The previously introduced concept of hole conduction, augmenting the familiar vacuum-tube theory of electron flow, explains the peculiar behavior that has been called transistor action. Since the transistor differs from the vacuum tube in principle of operation, it logically follows that vacuum-tube circuits must be revised for proper operation of the transistor.

A guide to all circuit revisions is the fact that the transistor is current-operated, not voltage-operated. A reasonable starting point, therefore, is the replacement of the constant-voltage source of the vacuum tube with a constant-current source. In fact, this principle may be extended to the entire circuit by replacing elements having certain voltage characteristics with elements having equivalent current characteristics. This method of approach, in many cases, will result in workable transistor circuits.

The applications illustrated in this section provide an introduction to transistor circuitry. Transistors are shown in basic amplifier, oscillator, and preamplifier circuits. Also included are hearing-aid and radio-receiving circuits which employ transistors.

BASIC TRANSISTOR CONNECTIONS

with Vacuum-tube Analogy . . .

The three basic transistor connections and their particular characteristics are illustrated in Figure 3. These characteristics apply to both point-contact and junction types. To one familiar with vacuum-tube circuitry, the analogy of the basic transistor connections with equivalent vacuum-tube connections provides a helpful introduction to transistor applications.

Throughout the applications section, the P-N-P transistors are illustrated; consequently, this discussion of the basic connections of the transistor will be restricted to the P-N-P type configuration. It may be stated in passing, however, that the P-N-P and N-P-N type transistors differ only in the polarity of the voltages applied to the collector and emitter. As was previously stated, the voltage applied to the collector of the P-N-P transistor (either point-contact or junction) is opposite in polarity to the voltage applied to the corresponding element (the plate) of the vacuum tube.

In addition to d-c voltages, the circuits in Figure 3 indicate the current directions which apply to both the point-contact and junction transistors. Base current, which is the difference between the emitter and collector currents, is not indicated in these diagrams, because its direction is not the same for both transistor types. In the point-contact transistor, the base current flows into the base; whereas in the junction transistor, the base current flows out of the base.

The grounded-base connection in Figure 3a is analogous to the grounded-grid circuit of the vacuum-tube triode. No phase
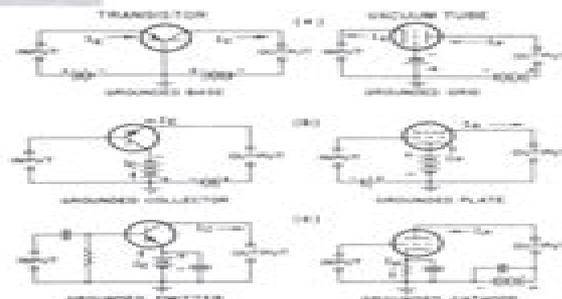

Figure 3 — Basic connections for point-contact and junction transistors with equivalent vacuum-tube circuits.

reversal occurs between the input and output of this circuit; and the common base resistance acts as a regenerative feedback path. Except in oscillator applications, this condition is not desirable and can be minimized by keeping the base resistance at a low value. Low input impedance, high output impedance, and moderate power gain are characteristics of the grounded-base connection. A disadvantage of this circuit is the necessity for two d-c sources.

The second transistor connection is the grounded-collector circuit in Figure 3b. Similar to the grounded-plate connection of the vacuum tube, this circuit has the peculiar characteristic of producing a phase reversal in one direction and none in the reverse direction. The input impedance is high and is dependent upon the load. Low output impedance and low power gain are further characteristics of this circuit.

The third connection, the grounded-emitter circuit in Figure 3c, corresponds to the grounded-cathode circuit of the vacuum tube. This circuit, probably the most popular of the three, provides a higher input impedance and lower output impedance than the grounded-base circuit. A transfer phase shift of 180° is produced with this connection. It has the further advantage of giving the highest power gain, with only one d-c source.

SINE-WAVE OSCILLATOR . . .

One of the many possible transistor oscillator circuits is shown in Figure 4. The conditions necessary for oscillation in transistor circuits are stated by the equation: $\alpha_{oe} - 1 \geq \dfrac{r_e + Z_e}{r_b + Z_b}$, where the characteristic α_{oe} is the current gain of the circuit. For practical applications, α_{oe} may be considered dependent upon the external collector impedance Z_c. The quantities r_e and r_b represent the resistances of the transistor emitter and collector respectively.

For a given transistor, the external impedances Z_e, Z_b, and Z_c are the only variables that can be adjusted to satisfy the above equation. Oscillations are achieved, therefore, by making Z_e small, Z_b large, and Z_c small (or large α_{oe}).

The frequency of oscillation is controlled by means of a resonant

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