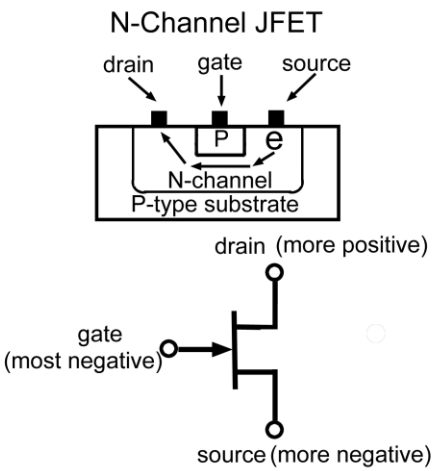
Chapter 5
Field Effect Transistors

5.1 FIELD EFFECT BASICS

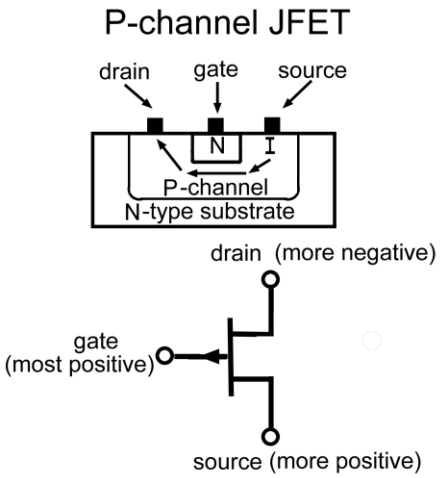
Bipolar transistors require input current in order to have output current. Remember the 95%-5% ratio? **Field Effect Transistors** or **FET**s are different in that they require very little input current. With a bipolar transistor, a change in current is used to control a large current. With **FET**s, a voltage is used to control a current. This should sound familiar as it is the way vacuum tubes work. There are two classes of **FET**s: **Junction FET**s (**JFET**s) and **Metal-Oxide Semiconductor FET**s (**MOSFET**s). **MOSFET**s are also known as **Insulated-Gate FET**s (**IGFET**s).

5.2 JFETs

There are two types of **JFET**s: **N-channel** and **P-channel**. With the N-channel an N crystal is used as the channel for current flow. One end of the N crystal is charged more negative. This is called the **Source**. The other end is charged more positive and is called the **Drain**. With this biasing, electrons will flow from source to drain. A piece of P crystal is attached to the N-channel. It is much smaller than the N crystal and is also doped more lightly than the N crystal. This P crystal is called the **Gate** and is charged more negatively than the source.

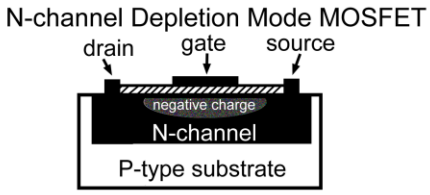


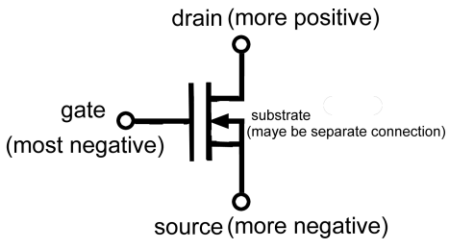
Since the gate is more negative than the source or drain, the PN junction is reverse biased. When a PN junction is reverse biased, a **Depletion Region** is formed. When a depletion region is formed it turns the crystal semiconductor into an insulator. With a JFET, the gate is doped more lightly than the channel. Because of this the depletion region penetrates into the channel, decreasing the area available for current flow. With decreased area the current flow decreases. Thus we can control electron flow from source to drain with a voltage on the gate.



With a **P-channel** JFET, the source is charged more positively, the drain is charged more negatively, and the gate is more positive than the source. With this biasing, current will flow from source to drain. The more positive the charge on the gate, the less current that can flow from source to drain.

5.3 DEPLETION MODE MOSFETs

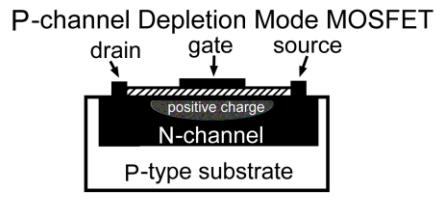


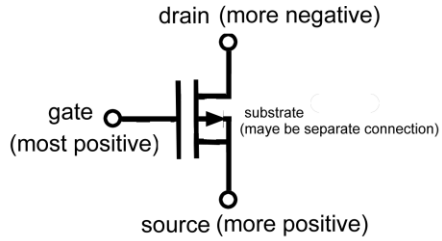


The JFET still utilizes a PN junction. Because there is a junction, even a reverse biased one, there is still a small amount of current flow at the gate. **MOSFETs** solve this by placing an insulator between the gate and the channel. The insulator is Metal-Oxide and the gate is simply a piece of metal instead of a crystal. The insulator is very fragile, so most MOSFETs have static warnings on them. The high voltage of static electricity is enough to destroy the insulator. The **Depletion Mode MOSFET** functions like a JFET except that there is no leakage current at the gate. The channel portion of the N crystal is doped less heavily than the drain and source portions of it. the charge from the gate creates the depletions region here, reducing the area for current flow.

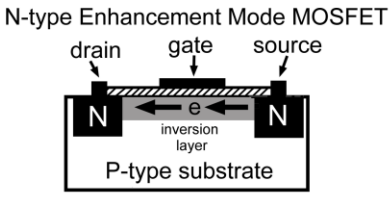
With a **N-channel Depletion Mode MOSFET**, the source is more negative and the drain is more positive. The gate is most negative.

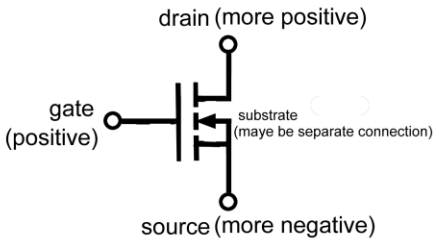
A **P-channel Depletion Mode MOSFET** needs to have its source more positive, the drain more negative, and the gate is most positive.





5.3 ENHANCEMENT MODE MOSFETS





The disadvantage with depletion mode MOSFETs is that a voltage on the gate can only decrease or deplete (thus the name depletion mode) current flow. With **Enhancement Mode MOSFETs**, a voltage on the gate allows current to flow. The source and the drain are separate crystals so no current can flow without voltage on the gate. A voltage on the gate (positive for an N-type, negative for a P-type) creates an **Inversion Layer** in the substrate. Electrons are pulled toward the gate, but cannot pass to it because of the insulator. The inversion layer spans from the source to the drain.

In a **N-type Enhancement Mode MOSFET** the source is more negative and the drain more positive. With a positive voltage on the gate the electrons in the inversion layer become the channel for electron flow from source to drain.

In a **P-type Enhancement Mode MOSFET** the source is more positive and the drain more negative. With a negative voltage on the gate the electrons in the inversion layer become the channel for current flow from source to drain.