Lecture 7: Transistors

Largely replaced the vacuum tube

Heart of modern electronics

Three-terminal semiconductor device

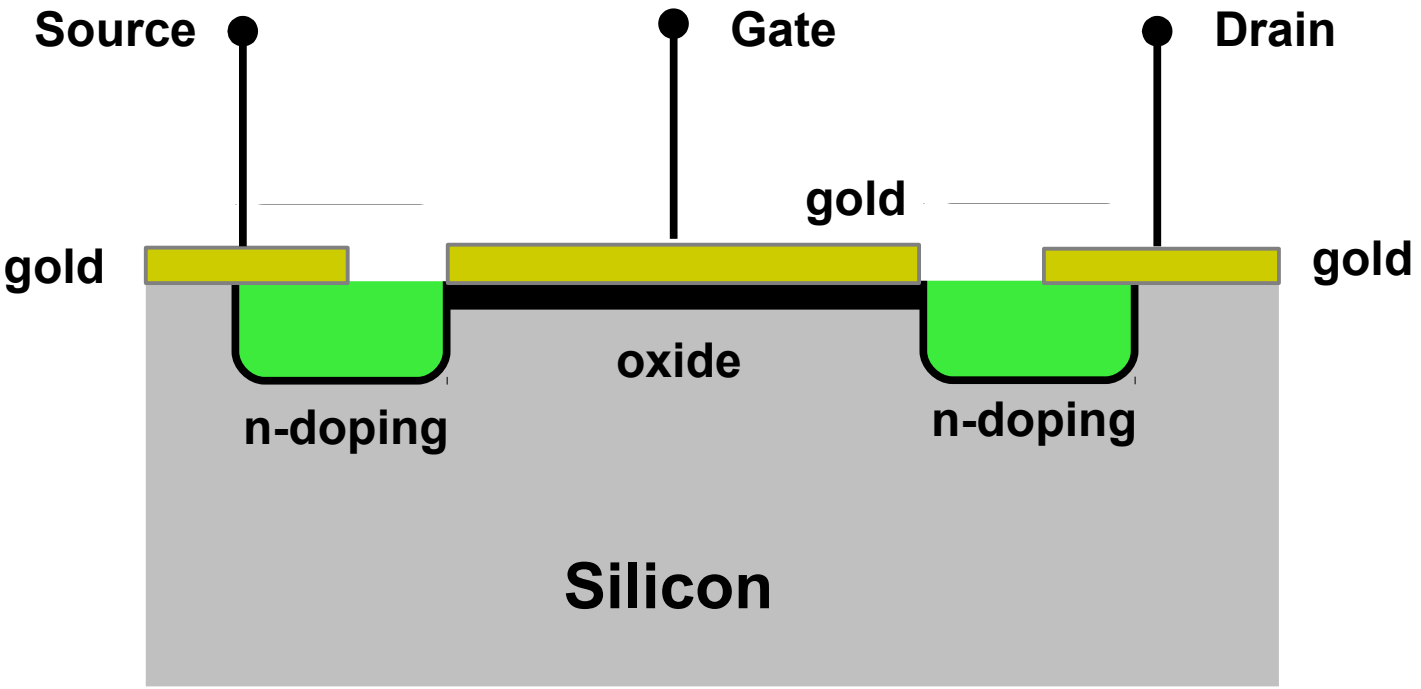
Amplification and switching

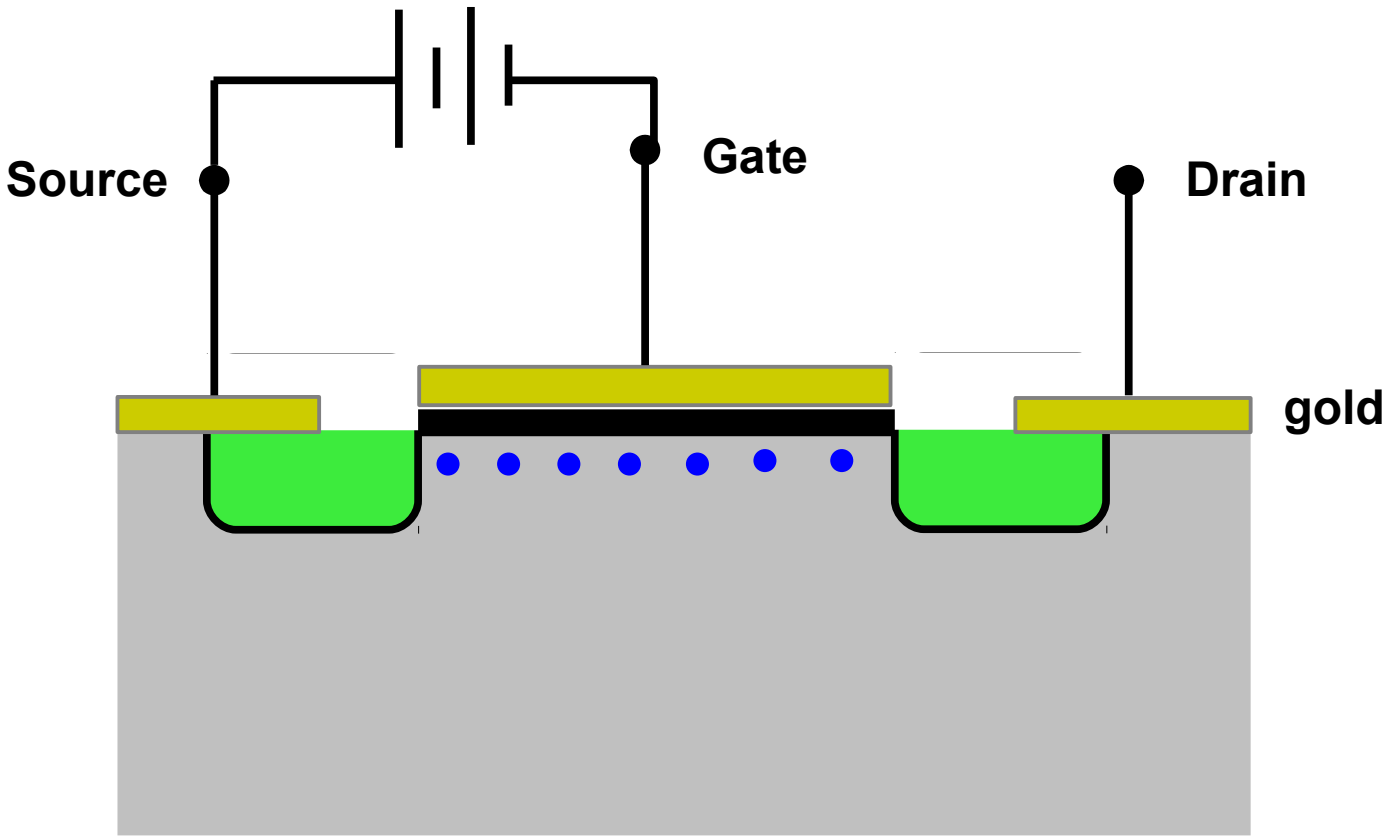
Two basic forms (BJT and FET)

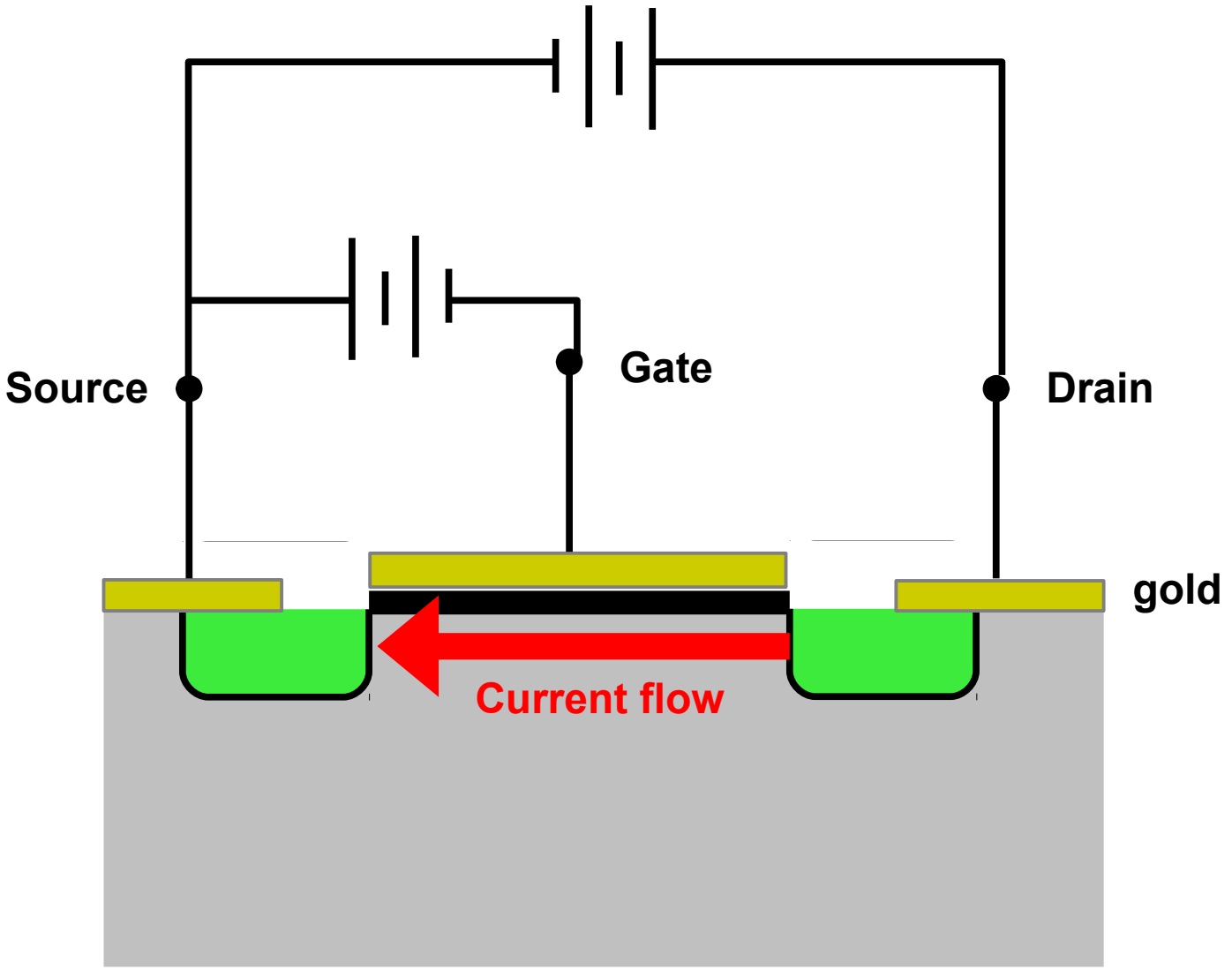
John Bardeen William Shockley Walter Brattain

1956 Nobel Prize in Physics

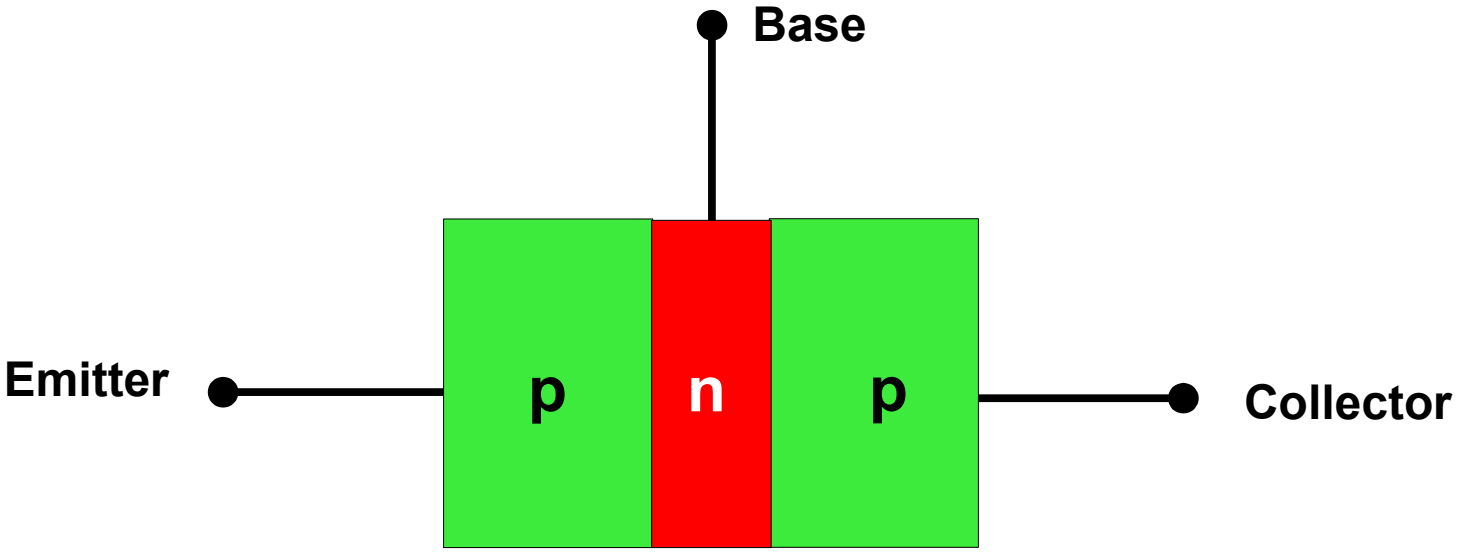
MOSFET: Metal-Oxide-Semiconductor Field-Effect Transistor




Source
Gate
Drain
gold


Source
Gate
Drain
gold
Current flow

BJT: Bipolar Junction Transistor



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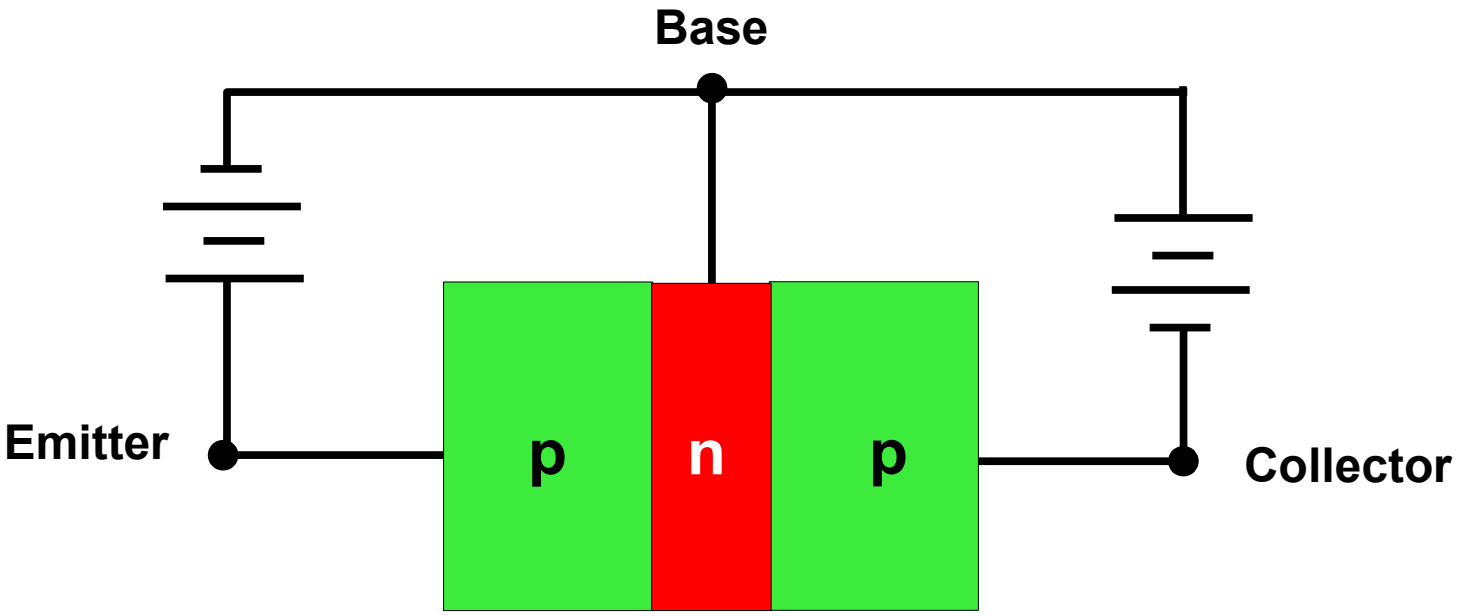

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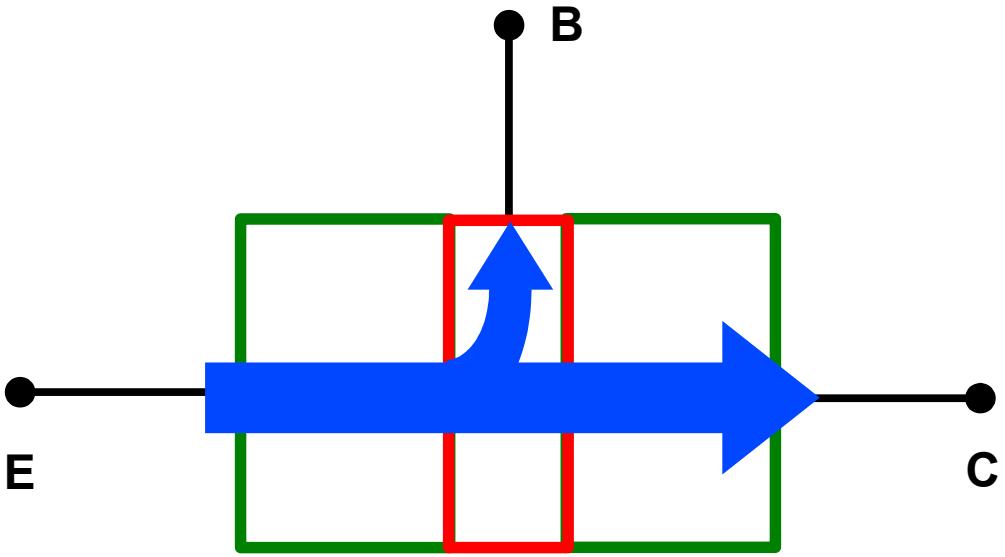
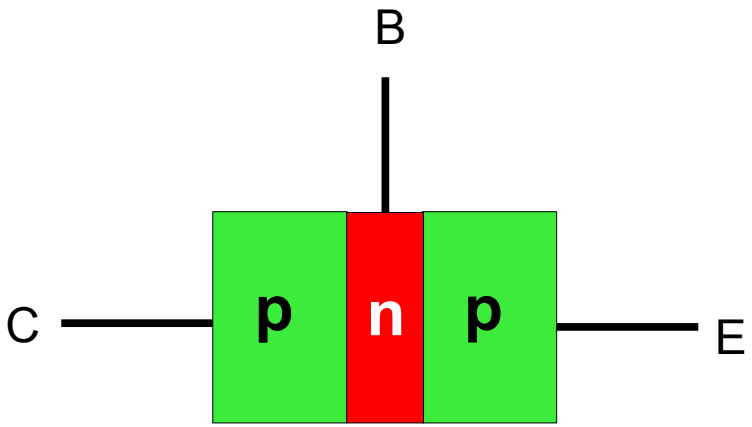
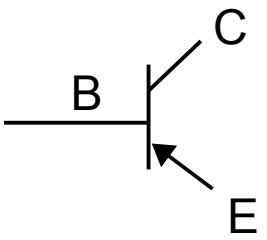
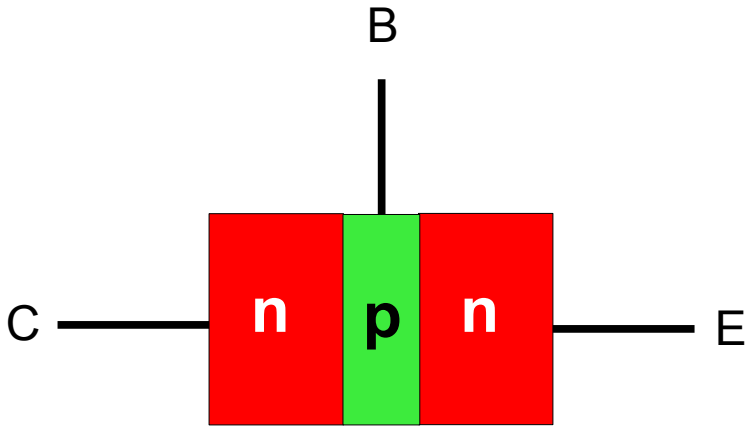
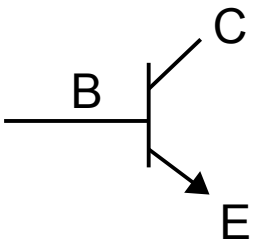


Small base current controls much larger collector current


B
C
p
n
p
E

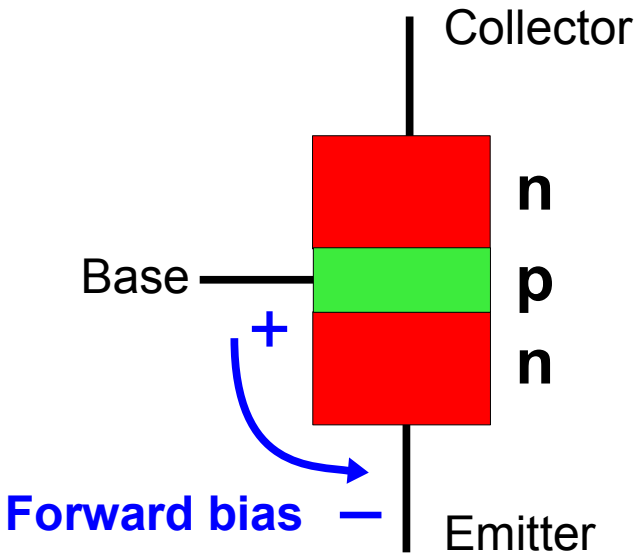

C
B
E

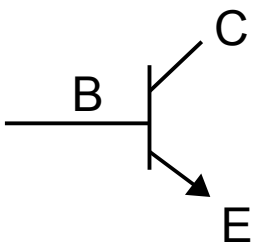

B
C
n
p
n
E


C
B
E

Getting the dc voltages correct: BIAS

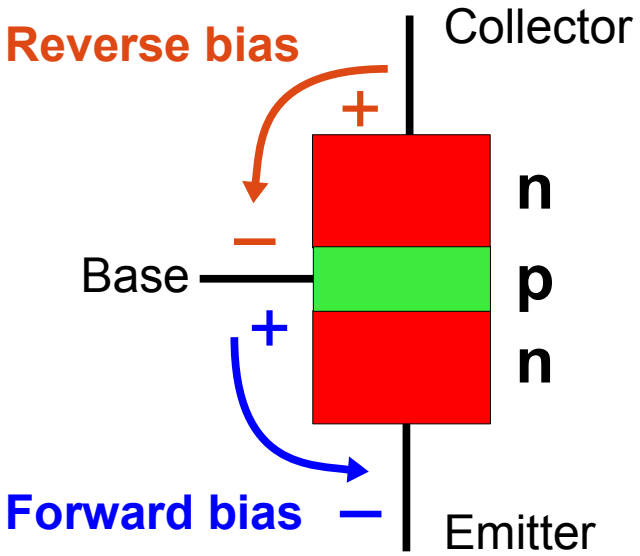
n-p-n transistor

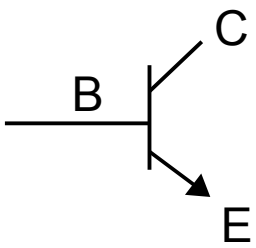




Getting the dc voltages correct: BIAS

n-p-n transistor





Getting the dc voltages correct: BIAS

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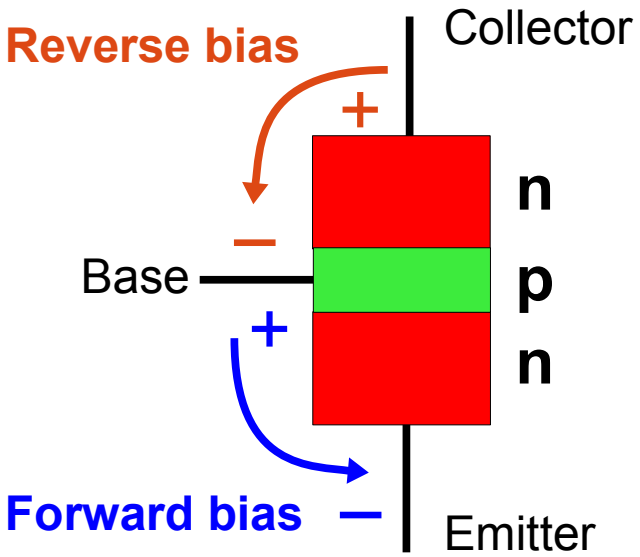
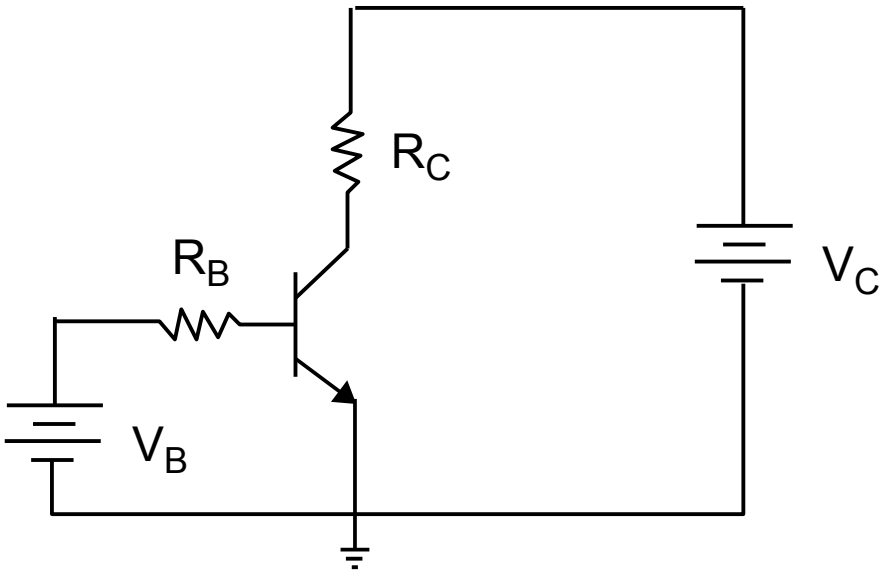
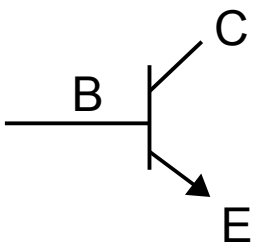
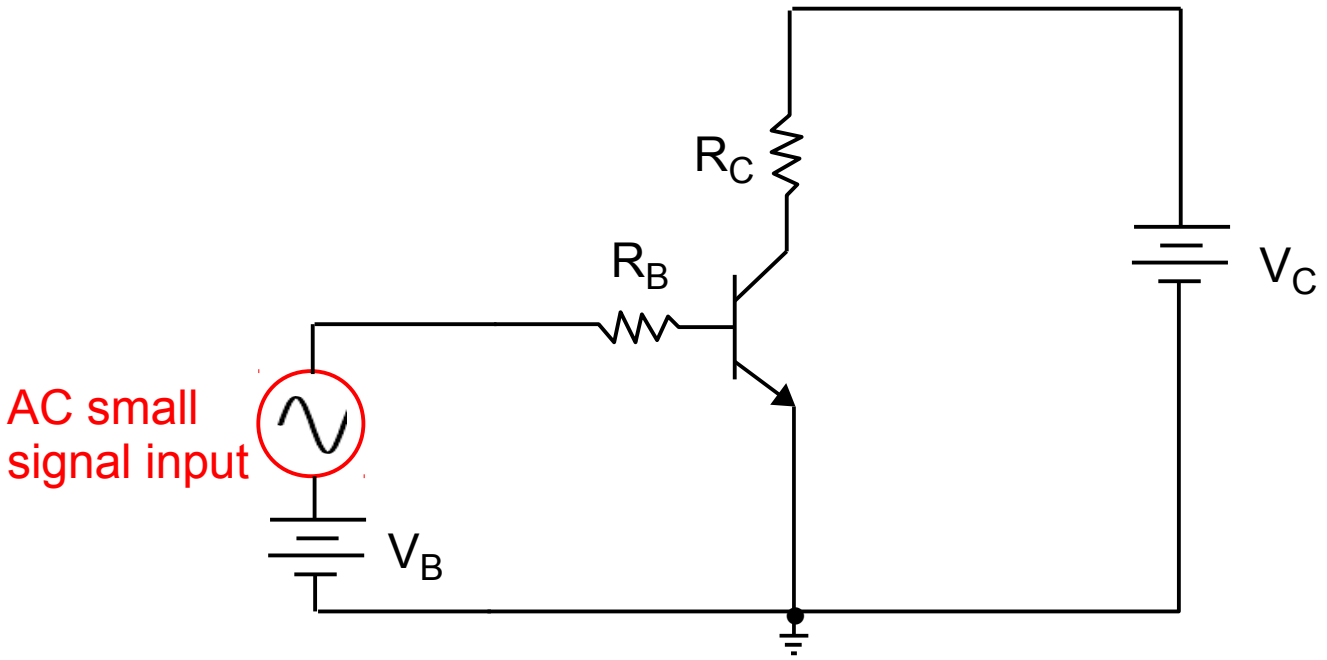






The BJT Amplifier



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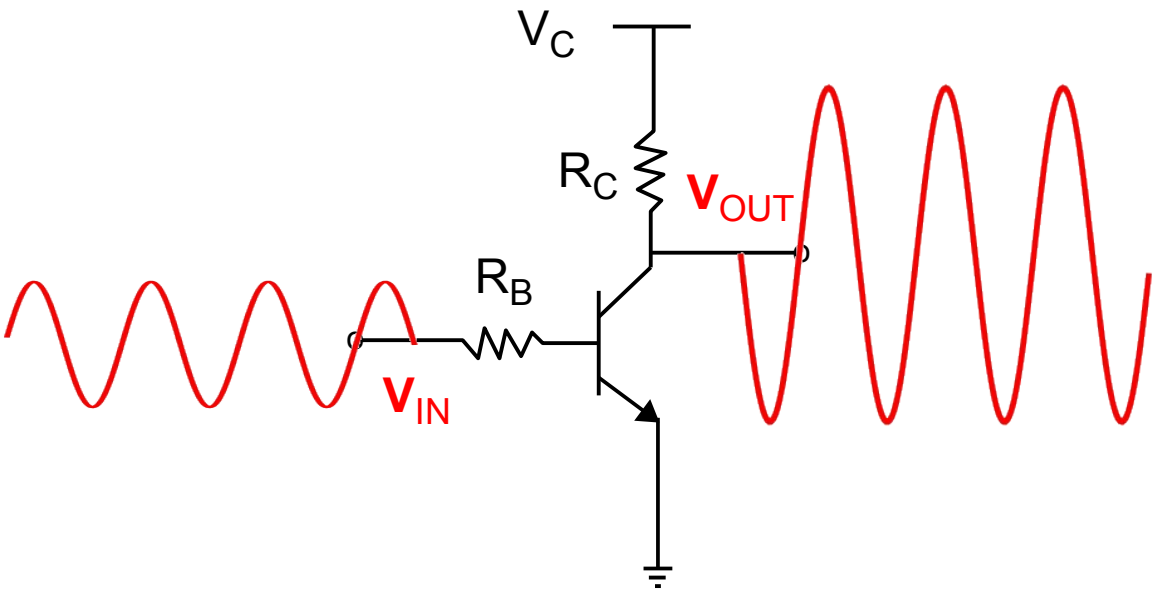
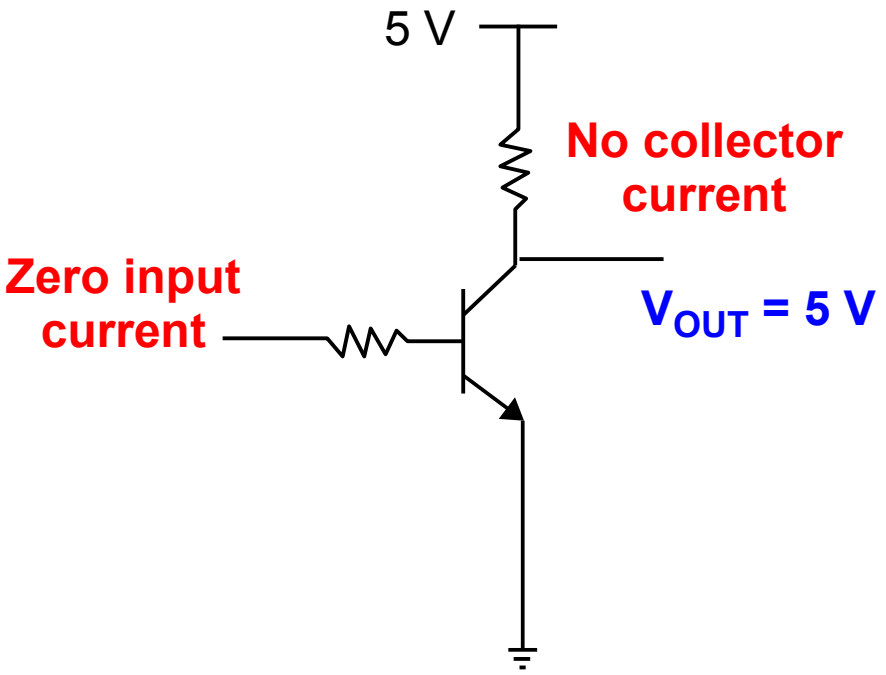


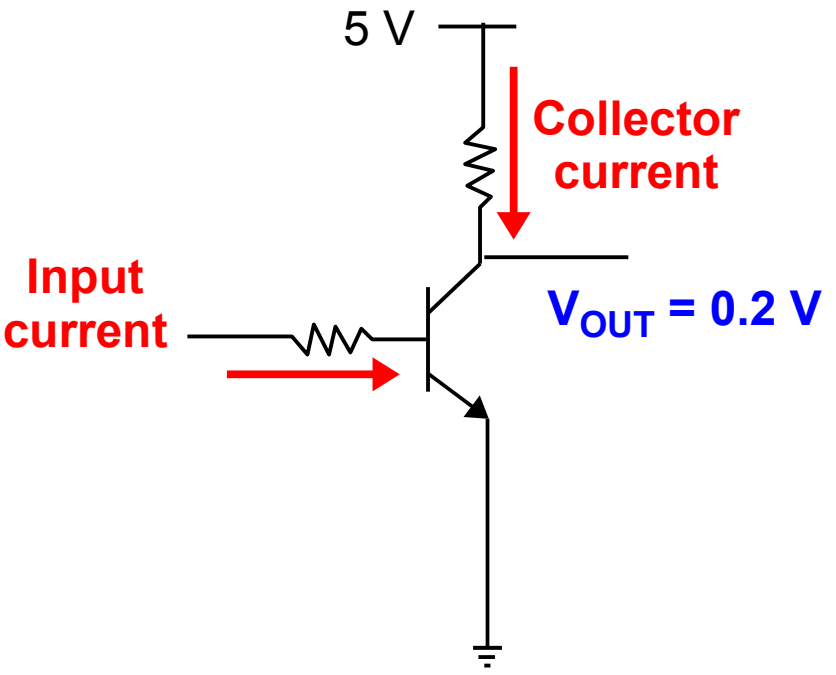
$$\frac{V_{OUT}}{V_{IN}} = \text{Gain}$$

The Transistor as a Switch

- No base bias voltage
- Input current turns transistor on and off

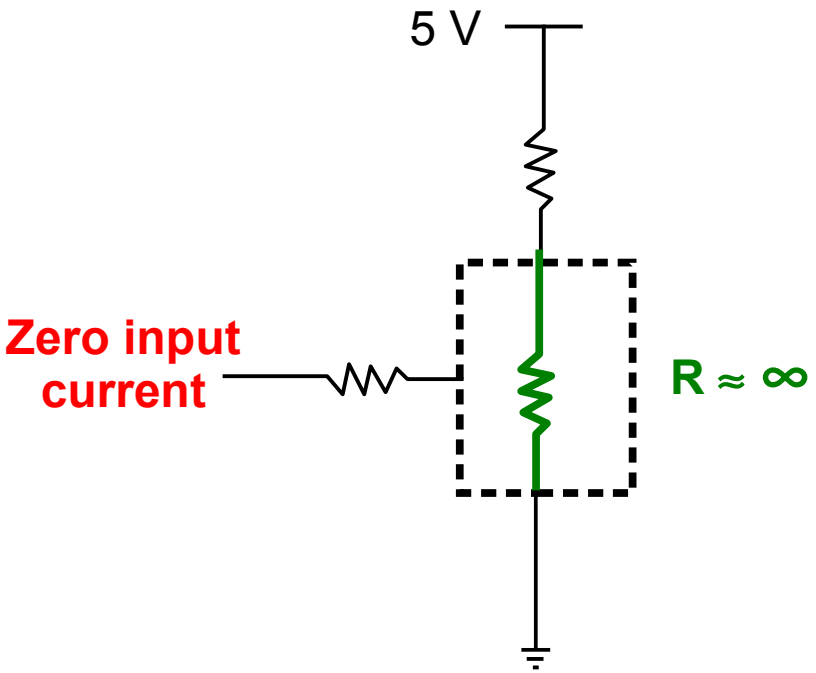


Transistor **OFF**

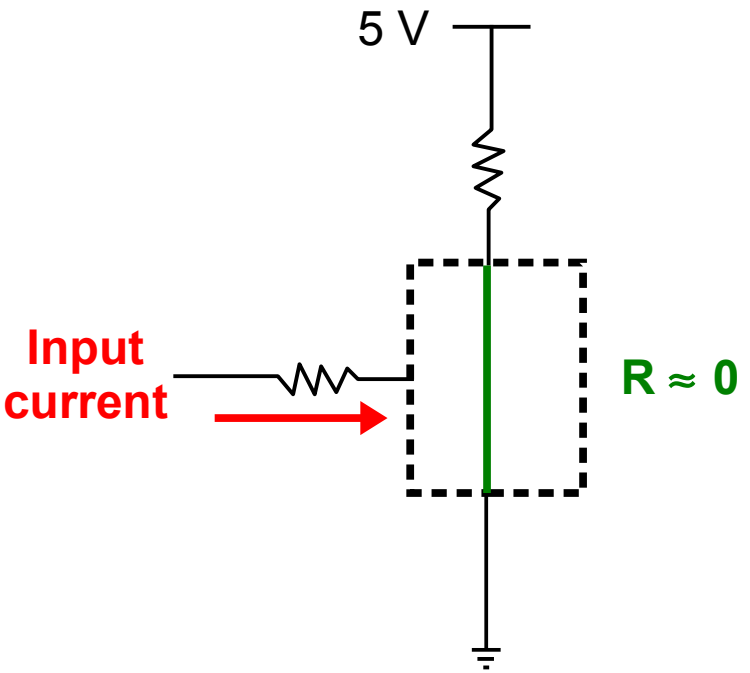


Transistor **ON**

Intuitive picture of the transistor switch:
Current-controlled resistor

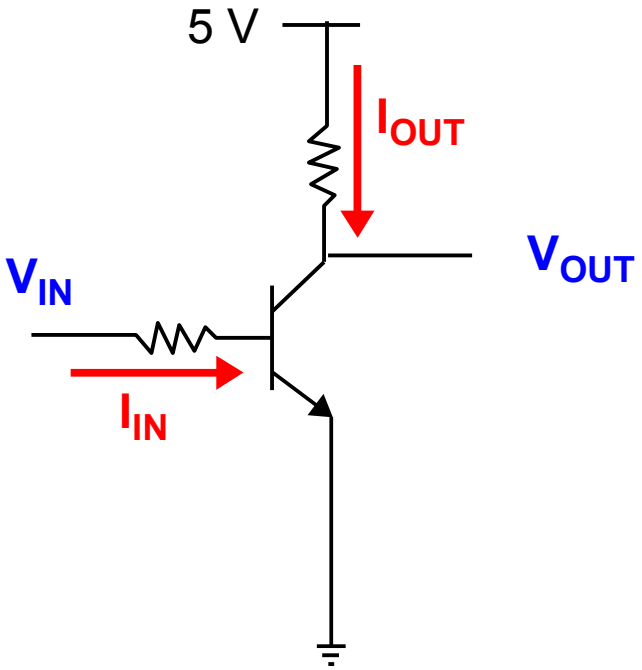


Transistor **OFF**



Transistor **ON**

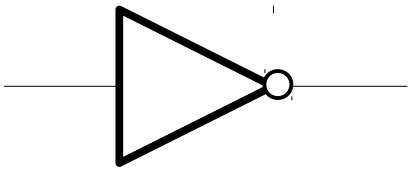
The Transistor Switch: Boolean Logic Device



LOGIC 0: VOLTAGE < 0.4 V
LOGIC 1: VOLTAGE > 3 V

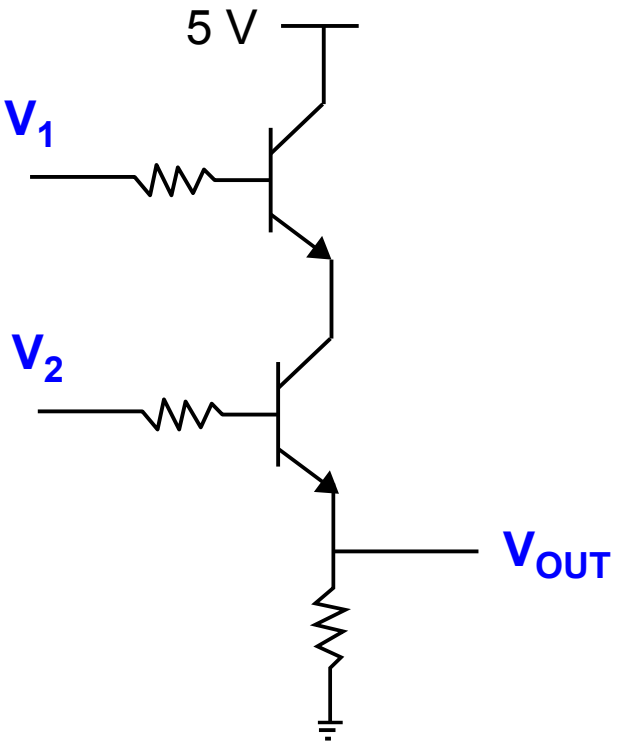
V_{IN}	I_{IN}	I_{OUT}	V_{OUT}
Logic 0	0	0	Logic 1
Logic 1	μA	mA	Logic 0

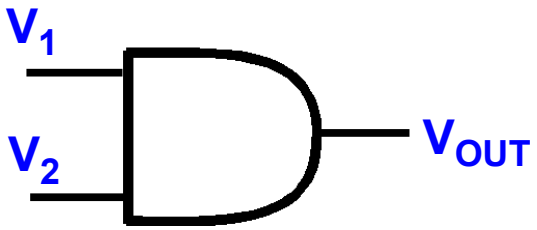
NOT Gate



The Transistor AND Gate

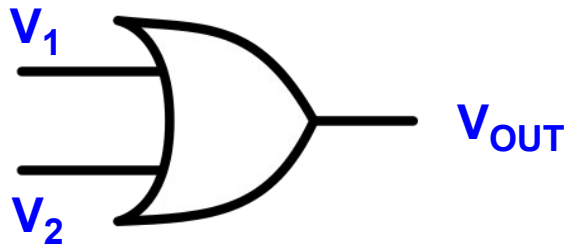
V_1	V_2	V_{OUT}
0	0	0
1	0	0
0	1	0
1	1	1

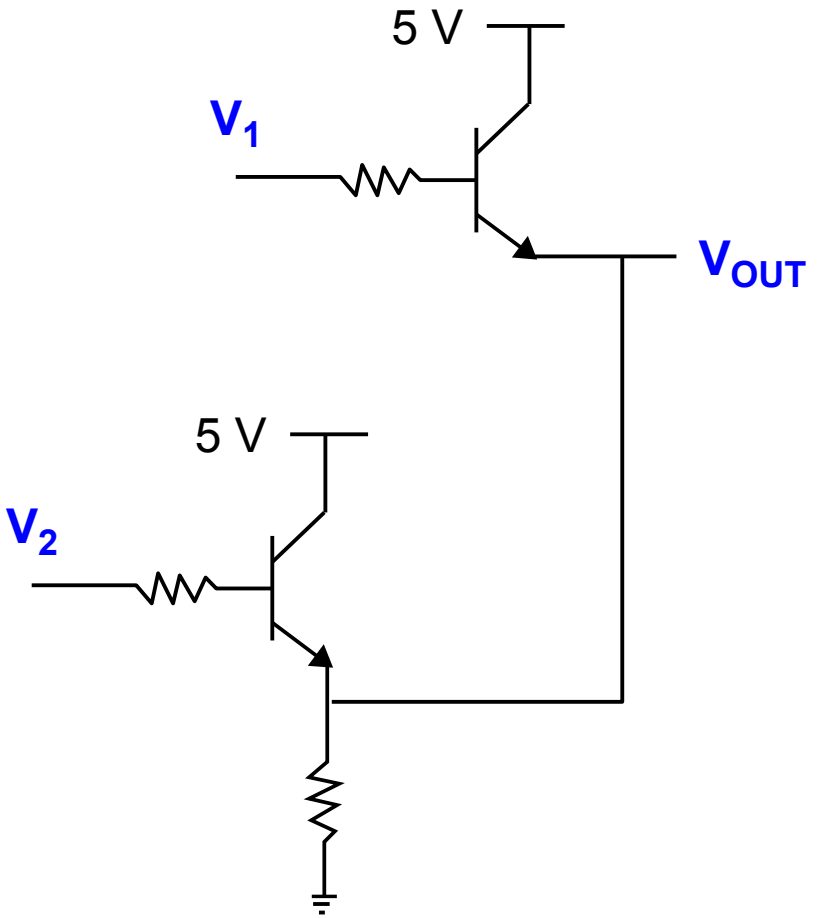




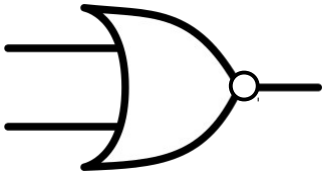
The Transistor OR Gate

V_1	V_2	V_{OUT}
0	0	0
1	0	1
0	1	1
1	1	1



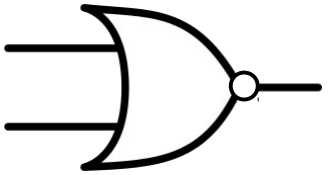


The NOR Gate

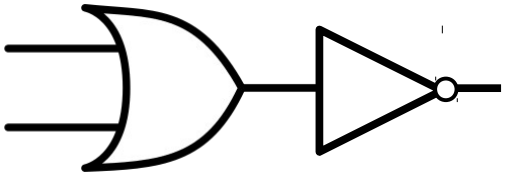


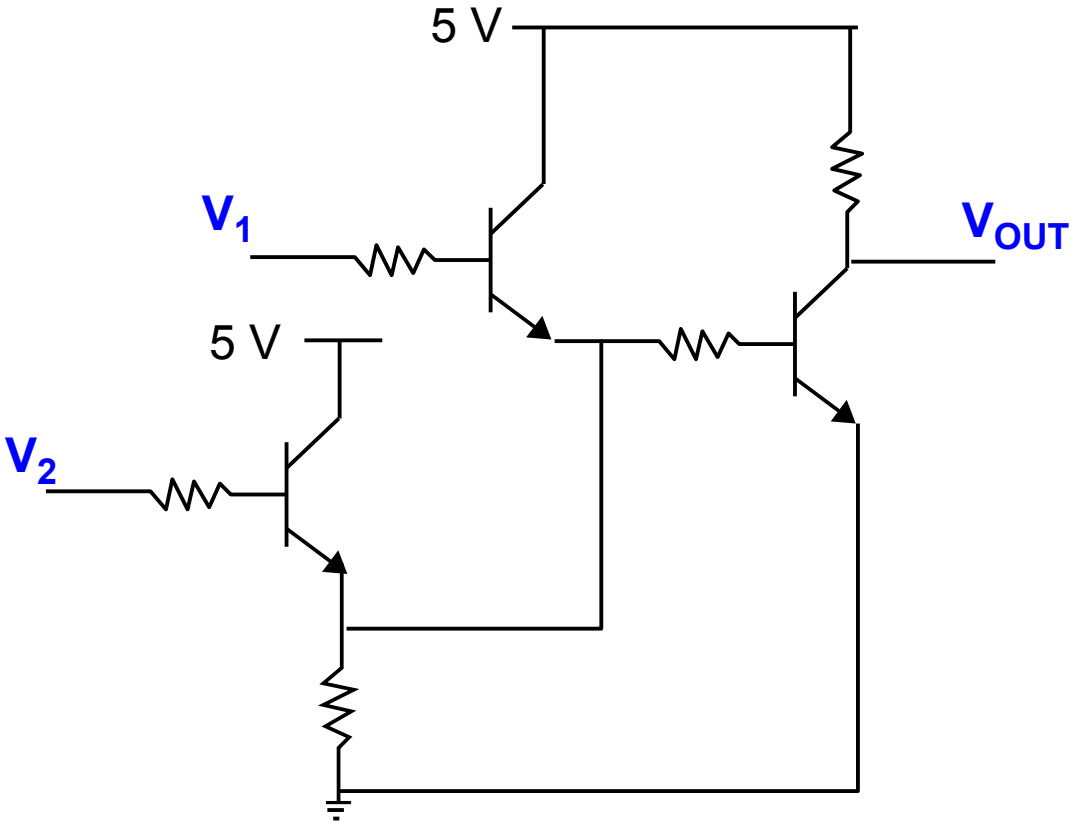
V_1	V_2	V_{OUT}
0	0	1
1	0	0
0	1	0
1	1	0

The NOR Gate

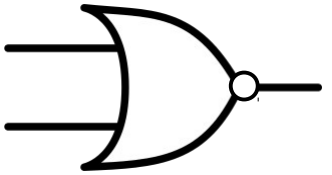


V_1	V_2	V_{OUT}
0	0	1
1	0	0
0	1	0
1	1	0

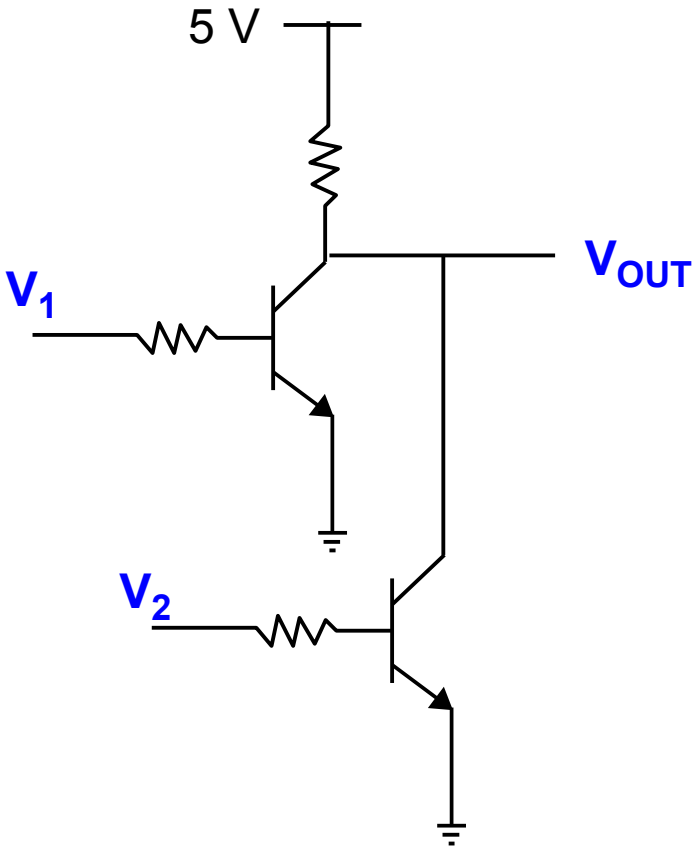




The NOR Gate



V_1	V_2	V_{OUT}
0	0	1
1	0	0
0	1	0
1	1	0



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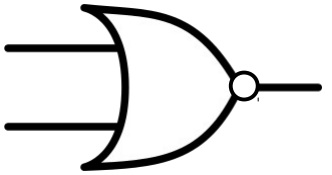

V_1	V_2	V_{OUT}
0	0	1
1	0	0
0	1	0
1	1	0