The Lenkurt Demodulator

NEWS FROM LENKURT ELECTRIC

VOL. 4 NO. 8 AUGUST, 1955

A Brief Description of the TRANSISTOR *and Some of Its Potentialities*

Although transistors are a comparatively new invention, they are beginning to play an important part in the electronics art. Moreover, it appears that this trend will continue in a manner even more rapid than the evolution of the vacuum tube.

This article has been prepared with the thought that a brief, not-too-technical discussion of the how and why of transistors and what they seem to offer for the future might be of timely interest.

One of the most dramatic developments which has taken place in the communications art since the advent of the vacuum tube is the discovery and evolution of the transistor. This device, which is now being used at a substantial and rapidly increasing rate, offers many new and important possibilities in circuit and equipment design. Among these are such things as small space requirements, marked economy in power consumption, ruggedness making for potentially long life and little, if any, maintenance.

In common with most other instrumentalities, particularly during the earlier stages of their development, the transistors now available also possess some disadvantages. Among these are sensitivity to temperature effects, variable characteristics, some limitations with respect to high frequency usage, limited load carrying capacity and susceptibility to noise effects. Notwithstanding their disadvantages, many of which will probably be overcome or reduced to tolerable proportions as the art progresses, transistors are being used satisfactorily in amplifier, oscillator, regulator and many other types of circuits. They are even being used as photosensitive devices.

Since the transistor is expected to become such an important instrumentality in the communications art, it is interesting to consider, briefly, what these versatile devices are and how they operate.

Characteristics

Transistors employ materials known as semiconductors. Among these are germanium and silicon crystals which, at present, are the principal materials used. Several types of transistors are derived

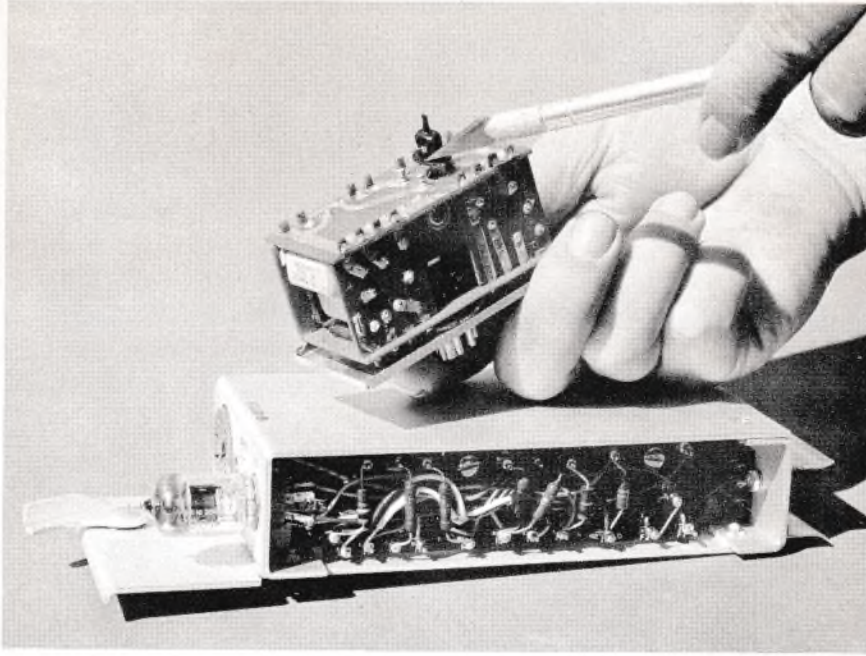


FIGURE 1. Experimental model of a transistorized, print wired, line amplifier compared to equivalent vacuum tube type. Pointer indicates transistor raised above its normal position.

from such crystals. These are the point contact, junction, field effect, intrinsic barrier and photosensitive types. Since it is not feasible to treat all of these in an article of restricted scope, the discussion which follows is confined to the junction transistor because it serves adequately for a generalized qualitative treatment of the subject.

In considering the operation of a transistor without going too deeply into the general subject of semiconductors and the realms of solid state physics, it is desirable to first call attention to certain related phenomena. In a state of purity semiconductors such as germanium are relatively nonconductive. However, when certain kinds of impurities are present and form a part of the crystal structure, it becomes a relatively good conductor. Moreover, the particular type or types of impurity present impart definite and important characteristics to the crystal.

If, for example, antimony or arsenic are present in a germanium crystal there will be an excess of electrons free to move about within the crystal structure. By virtue of the negative charges which they bear, current can flow within the crystal. Impurities which result in an excess of free electrons are known as "donors" and crystals containing such impurities are termed n-type.

The addition of a different type of impurity to a germanium crystal --aluminum or gallium, for example--results in a distinctly different situation. In this case, each impurity atom creates a positively charged region into which a free electron can flow. The acceptance of electrons by these regions in effect creates the flow of an electric current. Impurities of this type are referred to as "acceptors." Germanium crystals in which they are present are termed p-type.

Either type of crystal conducts current equally well in either direction. However, when a crystal contains both n and p regions within its structure, current can flow in one direction only. This accounts for the operation of the crystal detector used in the early days of the radio art. One detector crystal was more efficient than another because it contained impurities and therefore n and p regions to a greater or lesser extent. Although such crystals were conductive, they did not amplify.

Common Emitter Amplifier

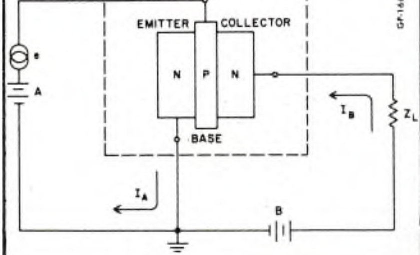
In the case of the junction transistor, amplification is obtained through the use of a crystal structure consisting of two layers of n-type material separated by an intervening thin layer of p-type crystal or two p-type layers separated by an n-type layer. In the first case the transistor is designated n-p-n; in the second p-n-p. Also, the outside layers are termed "emitter" and "collector," respectively. The intervening layer is referred to as the "base."

Figure 2 shows a greatly simplified amplifier circuit containing an n-p-n junction transistor. In the particular arrangement shown the input and output circuits are connected to the base and collector, respectively. Since the emitter connection is common to the input and output circuits, the arrangement shown is known as a "common emitter amplifier." Two other configurations, the "common base" and the "common collector" are also used, depending upon the particular manner in which the amplifier is required to function. The fundamental way in which the transistor itself operates is the same in all three cases. All of these configurations have their corresponding vacuum tube analogies.

Referring to Figure 2, assume for the moment that the voltage of the generator e is zero. Battery A causes a d-c current I_A to flow into the base and through the emitter, which is comparable to the cathode of a three-element vacuum tube. Under the influence of I_A and its negative biasing effect, a stream of electrons flows from the emitter into the base, which can be compared to the grid of a vacuum tube. Since the base is composed of a relatively thin layer of crystal of opposite type to that of the emitter, the electron stream from the latter passes through it and into the collector, which is comparable to the plate of a vacuum tube. The collector is receptive to the electron stream from the emitter because of the biasing effect of battery B upon it. Moreover, the flow of electrons in the collector permits the passage of a relatively large d-c current I_B through it and the load impedance Z_L.

Assume now that e (Figure 2), which is impressed upon the base, is not zero and that it is, for example, an a-c sine wave voltage. During its positive half-cycle, e will add to the voltage of battery A and subtract during its negative half-cycle. The potential of the base, with respect to the emitter, will vary in a like manner and cause the flow of electrons passing

FIGURE 2. Simplified Common Emitter Amplifier.



from the emitter to the collector, via the base, to vary with the instantaneous magnitude of e. As a result the current I_B and the power delivered to the load impedance Z_L have the characteristic wave form of e (which may be very complex in the case of speech) superposed upon them.

This indicates in a general way how the output of an n-p-n common emitter junction transistor can be made to have the characteristic wave form of the input through the action of the base as a control valve. At the same time, amplification takes place because small base power inputs can control relatively large amounts of power in the output circuit. As a result, the magnitude of the voltage variation across the output resistance Z_L can be many times greater than that of the variation in e.

A p-n-p junction transistor could have been considered in the preceding discussion with the same end result. However, the polarities of batteries A and B would have been reversed. Also conduction through the emitter and collector would take place by virtue of the flow of electrons into positively charged regions. Current flow through the base would result from an excess of free electrons within that portion of the structure.

Although the foregoing is true for purposes of generalization, the n-p-n and p-n-p transistors differ in detail with respect to each other. Different methods are used in their production. Moreover, n-p-n transistors are, at present, somewhat more adapted to high frequency usage, whereas p-n-p transistors possess potentially greater power dissipation characteristics.

Potential Benefits

While further progress in transistor technique is necessary before they can be applied as readily and as generally as vacuum tubes, they offer many advantages even now and they open up new horizons for the not-too-distant future.

Very substantial savings in power can be obtained with transistors in situations where their use is feasible. For example, a single tube amplifier employing a currently popular miniature pentode vacuum tube requires about 1300 mw of power for the plate circuit and 1000 mw for the heater circuit --a total of 2300 mw. The same amplifier using a transistor in place of such a tube would require only about 200 mw of power --a reduction of approximately 90 percent.

While the power economy potentially inherent in the transistor appears to be outstanding, it is enhanced by substantially reduced space and heat dissipation requirements because of its small size and ability to function without a heater circuit such as is commonly employed with a vacuum tube. These things facilitate simplified assemblies and tend to reduce couplings which are an important factor in circuit design, particularly at the higher frequencies.

Transistors are physically hardy and their characteristics appear to be subject to little change under the proper operating conditions. Consequently, they should tend to have indefinitely long life, particularly as production techniques improve. In addition they should require practically no routine maintenance testing such as is necessary with vacuum tubes.

Although transistors possess potential advantages, difficulties remain to be overcome to facilitate general usage. Among these are such items as temperature instability, more ready adaptation to high frequency applications, and the necessity for more uniform characteristics with quantity production. These difficulties have already been remedied to an extent which even now permits the limited use of transistors. Further improvements will undoubtedly be made as the art evolves. For example, silicon transistors, which are coming into use, are much better with respect to temperature effects.

The first transistors were comparable in price to the early vacuum tubes. However, transistor prices are decreasing as manufacturing techniques improve and production volume increases. At present one type of germanium transistor costs $1.95 as compared to a high quality vacuum tube (which it could replace) priced at $3.00. Another type of transistor is still in the $10 class. However, volume use is expected to reduce its price to a point comparable to a commercial type vacuum tube. In the long run the price may be even less.

A further and equally important factor in cost reduction through the use of transistors is the simpler circuitry required. This is of particular interest in relation to the future possible uses of printed wiring, a technique which is being considered carefully in Lenkurt's plans for the future.

In common with other segments of the electronics industry, Lenkurt's development program is directed toward the use of transistors and printed wiring to the extent desirable and as rapidly as it becomes practicable to utilize them. As a part of this program an experimental model of a transistorized and print wired signal oscillator has already had an extensive field trial. Further applications of a similar nature to channel units, regulators and line amplifiers (see Figure 1) are among the things being investigated actively with a view to making better communication equipment available to the industry.

Conclusion

If present indications are born out--and there appears to be no reason why they should not be--transistors can be expected to play an increasingly important role in the communications art. In addition to being somewhat spectacular, as most epoch-making inventions usually are in their early stages, transistors can be expected to bring about, over a period of time, marked economy in the first cost, maintenance and operation of electronic equipment.

THE COMPANDOR

Some Special Applications

A compandor, such as Lenkurt's Type 5090B, is most frequently thought of as a device for reducing the effects of noise and crosstalk. While this is usually the primary function of a compandor, it can also be employed as a power-limiting device to reduce possible overloading effects and, with certain limitations, to provide additional gain.

The general characteristics of the 5090B compandor were described in the March, 1953, issue of The Demodulator. As outlined there, a compandor consists of two main elements. One of these is known as the compressor; the other as the expandor. These elements, together with their general arrangement, are shown in Fig. 1.

In the operation of the compandor, the compressor can receive a relatively wide range of input power and compress it into a much narrower range before transmission to the line. As indicated in Fig. 2, power inputs of magnitudes above a given value, referred to as the focal point, are subjected to a loss, whereas power inputs below that value are amplified. Thus the compressor acts as a limiting device for all levels of power above the focal point and as an amplifier for power levels below the focal point. In either case the incremental output is one-half of the incremental input, with respect to the focal point of the compressor.

As shown in Fig. 1, the compressor of the 5090B compandor contains a variable loss pad which, by optional strapping, can be omitted or inserted in either the input or the output portion of the circuit. This pad, whose loss can be varied from 7.5 to 25 db, is usually employed to adjust the compressor for a nominal 0 db overall gain with respect to the desired focal point, which is -11 dbm in the case of -16 db level inputs. When the pad is inserted in the compressor output and adjusted for 12 db loss, the compressor output is -11 dbm for the same input and -13.5 dbm for a -16 dbm input, a gain of 2.5 db.

Available Gain

If, in the example given above, the pad is omitted, the focal output of the compressor will be +1 dbm and a -16 dbm input will result in an output of -1.5 dbm, a gain of 14.5 db instead of 2.5 db with respect to the -16 db input. The gains obtained with various magnitudes of input power, without any pad loss, are:

Input - dbm	Output - dbm	Gain - db
-13	0	13.0
-16	-1.5	14.5
-19	-3.0	16.0
-23	-5.0	18.0

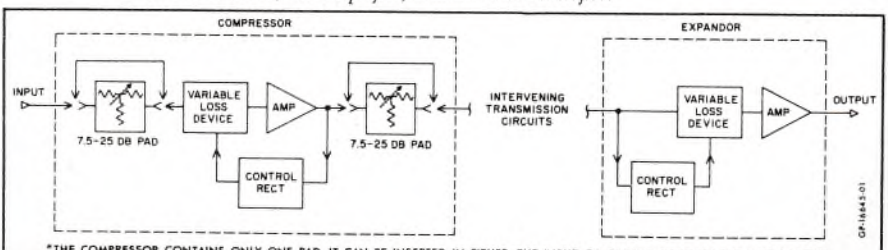
The practicability of realizing all or a portion of the available compressor gain depends upon the compressor output level desired, the location and adjustment of the compressor pad or any other pads which are or can be made available for the purpose and upon the following limitations:

1. The test power level input to vario-losser (see Fig. 1) should not be higher than -13 dbm or lower than -23 dbm.
2. The test power level at the compressor output should be such that, with any net gain from that point to the expandor, the input to the latter will not be higher than +10 dbm.

A Typical Example

Fig. 3 shows, schematically, an arrangement employed recently for channelizing a radio system in which the 5090B compandor was used as a power limiting and gain device. As indicated, a terminating set consisting of a hybrid coil and associated pad was used to provide for 4-wire transmission and reception at the compres-

FIGURE 1. Block diagram of a compandor. Both compressor and expandor consist of a variable loss device, an amplifier, and a control rectifier.



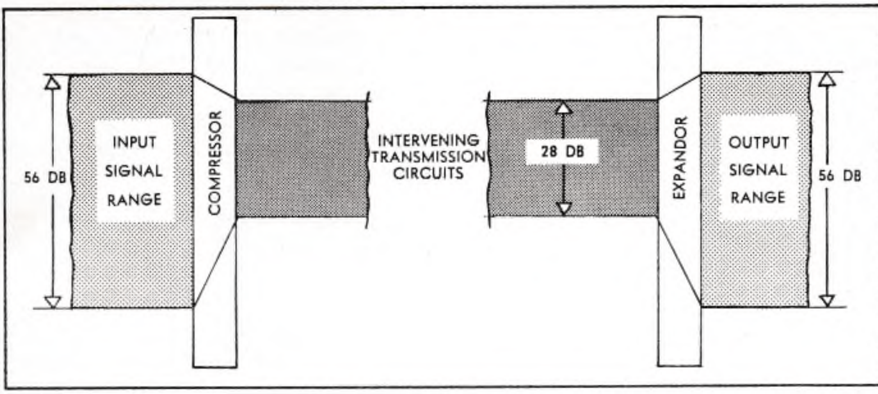


FIGURE 2. Compression and expansion of various signal intensities in a typical compandor for telephone applications. The compressor is at a −16 db level point. The expandor is at a +7 db level point.

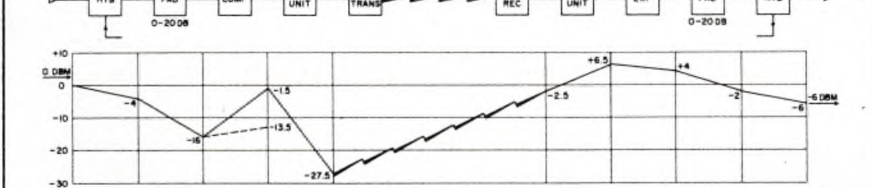
sor input and expandor output, respectively.

With the terminating set pad and compressor adjusted for the usual input and output levels, as shown by the dotted line in the level diagram of Fig. 3, the test power level at the compressor output is -13.5 dbm or +2.5 db above the input. Under this condition the pad in the compressor would be located in the output portion of the circuit and would be adjusted for a loss of 12 db.

The transmitting channel terminal used in this particular arrangement requires a -4 db input level, which corresponds to a test power level of -1.5 dbm. As adjusted initially the compressor output level is 12 db lower. Instead of providing 12 db gain, by adding an amplifier, for example, the pad in the compressor output can be removed. The compressor output is then -1.5 dbm, as required by the channel input. The carrier and radio channels are lined up to give the required levels at the various points shown in Fig. 3 and the pad in the terminating set at the receiving end is adjusted to give the desired receiving level, that is, -6 dbm at a -6 db level in this instance.

There are, of course, a number of details involved in the special use of compandors. Individual cases require specific consideration with respect to the desired levels, the gain available and the pad arrangements which can be employed for the purpose. Information of this character can be obtained readily through Lenkurt's distributors.

FIGURE 3. A channel arrangement and levels, in one direction of transmission, with compressor used as a gain and power limiting device.



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Editor . . . . P. C. DeMuth

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