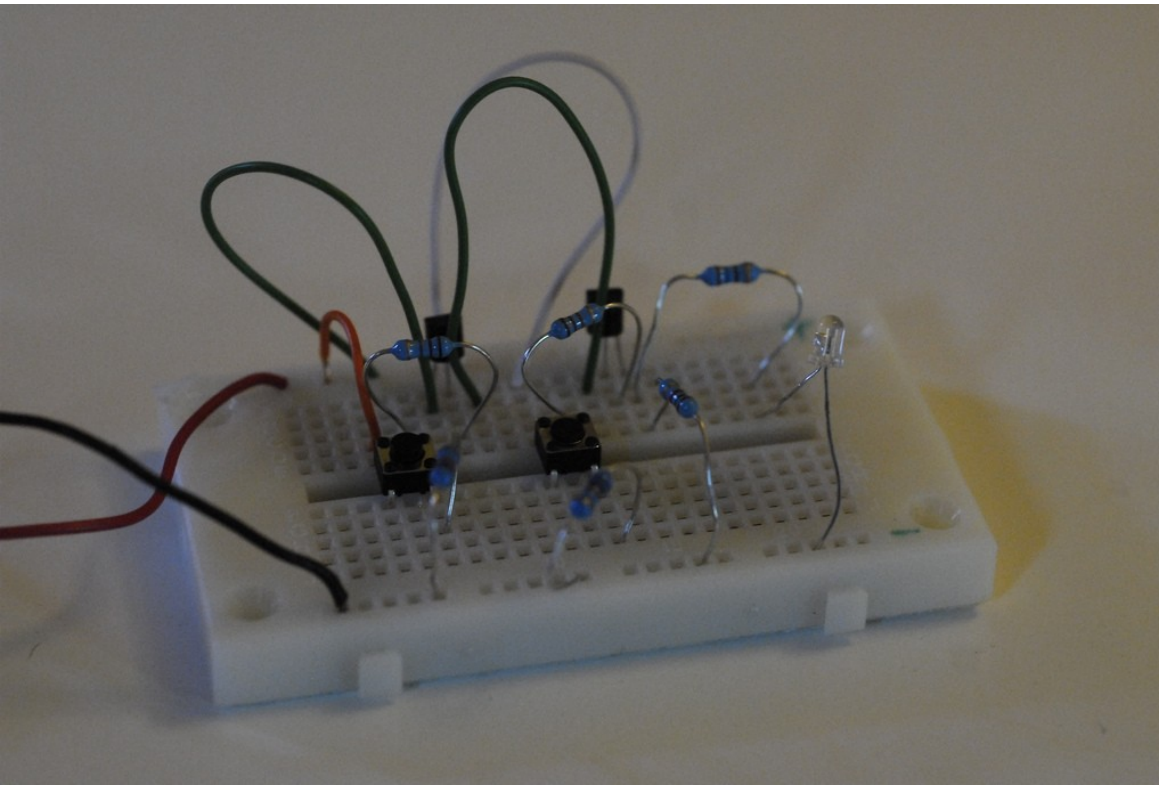


Transistors



Instructors: Morgan Redfield

Lisa Lafleur

2011 April 7

7-9:30 PM

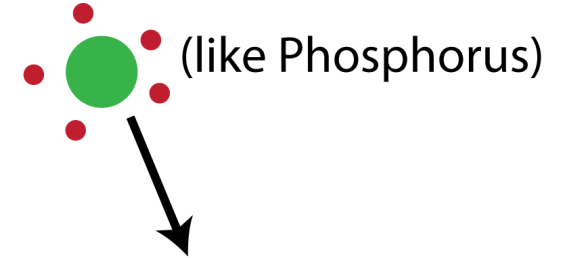
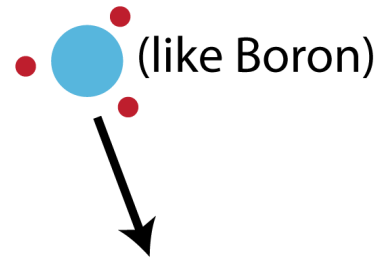
Today we'll be covering

- Background info about semiconductor junctions
- What are diodes and transistors
- BJTs, a very common transistor
- Basic Switches
- Logic Gates
- Amplifiers

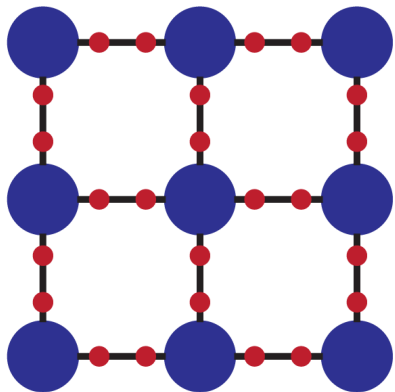
What is a semiconductor???

- Conducts electricity better than an insulator
- But worse than a metal conductor
- Made of things like silicon (Si) or Gallium Arsenide (GaAs)
- Properties are controlled by doping

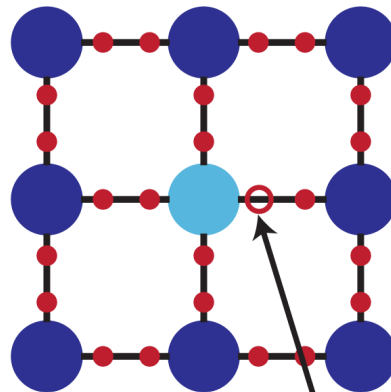
Doping



Lattice of only Si

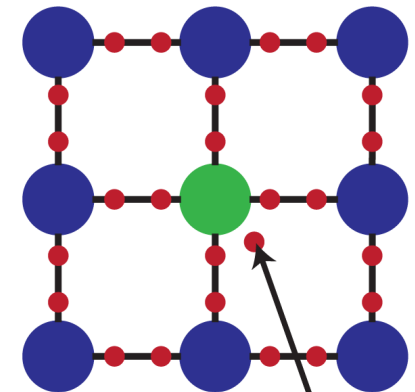


P-type doping



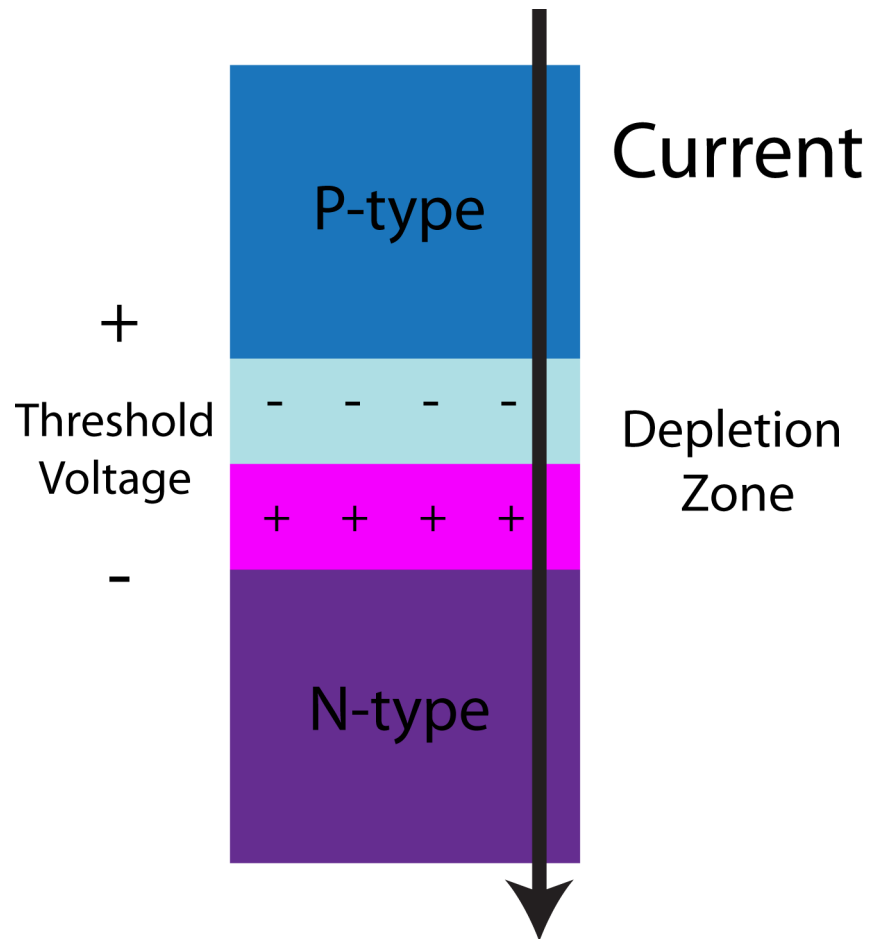
Hole
(Missing Electron)

N-type doping



Extra Electron

Diodes: the current valves



- Diodes let current through in only one direction
- They have a constant voltage drop.
- Two types of semiconductor mashed together (P-N Junction).

What are transistors?

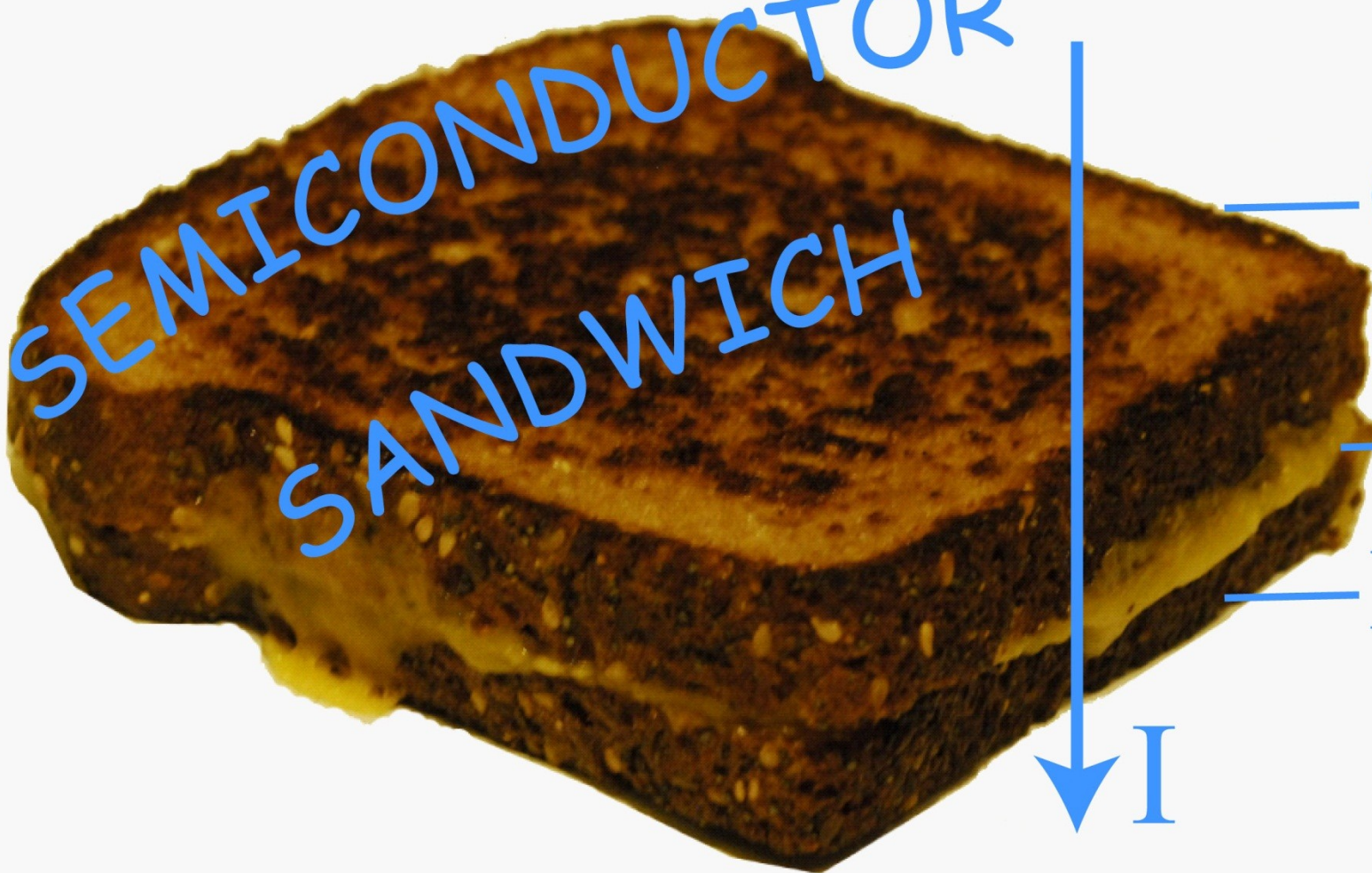


What are transistors (really)?



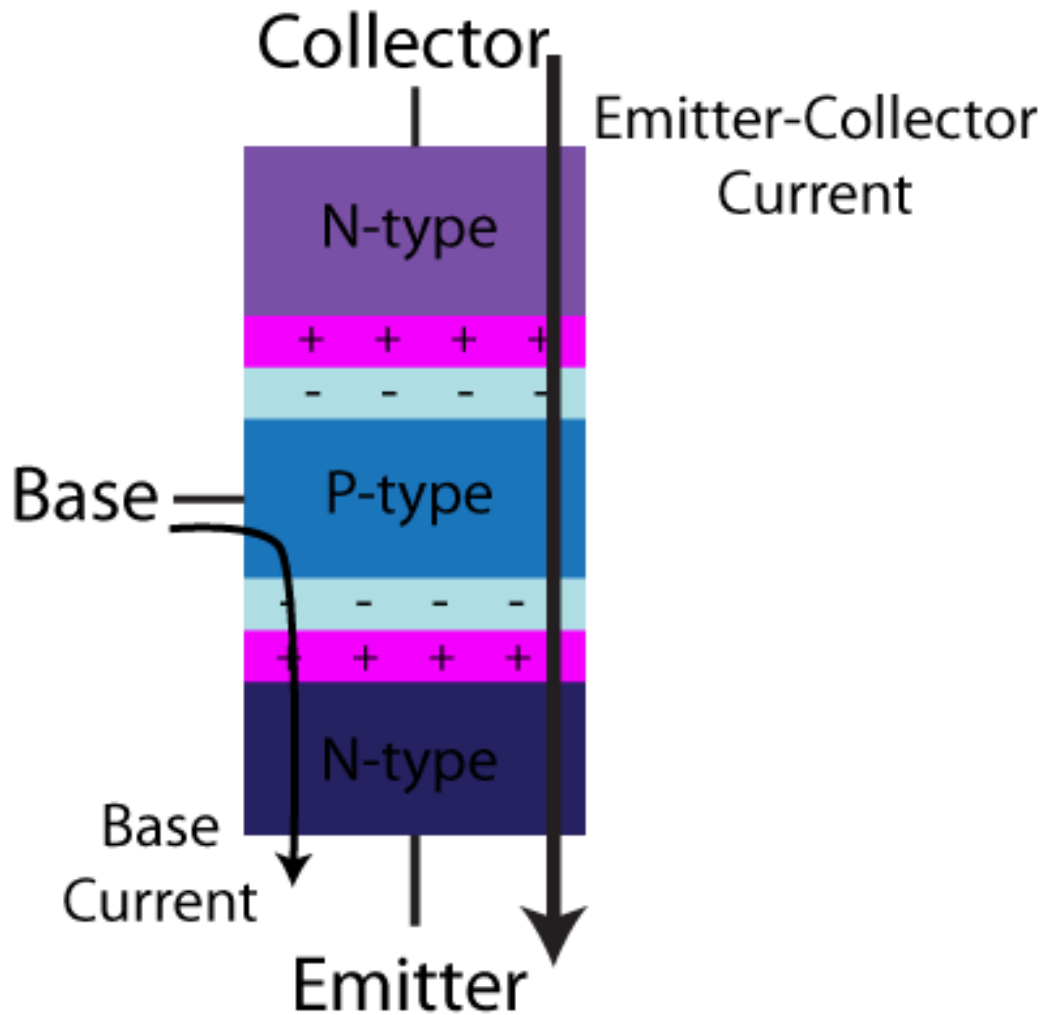


SEMICONDUCTOR
SANDWICH



C
B
E
I

BJTs

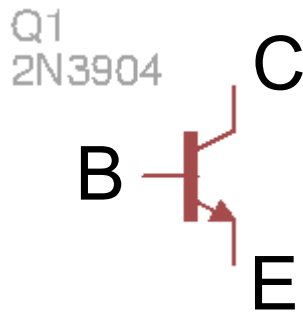


Used in:

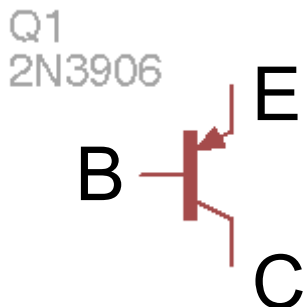
- Very common as discrete components
- Control current
- Low voltage amplifiers
- Cheap, easy switches

BJT

NPN

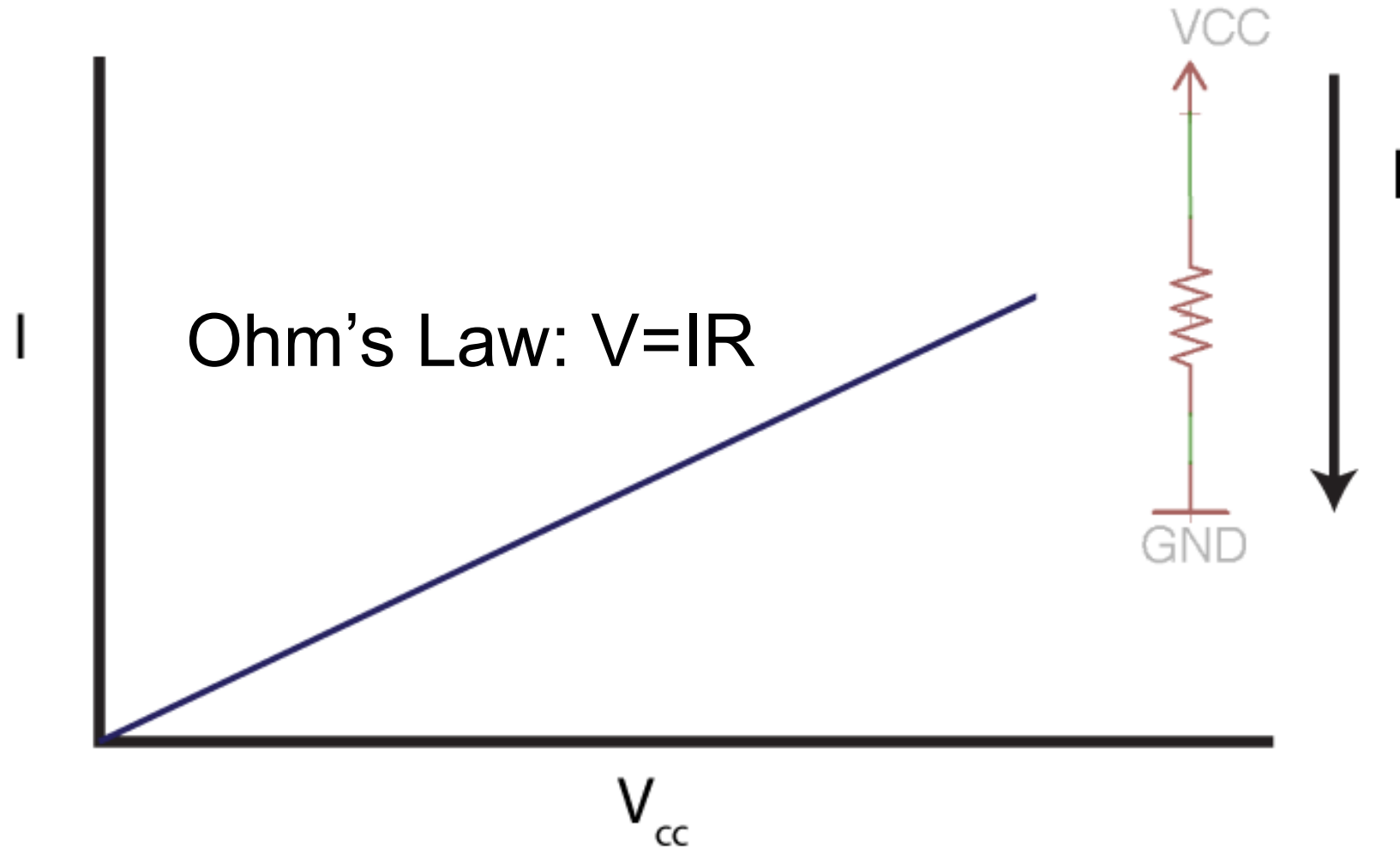


PNP



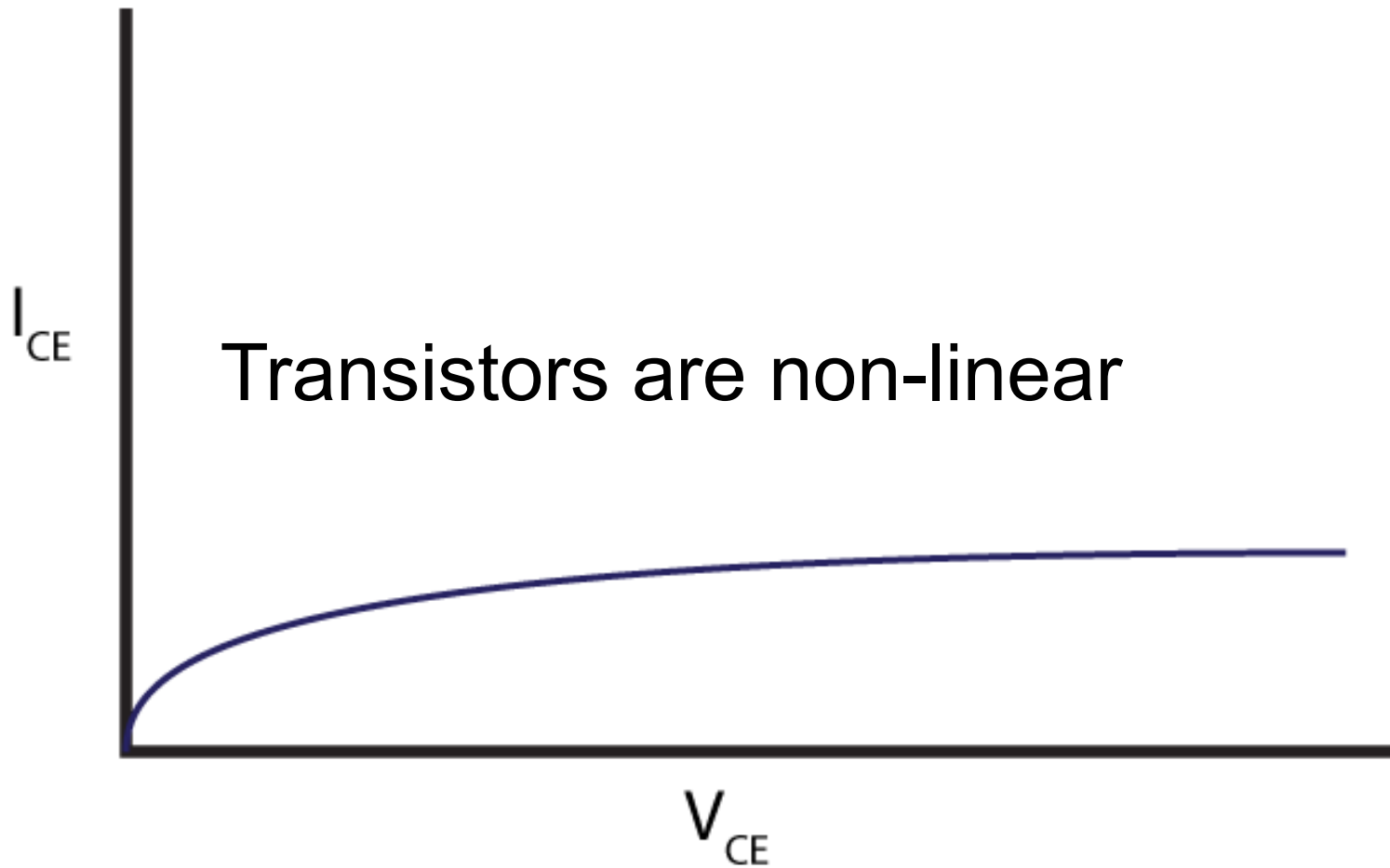
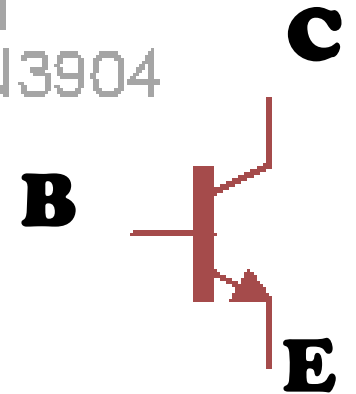
- Current controlled current amplifier
- Three main regions of operation
- Has current gain parameter β

Resistor Current-Voltage (I-V) curves are linear



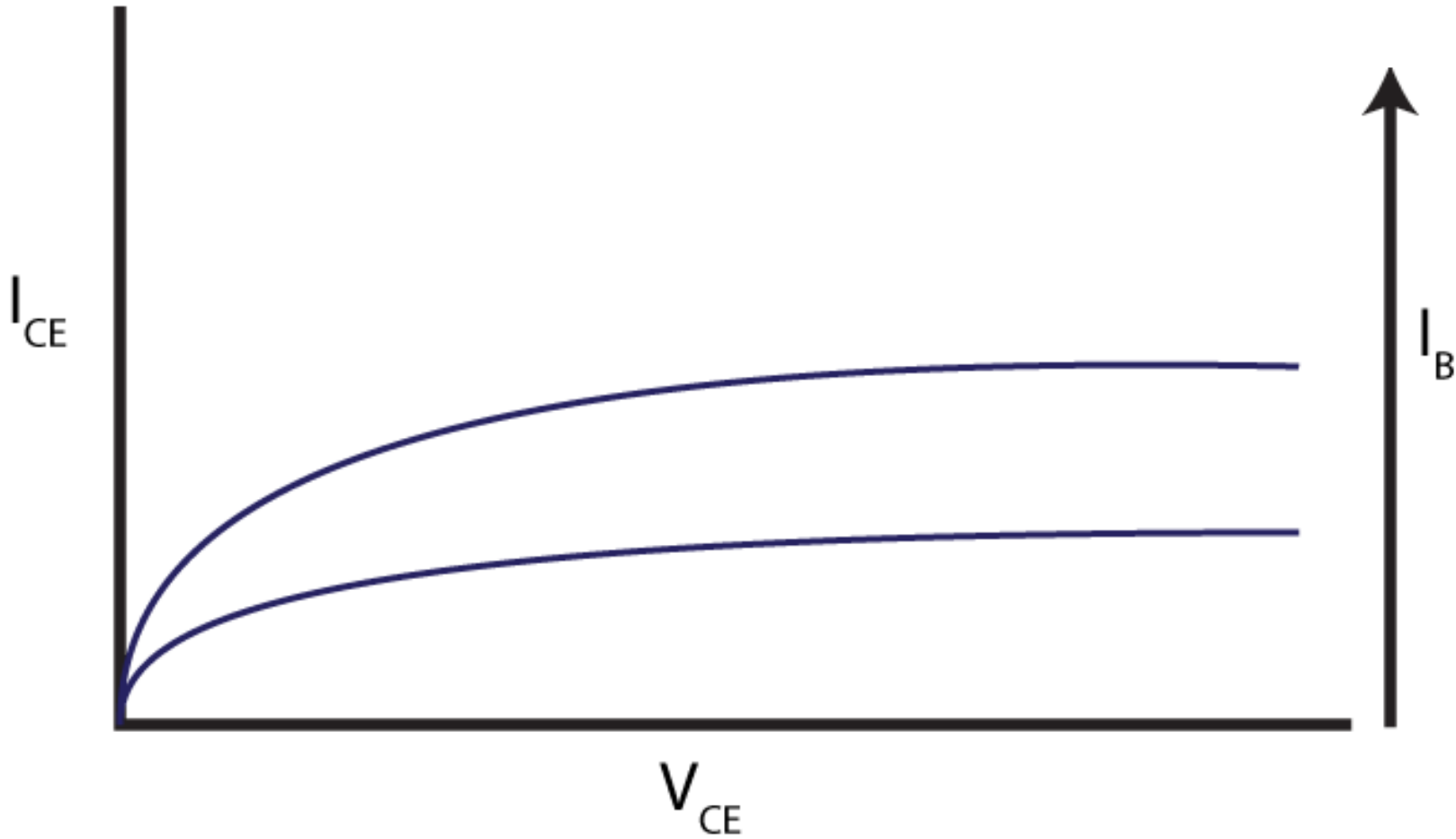
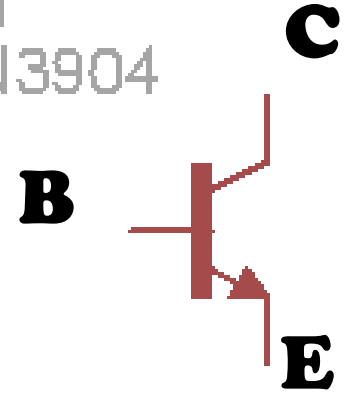
Current-Voltage (I-V) curve

Q1
2N3904



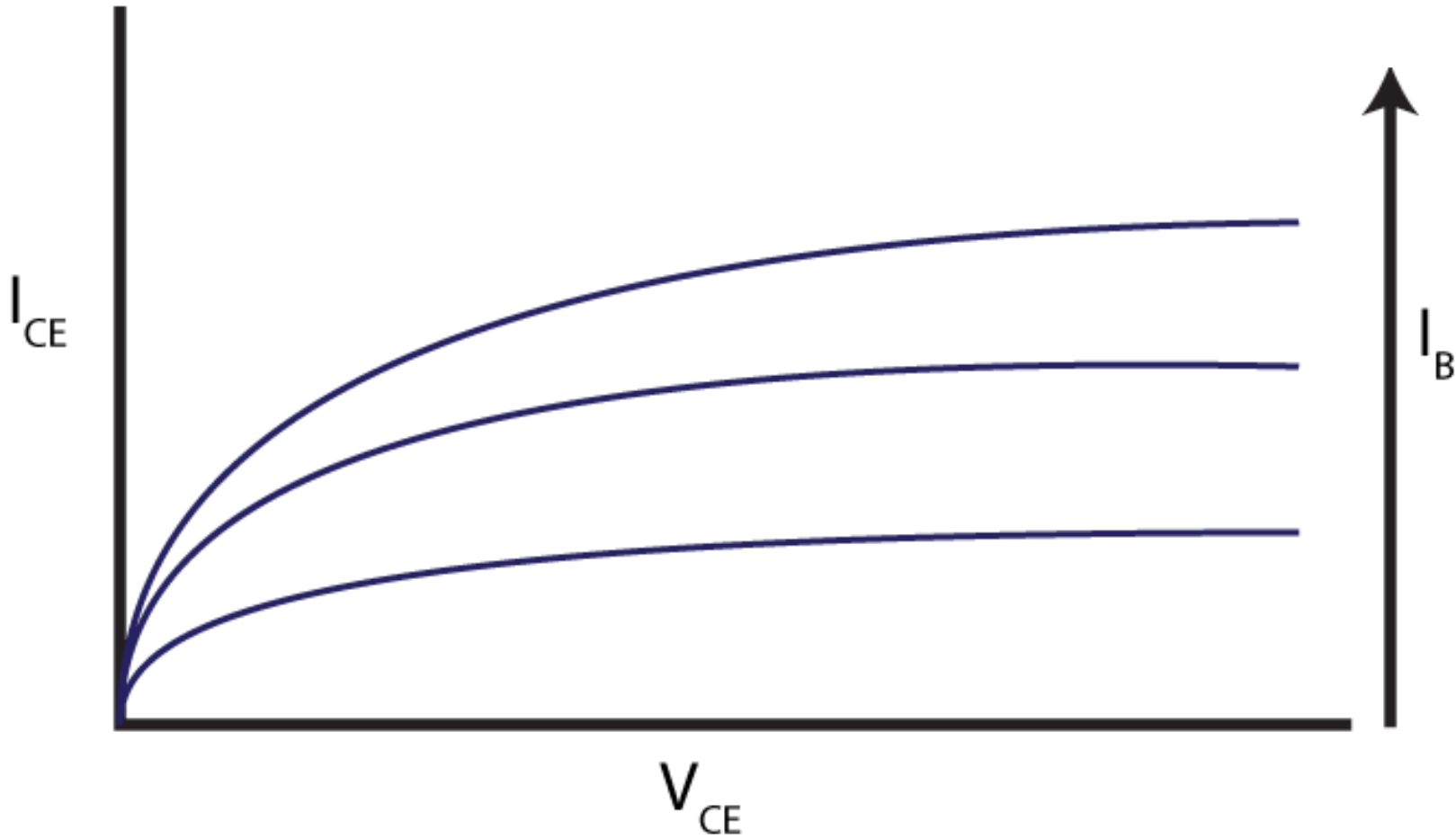
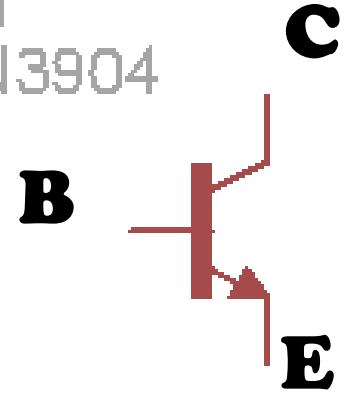
Current-Voltage (I-V) curve

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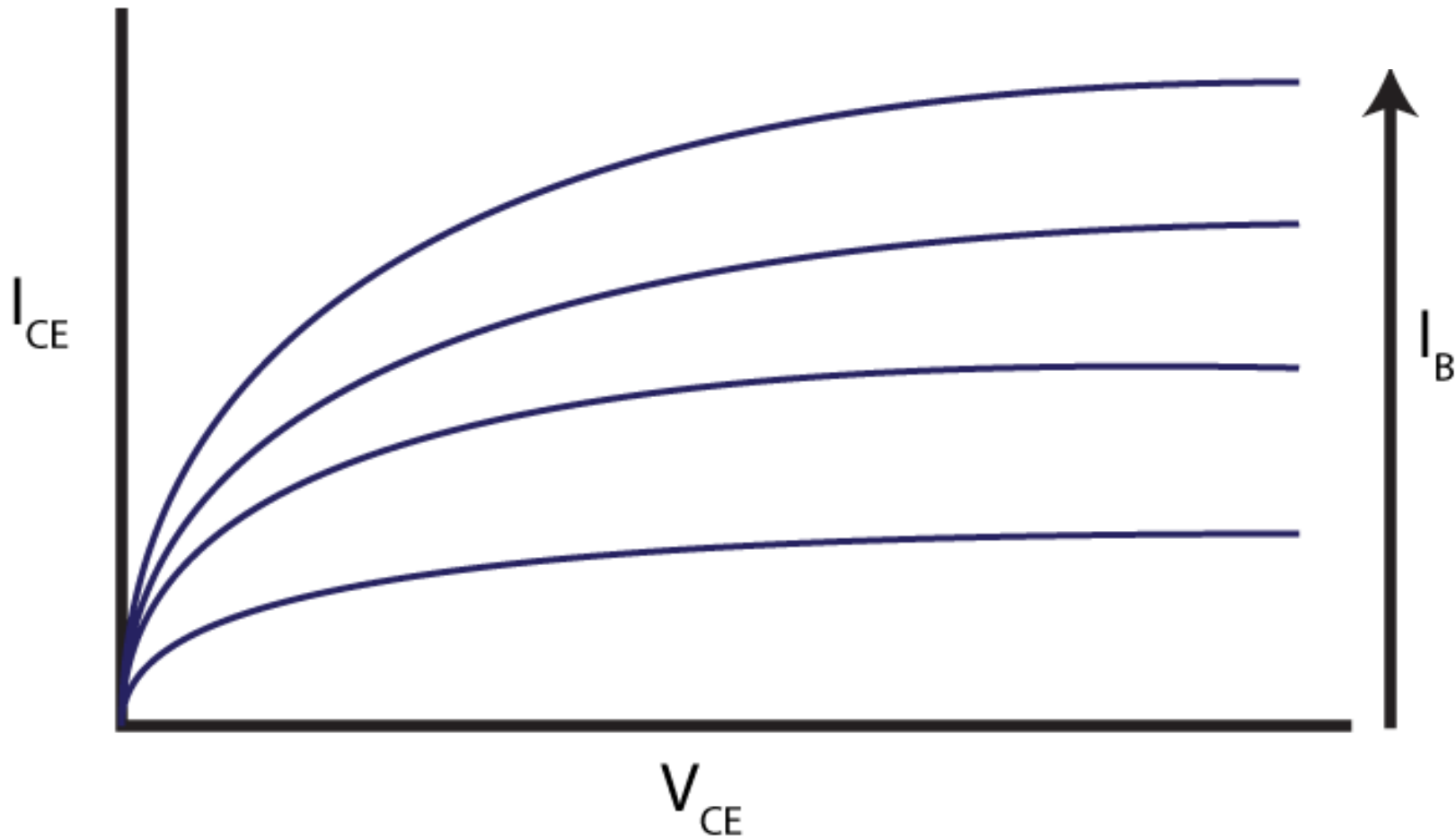
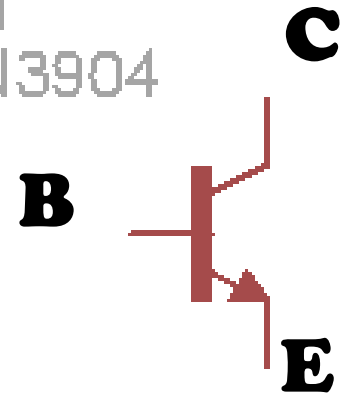
Current-Voltage (I-V) curve

Q1
2N3904



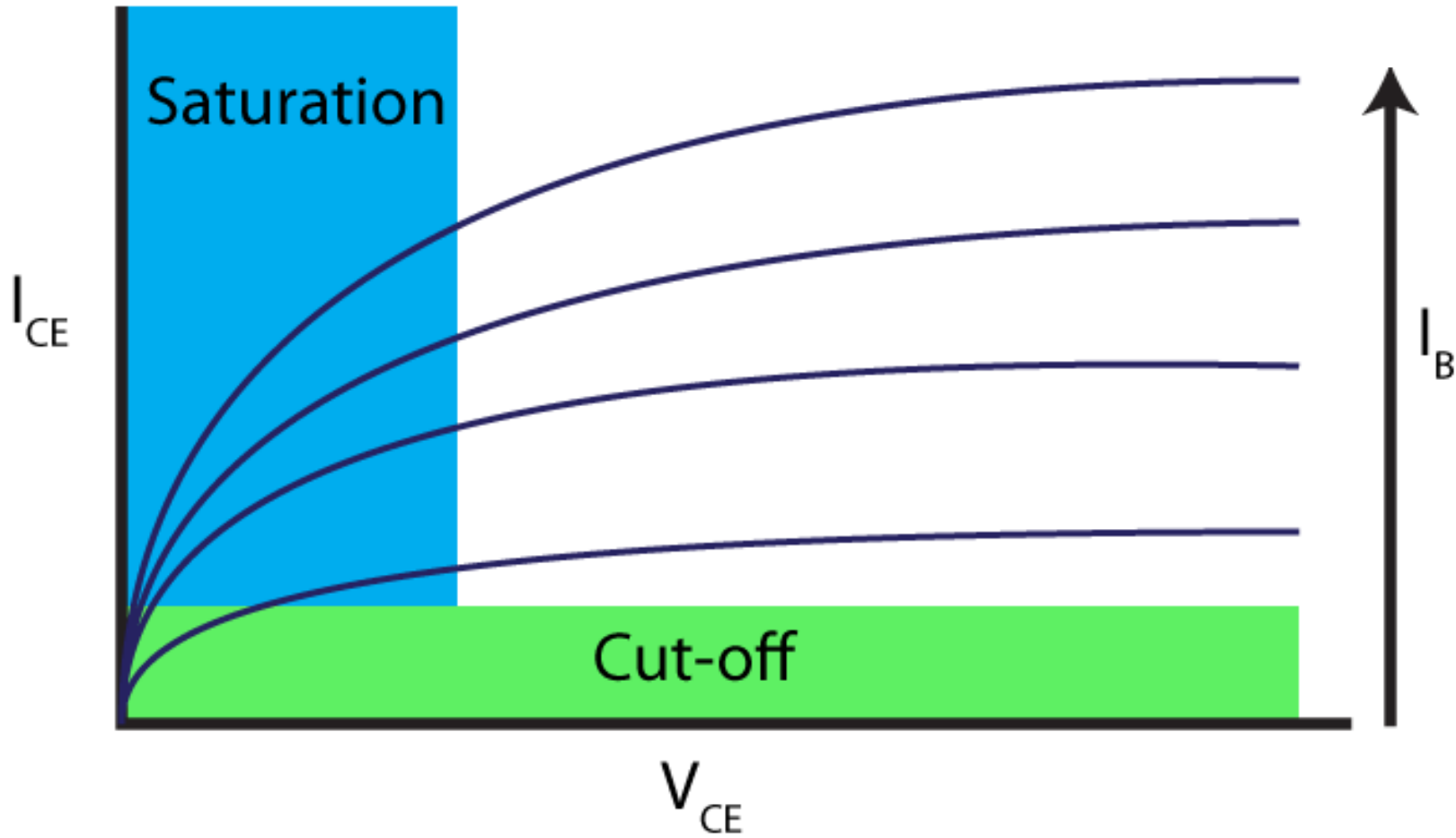
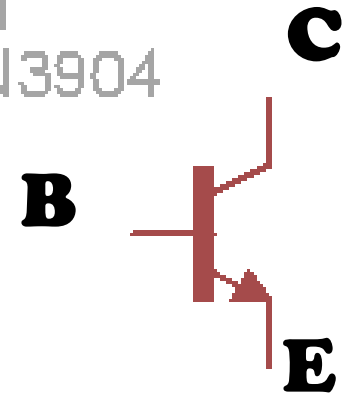
Current-Voltage (I-V) curve

Q1
2N3904



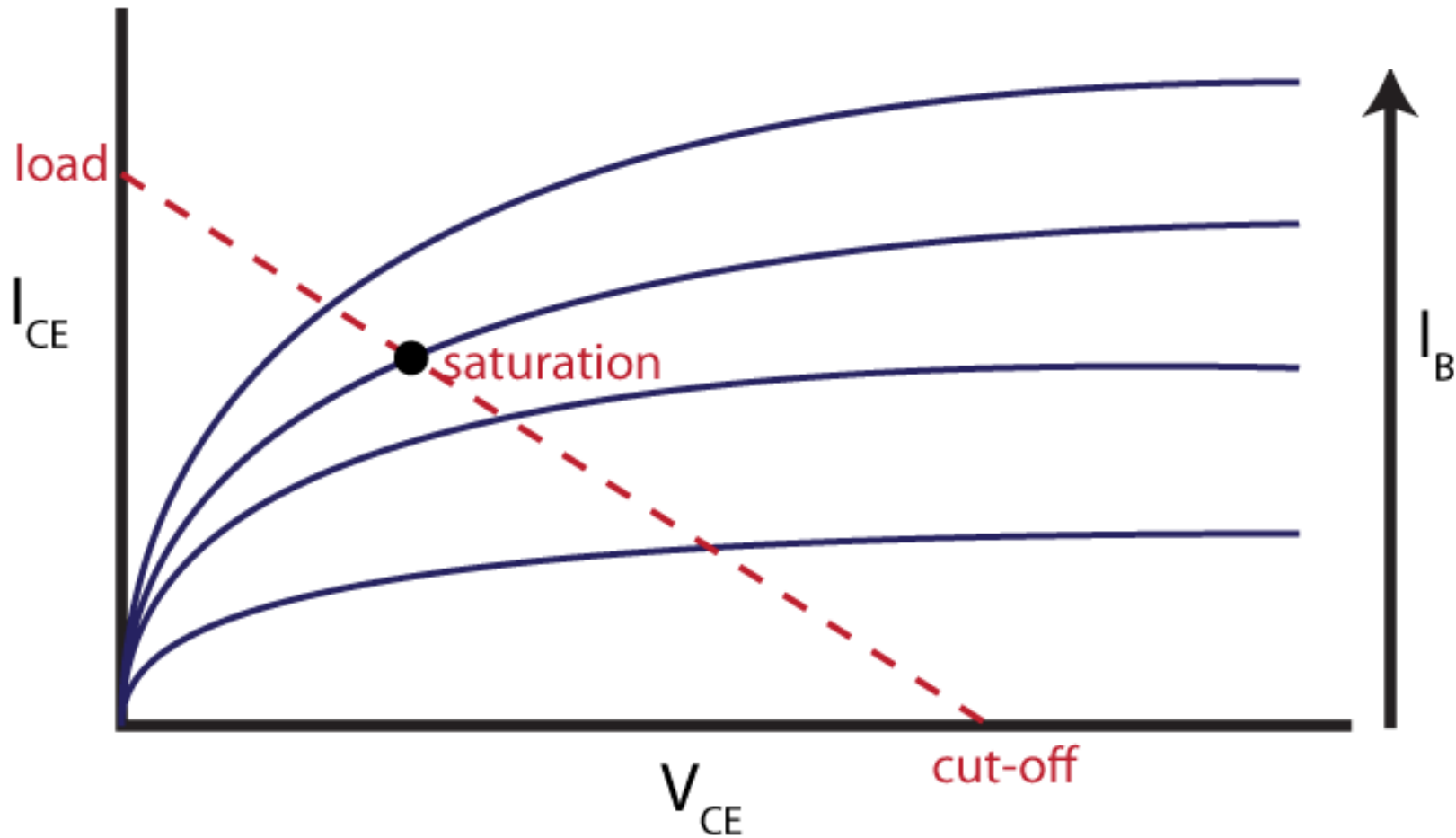
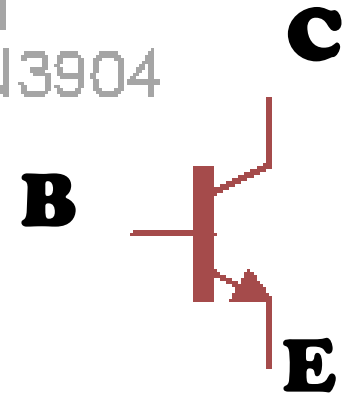
Current-Voltage (I-V) curve

Q1
2N3904

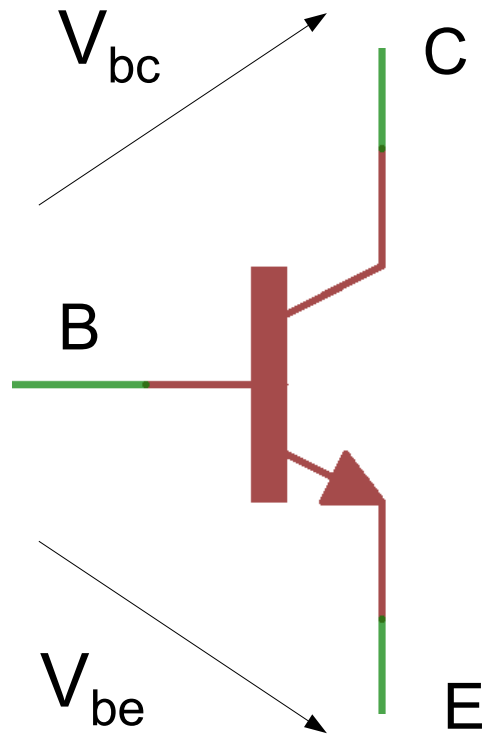


Changing I_{be} changes I-V curve

Q1
2N3904

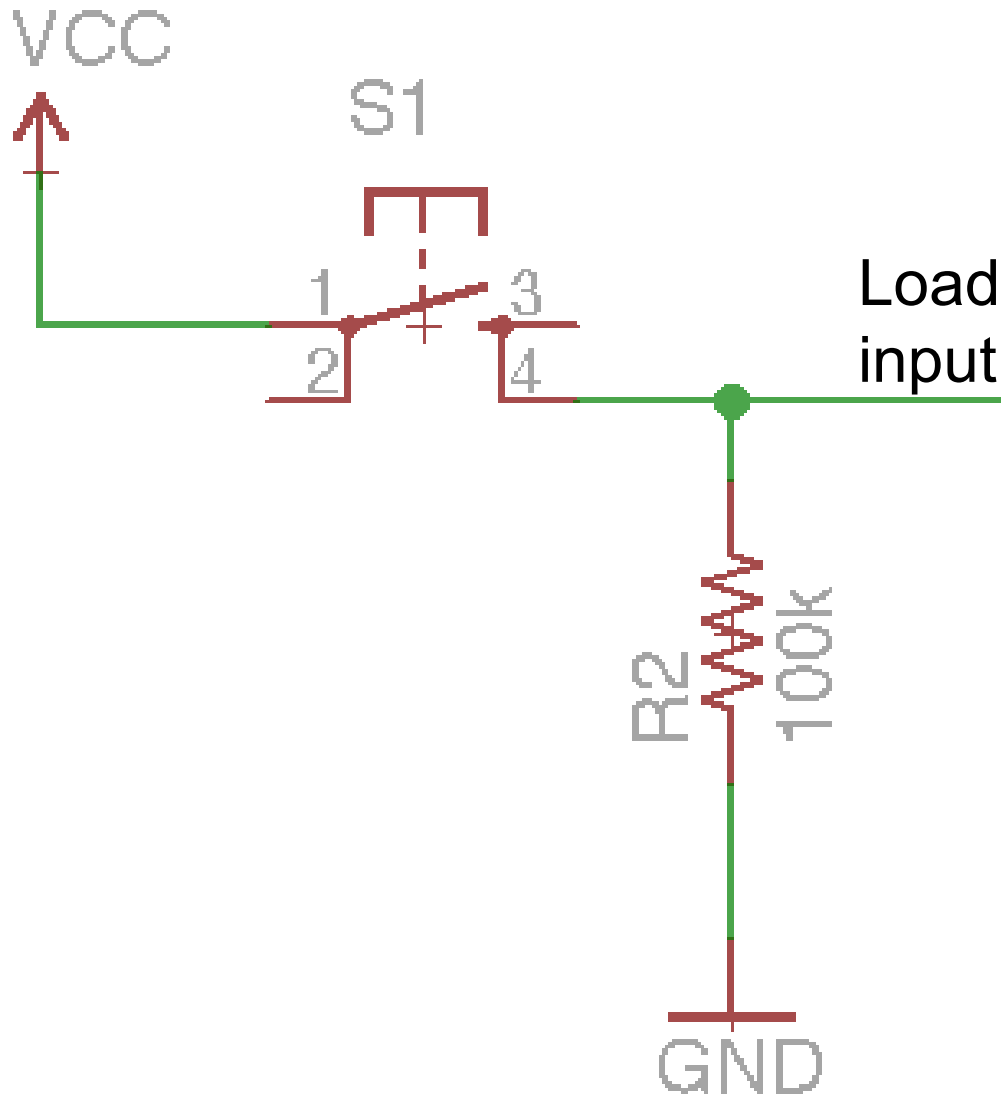


BJT NPN regions of operation



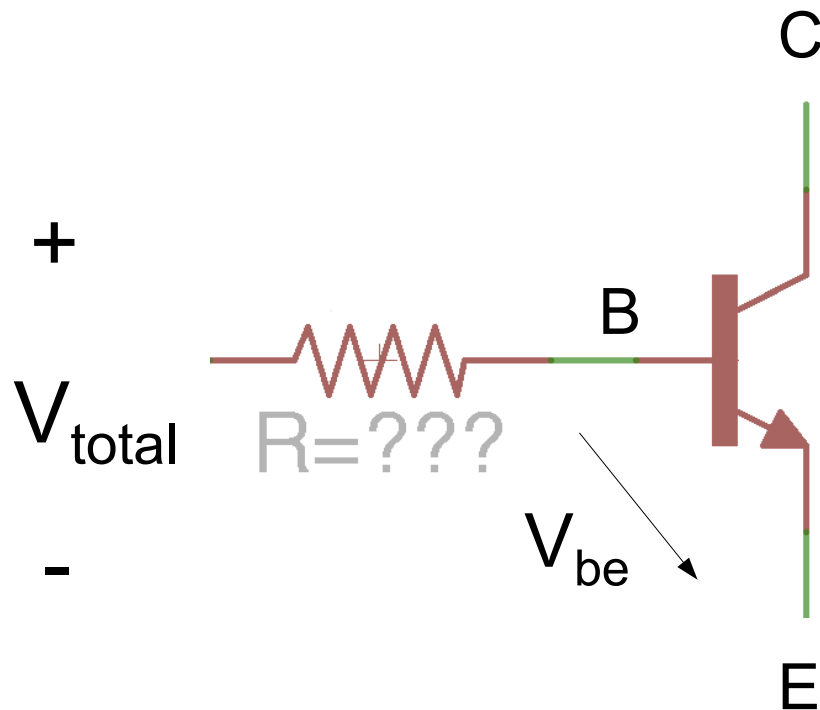
Mode	V_{be}	V_{bc}	I_{ce}
Forward Active	$> V_{th}$	< 0	$\beta_F I_{be}$
Saturation	$> V_{th}$	> 0	depends on load
Cut-off	$< V_{th}$	-	0

Pull-down resistors



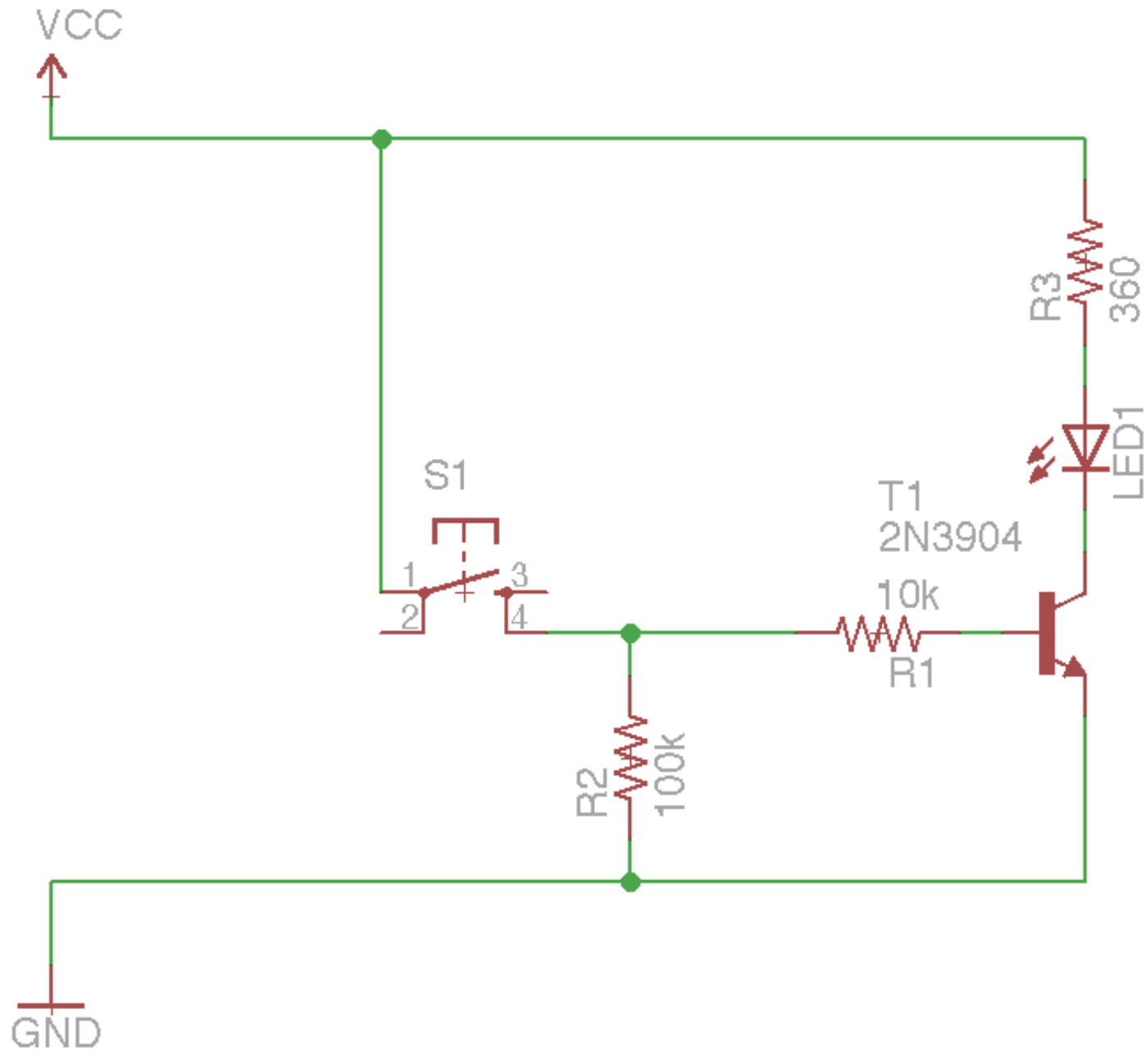
- Ensures that the input sees a certain (stable) voltage at all times
- Resistance is (mostly) arbitrary
- 10x load resistance is a decent rule

Current limiting resistors

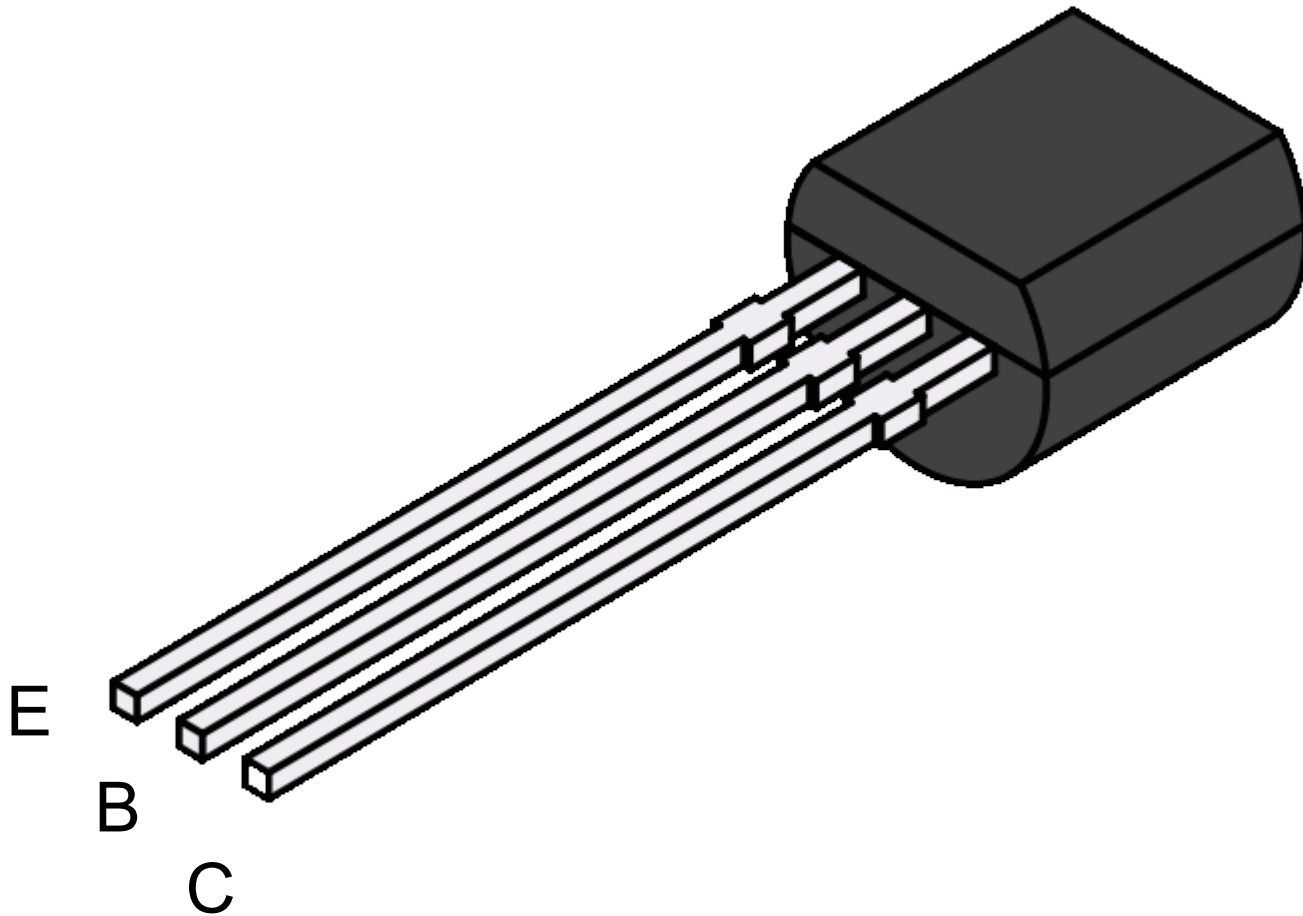


- Sets V_{be} and I_{be} (and thus I_{ce})
- We know desired I_{ce}
 - $I_{be} = I_{ce} / \beta$
- Calculate R via Ohm's Law
 - $R = V / I_{be}$
 - $V = V_{total} - V_{be}$

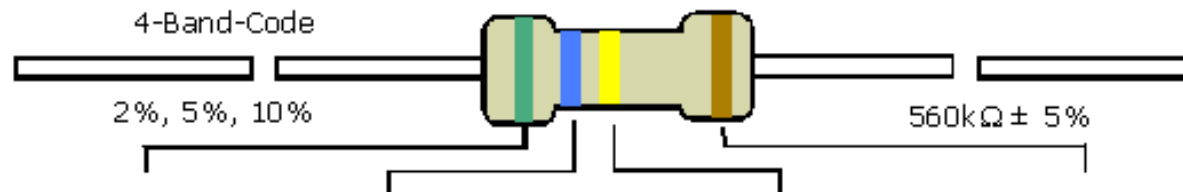
NPN Switch



The TO-92 package



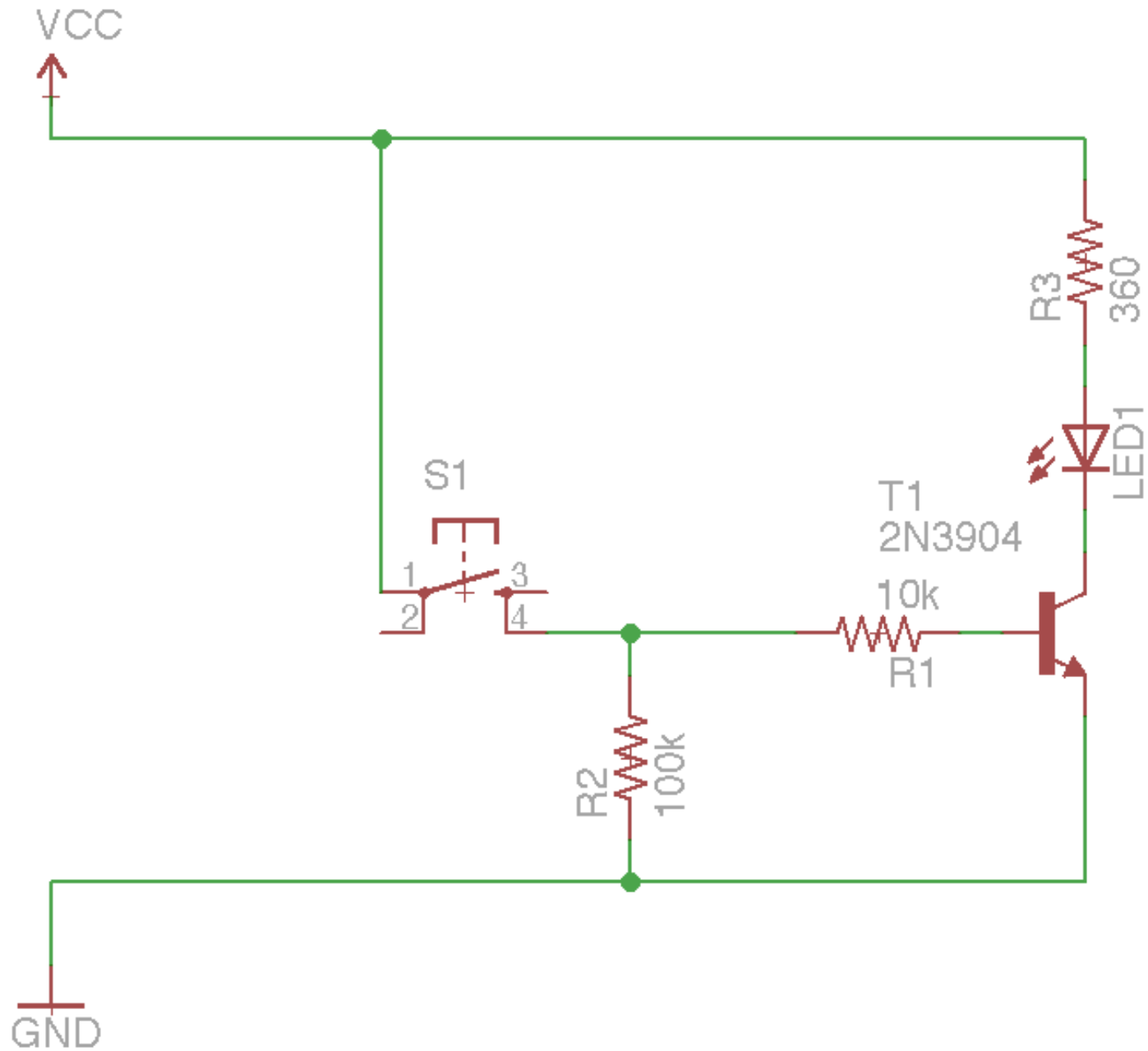
Resistor Values



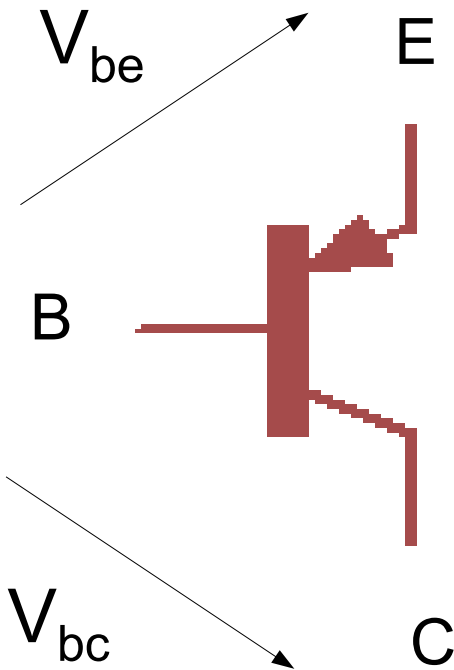
COLOR	1st BAND	2nd BAND	3rd BAND	MULTIPLIER	TOLERANCE
Black	0	0	0	1Ω	
Brown	1	1	1	10Ω	± 1% (F)
Red	2	2	2	100Ω	± 2% (G)
Orange	3	3	3	1KΩ	
Yellow	4	4	4	10KΩ	
Green	5	5	5	100KΩ	±0.5% (D)
Blue	6	6	6	1MΩ	±0.25% (C)
Violet	7	7	7	10MΩ	±0.10% (B)
Grey	8	8	8		±0.05%
White	9	9	9		
Gold				0.1	± 5% (J)
Silver				0.01	± 10% (K)



NPN Switch

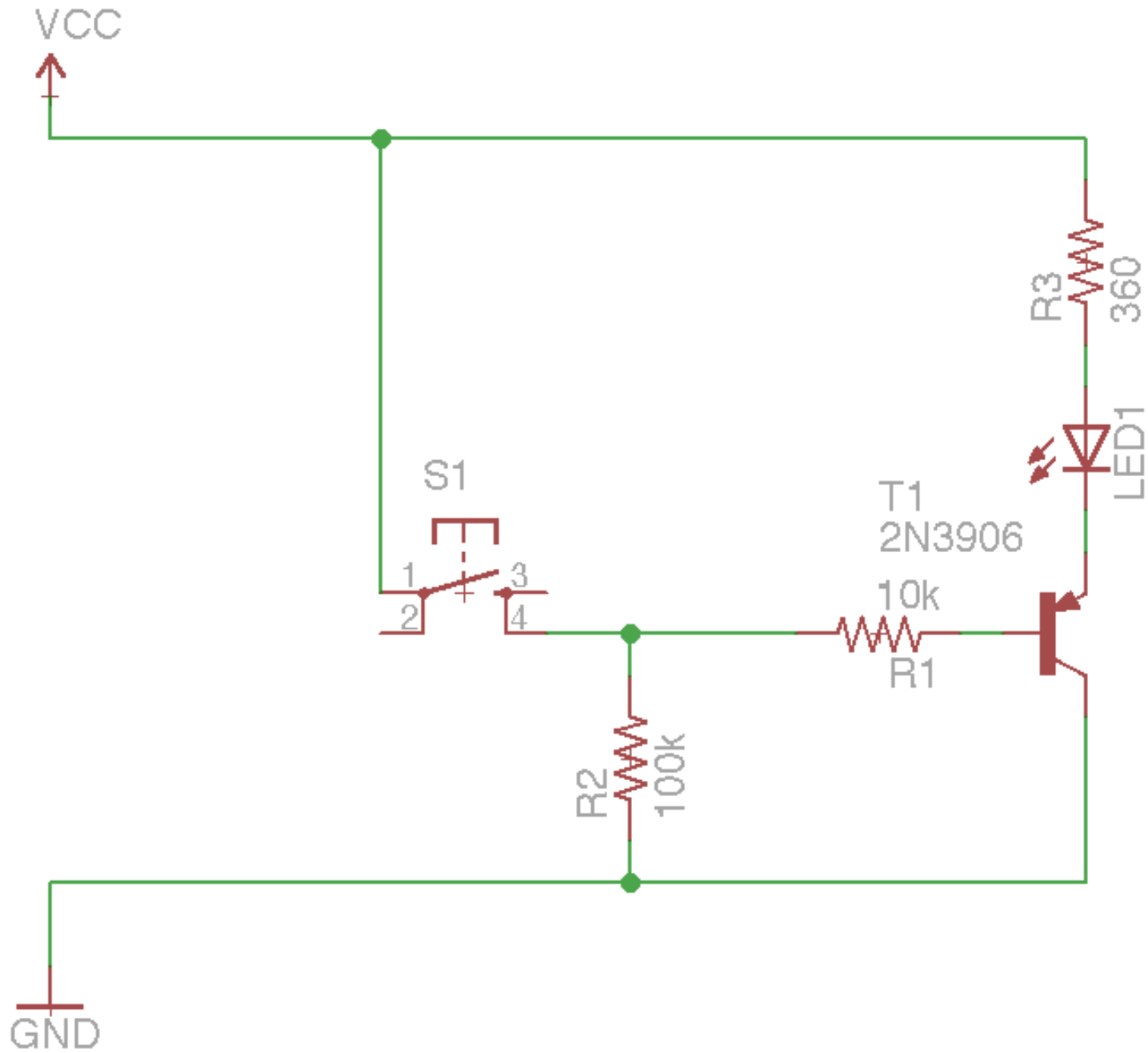


BJT PNP regions of operation

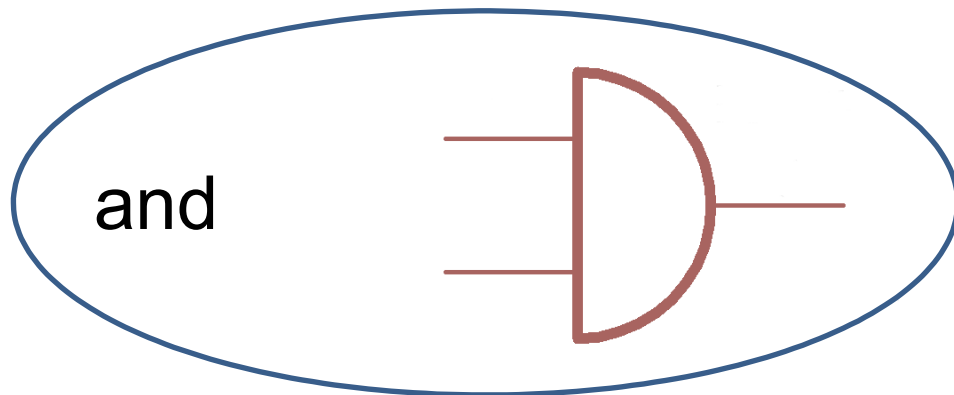
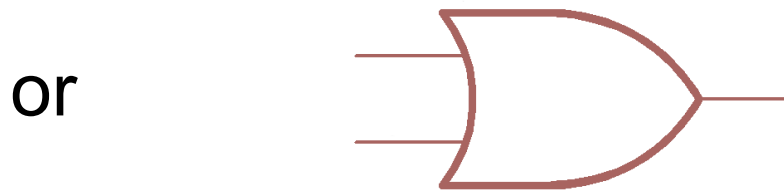
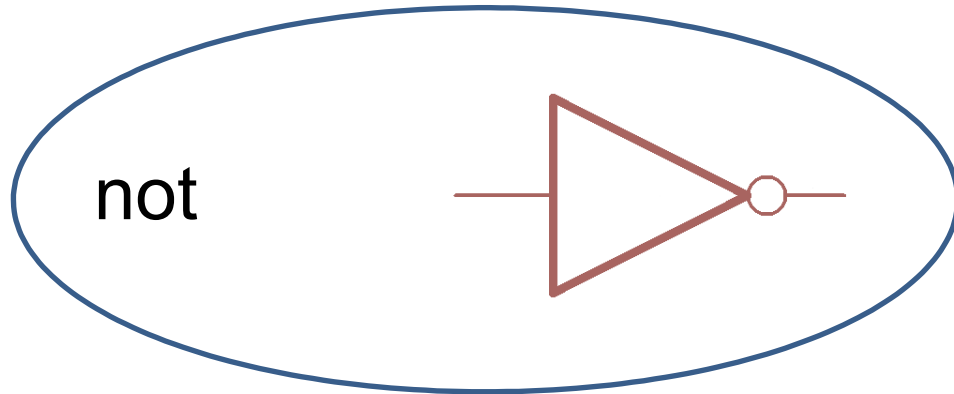


Mode	V_{be}	V_{bc}	I_{ce}
Forward Active	$< V_{th}$	> 0	$\beta_F I_{be}$
Saturation	$< V_{th}$	< 0	depends on load
Cut-off	$> V_{th}$	-	0

PNP Switch

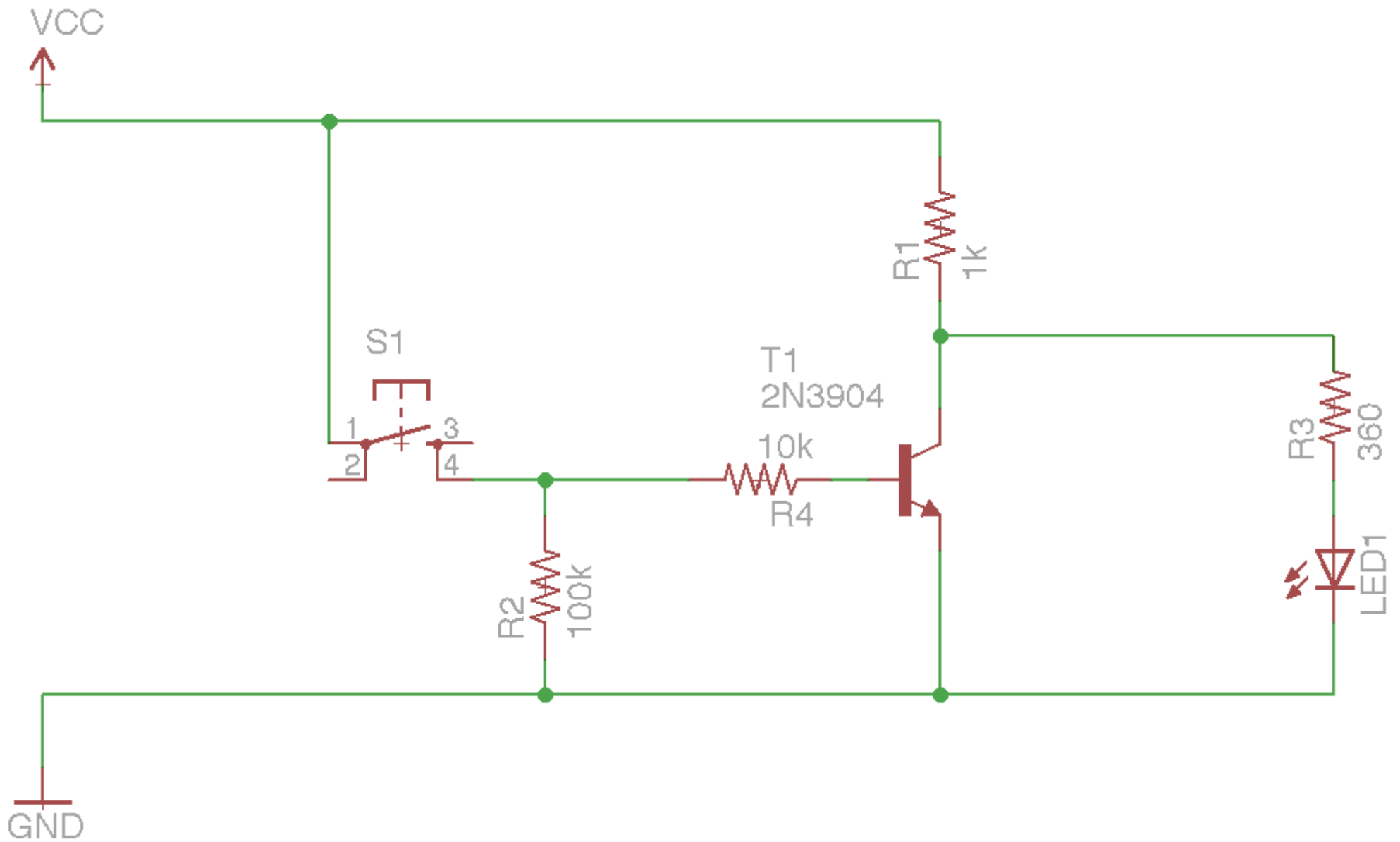


Logic Gates

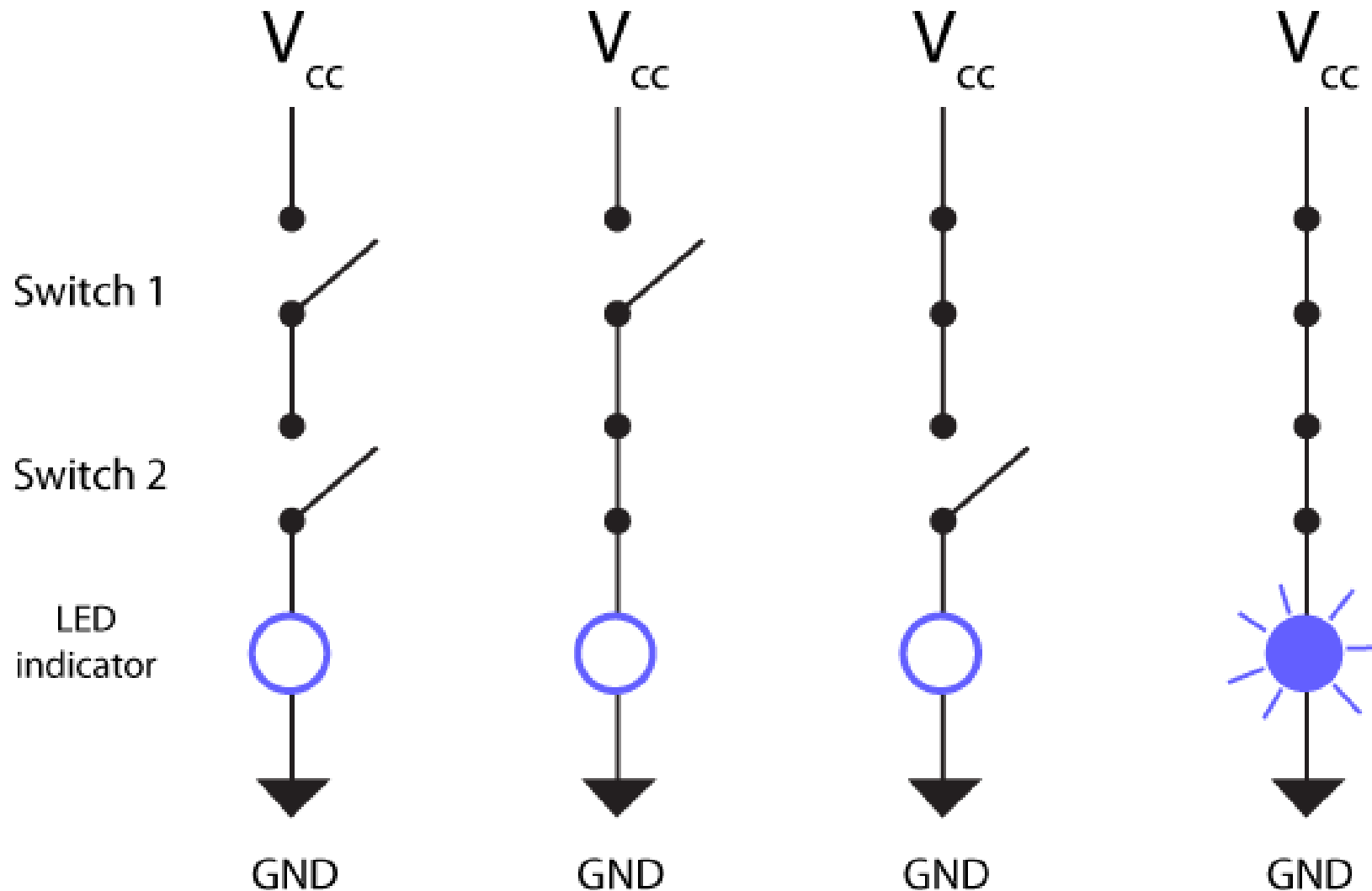


- Generate binary output from binary inputs
- Can be chained together to create complex systems
- BJT logic gates operate in the saturation and cut-off regions

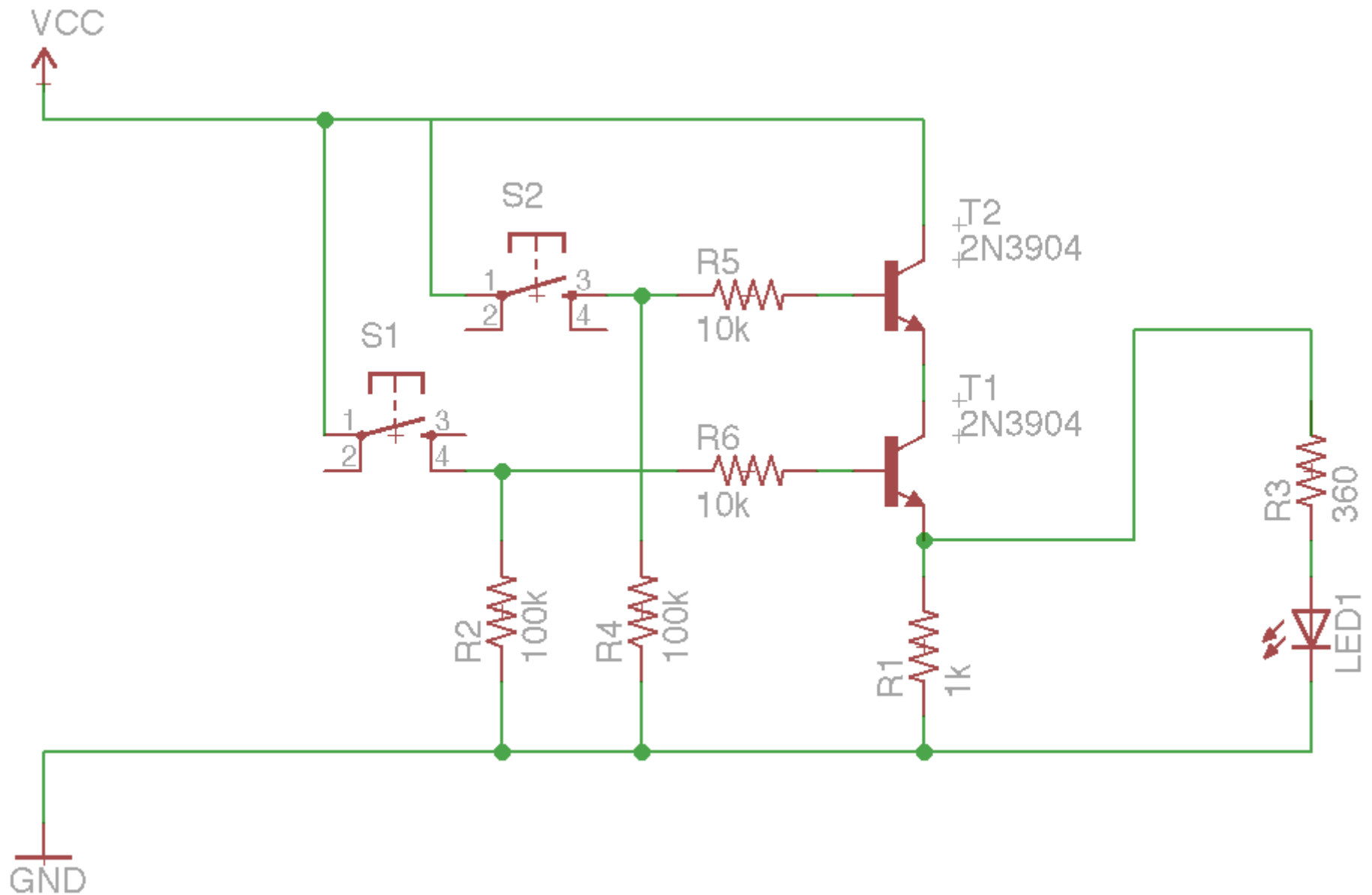
Not Gate



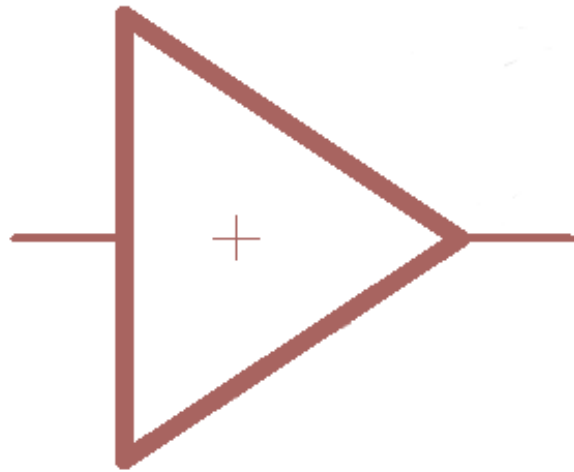
And Gate Diagram



And Gate

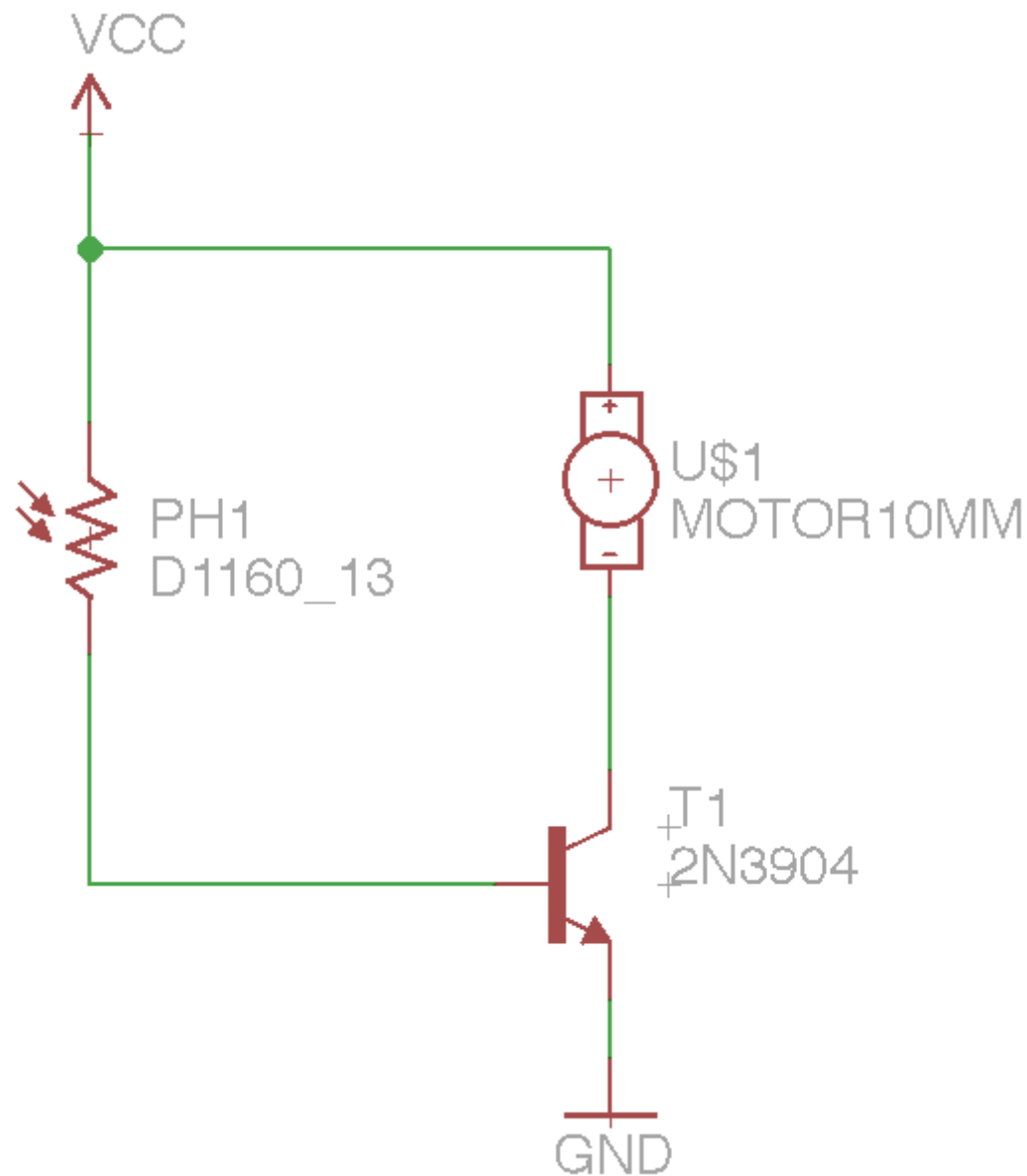


Amplifiers



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

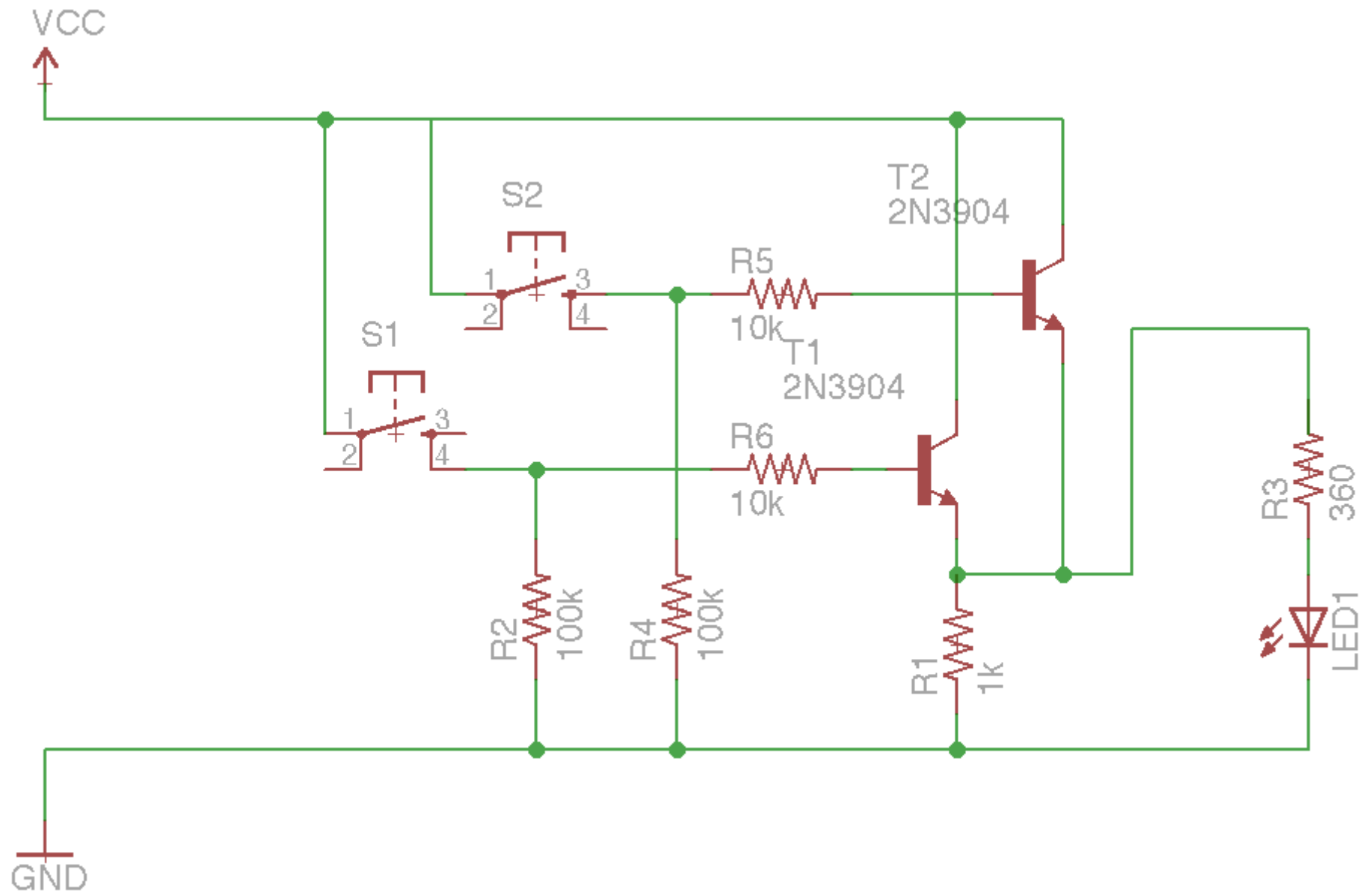
The simplest amplifier



Where do you go next?

- PSPICE
- Code, by Charles Petzold
- AC amps
- Advanced Transistors Course at Metrix
 - Interested?

Or Gate



Thanks to

- Jason Zack for the switch photo on slide 6
- Matthew Bowden for the faucet photo on slide 7
- Michael Frey for the TO-92 graphic on slide 22