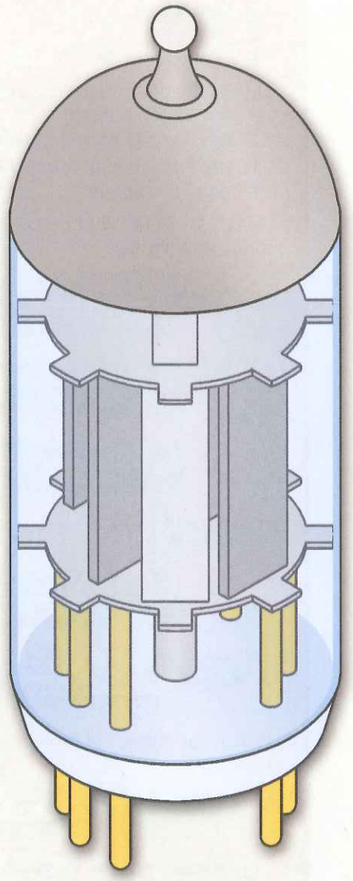
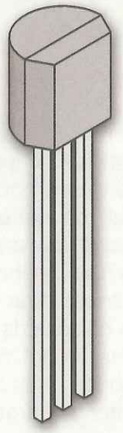
CHAPTER 5: TRANSISTORS

Learn By Doing®

The invention of the transistor proved to be one of the great discoveries of the 20th century. Originally developed to replace the large and inefficient vacuum tube amplifiers used in early radios, the little transistor is now used in ways its inventors could never have imagined.



Vacuum Tube



Transistor

The transistor was first developed in 1949 at Bell Telephone Laboratories, the name being derived from "transfer resistor". It has since transformed the world. Although it is mostly used in amplifier and switching circuits, engineers have used complex combinations of these circuits to create amazing new technologies.

Improvements in semiconductor manufacturing processes have allowed transistors to be miniaturized, leading to the development of today's computers. The importance flexibility of transistors should be obvious just by the number of snap circuits projects that use them.

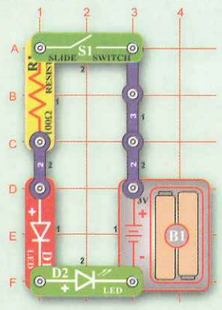
In this chapter you will learn how transistors work, and how they are used in many types of circuits.

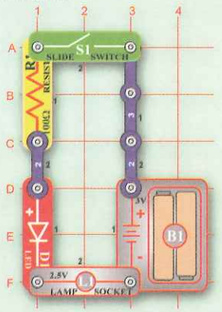
5-1 More About LEDs

Earlier we told you that LEDs are like low-current one-way lamps. But they also have other important differences.

Experiments

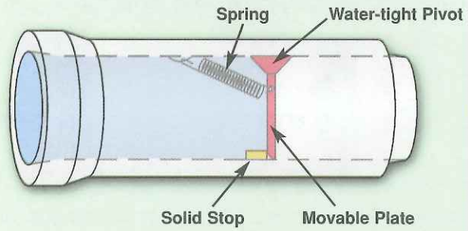
Consider these two mini-circuits:





If you build these mini-circuits you will see that nothing happens in the first while the red LED is on in the second. There isn't enough voltage to turn on the green LED or the lamp while also lighting the red LED.

The difference is that the green LED (and the red LED too) has a turn-on voltage level while the lamp does not. Instead of thinking of an LED as a water meter, think of it as a check valve like this:



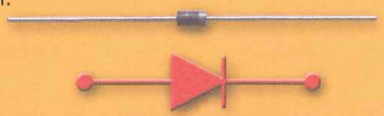
The small spring in the drawing represents a turn-on level of pressure that must be exceeded before any current can flow. The solid stop in the drawing prevents current from flowing in the other direction.

LEDs are made from materials called **semiconductors**, so-called because they have more resistance than metal conductors but less than insulators. Most semiconductors are made of Silicon but Gallium Arsenide is usually used in LEDs. Their key advantage is that by using special manufacturing processes their resistance is decreased under certain operating conditions.

The semiconductor manufacturing processes create two regions of permanent electrical charge, quite different from charging a capacitor. The effect is that once the voltage exceeds a small turn-on level (0.7V for Silicon, 1.5V for Gallium Arsenide LEDs) the resistance becomes very low in one direction (so low that the current flow must be limited by other resistances in the circuit to prevent damage).

Diodes: Diodes are used to block current in one direction. Most diodes are made of silicon and have a turn-on level of about 0.7V. LEDs (light emitting diodes) are a special type of diode made from Gallium Arsenide. LEDs have a higher turn-on level (about 1.5V) and also emit light.

The symbol for a diode is similar to the LED symbol:



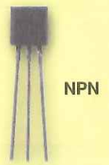
The green and red LEDs are the only diodes used in snap circuits.

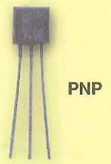
5-2 Transistors

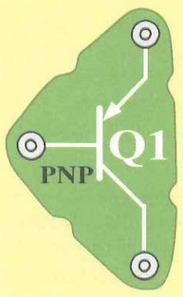
The transistor is best described as a current amplifier - it uses a small amount of current to control a large amount of current.

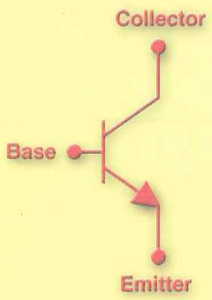
Introducing New Parts

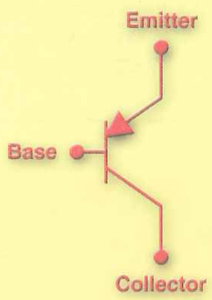
Snap circuits includes one NPN-type and one PNP-type transistor, made of the semiconductor silicon. These are the most widely used types of transistors. They have three connection points, called the emitter, base, and collector.





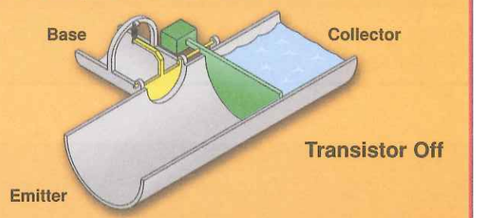


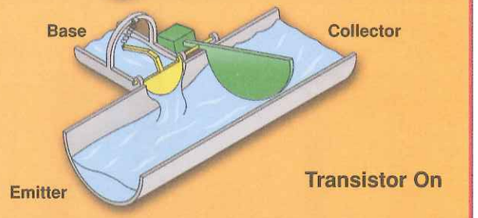




Like LEDs, transistors only allow current to flow in one direction. The small arrow in the symbol near the emitter indicates which direction the current will flow through the transistor.

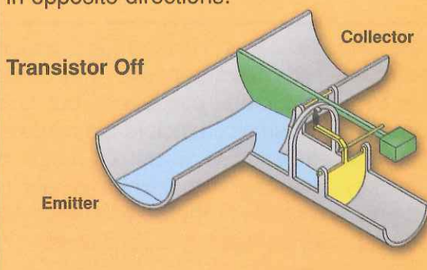
In water pipe terms, the NPN may be thought of as the lever pivot shown here:

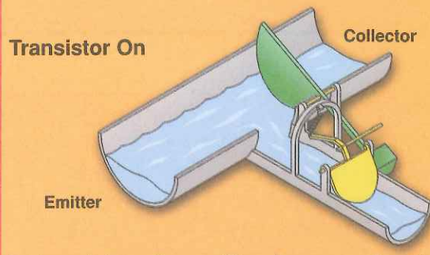




Notice that it includes a check valve that is connected to a lever arm. A small amount of current pushes on the check valve, which turns and opens the lever arm. But before this current can start to flow it must have enough water pressure to overcome the spring in the check valve (about 0.7V). If the base pipe is much smaller than the collector and emitter pipes, then a small base current flowing in will allow a large collector current to flow.

The PNP is just like the NPN, but the currents flow in opposite directions:



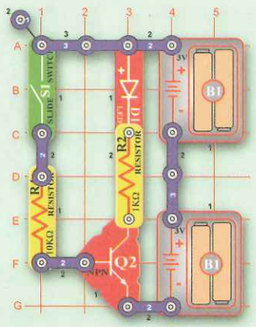


In transistors the emitter, base, and collector are different regions of permanent electrical charge, producing the effects described above for the lever pivot. The properties and uses of transistors will become clear after some examples.

5-3 Transistor Basics

Experiments

Consider this mini-circuit:

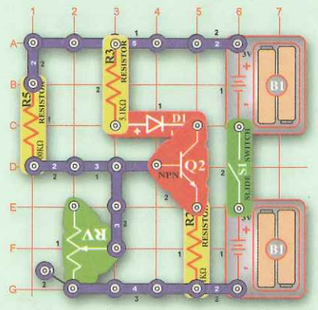


A small current through the switch will activate a larger current through the LED. This is a simple example of how transistors are used as electronic switches.

You're probably thinking "Instead of using a transistor, why not just put the LED in series with the switch?". But what if you wanted to have the same switch control 100 LEDs, each with the same brightness as the one in this circuit? With transistors you can, since the same switch can be used to control 100 separate transistors with their LEDs.

Experiments

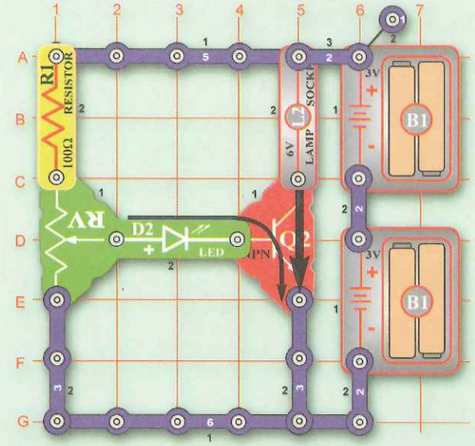
Consider this circuit (which is project 215):



The adjustable resistor controls the current into the transistor, and can set the LED to any brightness desired. This is the standard transistor circuit for amplifiers. To minimize the distortion in the signal being amplified, the adjustable resistor will usually be set so that the LED is at half brightness.

Experiments

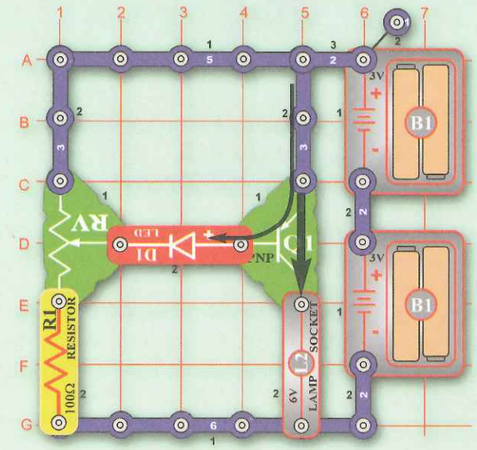
Consider this circuit (which is project 124):



If the adjustable resistor is set so that the green LED is on, the lamp will also be on. When a small current flows between the transistor base and emitter, a larger (amplified) current flows between the transistor collector and emitter.

Experiments

The PNP transistor works in almost the same way, the only difference is that current flows into its emitter and out of the base and collector. For example, consider this circuit (which is project 125):



This circuit uses the same parts (except for the transistor), only they are arranged differently.