Transistors

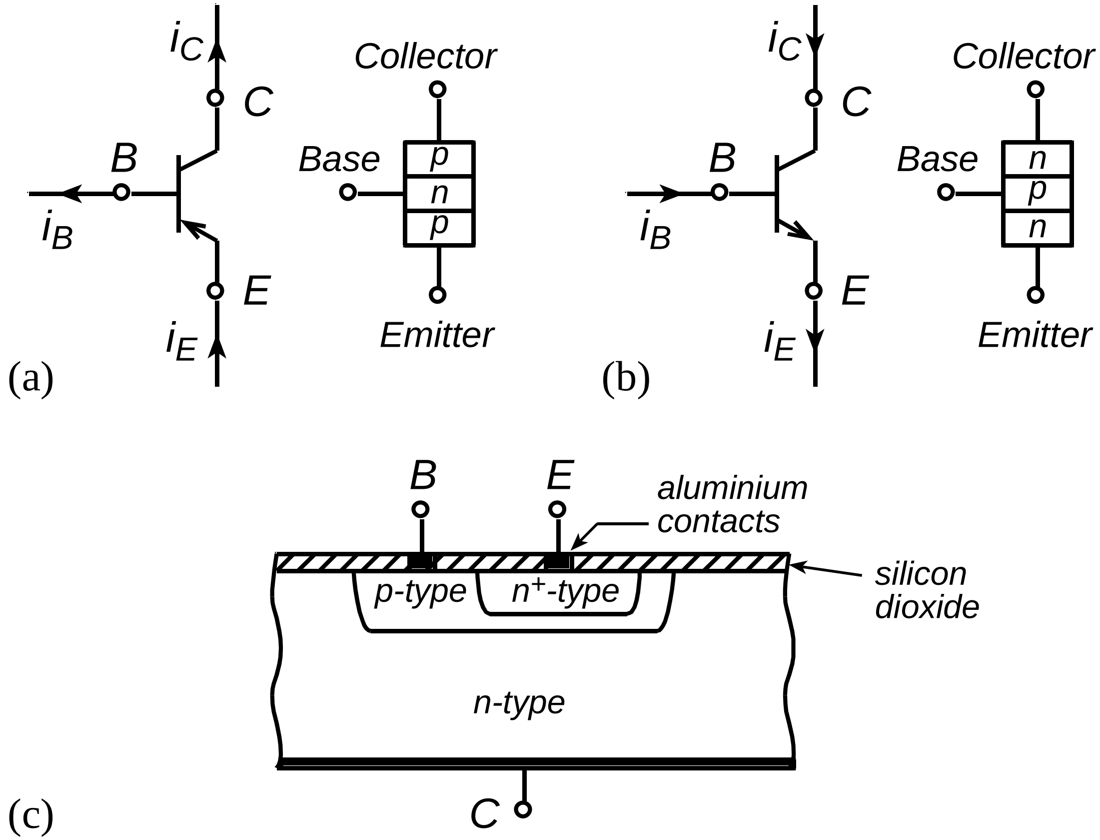
Introduction

Transistors are ‘active’ devices of electronics.

There are two principal types of transistor:

- the bipolar junction transistor (BJT)
- the field-effect transistor (FET)

Construction

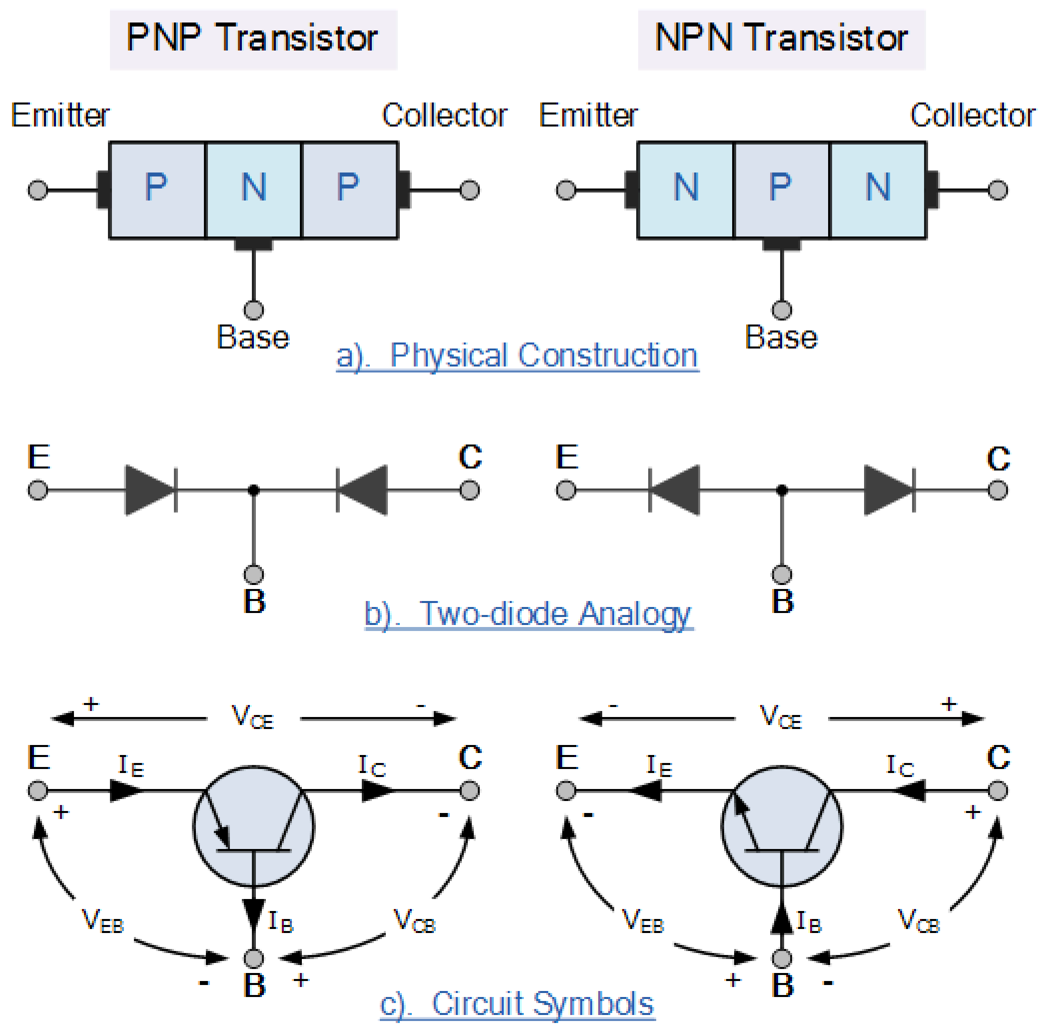


Bipolar transistors: (a) representation of a p-n-p transistor;

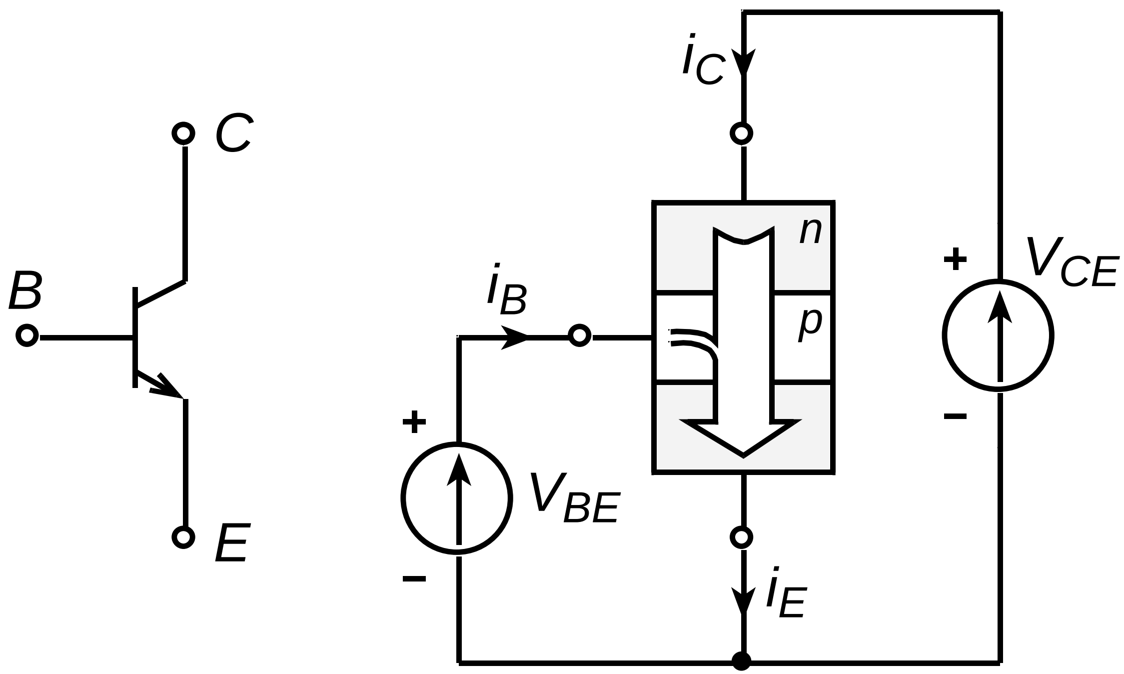
(b) representation of an n-p-n transistor;

(c) a typical structure of an n-p-n transistor

Construction (cont.)



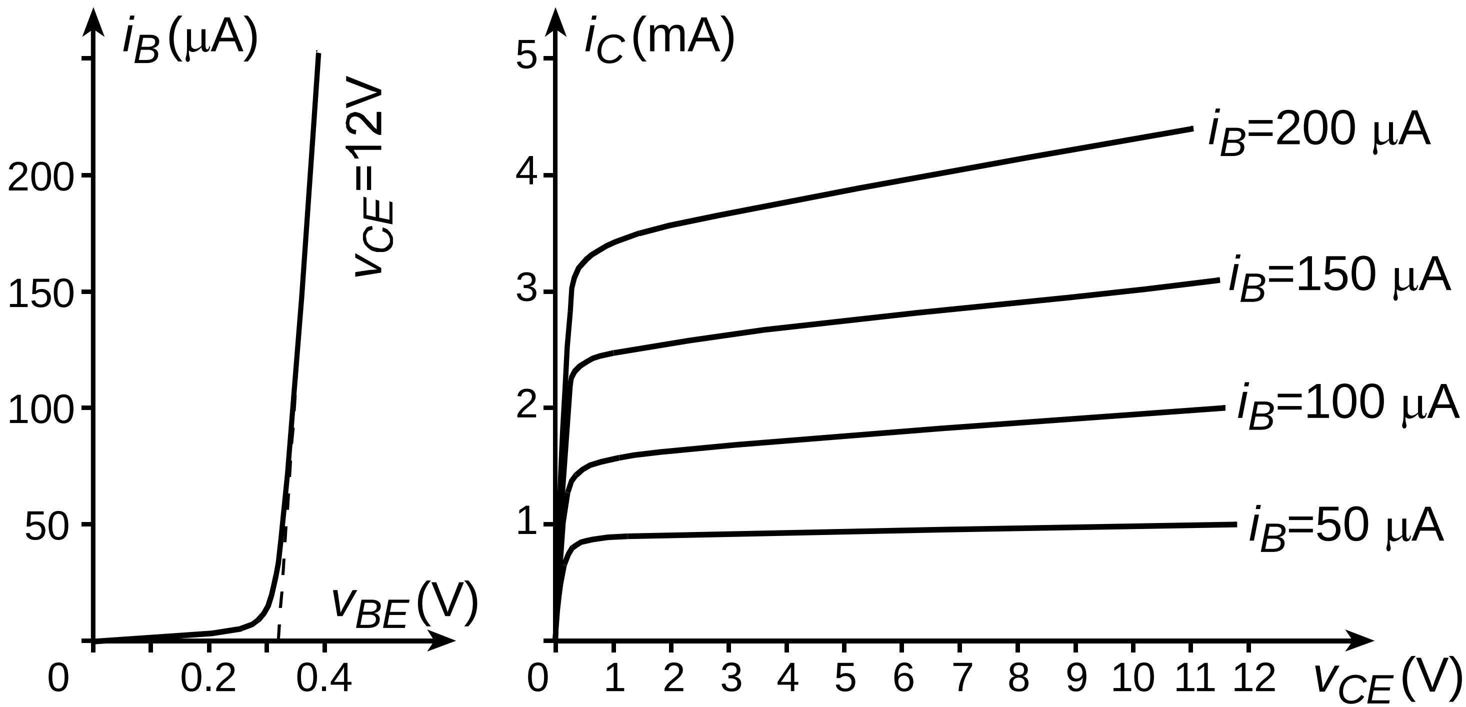
Currents in an n-p-n transistor



The main idea:

a small voltage applied between the base and emitter terminals makes the current flow in the collector circuit

The bipolar transistor d.c. characteristics



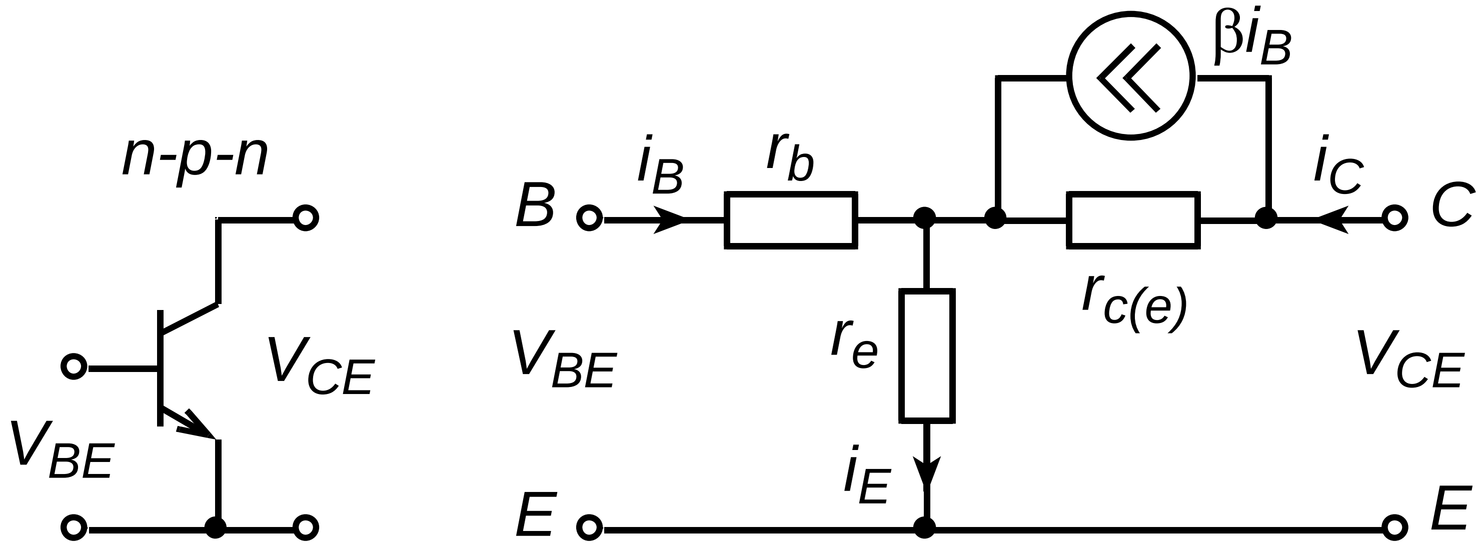
(a) the input characteristic (b) the output characteristic

Parameters

- The ratio of collector current to base current is an important transistor parameter, normally referred to as the **common-emitter current gain** β, where $\beta = I_C / I_B$.

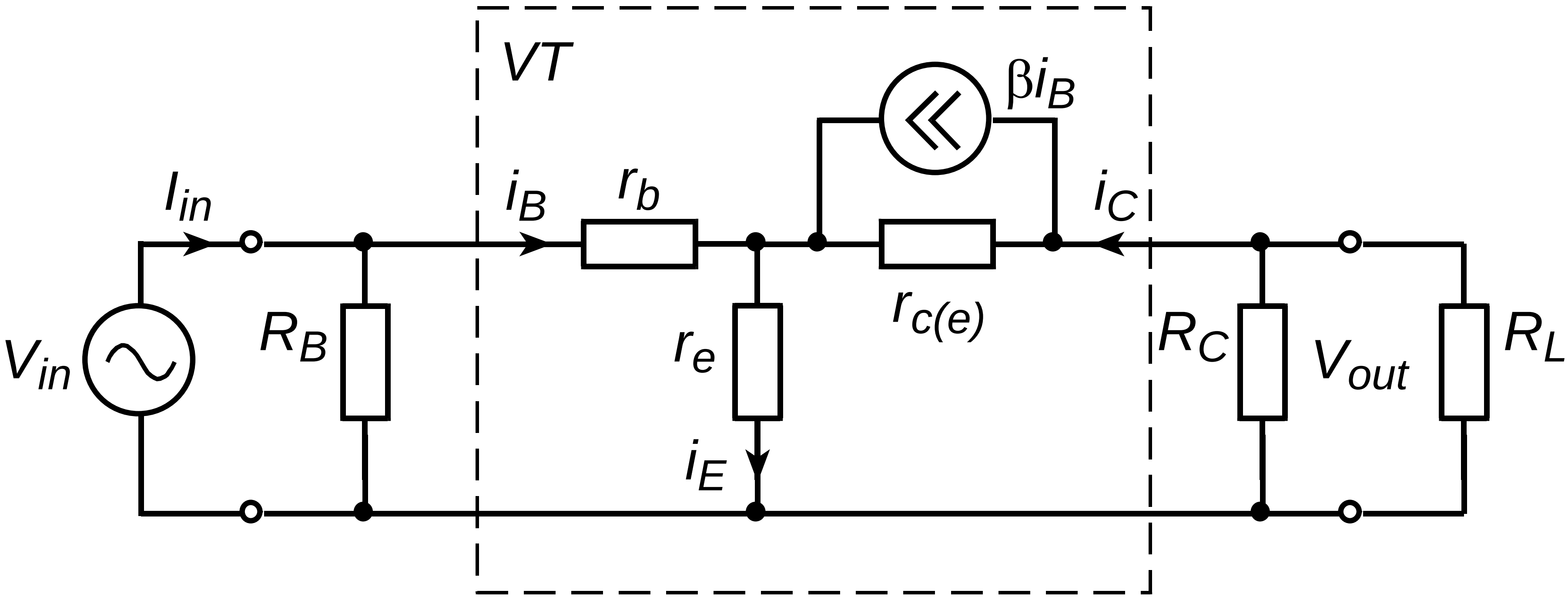
- The ratio I_C / I_E is called α, the **common-base current gain,** and its value is slightly less than one.

Model of Transistor



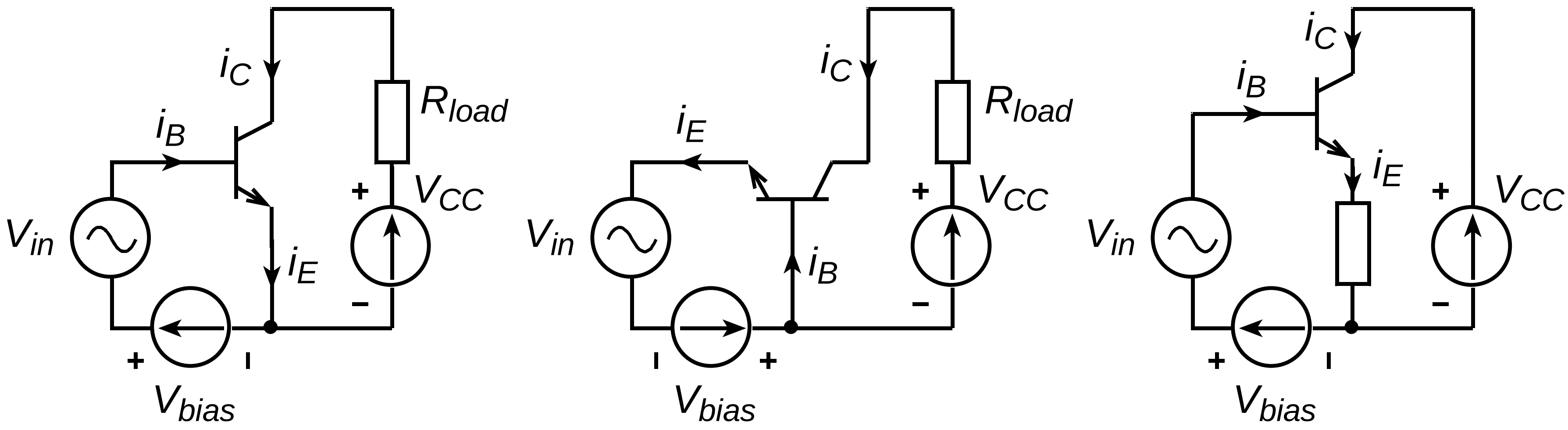
The small-signal a.c. equivalent circuit of an n-p-n transistor

Model of Transistor (cont.)



The small-signal a.c. equivalent circuit of the complete common-emitter amplifier

Types of Configuration



The bipolar transistor configurations:

(a) common emitter

(b) common base

(c) common collector

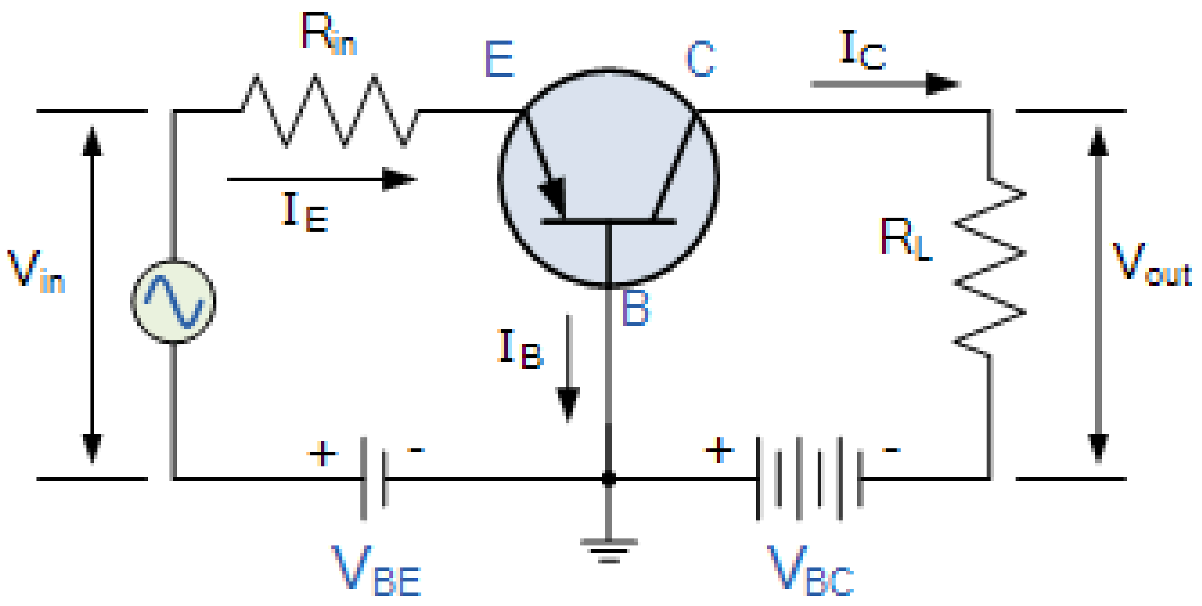
Types of Configuration (cont.)

- Common Base Configuration – has Voltage Gain but no Current Gain.

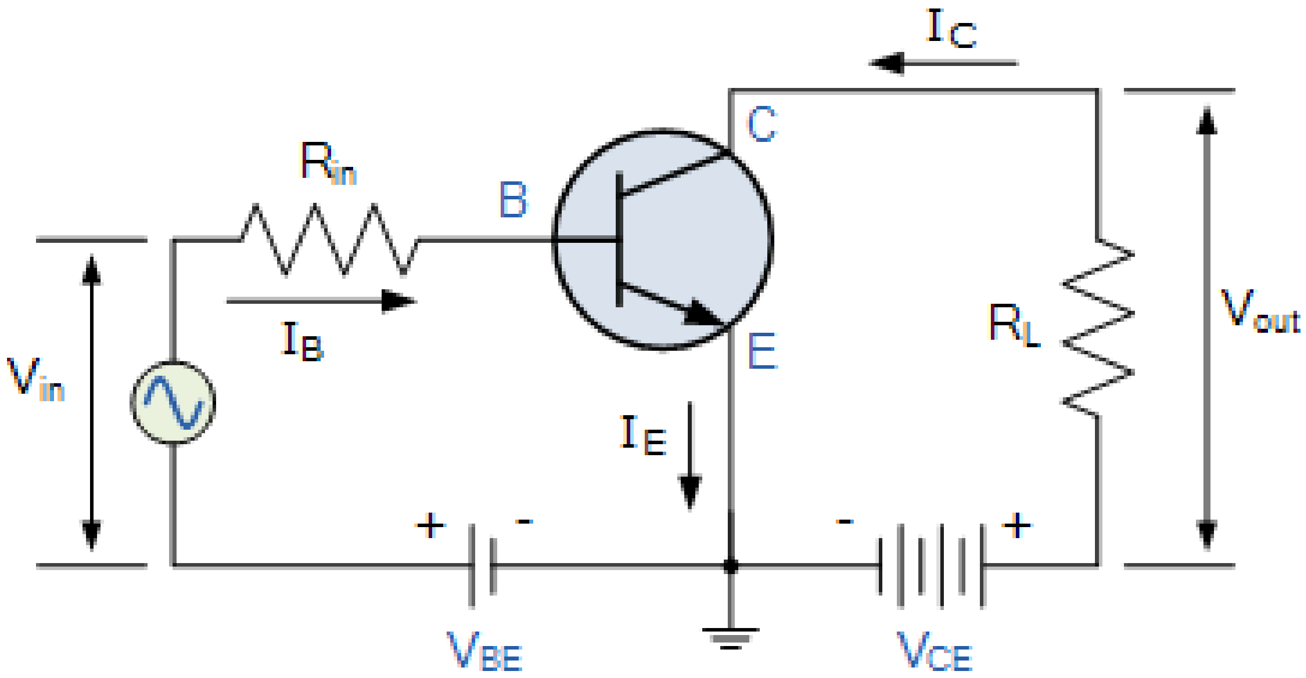
- Common Emitter Configuration – has both Current and Voltage Gain.

- Common Collector Configuration – has Current Gain but no Voltage Gain.

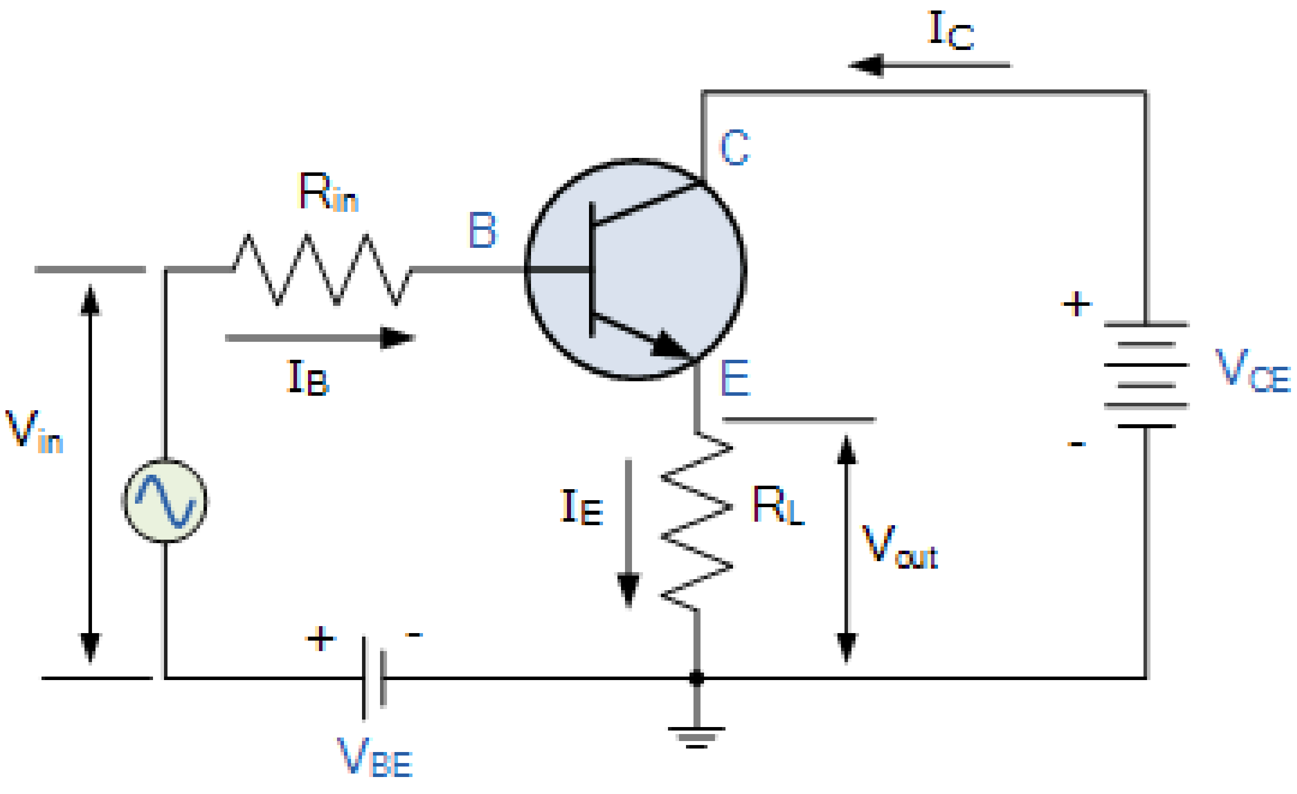
The Common Base (CB) Configuration



The Common Emitter (CE) Configuration



The Common Collector (CC) Configuration



The bipolar transistor configurations

Characteristic	Common Base	Common Emitter	Common Collector
Input Impedance	Low	Medium	High
Output Impedance	Very High	High	Low
Phase Angle	0^o	180^o	0^o
Voltage Gain	High	Medium	Low
Current Gain	Low	Medium	High
Power Gain	Low	Very High	Medium

Relationship between DC Currents and Gains

$$I_E = I_B + I_C$$

$$\alpha = \frac{I_C}{I_E} = \frac{\beta}{1+\beta}$$

$$I_C = I_E - I_B$$

$$\beta = \frac{I_C}{I_B} = \frac{\alpha}{1-\alpha}$$

$$I_B = I_E - I_C$$

$$I_B = \frac{I_C}{\beta} = \frac{I_E}{1+\beta} = I_E\left(1-\alpha\right)$$

$$I_C = \beta . I_B = \alpha . I_E$$

$$I_E = \frac{I_C}{\alpha} = I_B\left(1+\beta\right)$$

Modes of Operation

Bipolar transistors have five distinct regions of operation, defined by BJT junction biases.

The modes of operation can be described in terms of junction biasing:

- **Forward-active** (or simply, **active**): The base-emitter junction is forward biased and the base-collector junction is reverse biased.
- **Reverse-active** (or **inverted**): By reversing biasing conditions of the forward-active region, a bipolar transistor goes into reverse-active mode.

Modes of Operation (cont.)

- **Saturation**: With both junctions forward-biased, a BJT is in the saturation mode and facilitates high current conduction from the emitter to the collector (or the other direction in the case of n-p-n). This mode corresponds to a logical ‘on’, or a closed switch.

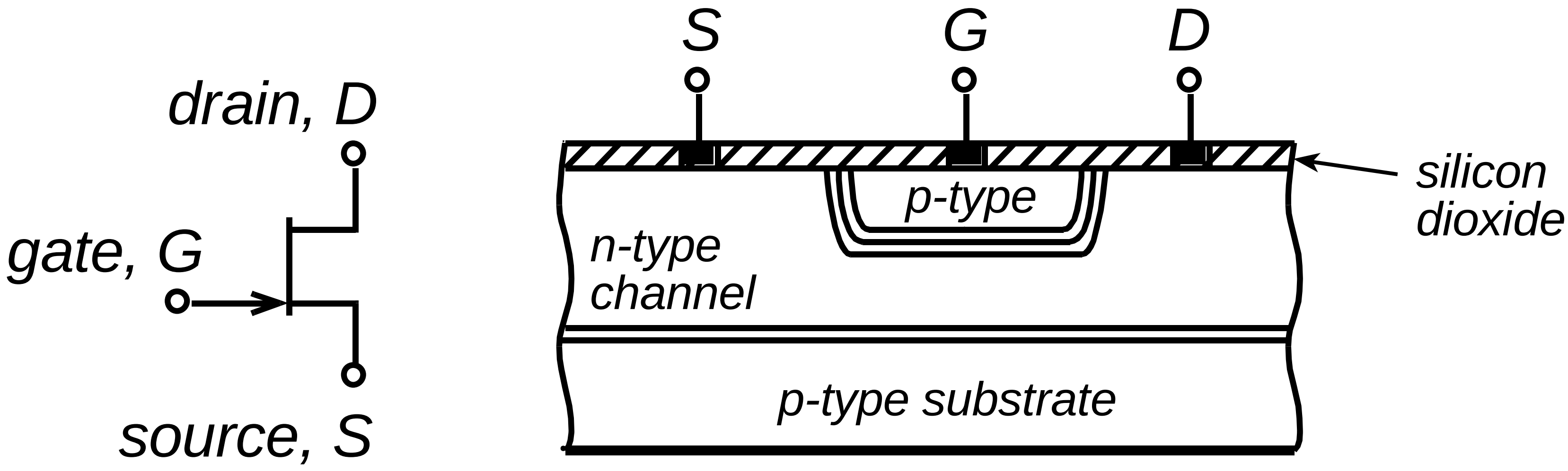
- **Cutoff**: In cutoff, biasing conditions opposite of saturation (both junctions reverse biased) are present. There is very little current, which corresponds to a logical ‘off’, or an open switch.

- **Avalanche breakdown** region: Breakdown is not generally a useful mode for transistor operation, and so we will avoid that mode.

Application

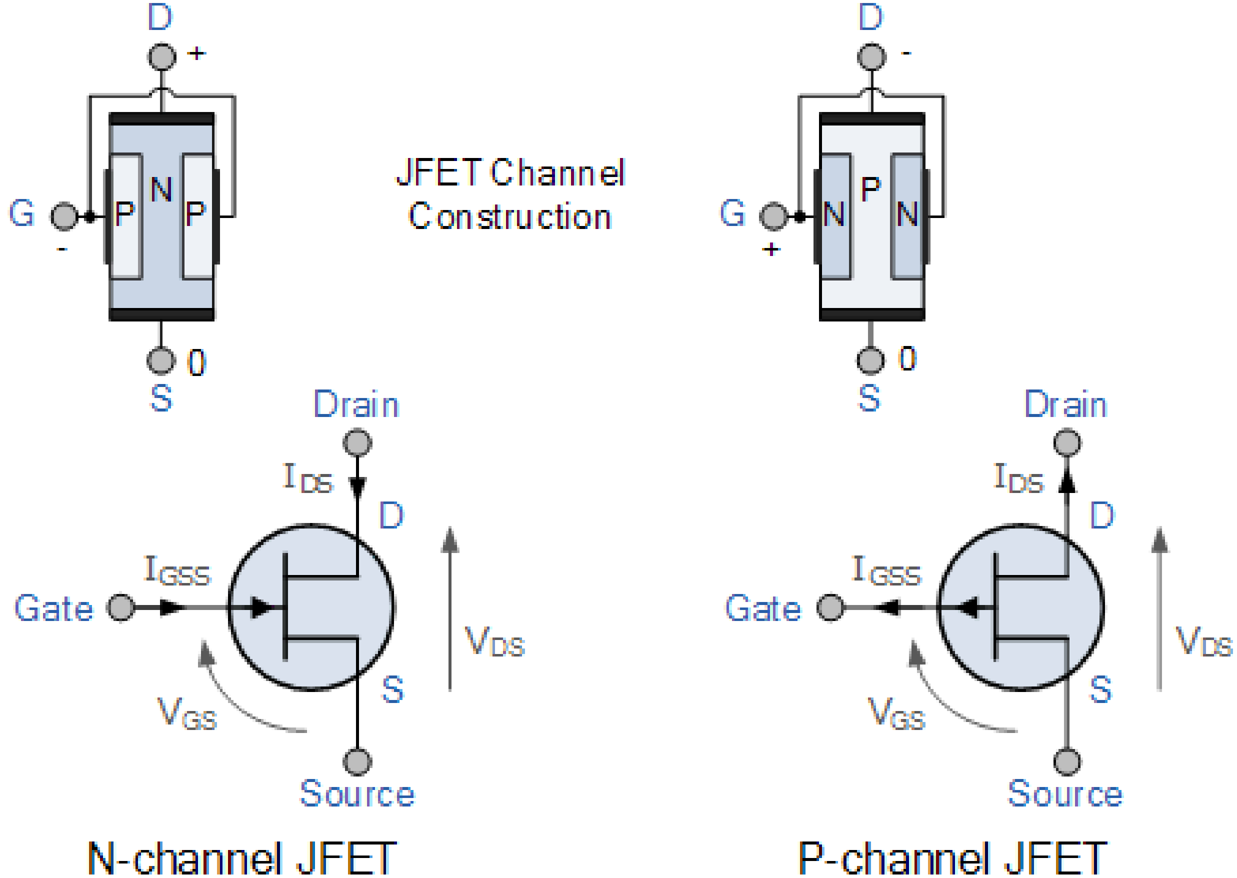
- Bipolar transistors are capable of controlling power from a d.c. power supply, in response to a low-power input signal, and providing much greater output power. So they can provide the power gain. This is the basic function of an amplifier.
- An analogue amplifier should do this with the minimum distortion of its input waveform.
- A digital switch or gate is also required to provide the power gain, but it should convert any ill-defined input voltage level into a ‘clean’ well-defined voltage level at its output.

Field Effect Transistors

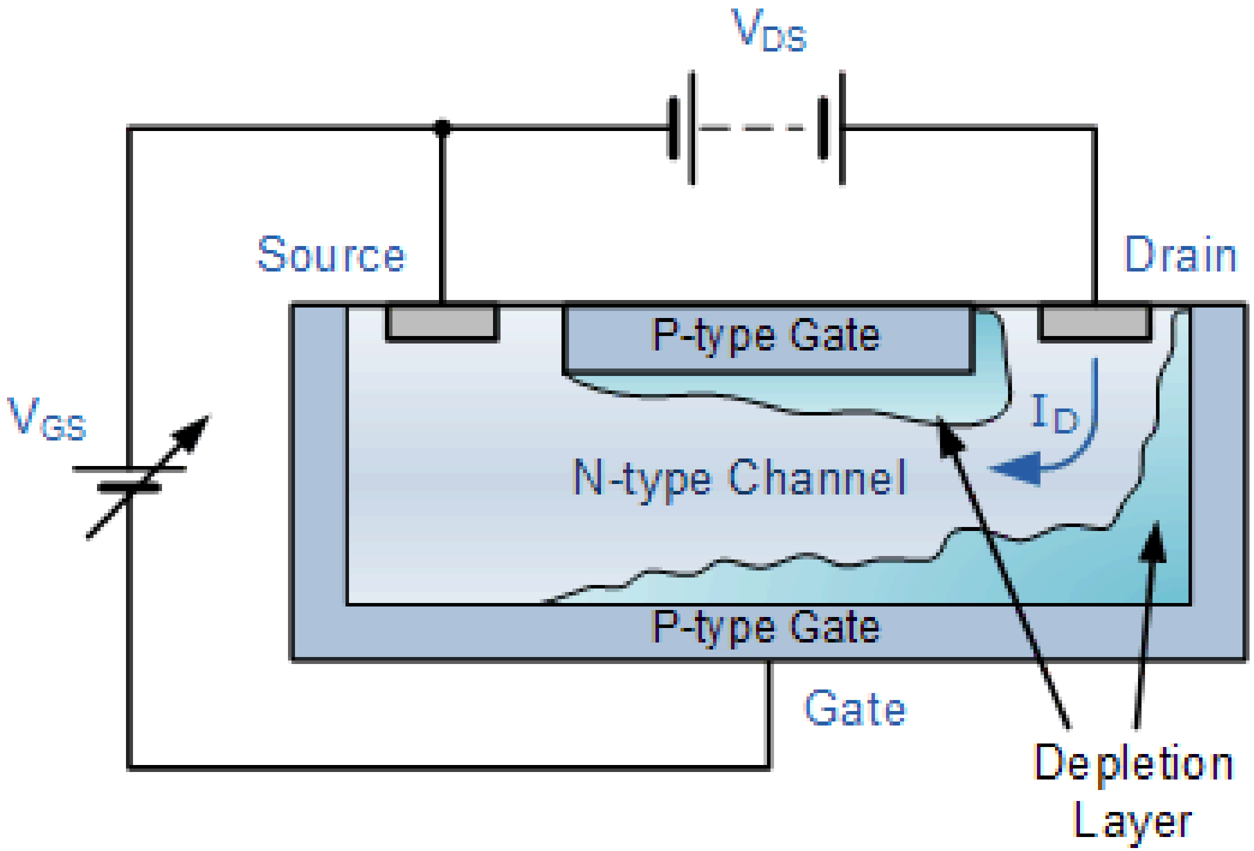


Symbol and typical structure of an n-channel JFET

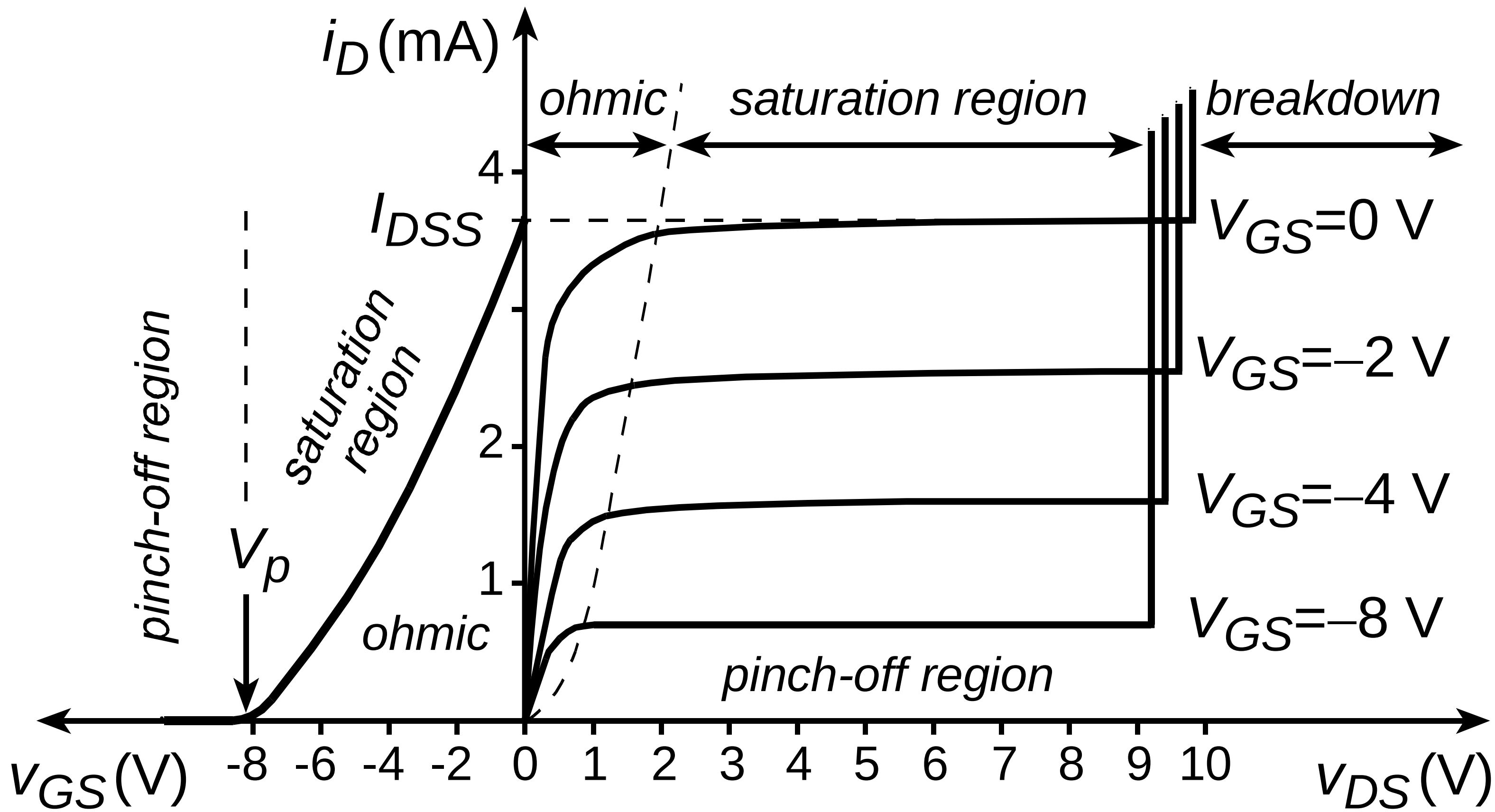
Basic construction for both configurations of JFETs



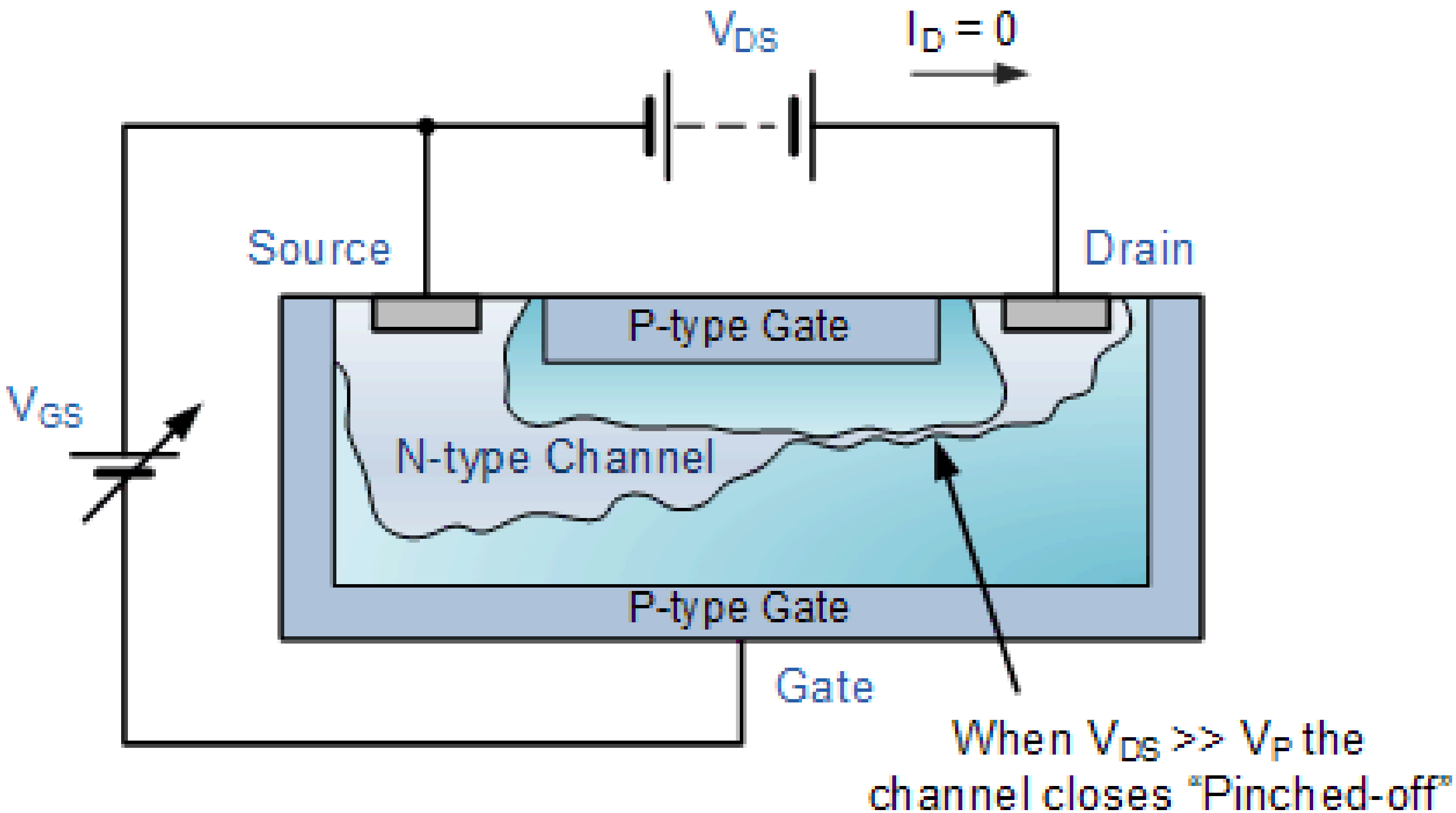
Biasing of an N-channel JFET



N-channel JFET characteristic curves

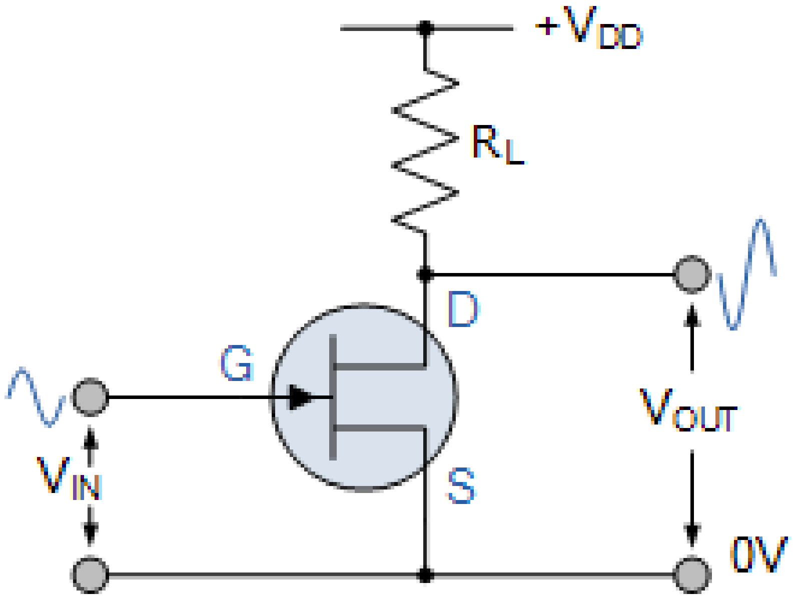


JFET Channel Pinched-off

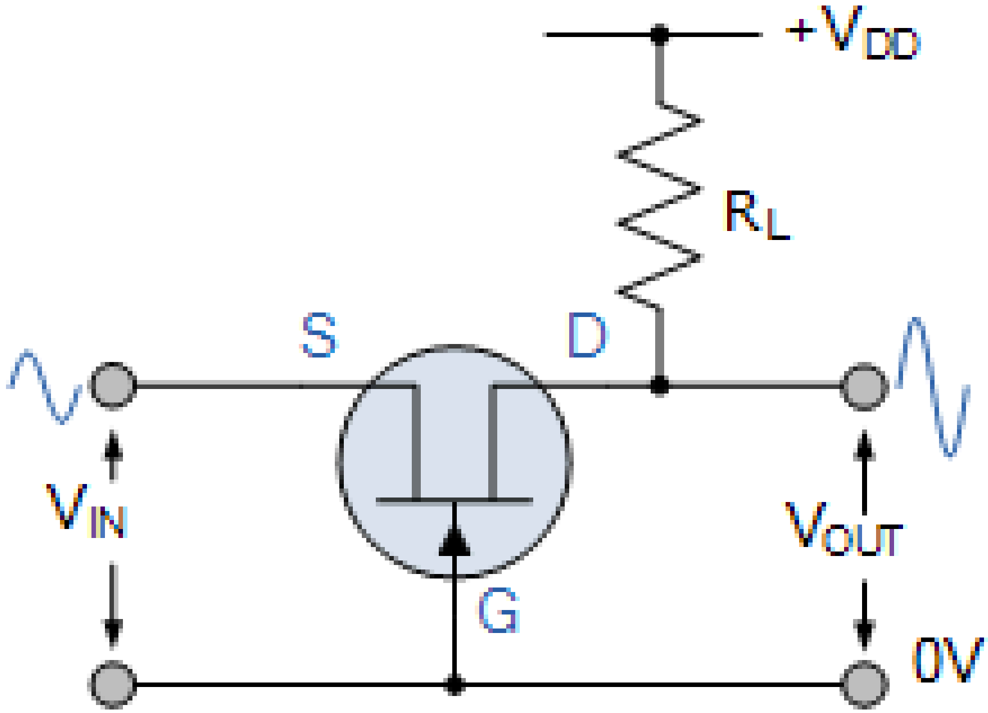


Modes of FET's

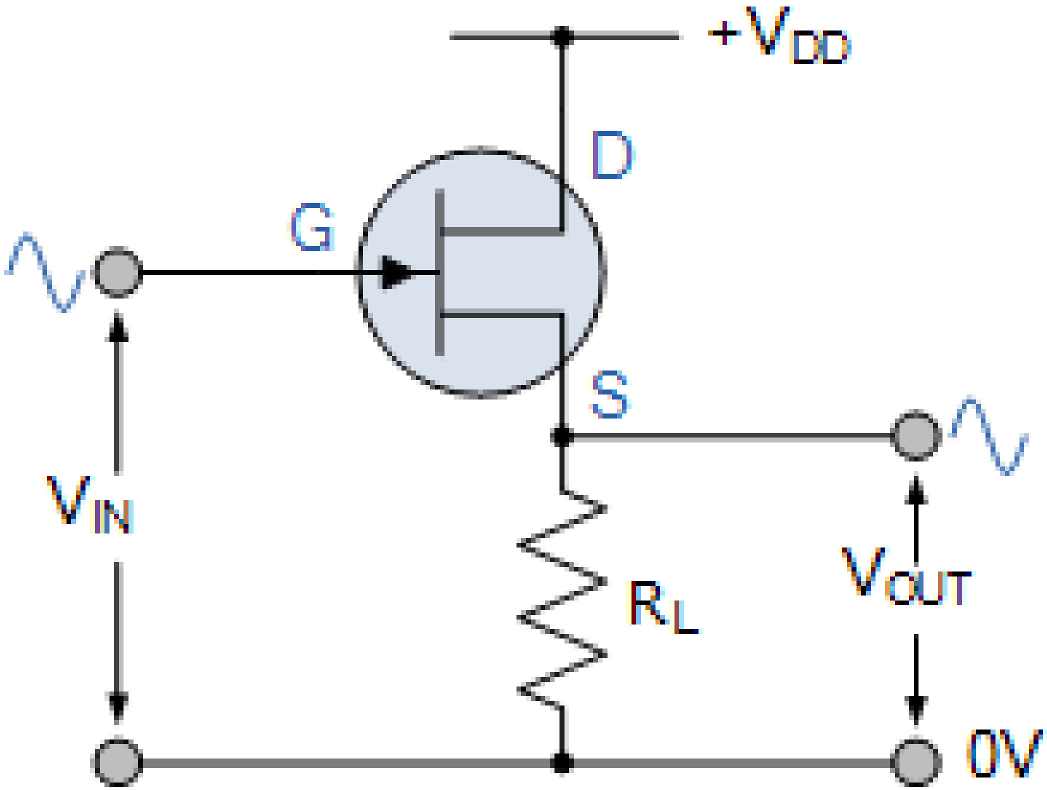
Common Source (CS) Configuration



Common Gate (CG) Configuration



Common Drain (CD) Configuration



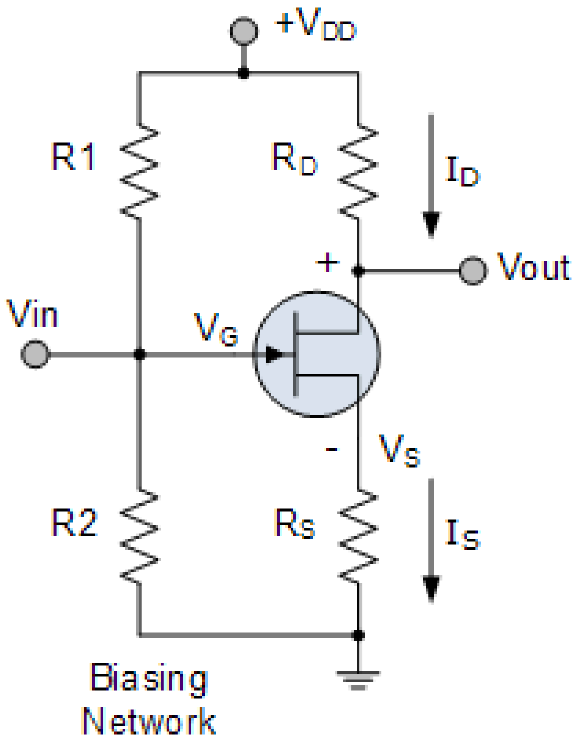
Biasing of JFET Amplifier

$$V_S = I_D R_S = \frac{V_{DD}}{4}$$

$$V_S = V_G - V_{GS}$$

$$V_G = \left(\frac{R2}{R1 + R2}\right) V_{DD}$$

$$I_D = \frac{V_S}{R_S} = \frac{V_G - V_{GS}}{R_S}$$



Applications

- Field-effect transistors, like bipolar transistors, are used for a wide variety of analogue and digital circuits.
- FET analogue circuits have close similarity with bipolar ones, differing mainly in their gate bias arrangements.
- The best way to look at an FET is as a voltage controlled variable resistor. The resistor is between the source and drain pins.

Thank you for your attention!