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Technical Memorandum

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196-54-51

BEHAVIOR OF TRANSISTORS IN A MAGNETIC FIELD (Supplement to 151-54-51)

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ABSTRACT

Experiments are described which show that the characteristics of both junction and point-contact transistors can be varied and controlled by passing magnetic fields through them. The gain of an amplifier can be controlled, and the amplitude of fixed frequency oscillator modulated by means of passing a magnetic field through the transistor. *(auth)*

These experiments follow those discussed in a previous article on the same subject, TM 151-54-51.

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BEHAVIOR OF TRANSISTORS IN A MAGNETIC FIELD (Supplement to TM 151-54-51)

Introduction

A previous article ^{1/} discussing transistors operating in a magnetic field was concerned only with point contact transistors. Also, the oscillators discussed were not necessarily sine wave generators. The experiments discussed now concern both junction and point contact transistors, employed as a sine wave generator and as an amplifier.

Junction Transistor Oscillator Amplitude Modulated by Magnetic Fields

A sine wave generator (oscillator) was constructed as shown in Fig. 1.

Fig. 1

Movement of the permanent magnet about the transistor caused amplitude control, or modulation of the output signal according to the following two effects:

Effect 1. Constant Flux Amplitude, Rotating Position. -- With a magnetic flux of fixed strength, the amplitude of the signal generated by this transistor oscillator varies in accordance with the angular position of the transistor in relation to the direction of the flux flowing through it.

Effect 2. Varying Flux Amplitude, Fixed Position. -- With the transistor and magnetic field direction in fixed positions, varying the strength of the field causes the amplitude of the signal generated to vary in accordance with the strength of the magnetic field flowing through the transistor.

^{1/} Behavior of Transistors In A Magnetic Field, Sandia Corporation, TM 151-54-51, August 11, 1954

Fig. 2

Figure 2 represents the physical arrangement of the transistor and permanent magnet for the circuit shown in Fig. 1. A permanent magnet with polarity in the position shown, ie, with the field from left to right (north to south) through the transistor, causes the amplitude of the oscillator signal to decrease (say by 50 percent for a field of 500 gauss) from its amplitude with no magnetic flux. Then, at a transistor-magnet position 90 degrees from that shown, ie, flux flowing through the transistor perpendicular to the plane of the leads, the magnetic field has practically no effect on the oscillator output. A transistor-magnet position relationship 180 degrees from that shown, ie, with flux flowing through the transistor from right to left, causes the amplitude of the oscillator output to increase (say by 50 percent for 500 gauss). Thus, reversal of a magnetic field through the transistor causes upward and downward modulation of the oscillator signal amplitude.

By proper selection of circuit values and magnetic field strength the amplitude of oscillator output can be varied smoothly from minus 100 percent to over plus 100 percent.

For an interesting effect, the value of R_1 (Fig. 1) can be adjusted so that the circuit will be nonoscillating with no magnetic field applied. Then, application of a magnetic field in a direction opposite to that pictured in Fig. 2 will bring the circuit into oscillation, the amplitude depending on the strength of the field. Thus we can pulse the output of a fixed frequency oscillator by intermittent application of a magnetic field to the transistor. A relay could be operated in this same manner.

Transistor Amplifier With Magnetic Gain Control

The oscillator just described (Fig. 1) is simply an amplifier with positive (in-phase) feedback. Thus it seemed evident that the gain of a transistor amplifier could be controlled by the application of a magnetic field to the transistor. The experiment proving this was perhaps the most impressive of all.

Fig. 3.

Fig. 4.

The circuit is shown in Fig. 3, this one, for the sake of variety, employing an RCA 2N32 point contact transistor.

With no magnetic field applied to the transistor, the amplifier has a gain of approximately 10. With a magnetic field of 1000 gauss applied as shown in Fig. 4, the gain drops to 5. With the magnetic field reversed, the gain rises to 20.

The gain of this amplifier is essentially flat from 200 cycles to well over 500 kilocycles, and the effect is the same throughout the entire frequency range.

Besides being a novel method of gain control, the small magnet necessary is certainly more economical than the potentiometer it replaces, not to mention the fact that there is nothing to wear out, no sliding (noisy) contacts, and no solder connections necessary. The gain control is simply a magnet, rotated about the transistor employed as an amplifier.

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Revival of Ruined Transistors

An interesting result was obtained when a transistor, previously "ruined" by an accidental transient over-voltage (sure tragedy for any transistor), was placed in the circuit (Fig. 3) and exposed to a magnetic field. The transistor, inoperative with no magnetic field, was again brought into operation and near normal gain by application of a magnetic field in the direction for upward gain (Fig. 4). This experiment was duplicated with another transistor and similar results were observed.

Conclusions

The gain characteristic (α) of transistors is apparently affected according to the strength and the polarity of a magnetic field caused to pass through the transistor. This was demonstrated by the "ruined" transistor experiment as well as by the other experiments. This transistor, in its "ruined" state, had an amplification factor of near zero. However, the application of a magnetic field of proper polarity caused the amplification to rise to a useful value (as long as the field remained).

Circuit parameters are, of course, important in any application of the magnetic effect. A transistor, operating in a circuit designed to yield maximum theoretical gain, does not have its gain further increased by the application of a magnetic field. But the parameters of such a circuit, ie, to yield maximum gain, are often impractical, whereas the gain of a transistor oscillator or amplifier, in a practical circuit, can be increased or decreased by magnetic fields as described.

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