Field Effect Transistors

Some of you may remember from your Biology classes that scientists make a distinction between "homologous" traits that can be shown to be related, and "analogous" traits that have the same functionality but are in no way related. In our study of BJTs, the PNP and NPN devices could be considered "homologous" in that they were clearly related in the way they were made and in the way they operated. When it comes to comparing BJTs and FETs, however, there is no "relatedness" between the way these devices are made, and yet, in a general sense, their behaviour is "analogous", in that they both respond to a manipulated input in order to control current flowing from a large DC source. And that's about all they share in common.

BJTs were Current-controlled Current Sources, where a small current injected into the Base controlled a large Collector to Emitter current.

FETs are Voltage-controlled Current Sources -- a voltage applied to a Gate controls a large Drain to Source current.

With the BJT, we could perhaps picture the action as using a small flow of water to erode a dam to let a large flow of water through. With a FET, we instead picture a clamp squeezing a pipe to stop the flow of water through the sluice. Nothng about the clamp ends up "getting wet" -- it is entirely outside of the conductive flow.

This is a good time to once again try to refine your understanding of the two basic elements of electricity: Current and Voltage. Current refers to the movement of electrical charge carriers through a conductor, whereas Voltage refers to electrical pressure or force. The two are not interchangeable, and should never be confused: Voltage is a potential difference between two points that could cause a current to flow. Voltage exists whether or not current is flowing. Current only flows if there is a conductive path from a higher potential to a lower potential. It is possible to have a very high potential difference with no current because the resistance is effectively infinite, and it is possible to have a huge current flowing with an almost unmeasurably small voltage if the resistance is nearly zero -- that's the scenario that exists for a few milliseconds when a mechanic drops his wrench across the terminals of a car battery: a dead short across the battery terminals will mean essentially zero volts, but the current will be hundreds of amps before the wrench explodes in a shower of molten iron.

Field Effect Transistors use an electric field (in essence, a potential difference or voltage) to control a current through a conductor by external means.

The simplest of these is the JFET, which can be pictured as in the meme below:

"Big Sister" is crimping the garden hose, and is about to let it go to allow a spray of water to hit her unsuspecting little brother's face. "Big Sister" doesn't get her hands wet because she is applying an external force (analogous to voltage) to the garden hose to prevent the flow (analogous to current). The natural condition of a garden hose it to allow water to flow; only by applying an external force can the current be stopped. That's the JFET.

The most common FET is called an Enhancement-Only MOSFET (E-MOSFET), and it is more like a spring clamp on the IV tubing in a hospital: Its natural condition is to prevent the flow of current, and a counteracting force needs to be applied to open up the channel to allow current to flow.

In between these two is an almost-nonexistent FET called the Depletion and Enhancement MOSFET (D-MOSFET) which behaves a lot like the JFET in that current normally flows and an external voltage needs to be applied to reduce or stop that flow, but putting a counteracting voltage across the device will allow even more than the normal current to flow.

2 FET   1 BJT

1. Current-controlled Current source
2. Voltage-controlled Current source