

AS-4 Semiconductor Components

Revision sheet

1 Diode

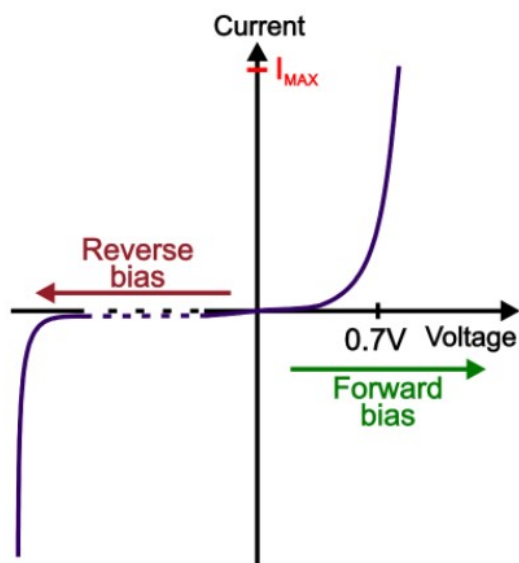
a = anode
c = cathode



The current can only flow in one direction, from the anode to the cathode. The anode is positive and the cathode is negative.

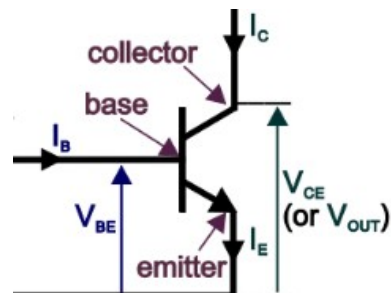
1.1 VI Characteristics

Current will only flow when voltage across the diode is greater than 0.7V.



As seen in the graph, if we apply enough voltage when in reverse bias, the diode will break (known as reverse breakdown) and current will flow. This is irreversible.

2 Bipolar Junction Transistor (BJT)



Transistors have three terminals - base, collector and emitter.

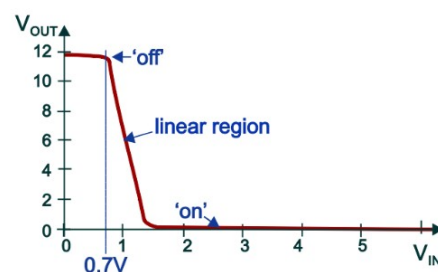
2.1 What Do Transistors Do?

Transistors are current amplifiers. A small current flowing from the base to the emitter, I_B , causes a much larger current to flow from the collector to the emitter. The equation $I_C = h_{FE} \times I_B$ links the collector and base currents. The h_{FE} value is the current gain and is usually between 30 and 800; it will usually be in the question.

2.1.1 Voltage in Transistors

Transistors have a 0.7V voltage drop from the base to the emitter. The transistor does not switch on unless $V_{BE} > 0.7V$.

2.2 Operating Regions



The transistor has three regions - cutoff (off); linear and saturation (on).

2.2.1 Cutoff Region

$V_{in} < 0.7V$ The transistor is off. $I_C = V_{CE} = V_S$. It is like an open circuit.

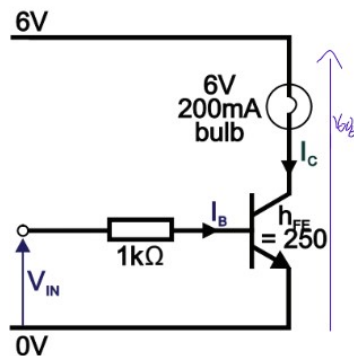
2.2.2 Linear Region

$V_{in} > 0.7V$ Transistor switches on. It amplifies current as specified in the equation. As I_C increases, voltage across the load increases therefore V_{out} decreases.

2.2.3 Saturation Region

V_{out} falls until 0. I_C is at its maximum. Transistor is 'saturated' or 'fully on'.

2.3 Transistors As A Switch

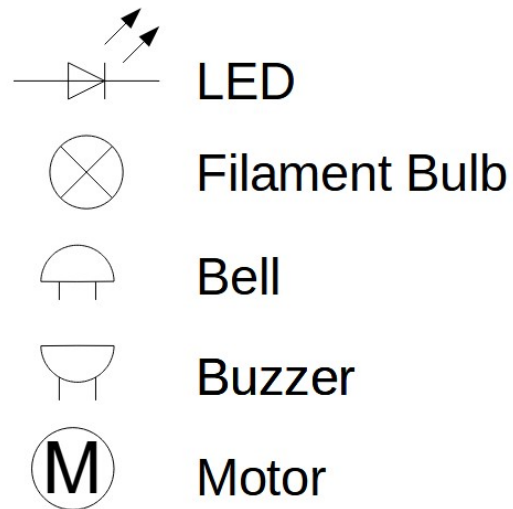


This only uses cutoff and saturation regions. When $V_{in} < 0.7V$, the transistor is switched off. $V_{BE} = V_{in}$, $V_{out} = V_s$. When $V_{in} > 0.7V$, the transistor is saturated (switched on). $V_{BE} = 0.7V$, $V_{out} = 0V$. The base resistor (1K in this example) limits the current flowing into the base to prevent damage to the transistor. The lamp could be replaced by any load.

2.4 Power Dissipated In A Transistor

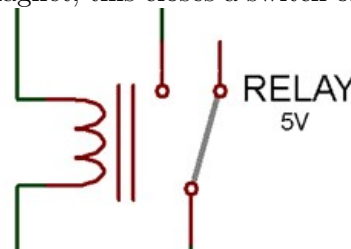
In the linear region, the transistor is on. I_C is flowing but it has some voltage across it therefore power is dissipated. $P = I_C \times V_{CE}$

3 Output Devices



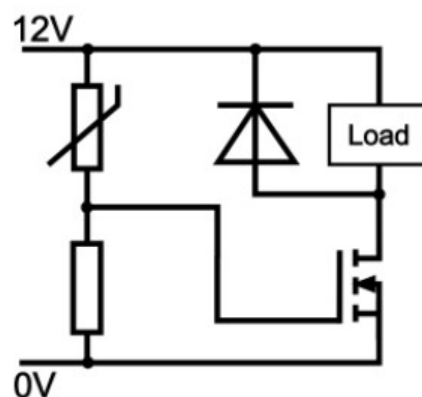
4 Relays

These are electromechanical devices. They allow us to control one circuit with another. They work by putting a current through an electromagnet, this closes a switch on the second circuit.



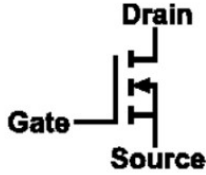
5 Back EMF

Any device with a coil generates a magnetic field when turned on. When it is switched off, the coil collapses and generates a high voltage pulse in the opposite direction, this will fry components. We can add a protection diode to fix this.



6 MOSFET

Metal Oxide Semiconductor Field Effect Transistor.



The gate draws no current. The MOSFET is voltage controlled, the gate voltage controls the drain current therefore increased gate voltage means more current flows (because resistance decreases between source and drain). When $V_{in} = 0V$, the MOSFET is off, no current is flowing. When V_{in} reaches the threshold voltage (3V) current starts to flow from the drain to the source.

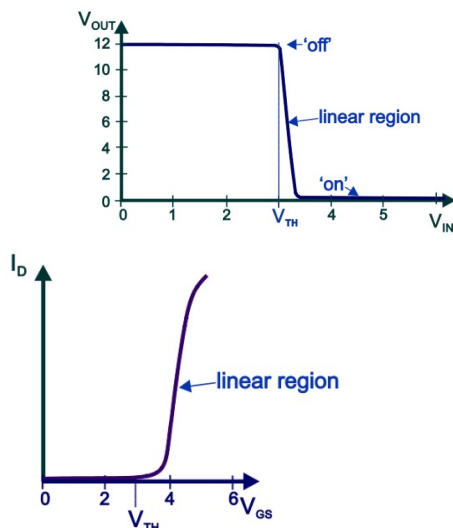
$$I_D = g_m(V_{GS} - 3)$$

Drain Current = Transconductance (Gate voltage - 3).

6.1 Transconductance

This is how much current increases for a given voltage increase. It is measured in S (Siemens). Generally, it will be between 2 and 10 S.

6.2 Transfer Curves



The linear region is very small. MOSFETs make good switches. MOSFETs have very low 'on-resistance', $r_{DS_{ON}} \approx 0.5$ to 1Ω

6.3 Power Dissipated

$$P = I_D^2 \times r_{DS_{ON}}$$

6.4 Advantages of MOSFETs

- Low 'on-resistance' and high 'off-resistance' therefore good as a switch;
- Very high input resistance therefore draws no current therefore can be driven easily by logic gates/sensor subsystems. Unlike BJT, MOSFET will not load subsystem;
- Very high current handling.