Chapter IV

TIMING APPLICATIONS

The bistable characteristics and high leakage resistance of the cold cathode tubes are particularly useful for timing applications. The basic circuit for a neon-timer is a resistance-capacitor network similar in some respects to the basic circuit of the relaxation oscillators described in Chapter II. The input voltage charges the capacitor until it reaches the breakdown voltage of the lamp, at which time the lamp fires, discharging the capacitor. Depending on the values chosen for the resistor and the capacitor, this period may be as short as .5 seconds or as great as about 40 minutes. The output of these timer tubes may be used in a variety of ways.

The neon glow lamp has several distinct advantages over using vacuum tubes for this type of application. While the vacuum tubes may have an actual running lifetime of 3,000 to 5,000 hours, the neon lamp's average lifetime is generally about 10 times this figure. In addition, life is determined for the neon lamp only by the time the lamp is actually conducting. Even though the circuit may be active, the neon lamp is not operative unless it is conducting. Therefore, its life is not being consumed during the time it is in the "off" condition. The neon lamp is a very rugged component with no filaments to burn out or be destroyed by vibration or shock. Finally, the neon lamp is far less expensive than the average vacuum tube.

The circuit designer using semiconductors such as transistors, unijunctions and 4-layer diodes, frequently finds that two serious shortcomings exist in such devices. One is because of the very low thermal mass in the barrier region, and the other is because of the very high voltage gradients which can exist in the barrier region.

The very low thermal mass causes semiconductor devices to be seriously damaged, in some cases resulting in complete failure due to current surges such as may occur when equipment is initially turned on. The surges can be of very short duration and still result in overheating of the barrier region.

The very high voltage gradients occurring at the barrier region can result in puncture in the reverse direction of semiconductors, such as transistors and diodes. These voltage transients occur on the power lines as a result of the removal of power from power contactors, transformers and other devices having inductance. These transients can be as short as one microsecond and still result in puncture and total failure of the semiconductor device.

Protection against both these sources of premature failure can be provided in many cases. However, these protective devices do add to the cost as well as to the number of components involved for a given control application.

Neither of these shortcomings exists in cold cathode devices. Neither voltage nor current surges of short duration cause failure or even damage to cold cathode tubes. As a consequence, for a given control, they are generally less expensive, less complex and require fewer auxiliary components than semiconductors.

Another big advantage of cold cathode tubes over semiconductor devices is their relative insensitivity to temperature changes. Temperatures normally encountered in industrial applications from 0° to 120° Fahrenheit result in little or no change in the characteristics of cold cathode tubes.

Semiconductors have low input impedance characteristics which require lower values for the timing resistor and much higher values for the capacitance than required by high impedance neon tubes. Thus, for a given time delay, the cost of the RC network using neon tubes is considerably less than if semiconductors were used.

The life of cold cathode tubes is determined by the amount of current at which the tubes are operated. Failures are generally not of a catastrophic nature but occur gradually. When the control begins to malfunction occasionally, it is time to check the cold cathode tubes. With semiconductors, generally the devices fail completely without warning.

Cold cathode circuits operate on voltages from a minimum of sixty to seventy volts dc to a maximum of 250 vdc. They can readily be used on 115 volts ac or its rectified counterpart which is readily obtainable from the normal power outlets available in industrial or commercial installations.

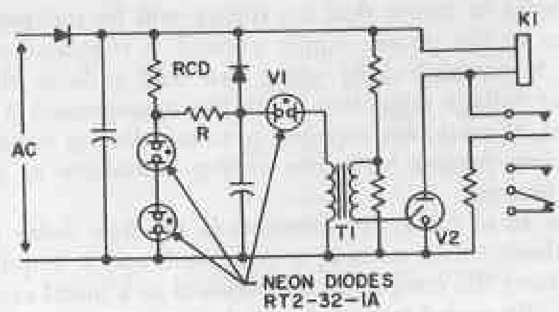
As with semiconductors no warm up time is required. However, semiconductor devices generally will require a step down transformer in order to reduce the supply voltage of 115 volts ac to voltages of the order of 25 to 50 volts. The low voltage aspects of semiconductors are, of course, advantageous for portable equipment where batteries or low voltage dc generators are available. This however, is not the case for most industrial timer applications which operate on 115 volts or 220 volts ac.

With the availability of radioactive isotope additives, cold cathode tubes are now available with stable characteristis regardless of incident illumination in a great variety of electrical characteristics. Cold cathode triodes (See Chapter V) are also available for control applications such as timers, electronic relays, level controls, wireless remote control, photo-electric controls, computers, temperature controllers and many other applications.

A recent development[1] which illustrates some of the advantages of a cold cathode assembly over a semiconductor assembly is the time delay relay which is illustrated in Figure 4-1. This is a device designed for operation from 115 volts ac employing three cold cathode diodes and one cold cathode triode in conjunction with an output relay to provide time delays in a range from .02 seconds up to 300 seconds.

In operation the ac power applied as shown is rectified, filtered and regulated by the two RT2-32-1A neon tubes and used to charge capacitor "C" through a resistance "R." When the charge on C reaches the ionization potential of neon V-1, it discharges C through transformer T-1 in a momentary impulse. This impulse is stepped up and used to ionize the cold cathode triode V-2, which energizes relay K-1. Time delay can

1. Wilson, George C., G. W. Wilson & Co. — "A Comparison of Cold Cathode Tubes and Semiconductors as Control Elements," *Signalite Application News*, Vol. 1, No. 2, and *Electronic Design*, December 6, 1963.



4-1 **Time delay relay**

be recycled before time out by momentarily shorting C. It can be recycled after time out by removing ac and shorting C, or by providing recycle diode RCD connected as shown. For remote time adjustment, resistor R is located outside of the timer. When the timer times out, contacts on relay K-1 remove the load from the output tube.

In view of the fact that cold cathode diodes can be constructed having extremely high leakage resistance, it is possible to use a very high resistance value with relatively small capacitors in order to obtain long time delays.

A similar semiconductor device would require a capacitance several orders of magnitude greater because of the low impedance nature of the semiconductor device. The cost of such a capacitor, for example, having a capacitance of seventy microfarads and low leakage current would be several times as great as the cost of the one microfarad capacitor required in the cold cathode delay unit.

The accuracy or repeatability of the time delay unit, of course, is dependent entirely upon the voltage breakdown characteristic of the cold cathode diode. Extremely good results have been obtained using a Type RT2-32-1A tube. This incorporates within the glass envelope a radioactive material which provides residual ionization so that stable, repeatable breakdown characteristics are available with varying light levels and over a long period of time.

In order to insure that the timing will be independent of variation in the power supply voltage, a regulated charging voltage is established by using two cold cathode diodes in series for voltage regulation. With this arrangement it is quite practical, at minimum expense, to obtain timing variations as low as two percent with line voltage variations as great as twenty percent.

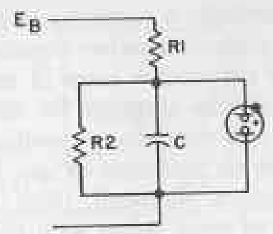
Since all of the active elements in the time delay unit are cold cathode tubes, no heat is generated, and it is quite practical to have the complete unit enclosed in a metal can, either hermetically sealed or as a dust-tight enclosure.

The time delay relay is not affected by voltage transients, is not damaged by current surges caused by turning it off and on, is not affected by temperatures in the range of 40 to 120 degrees Fahrenheit, and provides time delays in the range of .02 to 300 seconds for a selling price of $20.00 or less.

The basic circuit for the design of an electric timer is shown in Figure 4-2. In this circuit there are no restrictions to the values chosen for R and C except leakage resistance and economics. For this circuit to operate reliably, leakage resistance shall be at least 100 times greater than resistor R_1 used in the time constant. The leakage resistance referred to can be defined as the equivalent of the parallel combination of the leakage resistance of the neon lamp, the capacitor and the circuit wiring.

In order to design an electronic timer, three factors must be known. These are: 1) the time delay required; 2) the applied voltage of the circuit E_B; and 3) the breakdown voltage rating of the neon lamp, V_B. This latter is necessary because variations in breakdown voltage will result in variations in the time delay. It should be obvious, also, that the closer the tolerance is held on the breakdown voltage of the lamp, the more accurate the time delay will be. In all cases the breakdown voltage of the lamp should be equal to or less than 63% of the applied voltage E_B.

The calculations for designing a timer are similar to those for designing a low frequency oscillator as discussed in Chapter II. The first step is to determine K_1 from the following expression:



4-2 **Equivalent time delay network**

$$K_1 = \frac{V_B}{E_B}$$

From the graph in Figure 2-3 in Chapter II, determine the value of K_2. K_2 may be expressed as follows:

$$K_2 = \frac{T}{RC}$$

where T is time in seconds, R is expressed in ohms, and C is expressed in farads. Solving for RC:

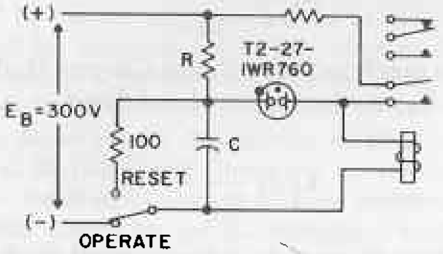
$$RC = \frac{T}{K_2}$$

This provides the RC factor which can be used with the nomograph in Figure 2-4 in Chapter II to determine specific values for R and C.

These calculations are all based on the premise that the applied voltage is direct current. If, instead, half wave rectified alternating current is used and the rectifier has extremely low reverse leakage, the time delay can be increased approximately three times over the direct current delay for the same value of RC and the same neon lamp.

One of the important side advantages of the neon timer is the ease with which the output of the lamp can be put to work for a wide variety of uses. These additional uses of output in no way affect the lamp's operation in the timing circuit since, after the lamp has ignited, it is conducting current. This current can be used to perform another function, such as the operation of a relay or some other form of readout. It may also be used to generate a pulse through, for example, a capacitor. Also, when ignited the neon lamp produces a light output which can be used as an indicator or can be used to operate another circuit through a photocell. (See Chapter VIII for a discussion of the use of neon lamps with photocells.)

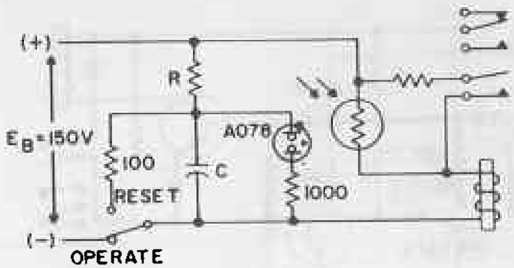
Figure 4-3 shows a typical circuit for using the output of the neon lamp in the timing circuit to operate a relay directly.



4-3 Use of neon-timer output to operate relay

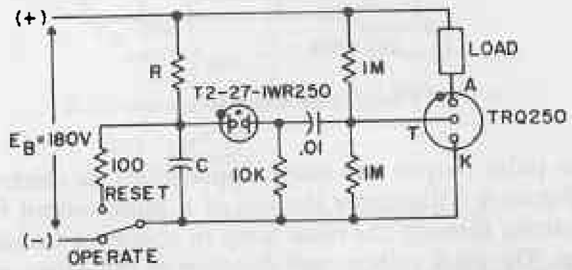
After the capacitor C charges to the lamp's breakdown voltage rating, the lamp ignites and conducts power at its design rating directly to the relay. The relay is then energized and locks itself up through its own contacts. The timer, including the timing circuit, is reset by means of a reset switch which causes the voltage on the condenser to be reduced to zero, and opens the current to the relay which returns the timer to rest. The cycle may also be reset by removing the applied voltage, E_B.

Use of the light output of the timer neon lamp with a cadmium sulfide or cadmium selenide photocell is shown in Figure 4-4. When the lamp ignites, its light falling on the photocell reduces the resistance, permitting the applied voltage to operate the relay. As above a contact on the energized relay locks the relay on. Again, the circuit is reset with an interrupter switch.



4-4 Use of neon-timer light output to operate photocell

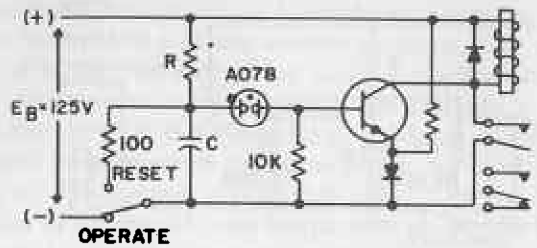
The voltage output of the timer neon lamp can operate a subminiature thyratron or three-element neon lamp as shown in Figure 4-5. The output pulse of the neon lamp is coupled to the trigger electrode of the thyratron causing it to turn on. Once the thyratron is ignited, it will stay on. With the components shown a load as high as 1/2 watt can be handled. This particular thyratron also has high light output for further photocell operation or visual indication that the circuit has operated. Again the circuit is reset with an interrupter switch.



4-5 Use of neon-timer output to pulse thyratron

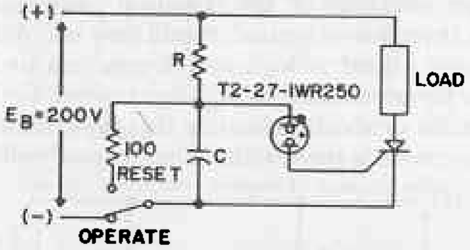
Operation of a transistor directly from the output of the neon lamp is diagrammed in Figure 4-6. The transistor is used to pull in the relay.

A circuit in which a silicon controlled rectifier is operated directly from the output of the timer neon lamp is shown in Figure 4-7. This circuit is essentially the same as the one shown



4-6 Use of neon-timer to operate transistor

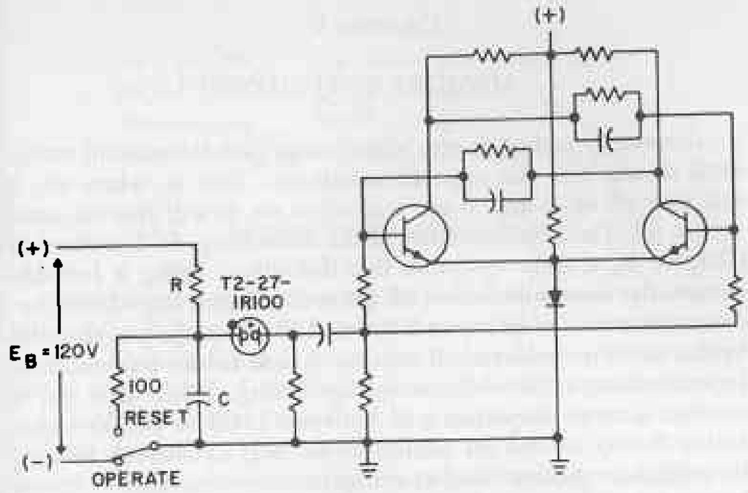
in Figure 4-3 except that the SCR has been substituted for the relay. Further discussion of the use of neon lamps with silicon controlled rectifiers may be found in Chapter IX.



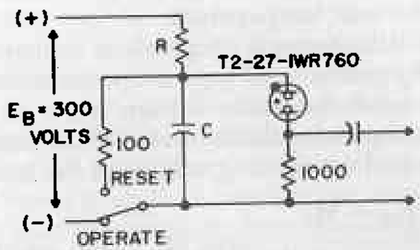
4-7 Use of neon-timer to operate SCR

The pulse output has many applications in electronic design. Figure 4-8 illustrates the use of a pulse output from the timer circuit through the neon lamp to operate a transistorized flip-flop. The peak voltage and duration of the driver pulse are determined by the selection of the capacitor between the neon lamp and the flip-flop circuit.

The basic circuit for providing a pulse output from the timing circuit is shown in Figure 4-9. With the values shown this will provide a plus going pulse of 100 volts minimum. As with all the circuits shown on these pages, no values have been given for R and C since these two components are selected on the basis of the time delay desired.



4-8 Use of neon-timer to pulse flip-flop



4-9 Neon-timer pulsing circuit

The few illustrations shown here are intended to demonstrate the principles of applying the electronic timing circuit to a variety of applications. It should be understood that many variations on these circuits may be made, and many other specific applications may be designed. Once the RC time delay has been determined and the neon lamp selected in accordance with the principles outlined earlier in this chapter, the output of the neon lamp in terms of maintaining voltage or light output is also known. Output can then be applied on this basis.