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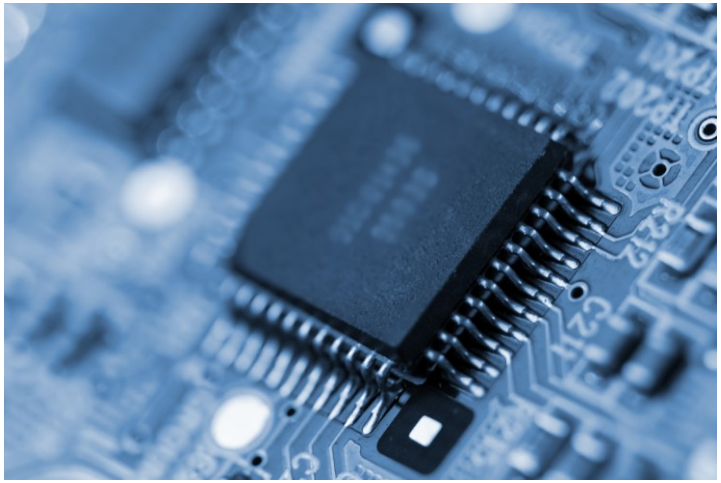
Computer Processors

Semiconductors & Logic gates



Lecture 2

Logic gates

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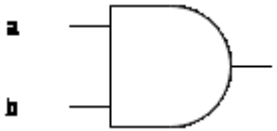
AND gates implement the conjunction operator as described in Fundamental Mathematical Concepts.

$$a \wedge b$$

a	b	$a \wedge b$
0	0	0
0	1	0
1	0	0
1	1	1



Logic gates

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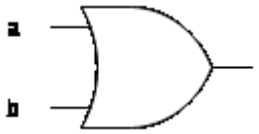
OR gates implement the disjunction operator as described in Fundamental Mathematical Concepts.

$$a \vee b$$

a	b	$a \vee b$
0	0	0
0	1	1
1	0	1
1	1	1



Logic gates

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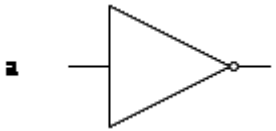
Not gates implement the negation operator as described in Fundamental Mathematical Concepts.

$$\neg a$$

a	$\neg a$
0	1
1	0



Logic gates (implementation as switches)

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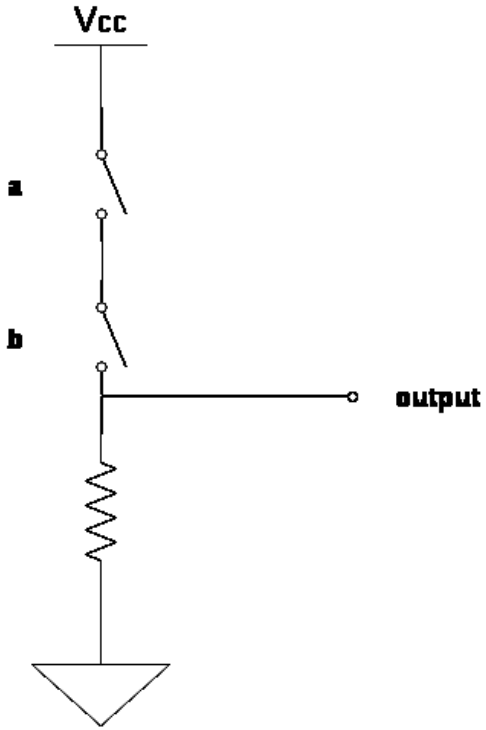
AND gates can be implemented as switches

When switches **a** AND **b** are closed then **output** is connected to Vcc (logic high).

When either **a** or **b** are open then **output** is connected to Ground (logic low).



Logic gates (implementation as switches)

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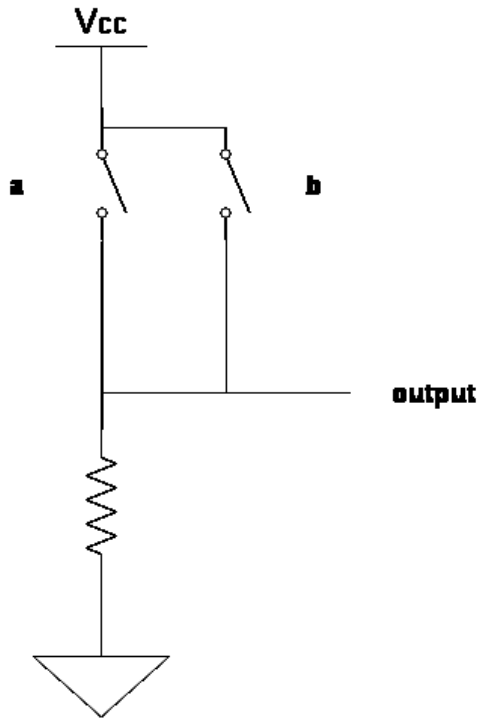
OR gates can be implemented as switches

When switches **a** OR **b** are closed then **output** is connected to Vcc (logic high).

When switches **a** and **b** are open then **output** is connected to Ground (logic low).



Logic gates (implementation as switches)

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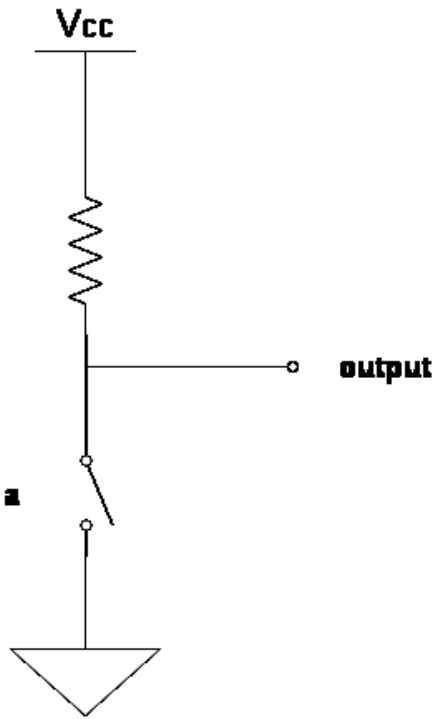
NOT gates can be implemented as switches

When switch a is open output is connected to Vcc (logic high).

When switch a is closed output is connected to Ground (logic low).



Valves

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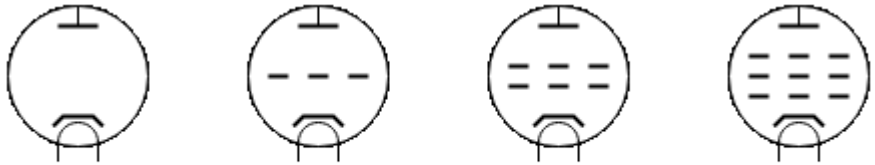
- Valves are electronic devices that control the flow of electric current. Invented in 1904 by John Fleming.
- Electrons are released by thermionic emissions of a heated plate
- The electrons are attracted towards an anode with a more positive potential (relative to the cathode).
- This flow of electrons onto the anode is a current flow.
- The flow of electrons can be controlled using a control grid.



Transistor

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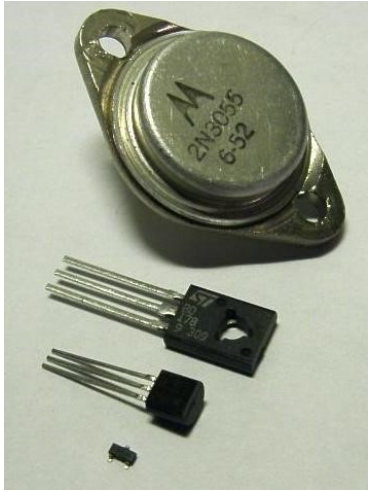
- Transistors are the successor of valve and resolve many of the obstacles to using valves.
- Transistors were invented in 1926 and practically implemented in 1947.
- Transistors are composed of semiconductor material.
- Two types of semiconductor material are used P-type and N-type
- The arrangement of P-type and N-type semiconductors produce different electronic properties



Bipolar Junction Transistor anatomy

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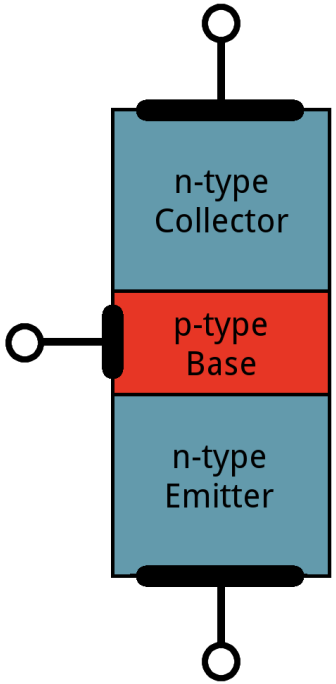
- Transistors are composed of P-type and N-type semiconductor
- P-type semiconductor have electron “holes”
- N-type semiconductor have added electrons (doped semiconductor)
- Transistors are produced by stacking semiconductors in either a NPN or PNP arrangement.



Transistor functionality

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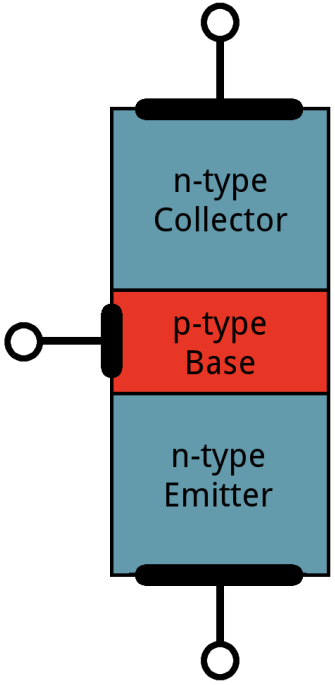
- Electrons can travel from N-type semiconductor to P-type semiconductor (with a little external force).
- Electrons *can* easily flow from the P-type base to the N-type collector as long as the base-emitter junction is forward biased (base is at a higher voltage than the emitter).
- The NPN transistor is designed to pass electrons from the emitter to the collector, subject to the current present at the base.



Remember electrons flow from negative to positive, conventional current flows from positive to negative.

Transistor functionality

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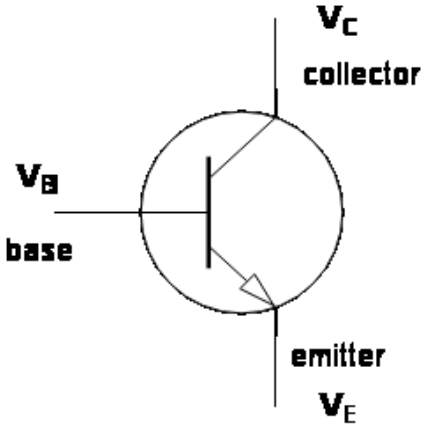
Saturation

- The transistor acts like a short circuit and current flows freely from the collector to the emitter
- For a transistor to be saturated $V_E < V_B$ and $V_C < V_B$
- As a result of the construction of a transistor the voltage at the base must be at about 0.6v to saturate the transistor (0.6v is approximately the voltage drop across a diode)



Transistor functionality

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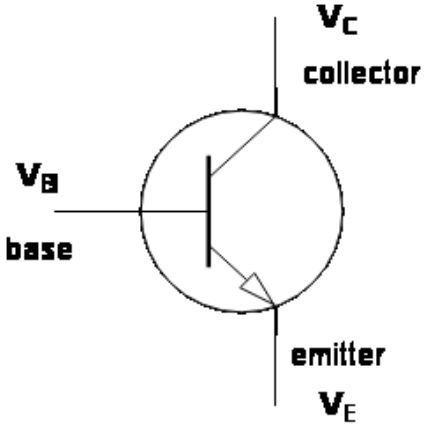
Cutoff

- The transistor is off
- The transistor acts like an open circuit and no current flows from the collector to the emitter
- For a transistor to be “cutoff” $V_C > V_B$ and $V_E > V_B$
- To achieve cut off the voltage across the base and emitter should be between 0v and 0.6v.



Transistor as switches

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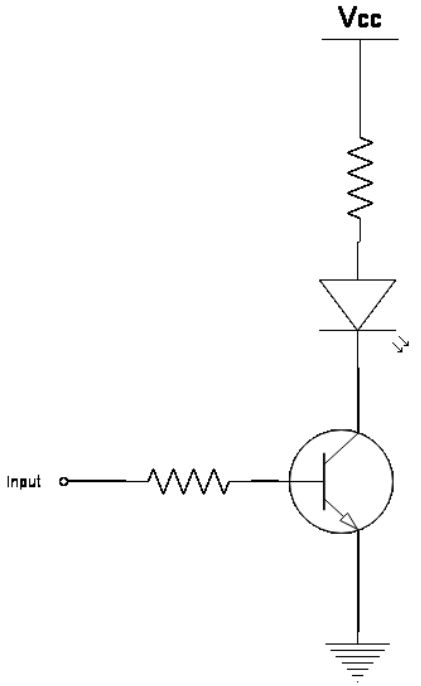
- As we have seen transistors can control the flow of current based on the voltage at the base
- We utilise the saturation and cutoff behaviours of a transistor to achieve switching

- Input = 5v the LED is illuminated
- Input = 0v the LED is not illuminated



FET as switches

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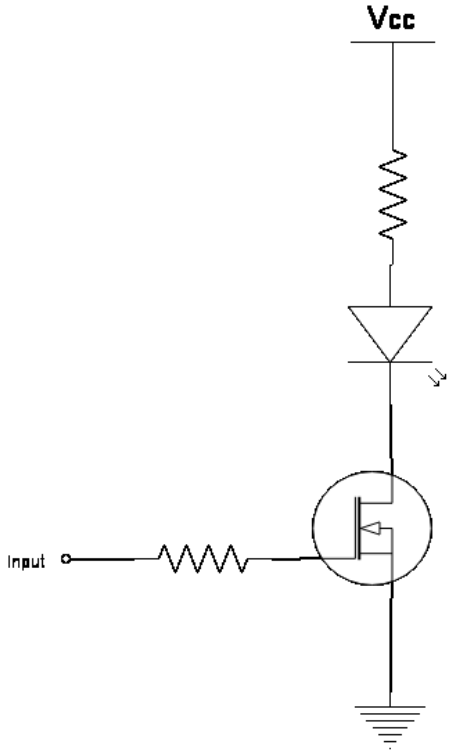
- Field Effect Transistors are another type of transistor that has comparable behaviour as a Transistor
- How they work and why they work is more complicated
- FET are more efficient

Note

Base is called the Gate
Emitter is called the Source
Collector is called the Drain



AND Gate

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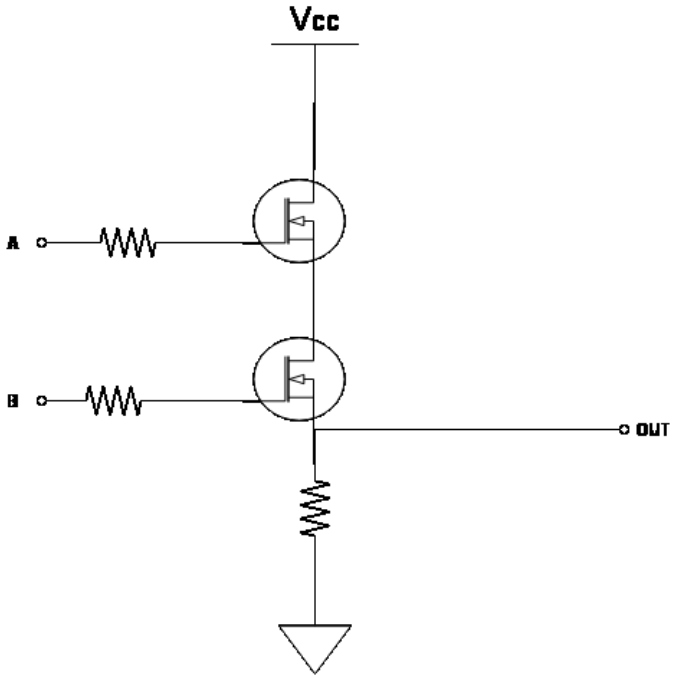
- Using two transistors we can make an AND gate
- When input **A** and **B** are high then both transistors are saturated, current flows freely across their Drain and Source
- Effectively connecting **OUT** to $\mathbf{V_{cc}}$ and consequently **OUT** is high (logic 1)
- When either input **A** or **B** are not high (or neither) then no current flows between $\mathbf{V_{cc}}$ and **OUT** and consequently **OUT** is low (logic 0)



OR Gate

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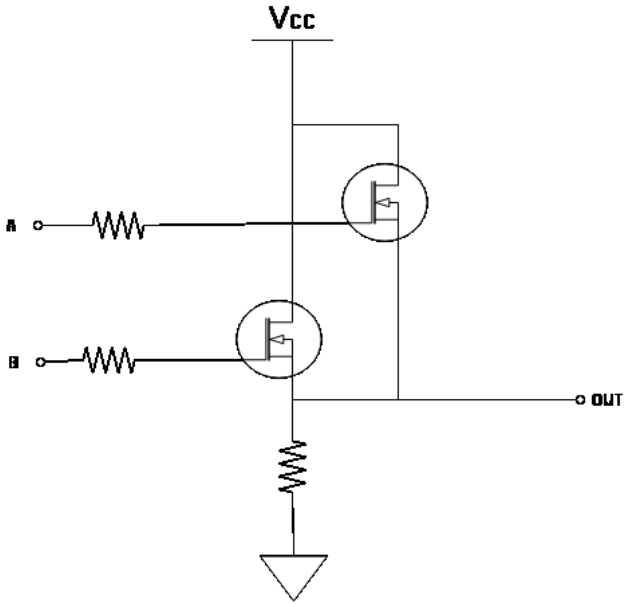
- Using two transistors we can make an OR gate
- When input **A** or **B** are high then at least one of the transistors are saturated, current flows freely across the Drain and Source
- Effectively connecting **OUT** to $\mathbf{V_{cc}}$ and consequently **OUT** is high (logic 1)
- When neither input **A** nor **B** are high then no current flows between $\mathbf{V_{cc}}$ and **OUT** and consequently **OUT** is low (logic 0)



NOT Gate

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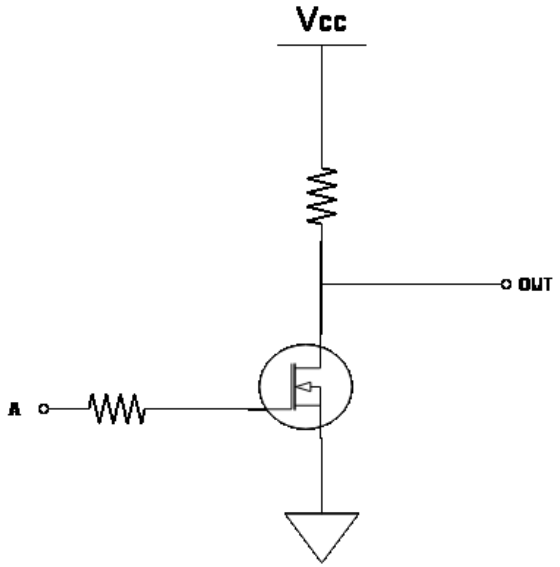
- Using a transistors we can make a NOT gate
- When input **A** is high then the transistors is saturated, current flows freely across the Drain and Source
- Effectively connecting **OUT** to **GND** and consequently **OUT** is low (logic 0)
- When input **A** is low then no current flows between the Drain and source, **OUT** is connected to $\mathbf{V_{cc}}$ and is consequently high (logic 1)



Summary

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- Introduced the circuit diagrams for logic gates (AND, OR, NOT)
- Introduced the concept of electronic implementations of logic gates using switches
- Provided a brief history of Valves and Transistors
- Provided a working model of a transistor (BJT and FET)
- Illustrated that logic gates can be implemented using semiconductors

Interested in electronics? The art of electronics