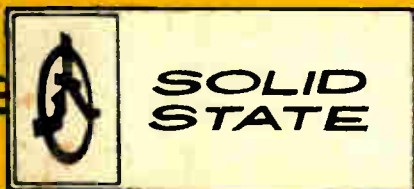


RCA VICTOR



BOOK ONE

A BASIC CONCEPT OF TRANSISTORS

PRODUCT PERFORMANCE

TECHNICAL PUBLICATIONS

RCA SALES CORPORATION

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A BASIC CONCEPT OF TRANSISTORS

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INTRODUCTION

Even though the transistor is a recent invention, its influence in electronic circuit design has been far reaching, and its use is rapidly finding application in every branch of electronics. Most literature presently available treats the subject of the transistor and its application in a somewhat complicated way, involving the elements of chemistry. The purpose of this manual is to describe some basic transistor concepts and circuits in such a way that the complexities of the device are minimized. The theory and the whys and wherefores might be considered “extra curricular” reading and for our purposes will be considered beyond the scope of this manual.

SERVICING TECHNIQUES FOR TRANSISTORIZED EQUIPMENT

The servicing approach for transistorized equipment is similar in many respects to that used in vacuum tube circuitry. Although some of the symptoms the technician utilizes in vacuum tube servicing may not be experienced in the transistorized circuit, it does not make the transistorized circuit more difficult to service. It simply means that many *troubles* found in tube type circuitry *do not occur* in transistorized equipment.

Indications such as open filaments, burned resistors, arcing conditions, etc. do not present themselves in the transistorized circuits due to the construction of the transistor and the comparatively low voltages employed.

After carefully checking the tubes in an instrument using vacuum tubes, signal tracing techniques are used to localize a malfunctioning stage, and voltage measurements are made to isolate the defective component. In the case of transistorized equipment the *first* step is to signal trace the circuitry and then evaluate voltage readings, since the transistor itself is very reliable. In fact when transistor failure does occur, it can usually be traced to misuse of test equipment or the application of an improper servicing technique.

The transistor is a compact device, and generates very little heat (except possibly in power output transistors); it accordingly lends itself very ideally to circuit board construction. Consequently, the technician should be familiar with printed circuit servicing techniques, and develop a systematic approach to servicing transistor circuits. He should have adequate tools, good lighting and appropriate service literature on hand.

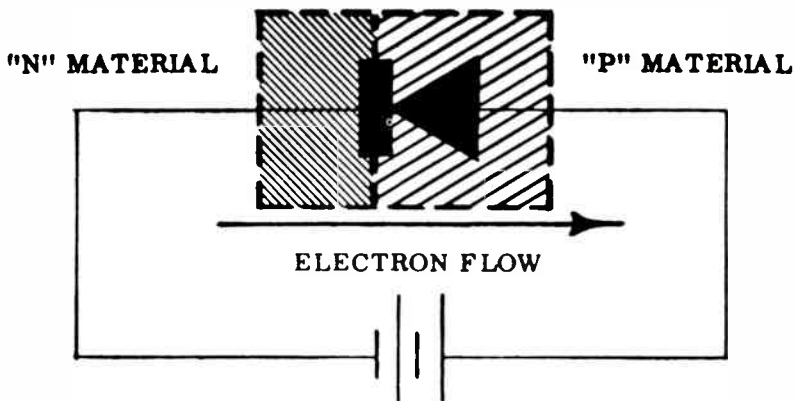
TRANSISTOR OPERATION

In solids, electrons (current) can flow from a material having an excess of "free" electrons, to a material that has a deficiency of electrons. That is, electrons flow from a negative (N) material to a positive (P) material.

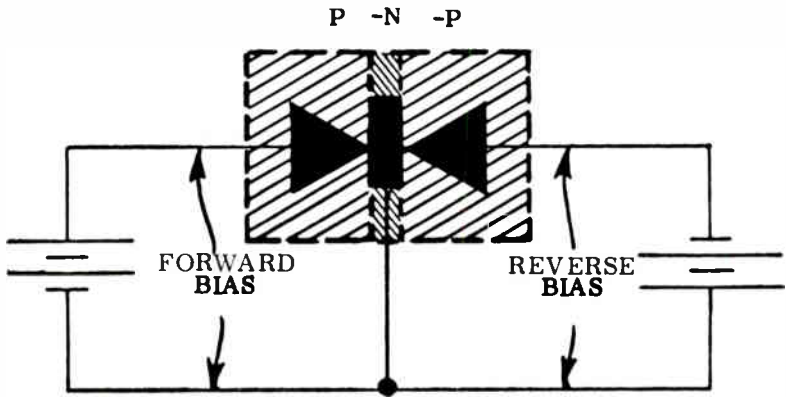
If a "P" type and an "N" type material have a common junction and a voltage is applied so that the "P" type is positive in relation to the "N" type, the junction will conduct heavily.

The most common form of a P-N junction is the diode. The cathode is composed of "N" type material and the anode of "P" type material. With no bias (electrical potential across the diode), negligible current will flow. As forward bias (properly polarized potential) is increased, more current flows, until at some point, maximum current flow is realized. With reverse bias (reverse polarity potential), the junction becomes more resistant to current flow as the reverse bias is increased.

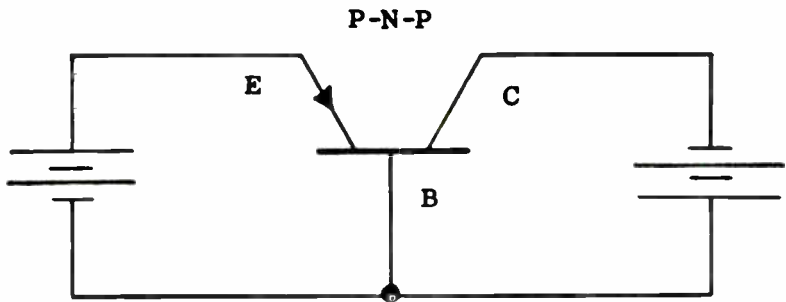
The practical ability of the diode to conduct in one direction only is utilized in rectifier circuitry. In such circuitry, with the anode of the diode connected to an AC voltage source and the cathode to the load, the diode will conduct only when forward bias is present on each half cycle. When reverse bias is established during the other half cycle, the diode junction offers very high resistance and no appreciable amount of current flows.



A transistor, for all practical purposes, can be depicted as two diodes with a common base. If one P-N junction is forward biased, and the other reverse biased, the circuit would appear as follows:

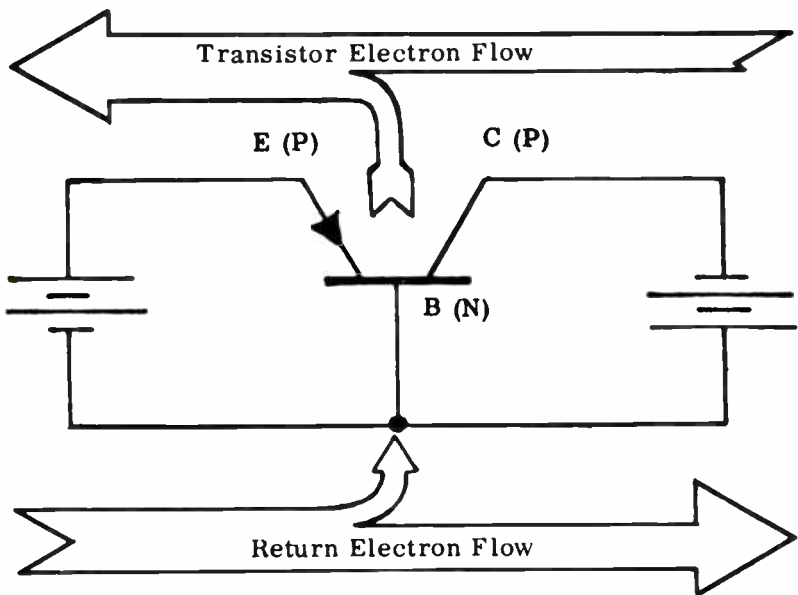


Pictorial Representation of a Transistor



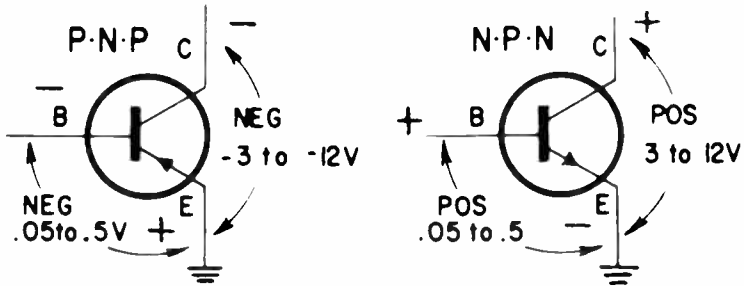
Schematic Representation of a Transistor

With forward bias on the emitter /base junction and reverse bias on the collector /base junction, it would seem that current flow would be heavy in the emitter /base junction and that almost no current would flow in the collector /base junction, and that there would be no interaction of the diodes. *Actually this is not true.* The greatest current flow would be from collector to emitter with some small portion flowing from the base, as is shown below. This phenomena is the basis of transistor action and contributes to its use as a signal control and amplifying device.



The two most common types of transistors are the P-N-P types and the N-P-N types. The P-N-P has the emitter and collector of positive type material and the base of negative material. With the N-P-N, the collector and emitter are "N" type material with the base of "P" type material. Bias conditions are the same with

either type: emitter/base junction has forward bias, and the collector/base junction is reversed biased. Voltages, if read from the emitter element, will always be in the direction of the base material, that is: positive with an N-P-N and negative with a P-N-P.

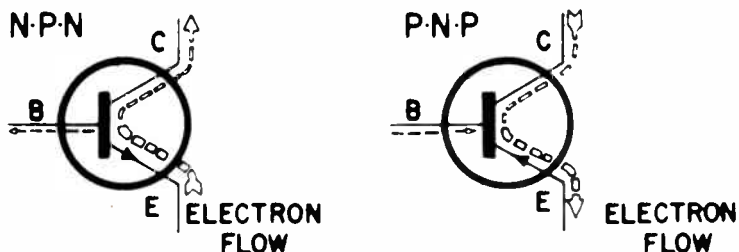


Electron flow is always opposite in direction to the identification arrow on the emitter symbol, from emitter to collector in N-P-N types and from collector to emitter in P-N-P types. As an aid in determining the type designation of a transistor from the transistor symbol, the “north rule” can be used; that is, the arrow always points to the “N.”

TRANSISTOR CHARACTERISTICS

The terms "Alpha" and "Beta" are used as a way of defining the ability of a transistor to amplify current.

Alpha is the forward current transfer ratio from the emitter to the collector. Since part of the current always flows through the base, the collector current is always less than emitter current, and Alpha is less than unity.



Since both collector and emitter currents are bias currents, their ratio is called DC Alpha. Normally Alpha is used to refer to the ratio of signal currents in the emitter and collector.

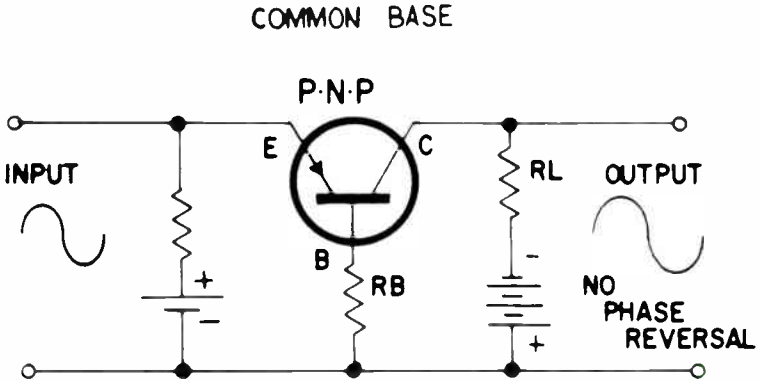
Current gain is obtained in a transistor when the signal is applied to the base element. The signal in the small base current causes a corresponding fluctuation in the much larger emitter current, which in turn causes the output electrode, the collector, to reproduce the input signal in the collector current. This current gain is defined as Beta, a ratio of the input electrode current to that of the output electrode current, or $BETA = \frac{COLLECTOR\ CURRENT}{BASE\ CURRENT}$

In practice this figure will range in the vicinity of fifty to several hundred.

Transistors are rather loosely defined as current amplifiers. This is merely a descriptive convenience. The characteristics of transistors are such that either current or voltage gain can be realized. This in turn is dependent on the way in which the transistor is used in the circuit. The three transistor circuit configurations are: (1) the common, or grounded, emitter; (2) the common, or grounded, base; and (3) the common, or grounded, collector.

COMMON BASE AMPLIFIER

The common base configuration can operate as a voltage amplifier, an impedance matching device or as a capacity isolater. A simplified circuit is shown below.



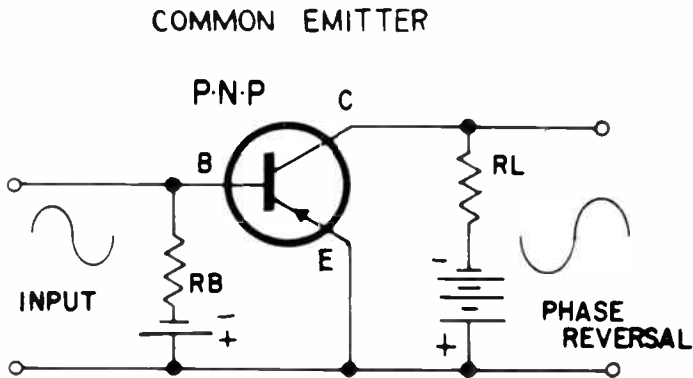
Transistor shown is P-N-P; voltage polarities would be reversed for N-P-N.

The input signal is applied to the EMITTER-BASE junction and the output signal is taken from the collector /base junction. Current gain is less than one, but voltage gain, the ratio of input to output voltages, can be quite high, up to 1500 times. Input impedance is low, normally 0.5 ohm to 50 ohm. Output impedance is high from 5000 ohms to 1 megohm. The signal has no phase reversal.

Power gain is also possible with the grounded base configuration since output current is essentially the same as input current (less base current); any voltage gain is directly proportional to power gain. For example, if 3 ma flowed through the emitter, essentially 3 ma would flow through the collector. Therefore if signal voltage at the input is 0.2 volt and at the output 2.0 volts, input power would be 6 milliwatts and output power 60 milliwatts, a power gain of 10.

THE COMMON EMITTER AMPLIFIER

The common emitter circuit configuration is the one most often used in transistor circuitry employed in Radio and Television instruments. A simplified common emitter circuit is shown below.

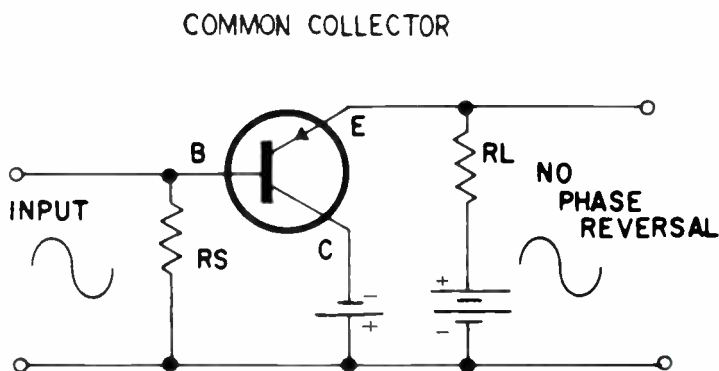


The transistor shown is a P-N-P; voltage polarities would be reversed for the N-P-N.

The input signal is fed to the base/emitter junction and output is taken from the collector/emitter junction. Voltage as well as current gain can be realized. Gain is measured between base and collector and signal has 180° phase reversal. Input impedance (base/emitter) is normally from 20 ohms to 5000 ohms and output impedances (collector/emitter) range between 50 ohms and 50,000 ohms. Power gain of 40 db or 10,000 times is possible with this circuit arrangement.

THE COMMON COLLECTOR AMPLIFIER

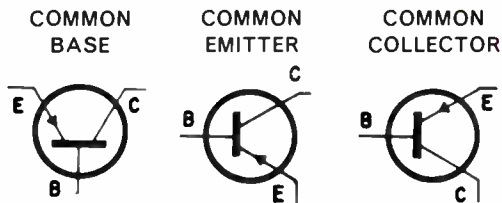
The common collector, or emitter follower circuit with its high input impedance and low output impedance is usually used as an impedance matching device, however it also offers current gain.



The transistor shown is a P-N-P; voltage polarities would be reversed for the N-P-N.

This emitter follower configuration is capable of large current gains but always less than unity voltage gain. With high impedance input and low impedance output this configuration is often used to match the high impedance output of a vacuum tube or a phonograph pickup to the low impedance input of a driver stage and at the same time provide stage gain—signal gain can be as much as 250 times.

PROPERTIES OF THE THREE TRANSISTOR CONFIGURATIONS



VOLTAGE GAIN	200 or more	200 or more	slightly less than 1
CURRENT GAIN	slightly less than 1	approximately 50	approximately 50
POWER GAIN	200 or more approximately the same as voltage gain	as high as 10,000	approximately 50 (same as current gain)
PHASE REVERSAL	No	Yes	No
INPUT IMPEDANCE	Low 10 to 50 ohm	Low 20 to 5 K ohms	High 5 K to 100 K
OUTPUT IMPEDANCE	High 2 K to 10 K	High 50 to 50 K ohms	Low 5 to 5 K ohms
INPUT SIGNAL APPLIED TO:	Emitter	Base	Base
OUTPUT SIGNAL TAKEN FROM:	Collector	Collector	Emitter
FREQUENCY RESPONSE	High	Medium	Low to High (Dependent on Application)

BIASING THE TRANSISTOR

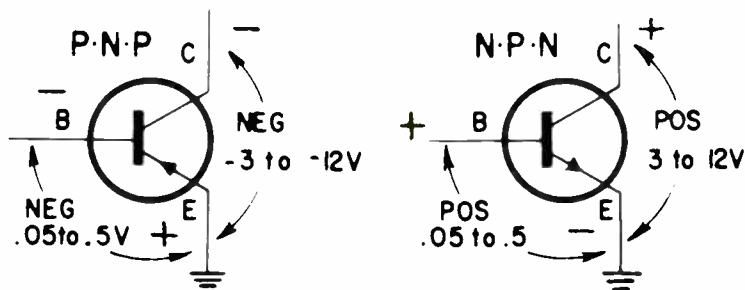
Transistor bias consists of forward bias across the emitter /base junction and reverse bias across the collector /base junction.

In general, biasing techniques follow these four simple basic rules:

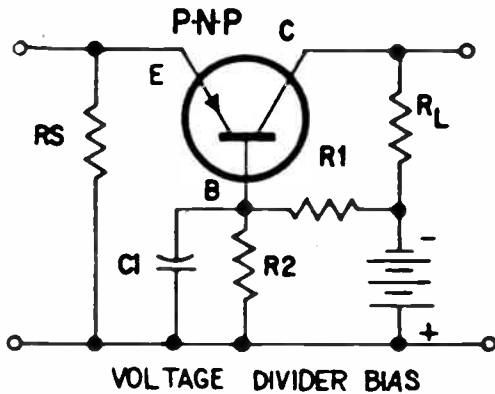
1. Battery, or voltage polarity, corresponds to the emitter material. That is, positive to emitter in P-N-P, and negative to emitter in N-P-N.
2. Forward bias is established by a small potential, 0.05 volt to 0.5 volt between emitter and base. Polarity corresponding to the base material.
3. As base potential changes in the direction of collector potential, transistor conducts toward current saturation.
4. As base potential changes in the direction of emitter potential, current decreases. At the same potential, transistor is at cutoff.

With the type transistors normally used in home entertainment type instruments, the emitter to collector voltages are in the range of 3 volts to 12 volts or more, and the emitter to base voltage differential between .05 volt and 0.5 volt.

When measured from the emitter, these voltages will be positive with the N-P-N types and negative with the P-N-P types.



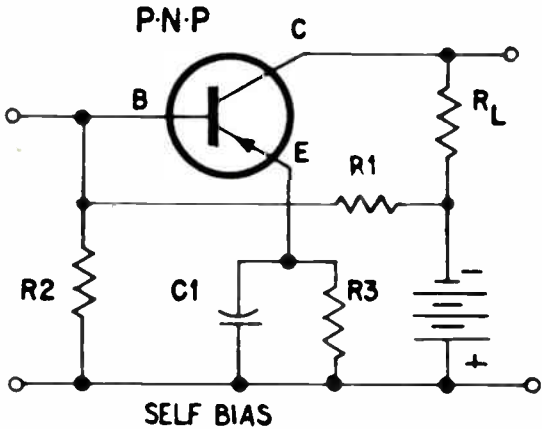
To obtain these bias voltages, practical circuits normally employ either fixed or self bias, the determining factors in each being stability, the transistor characteristics and the circuit requirements. Fixed bias is more commonly used in the common base configuration as illustrated below:



Resistors R_1 and R_2 provide both forward bias for the emitter /base junction and reverse bias for the collector /base junction. Current flowing through R_2 provides a voltage drop for the emitter /base junction.

Variations in transistors and their sensitivity to temperature change in many instances call for more accurate control of the base currents. One method of accomplishing this control is to tie the base to the collector circuit through a resistor (R_1), since any variation of collector current under these conditions will reflect a voltage change in the base bias. This will reduce the effective gain of the circuit but stabilize the operating point. An added bias resistor from base to emitter is sometimes used to further add to the stability of the circuit.

Another variation in circuitry which establishes bias and provides for stability is shown below:



In this form of circuitry the divider network consisting of resistors R_1 and R_2 establishes base bias. The bleeder current through R_1 and R_2 is sufficiently high, consequently changes in base current do not change base bias. This circuit also uses self bias in the emitter circuit for additional stabilization.

SUMMARY

A knowledge of the basic concept of transistors can contribute appreciably to a technician's ability in servicing transistor circuitry. A technician need not concern himself with transistor circuit design or transistor characteristics to service instruments that employ transistors.

The basic concepts of the transistor described in this booklet can be applied to all circuits found in transistorized products. Once the basic concepts are understood, the technician will recognize the common emitter, common base, and common collector type of circuit in a schematic diagram and the manner in which biasing is achieved. When transistor circuits are recognized in basic form, appropriate servicing techniques can be readily applied to locate transistor and component failures.

A practical understanding of how the transistor works in different circuits and how the transistor functions under varying conditions of bias will make it relatively easy for a technician to develop an effective approach to servicing transistor circuits.



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