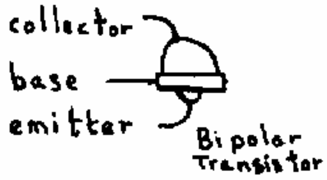
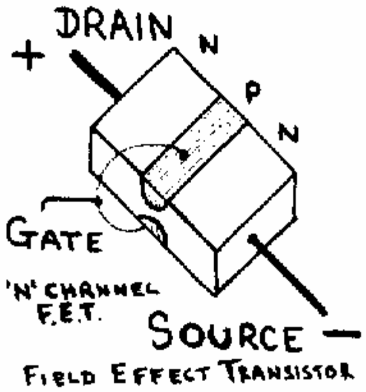
Lesson 6 introduced semiconductors and the (bipolar) transistors with their Emitter, Base and Collector. In simple terms they are low impedance, current operated devices.
This will have been "against the grain" for those of you familiar with thermionic valves. You may be more at home with a Field Effect Transistor.

Field Effect Transistors

Like the ordinary transistors, FET's are made up from N type and P type materials.
The following description will assume an N type device.
You will remember that ordinary transistors have a distinct "blob" (or pole) on each side of the base. In other words, there is no direct connection from the emitter to the collector.

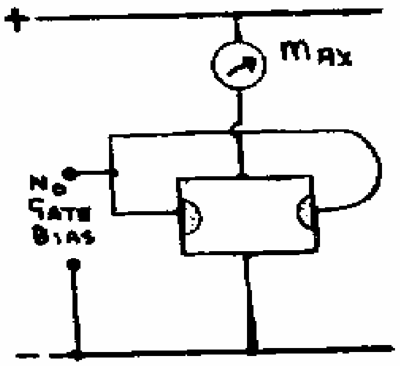


Looking at an FET shows that connections are made to each end of the N type channel material.
One end is called the *Source* and the other the *Drain.*



The positive supply is connected to the Drain and the negative supply to the Source. In this simple state, the bar of N type material will conduct the maximum current. The conduction channel will be wide open.

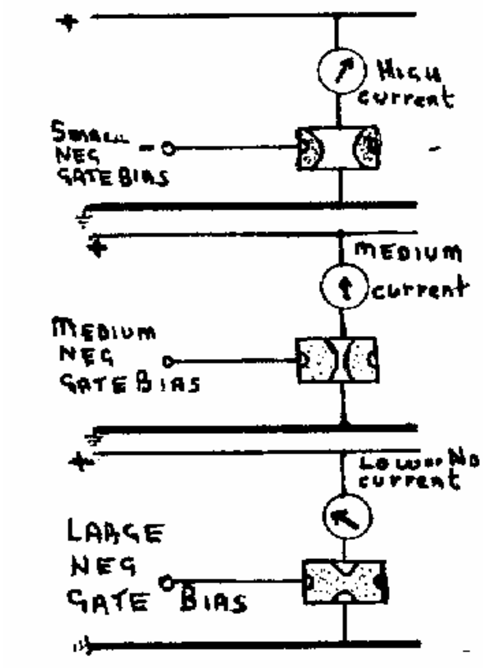
Apart from Source and Drain being unusual names, they appear to be round the wrong way. The current seems coming from the Drain and ending up at the source. But, note that these terms were conceived with *electron flow* in mind.
Remember that *electron flow* is opposite to *conventional current*. The electrons do, in fact, enter the channel bar at the Source and leave at the Drain.
To control this current, a Gate is added. If no voltage is connected to this gate, then the same maximum current will flow from Drain to Source.
However, applying a negative voltage to the Gate creates a 'depletion" layer around it. A depletion layer is an area depleted of mobile electrons (or holes) for carrying current.



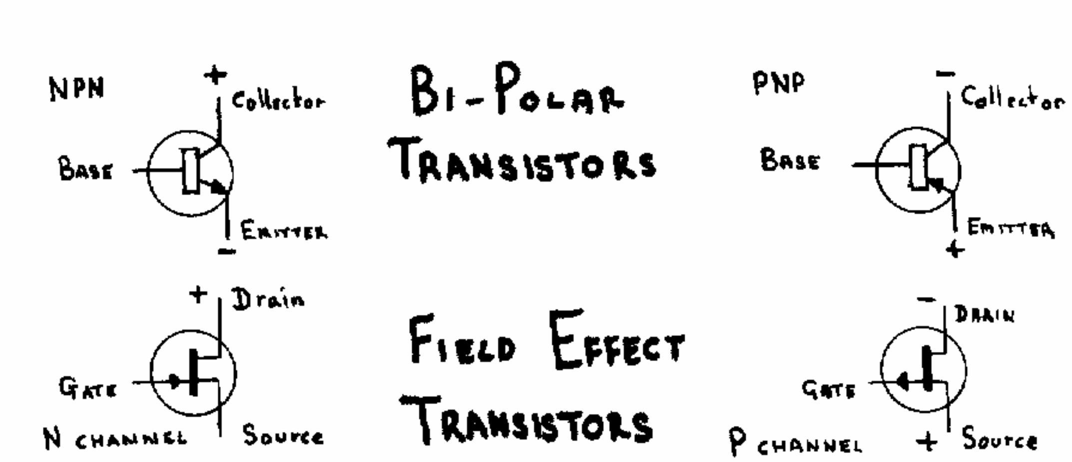
As a *small* negative Gate voltage creates a *small depletion area* and the current carrying channel is slightly restricted. -

A *medium* negative Gate voltage creates a *medium depletion area* and the current carrying channel is further reduced.

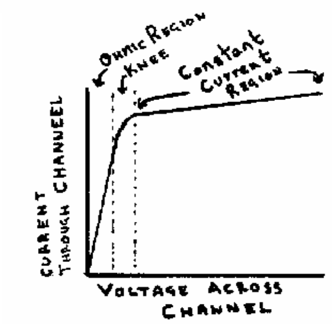
A *higher* negative Gate voltage makes the depletion areas meet in the middle. This completely blocks the channel, cutting off the current flowing from Drain to Source.

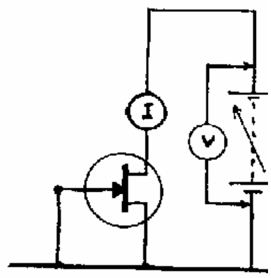


Symbols used for transistors



If the voltage between the Drain and the Source is gradually increased, plotting both current against voltage would give a graph like this.





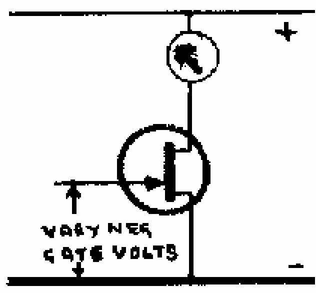
This is the result with zero volts on the Gate.

The steep part of the curve is known as the ‘Ohmic region’ as it is similar to resistance. The top straight part is called the “constant current” section as the current stays almost the same for a considerable change in voltage.

But, what does the Gate do?

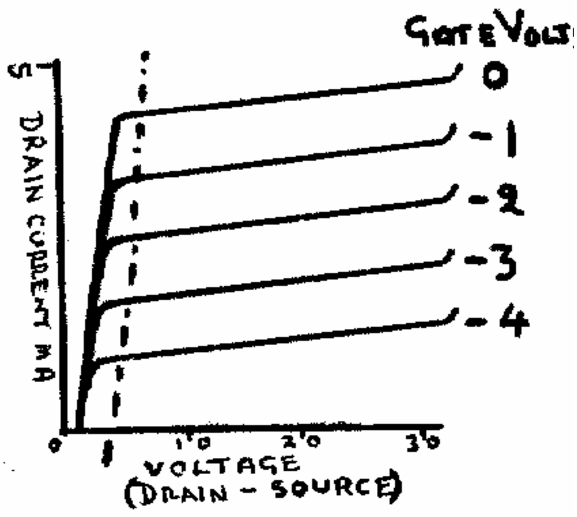
What do they normally do? If they are open , then a crowd can go through unhindered. If partly open, you will probably still get through but perhaps just one person at a time. When closed, no-one can get through!

It is similar with the Gate of a Field Effect Transistor.



When a negative voltage is connected to the Gate of a N-channel FET the current flaw is restricted or “controlled”. If Source or Drain current is plotted against voltage for various Gate voltages then this “family” of graphs (curves) will result.

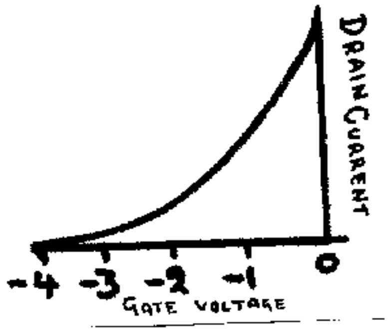
Assuming that the FET is used to the right of the dotted line the family can be converted into a very useful “transfer characteristic”.



Transfer what!
This graph is ver useful when designing FET circuits.

The input waveform can be drawn in and the output predicted.

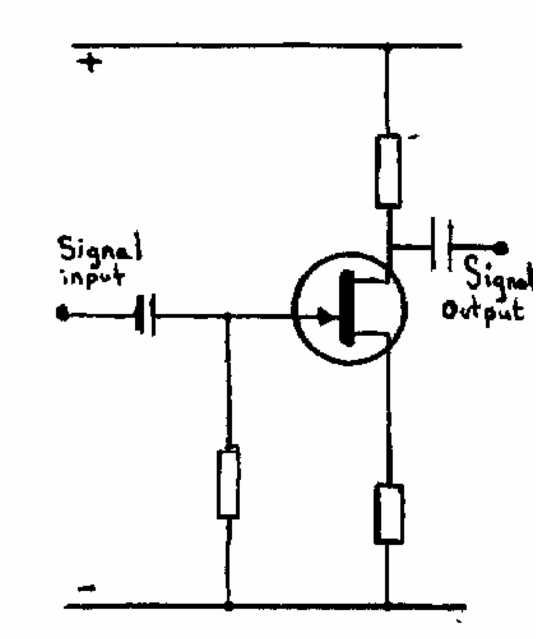
Any distortion will be visible. The input signal is drawn on the Gate/Source line.



This example shows *Class A* bias. The current flows during the whole of the cycle.

FET Amplifier

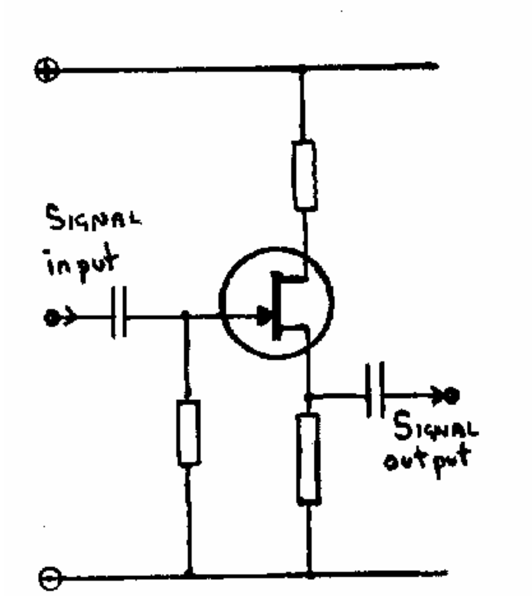
This is a common source circuit, typical of a small signal amplifier.



In order to bias the input signal, as shown on the Transfer Characteristic *(on* previous page) the Gate must be NEGATIVE with respect to the Source. This is achieved by having Rs in the Source lead. The Source (and hence Drain) current will flow through this resistor making the Source Positive with respect to earth. By connecting the Gate to earth via a very high resistance (say 10 MOhms) it will be biased correctly without "shunting" the input signal.

The small varying signal voltage on the Gate causes changes to the Drain/Source current flowing through the Drain load resistor. These current changes cause an AC voltage to be developed across this resistor. This is the output signal.
The Source resistor is by-passed with a large capacitor to prevent a reduction in the wanted AC Signal.
The input impedance will be very high; the same value of the gate resistor.
The output impedance will equal the Drain load resistor.

Source Follower



In this mode, the load resistor is in the Source lead.
This circuit would not be used for amplification but would be employed as an isolation or buffer stage.

For example, a Source Follower is used to isolate (or buffer) an oscillator's output from its load to improve frequency stability.

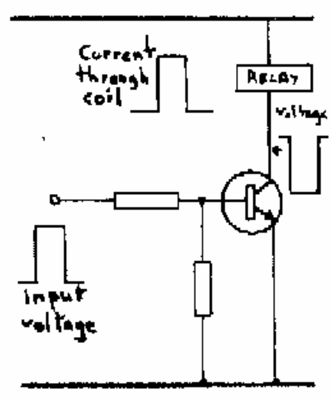
But take care how you dress!

Static Precautions

As FETs have a very high input impedance care has to be taken to avoid a build up of static electricity when they are handled. This even means not wearing a nylon shirt while soldering!

Solid State Switches

transistors, both bipolar and FET, have an important application other than signal amplification; it is *switching.*



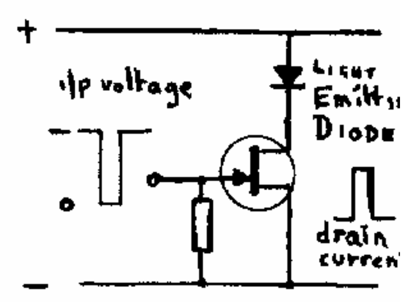
For example, a small very change in DC voltage can be made to operate a relay using a transistor as a switch.

The transistor is said to be 'ON' when passing the current and 'OFF' when preventing current flow. In this case the relay in the collector circuit will operate when the transistor is ON.

The input circuit and voltage is designed so that the base voltages changes from near zero to at least 0.6 V with respect to (wrt) the emitter, to turn ON the transistor.

Note that a positive going pulse at the input results in a negative going pulse at the collector. Therefore the collector voltage drops towards earth. This results in a maximum voltage across the collector load relay and it would operate for the period of the pulse, whether this is uSecs or hours!

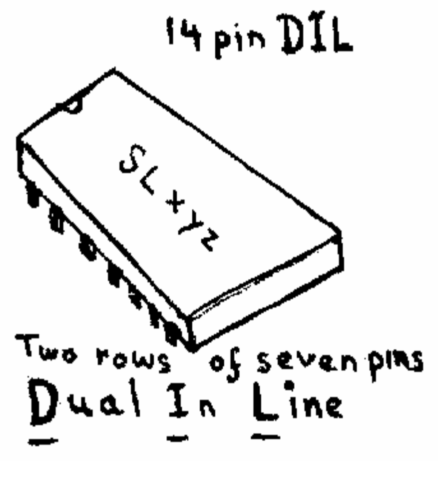
In this circuit, a FET is being used as a switch to control a Light Emitting Diode (LED).



Integrated Circuits are not something mathematical…

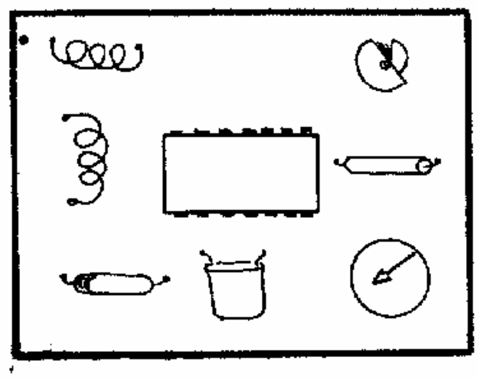
Not only can transistors be made of Silicon, but so can resistors and capacitors. This means that complete little circuits can be made on minute chips of silicon. In fact, complete amplifiers, mixers etc and a variety of digital circuits can be made into ICs that look like this.

The IC is connected to the printed circuit board (PCB) by the legs.



IC legs (or pins)

There are usually 6, 14 or 16 pins,but complex computer Ics can have up to 64 leg Virtually complete radioreceivers can be contained in an IC.
Variable capacitors, coils and loud speaker are, of course not contained, and have to be connected externally elsewhere on the PCB.



QUESTIONS for Lesson 6A

6a.1 Is the input impedance of a Common Source PET amplifier
A) Low B) Medium C) High D) Infinite

6a.2 What is the difference between QRM and QRN ?
A) QRM is caused by electric drills and QRN is caused by TV timebases
B) QRM is worse than QRN
C) QRN is worse than QRM
D) QRM is manmade and QRN is natural

6a.3 At 'Cut off' the Drain current is
A) zero B) 1 mA C) 10 mA D) maximum

6a.4 The drain/source current is usually controlled by:
A) supply voltage B) gate voltage
C) drain voltage D) source voltage

6a.5 Care in handling FETs is due to
A) the fragile nature of the encapsulation
B) the very high impedance of the device
C) the thin wire connections
D) power restrictions

6a.6 A dummy load is used to test
A) a receiver B) an aerial C) a transmitter
D) the earth conductivity

6a.7 Which portion of the 1.81 to 2.0 MHz Amateur Band can be used up to 26 dBW?
A) 1.81 to 1.85 B) 1.81 to 1.830 C) 1.830 to 1.850
D) 1.9 to 2.000 MHz

6a.8 Which frequency in the 1.81 to 2.0 MHz Amateur Band may be used, unattended, for the purpose of direction finding competitions?
A) 1.86 B) 1.69 C) 1.96 D) 1.99 MHz

