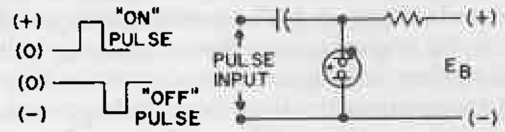
Chapter V

MEMORY SWITCHES

A memory switch is one which maintains its existing status until driven into the opposite condition. That is, when **off**, it will stay off until driven **on**, and when **on**, it will stay on until driven **off**. The characteristics of the neon lamp, as described in Chapter II, closely resemble this definition. Being a bistable device, the neon tube when off generally has an impedance between terminals of between 1,000 and 10,000 megohms shunted by 0.5 micro-microfarad. It can be driven to the **on** condition by exceeding its breakdown voltage rating. When it is on, it exhibits a series impedance of between 1,000 to 10,000 ohms, and will stay in the **on** condition as long as current flowing through it is greater than its critical current rating, I . It can be turned off by removing the applied voltage. Or with a constant source voltage, it can be driven off by a negative pulse which reduces the maintaining voltage momentarily, thereby cutting off the neon lamp current.

Figure 5-1 illustrates a simple neon memory switch which is operated by positive and negative pulses through the capacitor. In this circuit the source voltage, E_B, is at a level slightly below the minimum breakdown value of the lamp, and is greater than the rated maintaining voltage of the lamp. The resistor is equal to $\frac{E_B - M_V}{I}$, where M_V is the maintaining voltage rating of the lamp and I is the desired current of the circuit. Under these static conditions, the neon lamp will stay in the **off** condition.

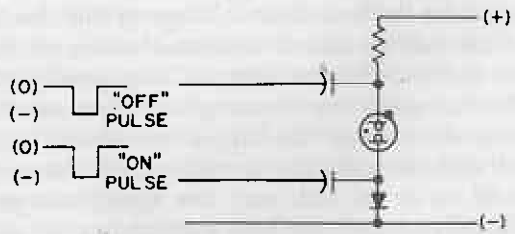
In order to turn this circuit on, a positive pulse is supplied to the input capacitor so that the pulse plus E_B exceeds the breakdown voltage rating of the lamp. This will ionize the lamp which will now stay in the **on** condition. The current flowing through the lamp is now the design current of the lamp, typically 300 microamps to 1 milliamp, and the voltage across the lamp is equal to the maintaining voltage rating of the lamp.



5-1 Memory switch with single input

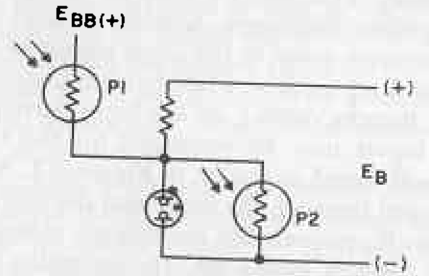
This memory switch can be turned off in a variety of ways, all of which have a common purpose. This is to reduce the current flowing through the lamp below the critical current rating of the lamp, I . The simplest method to accomplish this is to turn off the source voltage, E_B, or remove it from the circuit by switching. This may be done by a reset button or by means of capacitor discharge. Another method would be to introduce a negative pulse to the input circuit so that the voltage across the lamp is driven below its extinguishing voltage momentarily, thereby cutting off the lamp current.

Separate inputs may be employed for the turn-on signal and the turn-off signal as shown in Figure 5-2. A negative-going pulse applied between the diode and the neon lamp so that this pulse plus E_B exceeds the breakdown voltage of the tube will turn the memory switch on. The operating current is determined as described for Figure 5-1. To turn off this tube, a negative-going signal is applied between the current limiting resistor and the neon lamp so as to drive the voltage across the lamp below its extinguishing voltage rating.



5-2 Memory switch with separate on and off input

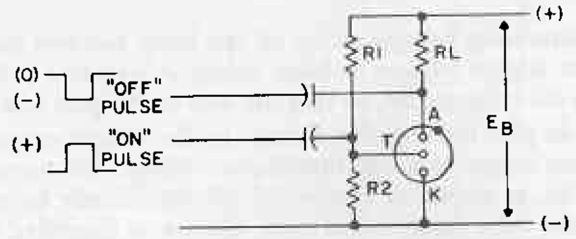
Photocells may also be used to activate the neon memory switch as shown in Figure 5-3. The conditions required for this circuit are that E_B is greater than the maintaining voltage rating of the lamp but less than its breakdown voltage rating. E_{BB} must be greater than the breakdown voltage rating of the lamp, and the dark resistance of P_1 and P_2 is much greater than the current limiting resistor. Then, light momentarily falling on photocell P_1 will cause the voltage across the lamp to rise to E_{BB} causing the lamp to turn on. The lamp will stay on, and the current flowing through it is determined as in Figure 5-1. Light falling on photocell P_2 momentarily will reduce the voltage across the lamp below its extinguishing voltage and the lamp will go off.



5-3 Operation of memory switch by photocells

Three-electrode neon lamps (cold cathode triodes) are frequently used in memory switch applications. These lamps have an advantage over the two-element lamps in that the input impedance of the turn-on circuit is several orders of magnitude higher than the two-element lamps. Consequently, they will turn on with extremely low input power. Because of the extremely close tolerances of the trigger breakdown voltage and the anode to cathode maintaining voltage, this memory switch can be turned on or off with very low signal voltages. These lamps can handle moderately high currents, in the order of 4 to 6 milliamps, and produce a higher than normal light output when compared to standard two-element neon lamps.

A typical circuit using a three-element trigger tube as a memory switch is illustrated in Figure 5-4. Here, the applied voltage E_B is less than the anode to cathode breakdown voltage but greater than its maintaining voltage rating, anode to cathode. The trigger electrode is biased close to, but below, the minimum trigger breakdown voltage. The anode resistor, R_L, is equal to the anode to cathode supply voltage (E_B) minus the anode to cathode maintaining voltage divided by the desired current of the circuit (design current of the lamp).

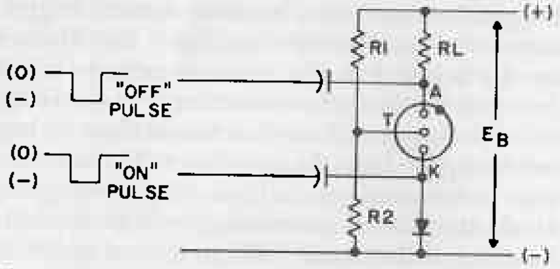


5-4 Trigger-driven 3-element lamp memory switch

To turn the memory switch on, a positive pulse is applied to the trigger, T, so that the bias on the trigger plus the pulse is greater than the maximum trigger breakdown voltage rating. To turn off the tube, a pulse is applied to the anode reducing the anode to cathode voltage below the tube's extinguishing voltage rating.

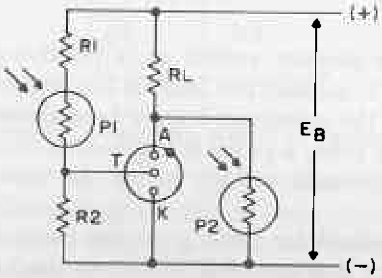
Another method for turning on the three-element memory switch is shown in Figure 5-5. In this method a negative pulse is applied to the cathode so that the sum of the positive bias on the trigger electrode plus the negative pulse to the cathode exceeds the maximum breakdown voltage rating of the trigger to the cathode. The tube is turned off by applying a negative pulse to the anode, reducing the anode to cathode voltage below the extinguishing voltage.

There are, of course, many methods for operating the three-element memory switch. Another is to apply a voltage across the anode to cathode elements greater than the anode to cath-



5-5 Cathode-driven 3-element lamp memory switch

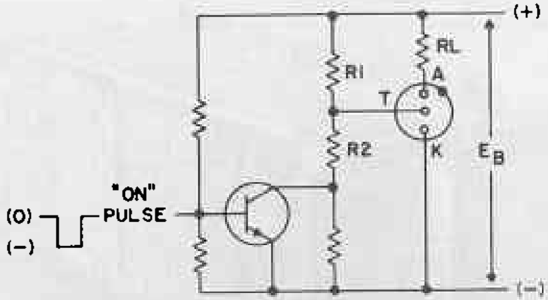
ode maintaining voltage rating of the lamp but less than the anode to trigger turn-on voltage rating. A negative pulse applied to the trigger then, so that the sum of the plus voltage on the anode plus the negative voltage on the trigger exceeds the maximum trigger to anode breakdown voltage, will turn on the tube. Also, as shown in Figure 5-6, photocells may be used to trigger the tube much in the same manner as described earlier for the two-element tube.



5-6 Operation of 3-element lamp memory switch by photocells

If transistors are to be used to operate the memory switch, a circuit such as the one shown in Figure 5-7 may be used. The transistor is in its normally saturated condition. Hence, R_3 is shorted. R_1 and R_2 divide the supply voltage, E_B, so that the voltage applied across the trigger to the cathode is slightly below the triggering voltage for the tube. When a signal is ap-

plied to the transistor causing it to cut off, the voltage on the trigger rises to a point determined by R_1 plus the combination of R_2 and R_3. In most applications the voltage across R_3 during the time the transistor is cut off does not exceed 25 volts. This tube may be turned off by any one of the preceding methods described above. It should be noted that in all cases the three-element tubes, like the two element tubes, may be turned off simply by removing the source voltage, E_B.

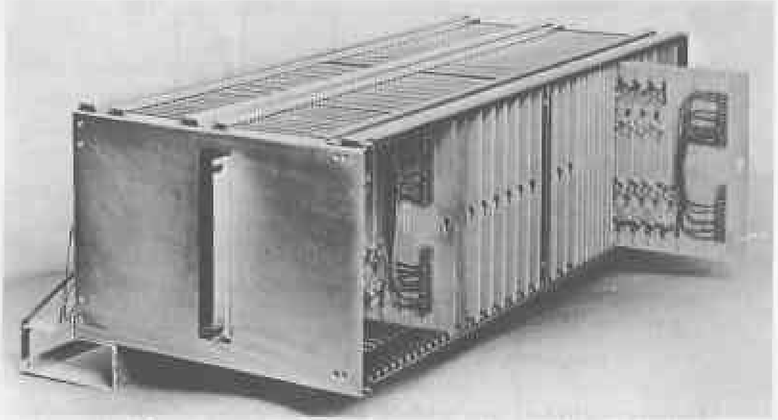


5-7 Operation of 3-element lamp memory switch by transistors

Memory switches are widely used in many electronic systems. One such system for which the neon memory switch provides a convenient and reliable design approach is in telephone number identification, timing, recording, routing and bill preparation.[1] The system described here was developed by Stromberg-Carlson primarily to meet the needs of the independent telephone industry for an economical, easy to service method. The identification process involves the application of an identifying signal to a third wire or sleeve lead in a form having digital significance with respect to the originating number and the transmission of the digital information to a recording medium.

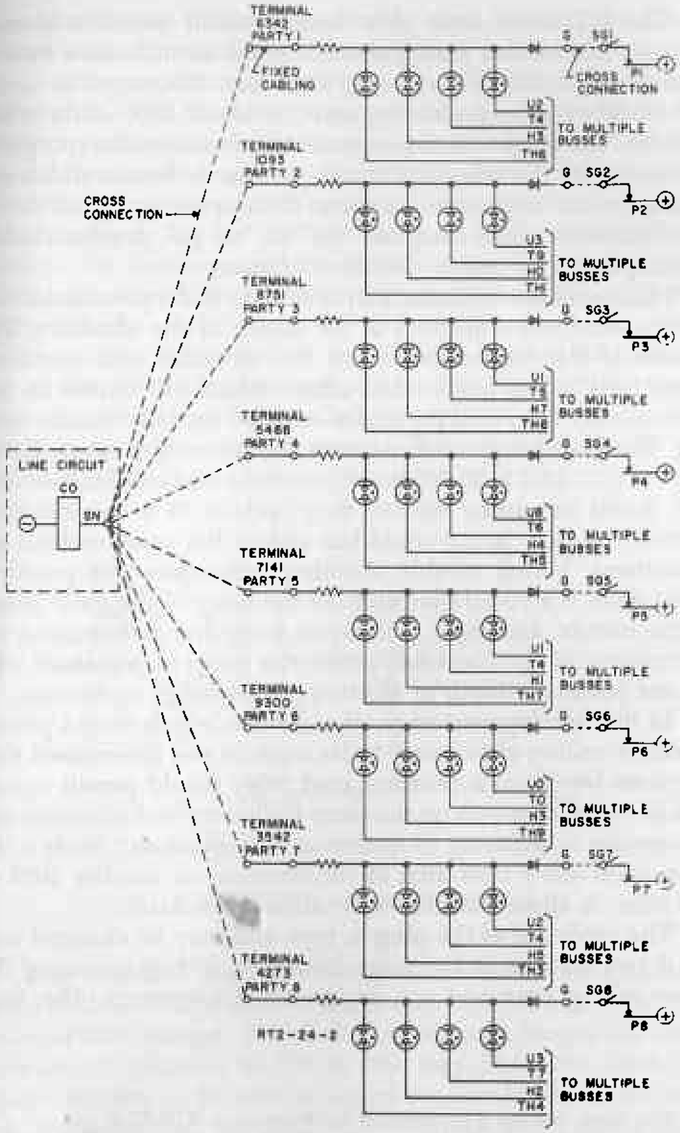
1. "Stromberg-Carlson Telephone Toll Ticketing System Uses Neon Glow Lamps In Number Identification Matrix," *Signalite Application News*, Vol. 1, No. 3.

The identification principle employed is based upon a matrix (Figure 5-8) in which standard neon glow lamps are used as gating elements. A pulse of positive potential is applied via the originating switch train sleeve to the originating line circuit and connector terminal, and thence to an associated cluster of neon diodes in a matrix. The diodes transfer the pulse to appropriate digital busses which are interrogated by a detector under the control of a synchronous scanning and pulsing circuit.



5-8 Photo telephone identification assembly

In operation, (Figure 5-9) each matrix cluster transfers the identification signal to four of a possible forty multiple busses having digital significance with respect to the terminal number. The anodes of all of the glow lamps in the cluster are connected in parallel through the resistor to the sleeve lead of the associated connector terminal. Thus, a voltage appearing on the sleeve also appears on the anodes of the glow lamps. The identification signal ionizes the glow lamps whose cathode is connected to one of the multiple busses in accordance with the thousands, hundreds, tens or units digits of the connector terminal number. This, in turn, causes a positive voltage to appear on the multiple bus to which the diode is connected.



5-9 Circuit – telephone identification matrix

The RT2-24-2[2] neon glow lamps exhibit excellent characteristics for use as a gating element in the identification matrix. The dc resistance drops from greater than 500 megohms in the deionized or non-conducting state to about 8000 ohms when ionized. For all practical purposes this characteristic completely eliminates the marginal signals on matrix busses which are characteristic of resistor matrices. Consequently, signal detection becomes a non-marginal "go" or "no go" process readily accomplished by simple detection circuitry.

Minimum maintenance requirements and operational simplicity were two objectives of the design of the identifier. The nature of the service for which the identifier was intended, often installed in unattended offices which are visited at less than weekly intervals, precludes reliance on daily routine testing. The glow lamps are consistent with these objectives. Rated life for RT2-24-2 is 25,000 hours, or about 3 years of continuous use. Based on a more realistic duty cycle of 3% in the identifier matrix, the glow lamps could last almost 100 years without replacement. Visual trouble shooting techniques are practical since there is a visual indication of the firing of the glow lamps in the matrix, and these techniques bring the maintenance requirements of the identifier within the grasp of personnel who do not possess a depth of electronic knowledge or training.

In the development of another device, which would permit selective calling of two-way radio units, it was determined that a system based on a resonant reed relay would permit operation of many receivers on the same frequency and eliminate the annoyance of listening to irrelevant transmissions.[3] Such a device could allow operation of the receiver on standby 100% of the time, in silence until it was called individually.

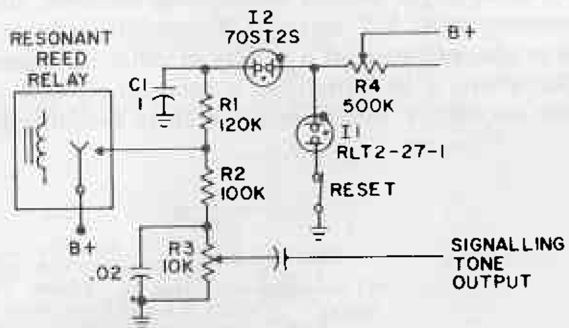
The reeds are of the plug-in type and may be changed easily if two systems in the same locality find they are using the same calling tone and are on the same frequency. The tone

2. This lamp has been superceded by Signalite's RT2-27-1.
3. Childs, Gailand, E. F. Johnson, Inc., "Call Alert for Two-Way Radio," *Electronics World*, July, 1965.

generator in the transmitter consists of a resonant reed controlled transistor oscillator. The selective calling tone unit in the receiver consists of a dual vacuum tube driver, the resonant reed relay, a neon lamp memory and the reset switch.

In operation, the resonant reed relay is activated when a tone of the correct frequency is received, causing the relay contacts to make intermittent contact. This intermittent contact converts the dc current into pulsating dc at the signalling frequency. The tone is passed into the audio amplifier and is heard on the speaker of the receiver, signifying that this station is being called.

In addition to the audible tone, it was decided that a memory device should be incorporated so that the operator would know his station had been called if he left the unit unattended. For this, a simple and economical "latched-light" circuit was included in the Tone Alert. (Figure 5-10)

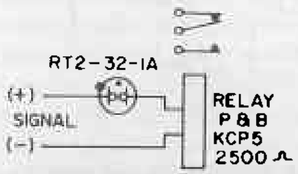


5-10 Station call memory circuit

Two standard neon glow lamps were used. The characteristics of these lamps allow reliable operation over a ±15% variation of line voltage. The first of these neon lamps, I-2, has a breakdown potential of 100 to 120 volts. It breaks down and ignites as soon as the unit is turned on. The second neon lamp, I-1, has a starting potential of 155 to 210 volts. Because the glow lamp with the lower breakdown potential always starts first, and the sum of its maintaining voltage plus the drop across the three resistors is less than the starting potential of the second lamp, I-1 will not ignite.

When the station is called, the resonant reed relay causes a voltage to be applied to the first glow lamp which is nearly equal to the voltage on the other side of the lamp. This drops the potential across the lamp below the lamp's maintaining voltage and the first lamp goes out. The total circuit voltage is then applied to the second glow lamp, the "call" indicator, which breaks down and ignites. Since the maintaining voltage of the second lamp is lower than the breakdown voltage of the first, the circuit is locked, or latched, until the operator, noting the call signal, resets the circuit by switching the unit to "Operate." This returns the circuit to its original condition, and the call indicator light goes out.

Neon lamps, either two-element or three-element, can be used in memory switches to perform a variety of functions. Some of these might include timers, ring counters, shift registers, memory cells, X-Y matrices, computer readouts, alarms, as well as the activation of a variety of other components. For example, where it is desired for a relay to operate within a narrower current or voltage range than is available from the

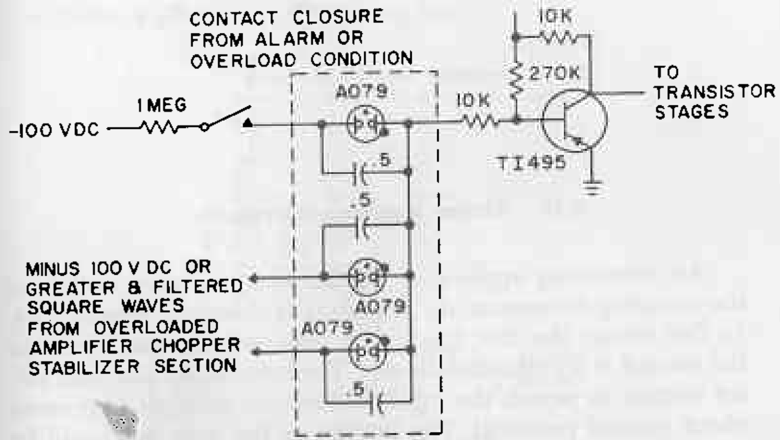


5-11 Relay with close pull-in and drop-out characteristics

standard characteristic of the relay itself, it is possible to use a neon lamp as an inexpensive control element. Figure 5-11 shows an RT2-32-1A lamp used in series with a P&B, KCP5, 2500 ohm, 18 volt, 7.2 ma relay to operate when an increasing applied voltage reaches about 75 volts.

When the circuit voltage reaches the firing voltage, the lamp will conduct and the 12 to 25 volt difference of the firing and maintaining voltages will appear across the relay causing operation. When the input voltage is reduced to approximately 63 volts, the voltage across the relay drops below the holding voltage and the relay de-energizes. Reducing the input voltage below 55 volts will cause the neon lamp to go out. In either case raising the input voltage to 75 volts or more will again pull in the relay. Therefore, we have a ratio of 75 to 63 volts, pull-in to drop-out.

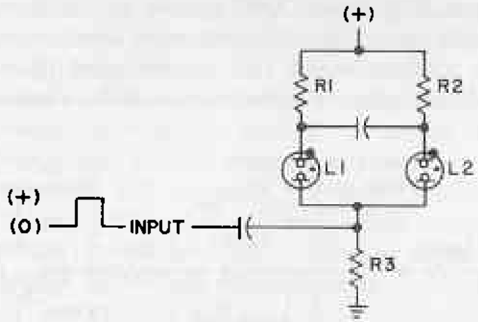
Many possibilities exist for using neon memory switches as computer logic circuit elements such as "OR" gates or "AND" gates. Figure 5-12 is an "OR" circuit application where the lamps provide visual identification as to which equipment in a system has malfunctioned and at the same time energize a transistor driven relay to actuate an audible alarm and control



5-12 Neon-memory switch in "OR" gate

circuitry. All inputs in this application have sufficient source impedance to limit the current flow through the lamps. The capacitors in parallel with the lamps cause them to flash as an eye catcher.

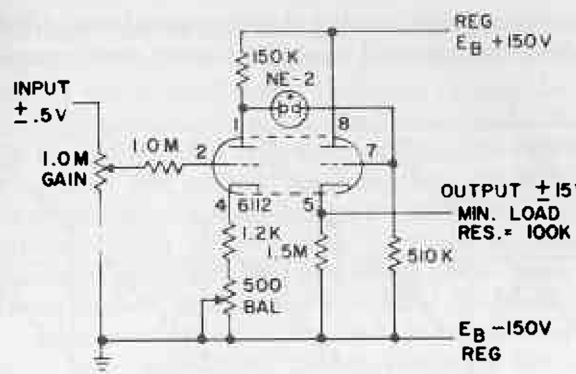
A driven bistable multivibrator can be constructed using neon memory switches as illustrated in Figure 5-13. Here, R_1 is equal to R_2. Thus, R_1 and R_3 or R_2 and R_3 will allow design current to flow through the tube that is on. When one tube is on, the voltage across R_3 reduces the voltage across the opposite tube below its breakdown voltage, preventing it from operating. A positive input pulse will turn off the lamp that is on, and turn on the lamp that is off. This condition will prevail until the next positive pulse is applied. Changing the relative values of R_1 and R_2 can change this driven multivibrator to a free running multivibrator or a mono-stable vibrator.



5-13 Driven bistable multivibrator

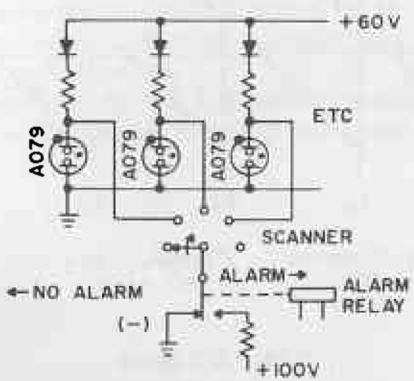
An interesting application of the neon memory switch as the coupling element in dc amplifiers is shown in Figure 5-14. In this circuit the first triode is a conventional amplifier and the second is a cathode follower. The neon lamp provides offset voltage to permit the input and output voltages to operate about ground potential. The bottom of the gain pot could be returned to the output terminal for increased long-term stability.

In the scanning annunciator, Figure 5-15, the position of the alarm—no alarm relay determines whether the lamp should be lit or extinguished as the scanner selects each alarm annunciation lamp. The diode in each lamp circuit prevents the 100 volt alarm-no voltage from raising the voltage on the 60 volt



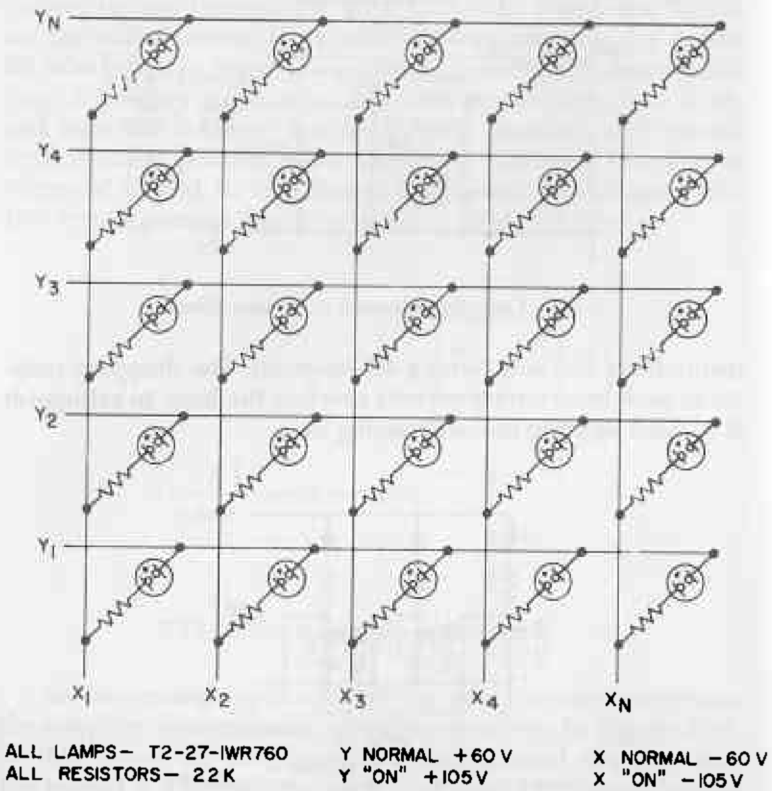
5-14 Coupling element in dc amplifiers

maintaining bus and turning all lamps on. The dropping resistor in each lamp circuit permits shorting the lamp to extinguish it without shorting the maintaining bus.



5-15 Scanning annunciator

Either the two-element or the three-element memory switch may be used in X-Y matrices. In Figure 5-16 the matrix is shown using two-element tubes. The three-element tube matrix would take advantage of the triggering characteristics of the additional electrode in the tube and would be slightly more complex.



5-16 X-Y matrix

The sum of the standby voltages on X and Y must be greater than the maintaining voltage and less than the breakdown voltage of the lamps used. In order to activate one lamp in the matrix, the voltage on the Y line to this lamp and on the X line

to this lamp each should be increased to a given voltage. The sum of these two new voltages is greater than the breakdown voltage of the selected lamp. However, raising the X line to this voltage with no change in the Y line results in a voltage across the lamp which is lower than breakdown voltage. Increasing the Y line and not the X line also results in a voltage less than breakdown of the lamps. Figure 5-16 shows a typical operational matrix circuitry with Y_N times X_N points. There are basically no limits to the number of points used.

It can be seen, then, that one or all of the lamps in the matrix can be switched on as required. It can also be seen that there are many methods for instant resetting of the matrix. The simplest is to remove both the X and Y voltages momentarily. Another simple method would be to reverse the polarity momentarily along either axis so that the potential difference across the lamp becomes zero.

Information, of course, can be fed into the matrix by the use of slow, manually operated X and Y switches to preselect a point, and then raise the voltage on the respective X and Y lines. Or the information can be supplied by an X ring counter and a Y ring counter so that the voltages raise at the proper step or sequence in time.

Typical readouts for an X-Y matrix would be visual or through photocells coupled to individual lamps and transistor circuitry.