XI. TRANSISTOR CIRCUITS

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A. INTRODUCTION

The transistor circuit research is aimed at problems of general interest in communication engineering. Fundamental principles of transistor circuit design and practical limitations imposed by available devices are being investigated for circuits useful in a wide variety of applications.

Present studies include work on sweep generators, temperature effects in dc amplifiers, and methods of stabilization. A miniature refrigeration unit is under development for stabilizing temperatures of critical circuits.

The study of noise in semiconductors is a closely related program.

H. J. Zimmermann

B. BIAS STABILIZATION OF JUNCTION TRANSISTORS

Since one of the most serious problems encountered in the application of junction transistors to ac amplifiers is the drift of the operating point with temperature, a study has been made of various methods of reducing this variation of the operating point. The major portion of the variation is caused by the temperature dependence of the saturation current (I_{co}). The simplest means of achieving bias stabilization employs reactive elements. These reactive elements cause the transistor to be in a grounded-base connection for bias currents; in grounded-emitter or grounded-collector connection for ac signals. Several methods of achieving bias stabilization have been studied and will be presented in a future technical report.

C. R. Hurtig

C. TEMPERATURE CONTROL

In many circuits where transistors and germanium diodes are employed, a satisfactory dynamic range cannot be achieved if the ambient temperature range is large. Since, in a number of applications, the tolerances allowed, for obtaining a satisfactory dynamic range, are greater at lower mean values of the controlled temperature, a study of methods of achieving temperature control at low temperatures has been started. Initial work has been aimed at

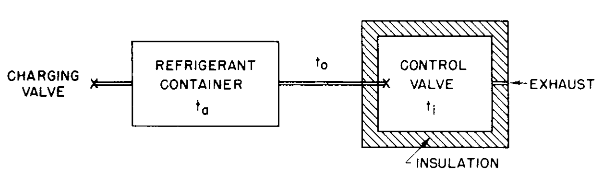

Fig. XI-1
An open-loop system.

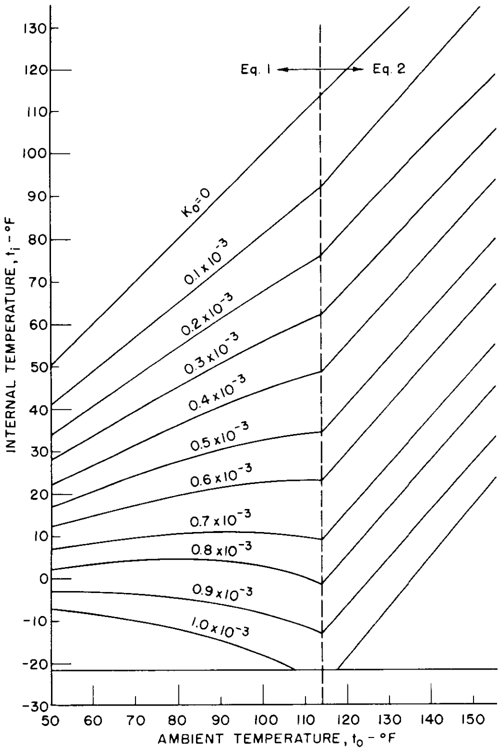

Fig. XI-2

Plot of t_i vs t_o for values of K_o.

a temperature control of ± 3°F at a mean value of 30°F. The units to be controlled are assumed to dissipate power of the order of 50-100 mw. The cooling system must satisfy three requirements: small power input, small physical size, and the temperature control mentioned above.

A simple method of obtaining a cooling device is to expand a refrigerant through a control valve. An open-loop system, employing this method, was designed. It is shown in Fig. XI-1. This system has a limited operational time, but requires zero work input during expansion of the refrigerant.

With component power levels of the order of 100 mw, the greatest heat source is conduction through the insulation surrounding the components. For a given ambient temperature (t_a), the internal temperature (t_i) will be a function of the cross-sectional area of the expansion valve. An analysis for finding the steady-state relation between t_a and t_i was made by means of a heat balance for the system. Expressing the variables in terms of t_a and t_i, the following approximate relation was obtained.

$$(t_a - t_i)^{5/4} = K_o \left[1.2\, t_a^{3.7} + 380\, t_a^{1.9} + 1800\, t_a^{1.8} + 560{,}000\right]^{1/2} (70.9 - 0.088\, t_a) \tag{1}$$

This relation agreed with the data in the lower range of ambient temperature, but not at the higher values. It was believed that the fluid flow was reaching a "choked" or maximum rate. Equation 1 was modified to account for a constant or "choked" condition, with the following result applicable above 114° F.

$$t_i = t_a - \left[K_o'(70.9 - 0.088\, t_a)\right]^{4/5} \tag{2}$$

where K_o and K_o' are constants that express system dimensions, area of the valve opening, and conversion factors. A family of curves for different valve openings, or K_o values is shown in Fig. XI-2. Experimental values of K_o agree with calculated values; values of K_o' are empirical. Test runs, covering a large part of the operating region, were made. In general, the results confirmed the theoretical values.

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D. TRANSISTOR SAWTOOTH GENERATOR

A study of methods of generating sawtooth waveforms has been started. One method, employing junction transistors, appears capable of providing high-current waveforms. This method employs a junction transistor operated in the grounded-emitter connection. The collector load consists of an inductance and resistance. Upon application of a square waveform of current to the input, the collector diode may be switched to provide an exponential variation of current in the inductance.

Particular attention has been focused on the factors that govern the rise-and-fall characteristics of the current waveform. The factors that control these characteristics are: the size of the inductance, the collector capacitance, the current gain, and the cutoff frequency. To generate high-frequency sawtooth waveforms, the size of the inductance is usually small, with the result that the resonant frequency of the LC combination is much larger than the frequency cutoff of the grounded-emitter connection. Thus, the latter determines the decay time of the waveform. To obtain long-sweep durations, large inductances are employed. The maximum length of sweep obtainable is limited by the inductors. The decay time of such sweeps is limited by the resonance of the inductance and collector capacitance.

The use of a grounded-emitter connection yields high current gain. With commercially available transistors current gains from 10 to 100 may be readily obtained. Furthermore, many transistor types nominally rated at 5 ma are capable of conducting at least 17.5 ma if the collector dissipation is kept below maximum ratings. Four transistors have been paralleled to yield a maximum sweep current of 70 ma with a current gain of approximately 12.

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