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SESSION IV

Friday, 2:30 p.m. - 5 p.m.

Nonlinear Applications of Junction Transistors

Chairman: A. W. Lo, *RCA Laboratories, Princeton, N. J.*

15. Large-Signal D-C Behavior of Junction Transistors

J. J. Ebers and J. L. Moll, *Bell Telephone Laboratories, Murray Hill, N. J.*

The d-c behavior of junction transistors when operated in large-signal applications, notable among which is switching, has been found to be expressible in analytic form, making possible quantitative design of large-signal circuits. Junction transistors, when operated as a switch, can perform many functions, some of which cannot be done by any other known electronic device. Junction transistors can be designed to have the characteristics required by specific switching applications. These factors, circuit designability, versatility, and device designability, make junction transistors particularly appealing for large-signal applications.

Even for the most generalized junction transistor in which practically no restrictions are placed upon the geometry, the d-c behavior in all regions of operation is given by the equations

$$I_E = a_{11} [\exp (q\varphi_E/kT) - 1] + a_{12} [\exp (q\varphi_C/kT - 1]$$

$$I_C = a_{21} [\exp (q\varphi_E/kT) - 1] + a_{22} [\exp (q\varphi_C/kT - 1],$$

where φ_E and φ_C are the junction potentials. Thus the transistor can be considered as a two-terminal-pair network and the behavior is specified by measurement of the a's. It has been shown that even for the most general cases $a_{12} = a_{21}$, which means that in the large-signal sense, junction transistors are bilateral. It can be shown that the a's are related to the two reverse saturation currents of the junctions and the two current gains or alphas (the normal alpha and the inverted alpha). Because of the bilateralism, only three of these quantities completely specify the a's.

The equations given above lead to equivalent circuits which are applicable in each region of operation. To take into account departures from the ideal transistor, additional circuit elements can be added to the equivalent circuit.

Measurements taken on transistors having various geometries show that the equations and equivalent circuits which have been formulated accurately describe the large signal behavior. Circuit examples have been worked out which demonstrate the utility of the theory.

(about 3 p.m., Friday)

16. Large-Signal Transient Behavior of Junction Transistors

J. L. Moll, *Bell Telephone Laboratories, Murray Hill, N. J.*

The large-signal transient behavior of junction transistors is presented in terms of equivalent circuits applicable to each region of operation. When the transistor operating point is in the active region, the equivalent circuit parameters change slowly with operating point. The part of the transient which corresponds to operation in the active region can therefore be analyzed by using the conventional equivalent circuit and standard methods of circuit analysis.

The transient behavior in the current saturation region can be described by adding several new circuit elements to the equivalent circuit. Particular attention is given to the transition between the active region and the current saturation region. A method is given for calculating the time when the transition occurs. Theoretical expressions are given for the times of transition into and out of the current saturation region for step function driving currents.

Equivalent circuit parameters of primary importance in determining the transition times are α_N, ω_N, α_I, and ω_I. The subscripts N refer to nomal active-region equivalent circuit parameters and the subscripts I refer to active-region equivalent circuit parameters with emitter and collector interchanged.

(about 3:30 p.m., Thursday)

7. Neutralization of Transistor Bandpass Amplifiers

F. P. Keiper, Jr., *Philco Corp., Philadelphia*

This paper will discuss the utilization of surface-barrier and junction transistors in bandpass amplifier circuits.

The equivalent circuits useful in bandpass amplifier design will be presented and the difficulties encountered in the circuits will be demonstrated. These include input and output circuit tuning interaction, instability and oscillation.

A novel neutralizing circuit requiring but two additional components to form a bridge with r'_b and C_c as two arms to eliminate the aforementioned difficulties will be discussed and practical circuits presented. The previous equivalent circuit will be extended to include in one equivalent circuit the transistor and the neutralizing network and expressions will be derived for the terminal impedances and available gain of the neutralized transistor amplifier. These expressions will illustrate the relative importance of the various parameters of the transistor in this application.

(about 3:50 p.m., Thursday)

8. Some Thoughts on Feedback in Transistor Circuits

S. J. Mason, *Research Laboratory of Electronics, M.I.T., Cambridge, Mass.*

A linear transistor model (or other linear two-terminal-pair device) is imbedded in a lossless passive network N and the properties of the complete system, as measured at two specified terminal pairs, are described by the open-circuit impedances Z_{11}, Z_{12}, Z_{21}, Z_{22}. The quantity

$$U = \frac{|Z_{21} - Z_{12}|^2}{4(R_{11}R_{22} - R_{12}R_{21})}$$

where R_{jk} is the real part of Z_{jk}, is defined as the unilateral gain of the transistor. Quantity U is independent of the choice of N and is (consequently) invariant under permutations of the three transistor terminals and also under replacement of the open-circuit impedances by short-circuit admittances. If U exceeds unity at a specified frequency, then N can always be chosen to make R_{11} and R_{22} positive and Z_{12} zero at that frequency. Quantity U is identifiable as the available power gain of the resulting unilateral structure.

An arbitrary coupling network may be decomposed into a portion which accomplishes unilateralization and a remaining complementary portion which provides feedback around the unilateralized structure. Such decomposition brings some of the methods of elementary feedback theory to bear upon nonunilateral circuit problems and offers a viewpoint from which signal flow and power flow can be simply related.