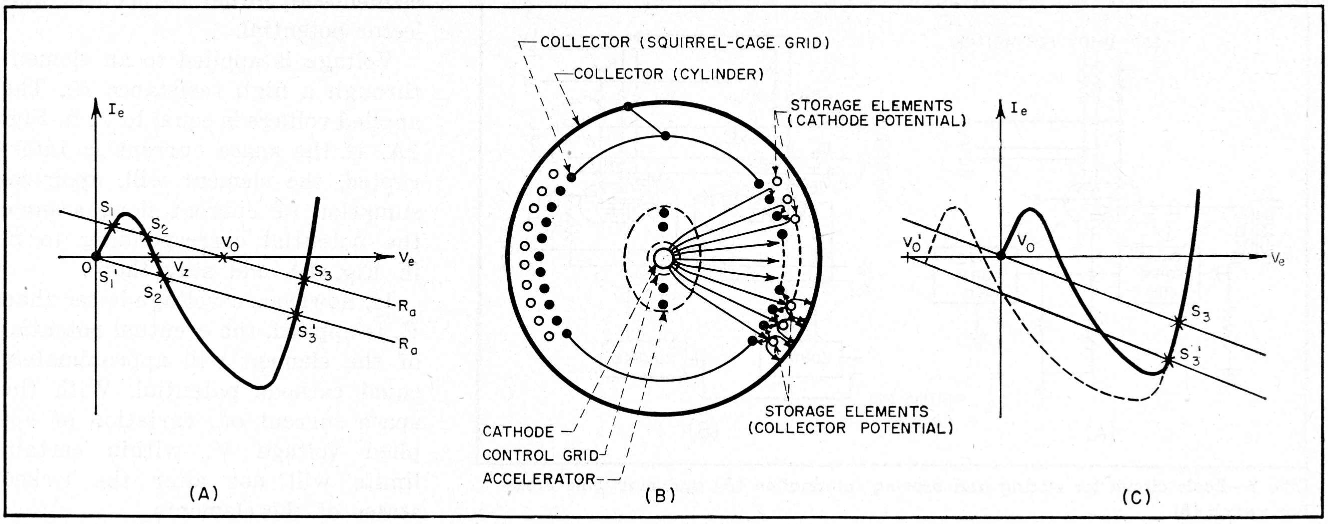

FIG. 1—Voltage-current characteristic of secondary-electron emitting surface illustrating negative slope (A), plan view of storage tube elements (B) and effect of sharply reduced cathode potential (C)

Storage Tube Employs Secondary Emission

Electronic storage tube having twenty secondary-electron emitting elements between its anode elements stores binary data in all-electronic telephone system. Circuit performs cross-bar switching function. Tube can be used in pulse-position modulation systems

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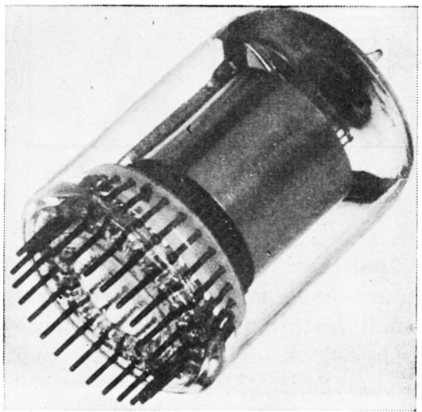
During development of an all-electronic telephone system a simple reliable storage tube was developed to meet specialized demands.

The tube makes use of the negative slope of the current-voltage characteristic of a secondary-electron emitting surface. See Fig. 1A. This surface is connected through a high resistance R_a to a positive voltage V_o, which is so high that the resistance line of R_a intersects the characteristic of the surface in three points S_1, S_2 and S_3. Only points S_1 and S_3 will correspond to stable states. Thus information can be stored on the emitting surface in a binary code.

The memotron, depicted in Fig. 1B, is a modified thermionic tetrode containing twenty secondary-electron emitting elements. The primary electron current (space current) emitted by an indirectly heated oxide cathode is controlled by a control grid and then accelerated by a second grid. The anode of the tube comprises a squirrel-cage grid and metal cylinder. These are electrically connected. The 20 storage elements are arranged in the annular space between the two anode elements. Each storage element has its own head which is brought out through the vacuum envelope as shown in the photograph. Thus all elements are separately accessible.



View of tube envelope. Note cylindrical anode and separate pins corresponding to the secondary-electron emitting storage elements

The resistance between elements at a potential corresponding to S_3 and the collector is low—between 10,000 and 100,000 ohms in practical tubes. The resistance between the elements at a potential corresponding to S_1 and the collector is

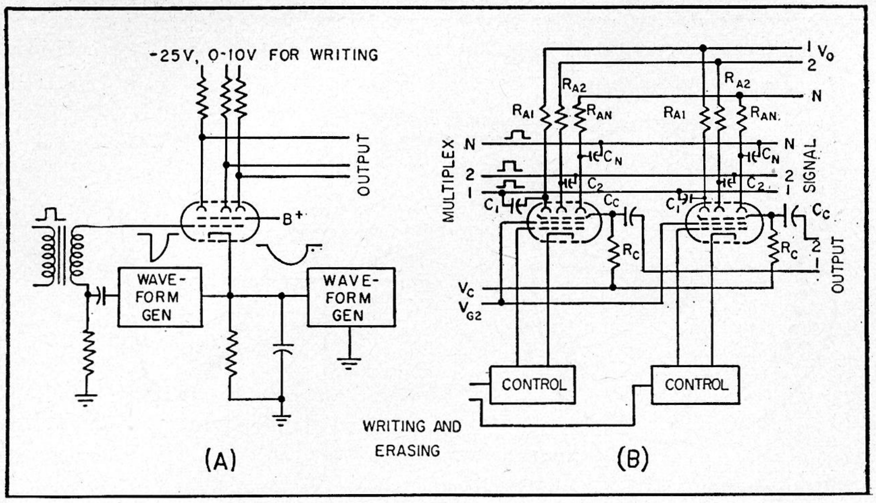


FIG. 2—Basic circuit for storing and erasing information (A) and electronic crossbar switch (B)

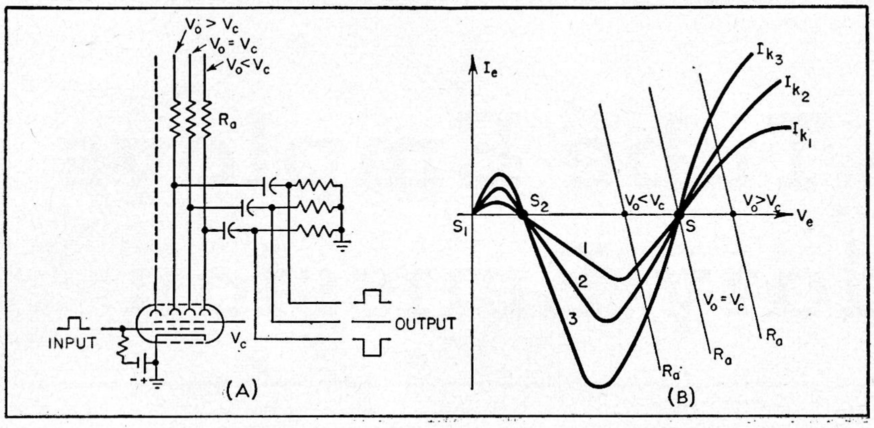


FIG. 3—Basic circuit connection (A) and emitting surface characteristics (B) illustrating how tube can be used to change polarity of input signal

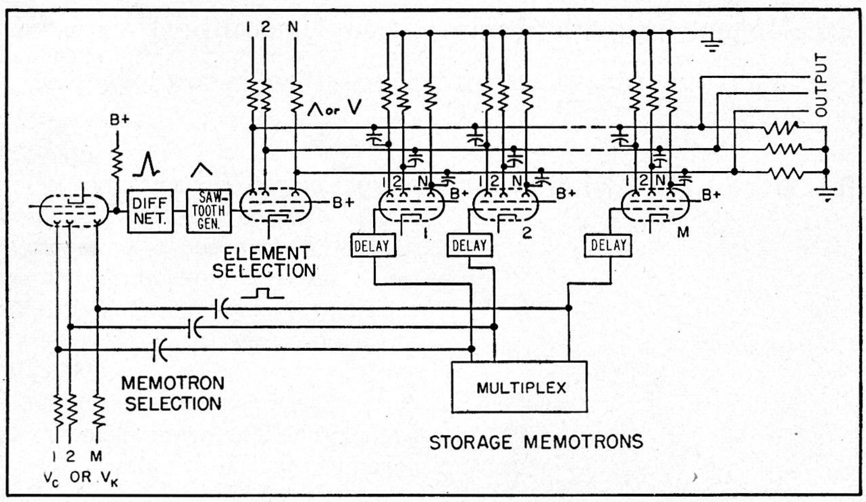


FIG. 4—Combination of circuits for introducing binary information into several secondary-emission storage tubes

very high. Thus a signal may pass between locked-up elements and the collector or vice versa but not between locked-down elements and the collector.

A long tube life has been attained by using pure metal elements activated by the evaporation from the oxide cathode. Some tubes life-tested for approximately 15,000 hours have shown only relatively small variations of their characteristic which do not impair their proper functioning.

Storing Information

Information may be stored in the memotron by locking storage elements to either cathode or collector potential.

Voltage is applied to an element through a high resistance R_a. The applied voltage is equal to V_o in Fig. 1A. If the space current is interrupted, the element will, upon resumption of current flow, assume the potential corresponding to S_3 in Fig. 1A and stay there.

If, however, a voltage lower than V_z is applied, the eventual potential of the element will approximately equal cathode potential. With the space current on, variation of applied voltage V_o within certain limits will not alter the locked states of the elements.

Modified Operation

A modification of this method as shown in Fig. 2A is especially useful when several tubes with common storage input are used in parallel with writing and erasing processes carried out independently in different tubes. The marking voltage applied to the elements is either zero or negative with reference to the normal cathode potential. However, when introducing information, the cathode potential is shifted (Fig. 1C) so far negative that the fixed element potential moves to the unstable part of the characteristic and finally to point S_3.

A voltage corresponding to V_o' is applied to those elements that are to remain at cathode potential. The elements that were previously at point S_3 may be brought to cathode potential simply by interrupting the space current. Space current has to be cut off during part of the writing procedure.

Locking storage elements to either cathode or collector potential may also be accomplished by feeding appropriately shaped voltage pulses to the elements. In this case, it may be advantageous to pulse the space current.

Assuming that an element is initially at collector potential, a negative voltage pulse with a steep rise and a slow decay is applied to the element. The pulse begins during the interval between two space-current pulses, reaching its maximum when the space current sets in again, and decays slowly during the space-current pulse duration. The amplitude of the negative voltage pulse must be so large that when the space current returns, the potential of the element corresponds to some point to the left of V_z (Fig. 1A). The returning space current will force the element to cathode potential.

The corresponding process may be carried out with an element originally at cathode potential by using an appropriate positive pulse. This procedure will work even with the space current flowing. Care has then to be taken to choose the shape and amplitude of the voltage pulses such that the displacement current through the coupling capacitor is high enough to override the holding action of the primary and secondary currents in the storage element.

Extracting Information

Any method for determining the potential of the storage element may be used to extract stored information. If for example the collector potential is modulated with pulses, the locked-up elements will follow this modulation, but the locked-down elements will not. The primary electron current may likewise be modulated.

This latter method is particularly useful when the corresponding storage elements of several memotrons are connected in parallel. If the collector voltage of one tube is modulated, a signal will appear at the locked-up elements. When the corresponding parallel-connected elements in different tubes are at collector potential, the impedance of these elements with respect to their collector will be relatively low. This will act as a shunting resistance for the output resistor of the element in question and absorb part of the output signal. If, however, the space current of the tubes is pulsed in sequence, no such effect will occur, since during the reading process current flows only in the tube from which an output signal is obtained.

Other Applications

An application of the memotron as a coupling device is shown in Fig. 2B. It makes use of the tube's gating property. This circuit may be considered as the electronic equivalent of the crossbar switch in a telephone system. The collector electrodes correspond to the bars and the secondary-electron emitting elements to the contacts. The example shows two tubes having output terminals 1 and 2 and N input terminals corresponding to the number of elements in each tube. A pulse train is used as a signal.

The pulses of the trains applied to the N input terminals are shifted in time relative to one another. They are fed to the elements through capacitors C_1 to C_N. The d-c voltages, for locking the elements to either collector or cathode potential, are fed to the elements from the common d-c sources V_{o1} to V_{oN} through separate resistors R_{A1} to R_{AN}.

The storing and erasing of coupling-information is determined by a control circuit. The output circuit comprises resistor R_c and the capacitor C_c. In this circuit a pulse train appears, the phase of which is determined by the number of the locked-up element. If several elements are locked up, a pulse train comprising the sum of the trains applied to the locked-up elements will appear at the output terminal. It is thus possible to sort out one or more pulse positions in a time-division multiplex system.

Signal Inversion

Figure 3 illustrates how a memotron may be used for converting the input signal applied to the control grid into a signal with the opposite sign, passing it unchanged or suppressing it depending upon the voltage applied to the secondary emitting element.

If the voltage applied to the element through resistor R_a correspands to point S_3, no signal will appear at the output terminal. If the voltage is higher than S_3, a negative signal will appear. If the applied voltage is lower than S_3, but not lower than S_2, a positive signal will appear.

Figure 4 shows a combination of circuits for introducing binary information into several memotrons. A pulse-generator pulses the control grids such that space current flows in only one tube at a time.

The memotron selection circuit contains one memotron to select the storage memotron in which information is to be stored or in which stored information is to be changed.

The element selection circuit selects the desired storage element of the memotron selected by the memotron selection circuit and the sign of the information being introduced.

Information Storage

The storage elements of the single selection memotron are connected to the output terminals of a multiplex pulse-generator. As long as these elements are at cathode potential or at a potential negative with reference to the cathode, no signal will appear at the collector. As soon as the element is brought to collector potential, the pulse arriving from the pulse-generator will appear at the collector.

From there it will pass through a differentiator to a saw-tooth generator. When thus triggered the saw-tooth generator delivers one pulse. The pulse passes to the element selection circuit. This circuit will deliver either positive or negative saw-tooth pulses, or no pulse at all, to the storage memotrons, depending upon the bias applied to the memotron elements.

The saw-tooth pulses are fed to the elements of the storage memotrons 1-M and influence their potentials as described earlier in this article. The delay circuits insure that the space current pulses in the storage memotrons 1-M are delayed so that the rise of the pulses delivered by the multiplex device occurs in the interval between space-current pulses. This is desirable since otherwise much more power would have to be delivered by the input memotron or by an amplifier inserted between it and the storage memotrons to override the holding action of the space current. The space current may be pulsed to read out the information stored in memotrons 1-M.

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