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HILO—An Improved Transmission Scheme for Semiconductor Switching Networks

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I. INTRODUCTION

Foremost among the problems in semiconductor switching network implementations is the difficulty of fabricating a semiconductor crosspoint which duplicates the characteristics of metallic crosspoints of nearly zero "on" impedance. A low crosspoint impedance is necessary for low signal loss through the switching network.

A transmission technique is described in this paper which relieves the requirement for low crosspoint "on" impedance and which allows excellent voice-band transmission characteristics with unbalanced semiconductor switching networks. The technique called HILO converts voltage inputs to the network into current changes using a high input impedance current source and transmits the current changes through the network crosspoints by modulating the network bias current. A low output impedance is provided at the networks receiving terminal, where the modulated currents are decoded to recover normal voltage-current levels.

II. CURRENT TRANSMISSION

The ac equivalent of the HILO current transmission circuit is shown in Fig. 1. Assuming idealized transistor characteristics (zero emitter impedance, infinite collector impedance, and unity α), an input signal e_i controls the current source, Q_1, converting the input into a current change $i = e_i/R_i$. The current change is transmitted through a network path and is supplied as an input to a common base amplifier, Q_2, at the receiving terminal. The recovered output is given by

$$e_0 = iR_0 = R_0/R_i e_i . \quad (1)$$

Although equation (1) assumes idealized transistor characteristics to

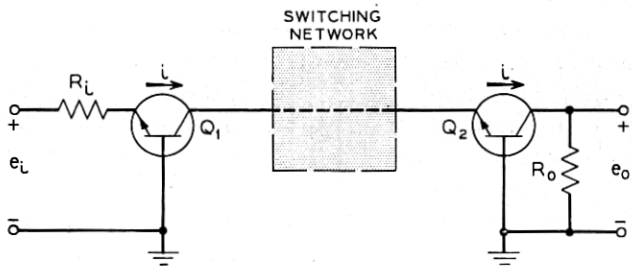

Fig. 1 — Current transmission circuit for switching networks (assume $\alpha \to 1$).

keep the exposition simple, the equation remains reasonably valid for voice-band applications using Darlington transistor pairs and normal (600-ohm) transmission impedance levels.

Because information is transmitted only as a current change within the switching network, crosspoint resistance and crosspoint nonlinearities do not impair the characteristics of the recovered signal. Recovered transmission level becomes primarily a function of R_i and R_0. As a result, network gain (loss) characteristics can be accurately controlled.

In addition to providing good signal transmission capability, the technique allows nearly ideal isolation between network paths. Capacitive crosstalk is minimized because only a small voltage change is produced within the network transmission path as a result of the transmitted current changes. This is the result of a low input impedance at the common base output stage and the result of relatively low series resistance of the network crosspoints.

Inductive crosstalk is reduced because the high output impedance of the current source driver makes the transmitted currents relatively insensitive to inductive coupling between network paths.

III. BIASING, TRANSMISSION, AND CONTROL

As an example of current transmission, Fig. 2 illustrates the biasing, transmission, and control circuitry necessary for operating an unbalanced thyristor network. Only a single direction of transmission is shown. For a bidirectional connection, a second, identical circuit is required.

To establish a connection through the network, a CONNECT signal is applied at the transmit terminal. The signal sets the control flip-flop, thereby turning off Q_1. As a result current source transistors, Q_2 and Q_3, become forward biased. The CONNECT signal also saturates Q_4 which allows Q_2 and Q_3 to saturate during selection.

Next, appropriate thyristor base selection lines are pulsed simultaneously to form a path through the network stages. Crosspoints are activated when the selected current path appears at the cathode terminal and when a thyristor selection control signal is applied at the base terminal. Thus, thyristors turn on in sequence starting with the stage nearest the network input terminal.

Holding current for the crosspoints is supplied through thyristor base terminals of successive stages until a path has been established from the transmitting to the receiving terminal. At this time, appropriate holding current is supplied through Q_5 and Q_6 and thyristor selection inputs may be terminated. Finally, the CONNECT input is removed, causing Q_4 to turn off and forcing Q_2 and Q_3 to function as a current source.

Supply voltage V_2 is selected to set the level of the current source collector voltage (Q_2 and Q_3) at a higher potential than the thyristor base selection inputs. This prevents faulty connection to already active network paths.

A network path is disconnected by applying a DISCONNECT input to the control flip-flop. This causes Q_1 to saturate, terminating the current flow in the network path and thereby tearing down the connection.

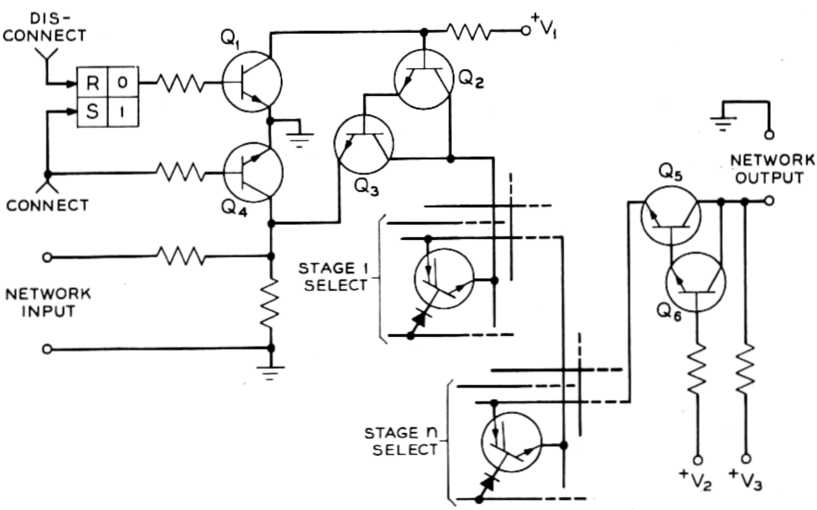

Fig. 2.—Thyristor network using current transmission.

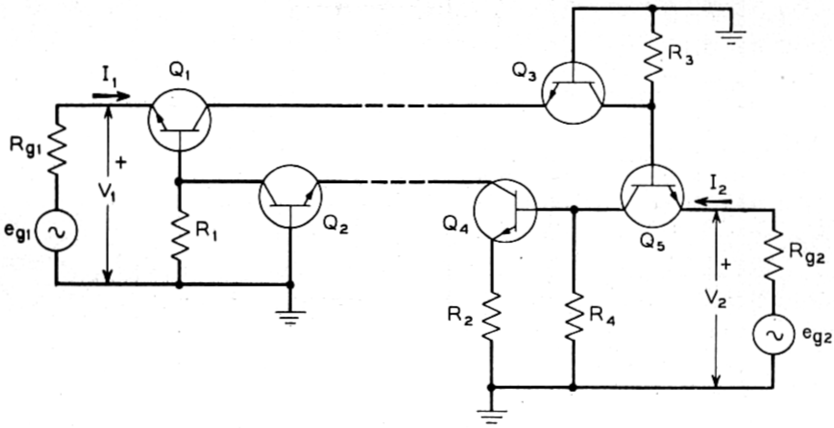

Fig. 3—Combined hybrid and transmission gate (assume $\alpha \to 1$).

IV. COMBINED HYBRID AND TRANSMISSION CIRCUIT

A loss-less electronic hybrid can be combined with the transmission and biasing circuits to convert two unidirectional transmission paths in the switching network to bidirectional transmission paths at the network terminals. Figure 3 shows the ac equivalent of the hybrid circuit.

Currents appearing at the emitter of Q_1 are transmitted to the emitter of Q_5 via Q_3 ; whereas, currents at the emitter of Q_5 are transmitted to Q_1 via Q_4 and Q_2 . Inverter stage Q_4 is necessary for proper phase relationship in the transmission loop. The circuit can be described by the following z-parameters

$$\begin{bmatrix} V_1 \\ V_2 \end{bmatrix} = \begin{bmatrix} 0 & -R_1R_4/R_2 \\ R_3 & 0 \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \end{bmatrix}. \tag{2}$$

Consequently,

$$V_2 = \frac{R_2R_{g2}}{R_1R_4} V_1 \tag{3}$$

and

$$V_1 = -\frac{R_{g1}}{R_3} V_2 . \tag{4}$$

The input impedance at the two input terminals is given by

$$Z_1 = \frac{V_1}{I_1} = \frac{R_1R_3R_4}{R_2R_{g2}} \tag{5}$$

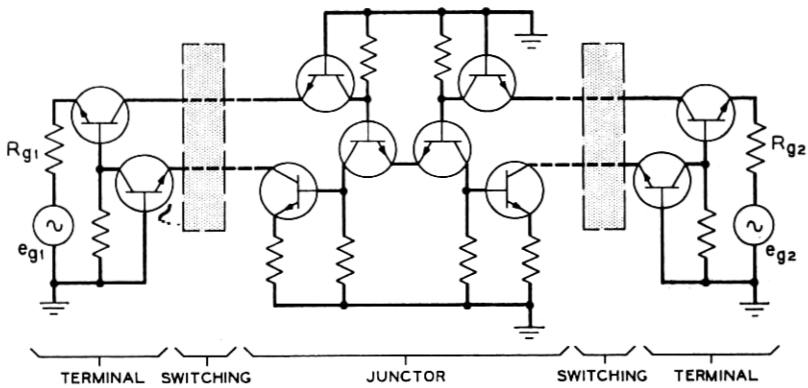

Fig. 4 — Combining two hybrid-transmission circuits in a switching network.

and

$$Z_2 = \frac{V_2}{I_2} = \frac{R_1R_3R_4}{R_2R_{g1}}. \tag{6}$$

To cancel the inverse effect of R_{g1} and R_{g2} on input impedance two identical circuits are cascaded between network terminals. Assuming R_1, R_2, R_3, and R_4 of the circuits are identical, the circuit acts as a gyrator and termination impedances are reflected through the network to the input terminals such that

$$Z_1 = R_{g2}, \qquad Z_2 = R_{g1}. \tag{7}$$

For symmetry, two stages are connected as shown in Fig. 4 to form a switching network with unidirectional network paths and bidirectional network terminals.

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