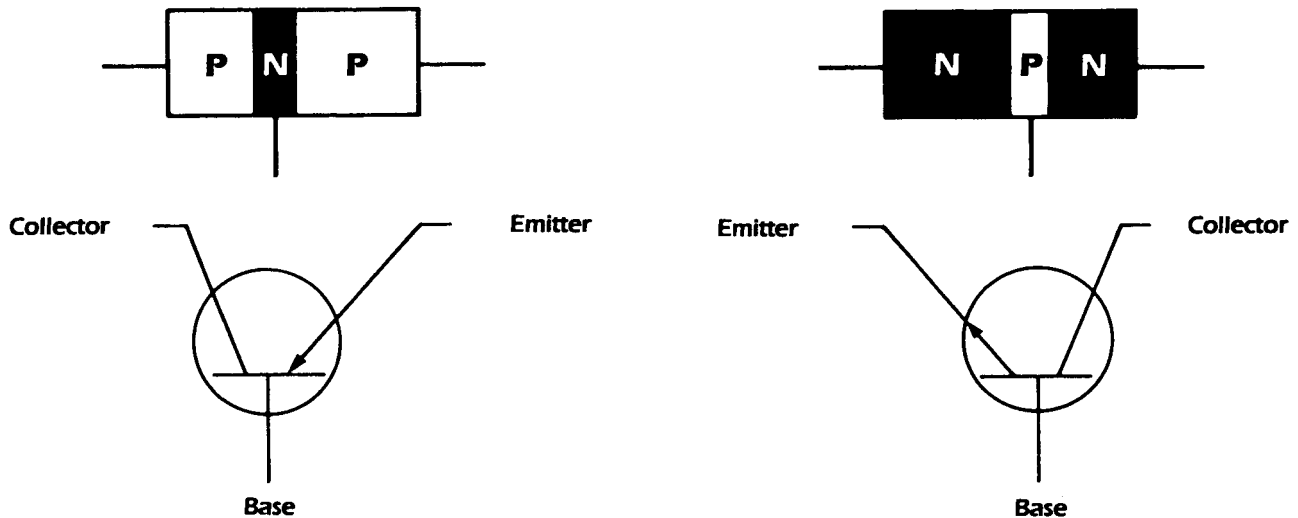


## THE BIPOLAR TRANSISTOR



## TRANSISTORS

A transistor can be used as an amplifier to control electric motor speed such as AC blower motors, or as solid state switches to control actuators such as fuel injectors.

This chapter will cover each of the following four areas:

*Transistor Operation*

*Transistor Applications*

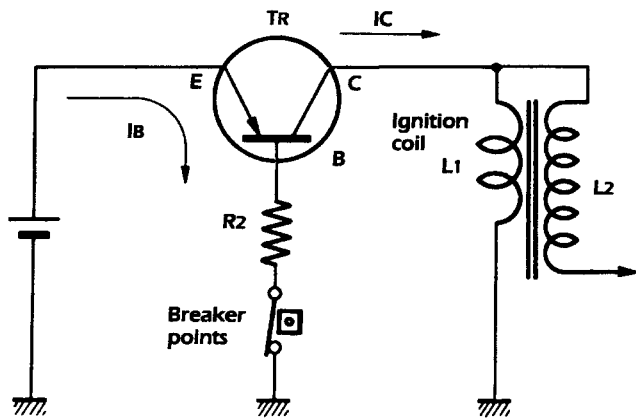
*Transistor Gain*

*Integrated Circuits*

Transistors are made from the same N-type and P-type materials as diodes and employ the same principles. Transistors, however, have two PN junctions instead of just one like a diode has. The two PN junctions allow a transistor to perform more functions than a diode, such as acting as a switch or an amplifier.

The bipolar transistor is made up of three parts: the emitter, the base and the collector. There are two types of bipolar transistors: the PNP and the NPN. In the PNP transistor the emitter is made from P-type material, the base is N-type material and the collector is P-type material. For the PN transistor to operate, the emitter must be connected to positive, the base to negative and the collector to negative.

The NPN transistor has an emitter made from N-type material. Its base is P-type material and the collector is N-type material. For the NPN transistor to operate, the emitter must be connected to negative, the base to positive and the collector to positive. Aside from the way in which the NPN and PNP transistors are connected in the circuit they operate the same way. Both transistors have a forward biased junction and a reverse biased junction, and three parts—the emitter, the base and the collector—formed in a three-layer arrangement.



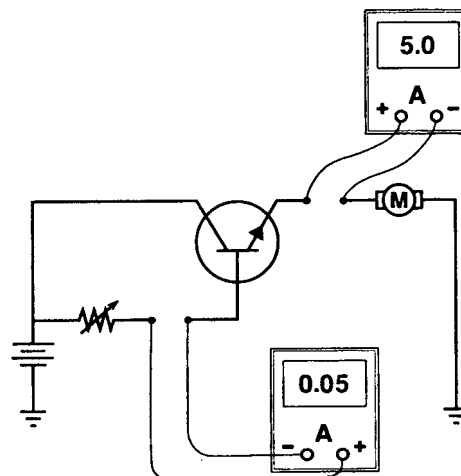
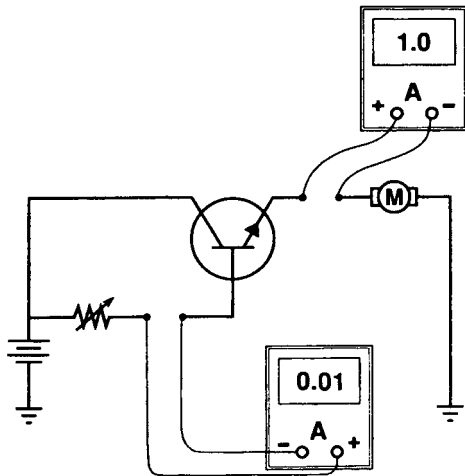
Current flow between the emitter and base controls the current flow between the emitter and collector. The emitter of the transistor is the most heavily doped so it has the most excess electrons or holes, depending on whether the emitter is P-type or N-type material. The collector is doped slightly less than the emitter and the base is very thin with the fewest doping atoms. As a result of this type of doping, the current flow in the emitter-collector is much greater than in the emitter-base. By regulating the current at the emitter-base junction, the amount of current allowed to pass from the emitter to the collector can be controlled.

The symbols for both PNP and NPN transistors are very similar. The distinguishing feature is the arrow, which is always located in the emitter and always points in the direction of conventional current flow. The base is part of the symbol which looks like a "T" and the remaining line, opposite the emitter, is the collector. In the symbol for a PNP transistor the arrow in the emitter points toward the center so the current flow is from emitter to base and from emitter to collector. In the NPN transistor the arrow

in the emitter points away from the center so the current flow is from the base to emitter and from the collector to emitter.

One of the most common uses of a transistor in an automobile is as a switch. Switching transistors can be found in solid state control modules and computers. They control devices on the car such as the fuel injector in an EFI car or a mechanical relay that operates the retract motor on a car with retractable headlights. When an NPN transistor is used as a switch, the emitter of the transistor is grounded and the base is connected to positive. If the voltage is removed from the base, no current flows from the emitter to the collector and the transistor is off. When the base is forward biased by a large enough voltage, current will flow from the emitter to the collector. Essentially, the transistor is being used to control a large current with a small current like a starter relay. A small amount of current to the relay will complete a circuit so a large current can flow.

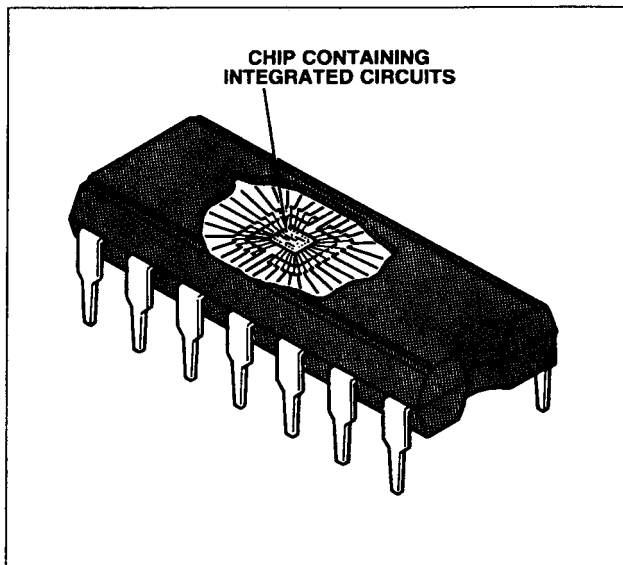
## TRANSISTOR GAIN



We know that the current flow between the emitter and base controls the current flow between the emitter and collector. Also, the amount of current flow between the emitter and base will affect the amount of emitter collector current. The ratio between these two currents is known as the "gain" of the transistor. This gain allows us to use a transistor to control a large current with a very small current similar to the way a relay operates. Example shown: if a transistor had a gain of 100 and the emitter-base current was increased by 10 milliamps or .01 amps, the emitter collector current would increase by 100 times or 1 amp. This type of increase will occur until the transistor reached saturation. This is the point where increasing the emitter-base current does not increase the emitter-collector current. Transistors used for switching usually operate at the saturation point when turned on, while transistors that are used for amplifiers operate in the range between off and saturation.

Another application for a transistor is amplification. This situation takes advantage of the relationship between the emitter base current and the emitter-collector current. Since a small change in current flowing through the transistor from the emitter to the base has a proportionally larger effect on the emitter-collector current, we can use transistors to increase the strength of a small signal in a radio or to provide a variable control for a motor.

On some Toyota models, transistors are being used to provide variable speed control such as the AC blower motor on the Cressida and the electric motor that runs the power steering pump on the 1991 MR2. By varying the emitter-base current of the transistor, the current flowing through the motor can be varied, thereby varying the motor speed.



ICs are classified by the number of parts included on one chip. The Small Scale Integration (SSI) IC has about 100 elements; the Medium Scale Integration (MSI) IC has 100 to 1,000 elements; the Large Scale Integration (LSI) IC has 10,000 to 100,000 elements; and the Very Large Scale Integration (VLSI) IC has more than 100,000 elements.

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### INTEGRATED CIRCUITS

An integrated circuit (IC) is nothing more than many transistors, diodes, capacitors and resistors connected together with conductors and placed on a single silicon chip. A single IC is a system within a system, with several to several thousand electrical circuits built into or onto a several-squaremillimeter silicon chip in a ceramic or plastic package. The advantages of the IC are the size and low cost of mass production along with low power consumption and reliability. An IC can be anything from simple logic gate to a microprocessor to almost a complete computer on a chip.

ICs are more reliable than non-integrated circuits because all the elements can be built into and onto a single silicon chip, thereby reducing contact junctions. In addition, the number of components is reduced.

## ASSIGNMENT

NAME: \_\_\_\_\_

1. Describe the basic construction of a Bipolar Transistor.
2. Draw a PNP Transistor and label its parts.
3. Explain the two current paths of a bipolar transistor.
4. Explain the purpose of the arrow on the emitter and why is the direction of it important.
5. If the arrow on the emitter is pointing toward the base. What type of transistor is it and what voltage signal (positive or negative) is needed to the base in order to forward bias the transistor?
6. Explain and provide an example of “transistor gain”.
7. Describe what an integrated circuit is.