the Transistors

The transistor is certainly one of the most important inventions the electronics industry has ever seen. It replaced the vacuum tube in the late 50's and 60's and we often see statements about how important this device is in making equipment small, light and therefore portable. Pundits often talk about the transistor's low power requirements and resultant long battery life. While those factors are very important, the transistor contributes another feature that is more important than all others: *reliability*.

The transistor's "robustness" and durability are inherent in solid-state devices. Another plus is the low voltage needed in transistorized circuits adding to very long component life. Old, higher voltage devices ran hot and broke down easily; the vacuum tube was inherently fragile when compared to a transistor or a diode.

In this book, we introduce the first (bipolar) transistor types, which are still the most common in use today. We will leave out most detailed technical information as our goal is simply to help you identify the part, and know for certain how to solder it into a circuit.

Other parts discussed so far, such as the resistor, capacitor etc., are thought of as 'passive devices', the transistor is an ***active*** device. While other parts just 'sit there' and let things happen, the transistor is actively involved in controlling the energy in the circuit.

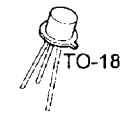
The "N" stands for 'negative' and the "P" stands for "positive". NPN and PNP describe the transistor's internal structure.

Let's begin with the 'original' transistors, still very much in use. There are two and these are the NPN and PNP bipolar transistors. You will encounter them in many kits and projects you'll see in magazines.

The transistor is a powerful current amplifier. Another way of saying that is that a transistor can control a large amount of power with just a tiny amount of power. This means that we can amplify a tiny audio signal, such as the one from a tape player's magnetic head or from a microphone, and make it strong enough to 'drive' a loudspeaker so that we can hear it quite clearly. The transistor can also act as a switch, allowing power to flow; or not.

There are three lead wires, or 'pins' on the bipolar transistor: the **emitter,** the **collector,** and the **base. Please remember these terms. Note that in the circuit below, these are abbreviated to E, C and B on a schematic diagram.**

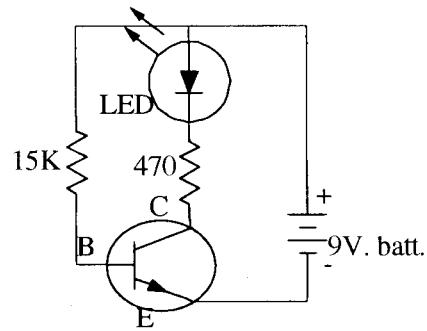
Imagine that a large current circuit is connected to the collector and emitter of a transistor. If a small current is applied at the base of the transistor, then the 'big' current can flow from the collector pin, through the transistor and out the emitter.



This emitter-collector current has the power of the battery behind it but is controlled by the much smaller current that is applied to the base of the transistor.

If our LED were a speaker and the current at the base of the transistor were a weak little audio current, such as from a microphone or the detector section of a radio receiver, the output to the speaker (the emitter-collector current) is going to have the 'look' of the current at the base of the transistor. This is an over-simplification, because we actually need to cascade several transistors to get enough amplification to drive a speaker. But we are only trying to give a general idea here; not an engineering degree.

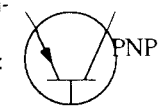
Remember that: Whatever is input at the base, is happening much, much bigger at the collector-emitter junction. A wobbling little sound can be exuded as a wobbling BIG sound.

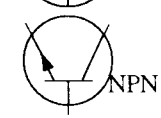


In our schematic circuit here, the 'big' current wants to flow from the battery and through the LED to make it light up. A very tiny current gets to the base via the 15K resistor, which opens the transistor for a much larger voltage to flow through the *Collector to Emitter junction.* If you remove the 15K (15,000 ohm) resistor then the transistor base has zero current and the transistor does not conduct. The LED would go out. You could try this with any LED and a PN2222A type transistor.

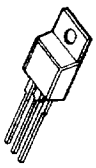
Pinouts of the PN2222A

Here is one more analogy for those not quite following us here. Imagine that you are standing by a terrifically huge water pipe, and the water inside can flow out with such huge volume and big pressure that it could blow an automobile across a football field. In front of you is a spring loaded valve, just like a valve on the spigot for your garden hose; except spring-loaded. This valve you open quite easily, just like putting a small current on the base. The more pressure you apply to open (the bigger the current on the base), the bigger the flow of water gushing out. You may not be very strong, but you are in control of a lot of power!



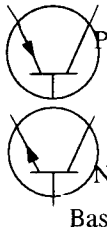


Try to remember the schematic symbols for a **PNP** and **NPN**, which respectively stand for PositiveNegativePositive and



TO-220

NegativePositiveNegative. These terms relate to the internal construction of the transistors. We refer to these as an "NPN type" transistor; or a "PNP.



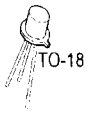
Note that the arrow pointing 'out' is an NPN; this author always remembers that as "a negative attitude", the arrow indicating a desire to "get out of there". Which may be silly; but I've never forgotten which symbol represents the NPN or PNP.

The arrow lead wire is always the **emitter;** the **base** is pretty obvious and the one remaining lead is the **collector**

the Transistor's 'PIN OUTS'

The TO-92 transistor case style.

Transistors come in a number of case styles, the TO-92 is one of the most common types. The case is black plastic (epoxy) and hundreds of different transistors are made in this case. Usually, an industry number is on the case so that you will know what it is.



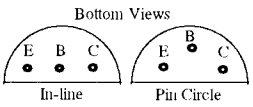
TO-18

Looking at this TO-92 device from the flat side and leads pointing downward, the lead wires from left to right are the *emitter, base* and *collector* IF this is a 2N3903 type transistor. The PN2222A transistor from National Semiconductor also has the same 'pin outs' . It is absolutely imperative that you get each lead in the right spot when you mount this part in a circuit; or nothing works!

You will run into other transistors where the leads (pins) are different, such as CBE or BCE and you need to be certain of the pinouts of each to be able to mount it in a circuit.

TO-236

Transistors come in styles such as the TO-18 and TO-220; there are different reasons for using different case styles. For example, a power transistor or a high power amplifier transistor might be made in a TO-220 case because it has a metal tab that can be used as a 'heat sink' ; without the heat sink, the unit could burn up in its own heat.

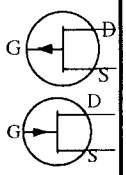


Here is a bottom view of our little TO-92 transistor and note that some will come with pins In-line and others with pins in a semi-circle. ***Whenever you solder a transistor into a circuit, you must look up the pinouts and be sure the lead wires each go to the right places.***

The FET

Now one more transistor type, the Field Effect Transistor, most often simply called the FET. The FET controls power flow between two points but does so differently from the bipolar transistor. Current moves from the Source connection to the Drain connection. The Gate controls the current flow; by creating a *field.*

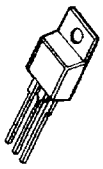
There are N-channel FETs and P-channel FETs. Current flows via a channel when the field at the gate has current. The *Gate,* the *Drain* and the *Source are the lead wires and must be soldered in the right spots.* Some FET's come in the TO-92 case and there are other case styles (such as the TO-18). FET's can do about the same things as bipolars and we won't dwell on all of the advantages of one or the other at this time. There are thousands of transistor types, bipolar and FET, but they are simply variations on the same idea.



TO-236

TRANSISTOR MANUALS

Any of the name brand manufacturers will have transistor manuals available. These are handy for both detailed technical information and for pinouts. You may want to acquire manuals from Motorola, National Semiconductor etc. as your knowledge grows. In the meantime, kits and magazine articles generally try to give a clear sketch of pinouts. ONE Word of CAUTION; sometimes pins are described looking down onto the PC board and sometimes they will be given as the 'bottom view'. So, pay attention or you may reverse connections.



TO-220

GENERAL REPLACEMENTS

When you walk into a local distributor's store and ask for a no. 2N2222 transistor, you may be told that they don't stock it, they have an ECG or NTE or RCA replacement instead. Because distributors could not stock all of the different (makes of) transistors, NTE, ECG and RCA have been successful in offering 'general replacements'. These are usually good substitutes and, unless a project's instructions tell you not to do so, you may substitute freely.

Asking for the industry number 2N2222 will get you an NTE123A or and ECG123A or an RCA no. SK3444 (depending upon which line is stocked). Or you might buy a Radio Shack 276-1617. These companies are pretty good at looking at a transistor's characteristics and 'plugging in' a generic transistor that will normally do the job for that transistor. It will be rare when you have a circuit that does not perform due to a bad substitution by these companies. If you are feeling like being fussy and want the *Exact* part, you may want to order from a mail order catalog . But be prepared to put together a minimum order of at least 25 bucks, as mail order operations don't like to process an order and pack it up for less. Your local distributor, will probably not have a minimum for a cash purchase, and a low one for credit card or check. And, although catalogs are handy, we like to browse the local stores as it is always interesting. † †

The TO-92 transistor case style.