# PREFACE

While the neon glow lamp has been around for many years, its widespread use in electronic circuitry is relatively new. Prior to Signalite's development of close tolerance lamps, which are compatible with other electronic components in terms of quality and reliability, the neon lamp was limited to non-critical applications. To utilize neon indicator lamps for sophisticated electronic circuitry, it was usually necessary to test and discard many lamps in order to find the few which would meet the more stringent requirements. From a cost standpoint, the inexpensive lamp suddenly became quite expensive.

However, with the advent of lamps which consistently exhibit close tolerance characteristics has come an ever-widening spectrum of uses for this component. It is in recognition of this fact that this book has been compiled.

The circuits and applications that are described in the book have come primarily from actual applications on which our customers and friends have consulted us. Many longtime readers of *Signalite Application News* will undoubtedly recognize some of the circuits published here. We have drawn heavily on the *News* and on our own Applications Engineering files in order to provide down to earth, workable examples of uses of neon lamps, rather than to concentrate on theory. With most circuits, for example, values for components are given and the recommended Signalite glow lamp is indicated. Specifications for these lamps are listed in the appendix.

It has been our intention to provide a thoroughly useful reference tool which, while it may not necessarily answer a given circuit question directly, should provide the reader with representative answers and a direction to follow that is most likely to be productive.

It is not possible, of course, to illustrate every conceivable circuit application for neon glow lamps. What we are attempting to demonstrate are representative types of applications. The reader is encouraged to extrapolate from the specific examples included here to solve problems of a similar nature.

We are always eager to learn of new uses for neon glow lamps, for through this means we are provided the opportunity to develop new and better products. Through the medium of Signalite's *Application News,* we regularly disseminate just this type of information. In addition, our Applications Engineering Department is set up to answer specific questions on the use of glow lamps and, when desired, will assist designers with circuit design information.

We recognize that in the exploration of new fields and the development of new products we have a responsibility to share the knowledge we gain with as many people as possible. We hope that through the pages of this book, and with our *Application News,* we are living up to that responsibility.

September 1966 EDWARD BAUMAN

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## LIST OF ILLUSTRATIONS

FIGURE



FIGURE

FIGURE



# APPLICATIONS OF NEON LAMPS AND GAS DISCHARGE TUBES

CHAPTER I

# EVALUATING AND APPLYING NEON GLOW LAMPS [1]

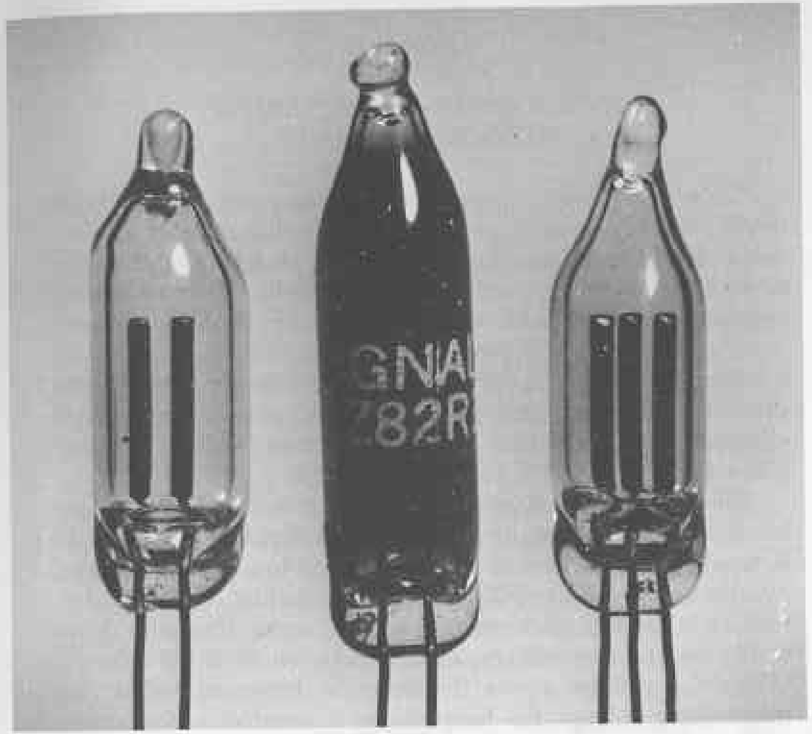
Neon glow lamps, or perhaps more correctly cold cathode diodes, are becoming a product of increasing interest to electronic design engineers. Because of their versatility and ability to do a variety of jobs well and economically, they are finding increasing applications in electronic circuitry. Because it is now possible to design and produce neon lamps to the same close tolerances and specifications as other electronic components, they are now used with complete confidence as circuit logic elements, photochoppers, voltage regulators, timers, X-Y matrices, memory circuits, and in many other circuits.

The neon glow lamp consists of an anode and cathode housed in a glass container filled with rare gases. (Figure 1-1) It breaks down or ionizes when subjected to a certain voltage, usually between 66 and 200 volts dc depending on design. Immediately after breakdown, the voltage across the lamp drops to the maintaining voltage, usually between 48 to 80 volts dc. When the voltage across the lamp is decreased below this maintaining voltage, the lamp ceases to conduct and abruptly extinguishes.

Neon lamps operate with currents ranging from .1 milliamp to 10 milliamps. Lifetimes can be greater than 50,000 hours of continuous operation. Lamps meeting specific values within these ranges can be designed.

The amount of time it takes for the lamp to start conducting after application of the breakdown voltage is known as the ionization time. If the applied voltage is just equal to the lamp's specified breakdown voltage, this time may be hundreds of milliseconds. However, if the applied voltage is 30% or greater than the breakdown voltage, the ionization time may be as low as 10 microseconds. Recently developments in lamp design, however, have produced lamps which ionize as fast as 4 microseconds.

1. Bauman, Edward, Signalite Inc., "The Complementary Use of Neons and Transistors," *Signalite Application News*, Vol. 2, No. 5.



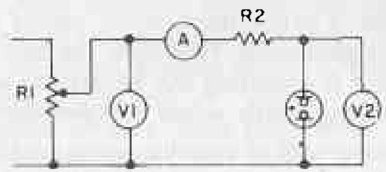

1-1 Types of neon glow lamps

Neon lamps may also be designed with three electrodes instead of two for use in certain switching applications. Characteristically, these lamps will have a relatively high breakdown voltage rating between the anode and the cathode. Applying a voltage to the third electrode, the trigger, however, will ionize the gas in the tube which, in turn, permits current to flow between the anode and the cathode.

The circuit for measuring standard two-element glow lamp parameters is shown in Figure 1-2. With the lamp in the position shown, the potentiometer is turned up until the lamp ignites. At this point breakdown voltage is read on voltmeter, $V_1$. Then the pot is adjusted until the ammeter reads the design current of the lamp. At this point voltmeter, $V_2$, reads the maintaining voltage. Turning the pot down until the lamp



stops conducting will indicate the extinguishing voltage on $V_1$. Ionization time is usually measured on a high speed oscilloscope.




1-2 Circuit for measuring glow lamp parameters

All neon glow lamps require ballasting in the form of a resistor in series with the lamp. The value of the resistor depends on the applied voltage, current, and desired lamp characteristics.

There are also external conditions which affect the operation of neon glow lamps. For example, the existence of an electrostatic field in the vicinity of the glow lamp will noticeably affect its performance. Such a field may decrease the rated breakdown voltage, and cause the lamp to ignite at levels significantly below normal. Electrostatic fields have no effect on maintaining voltage characteristics. High intensity radio frequency can cause the neon lamp to ignite with no applied voltage. These characteristics in themselves may suggest other possible applications.

Neon lamps exhibit a negative temperature characteristic, normally about 40 to 50 millivolts per degree Centigrade. In a voltage regulator this temperature coefficient may be as low as 2.0 millivolts per degree C. This temperature coefficient is small compared to zener diodes of the equivalent voltage. The normal operating temperature specifications for electronic circuitry of —60°F to +165°F are perfectly acceptable to neons.

Another factor that may affect the performance of glow lamps is operating in the absence or presence of light. Lamps operating in total darkness tend to have a higher breakdown voltage than in the light. This light effect, however, can be minimized or eliminated by the addition of a small amount of radioactive material to the lamp during manufacture.

Light output of neon lamps in circuit applications is usually not a matter of prime importance, except when they are being used with photocells. However, the fact that the lamp does glow when it is operating can be used as an indication of circuit operation, especially when inexperienced or untrained personnel are being used to monitor equipment operation. Also, since the glow in a direct current application is confined to the cathode, this characteristic can be used to determine polarity.

Light emitted by standard neon lamps generally averages about .06 lumens per milliamp. The high brightness lamps average about .15 lumens per milliamp. Meaningful measurement in this area is limited because conventional N.B.S. standards are about 1,000 times brighter than neon glow lamps. The light itself is confined mainly to the yellow and red regions of the spectrum between 5200 and 7500 Angstrom. A band in the infrared region between 8200 and 8800 Angstroms is also emitted.

The rated life for neon glow lamps is the length of operating time, expressed in hours, which produces certain specified changes in its characteristics when run at its design current. In lamps used as circuit components, these characteristics are usually the breakdown and maintaining voltage. Because this change is gradual, the end of life occurs when the lamp no longer meets specifications, rather than as a catastrophic failure. Life testing of neon lamps must be conducted at design current and cannot be accelerated. Running a lamp at currents above its design current causes heating of the cathode emissive material. This, in turn, will increase the sputtering of the emissive material, changing the lamp's aging characteristics at a rate that is not reproducible or easily related to its life at normal usage. Consequently, any attempt to accelerate aging at higher currents will not be applicable to actual service.

In most circuit applications, neon glow lamps are not "on" all of the time. In these applications only the time during which the lamp has current passing through it determines the



useful life. If this period is a short duration, as in pulsing applications, the rated life will have to reflect the fact that the lamp's useful life is not being consumed while it is inoperative. Actual life would be equal to the lamp's rated life divided by the operating duty cycle. In many applications, the actual rated life, i.e. calculated operation time of the lamp, will exceed by many times the estimated lifetime of the equipment or circuit in which the lamp is installed.

The life expectancy of a neon glow lamp, of course, depends on the operating conditions of the lamp, with life increasing as operating currents are decreased. If the lamp is installed in a circuit where it will be subjected to pulsing, the peak current, pulse wave shape and pulse duration all will have their effect on lamp lifetimes. Lifetimes may range from 1,000 to 50,000 hours of continuous operation. Operation on direct current rather than alternating current will shorten figures, perhaps up to 50% in some installations, because of the fact that only one electrode is being used instead of both. As a rule of thumb, average circuit component neon lamps will have rated lifetimes in the area of 7,500 hours of continuous operation.

Because of the wide variation of lamp characteristics available, and because of the wide variation in conditions of application, it is extremely important to consult with the engineering group of the glow lamp manufacturer in the determination of the proper lamp to use in any given situation. Where a standard lamp may be completely unsatisfactory for circuit component use, with only minor design changes, it may be made to perform well. The cost of such changes, even the cost of designing a completely new lamp, is almost always relatively insignificant when viewed in terms of the job to be done, the cost of other components in the system, or the cost of alternative ways to accomplish the task.

## Ten Key Points in Evaluating and Applying Neon Glow Lamps

1. Consider the neon glow lamp in the context of a circuit component, not as an extension of the classical indicator lamp. It can meet critical specifications.

2. Know the important parameters and characteristics of neon glow lamps for circuit application, and specify lamps within them.

3. Relate your measuring techniques of these parameters to those used by the manufacturer. This can save untold time and expense in inspection.

4. Use the neon glow lamp for the purpose for which it has been designed or recommended. Misapplication of lamps can be costly in terms of discarded units and rework of equipment.

5. Remember that the operation of glow lamps is affected by such external conditions as the presence of electrostatic fields and RF interference.

6. Evaluate the possible effects of other external conditions such as ambient light and temperature.

7. Determine the importance of light output of neons in the application, and the advantages it may offer.

8. Do not attempt to evaluate performance of neons based on accelerated testing programs. Neon glow lamps designed as indicators can not be aged into the reliability required by electronic circuits.

9. Neon glow lamps are long life components. Estimate their lifetimes based on the operation times of the lamps in the circuits. They do not age when not operating.

10. Most important of all, consult the Applications Engineering Group of the neon glow lamp manufacturer for the proper design or selection of circuit component glow lamps.

## CHAPTER II

# OSCILLATORS

A relaxation oscillator may be defined as an oscillator whose frequency is determined by the time constant of a resistance-capacitance network rather than the resonant frequency of an inductance-capacitance network. The basic principle of operation is the charging of a capacitor at a given rate. When the voltage across the capacitor reaches the breakdown voltage of the switching device, the switch turns "on," rapidly discharging the capacitor. When the capacitor is discharged, the switch turns "off," and the capacitor starts charging over again. This cycle is repeated as long as there is source energy to charge the capacitor. The resultant output is a sawtooth waveform available in frequencies from as low as one cycle in 45 minutes to as high as 20,000 cycles per second.

Among the many circuit component applications for neon glow lamps, their use as switching elements in relaxation oscillators is certainly among the most common, as well as one of the earliest. The neon glow lamp relaxation oscillator served as the time base generator for the first cathode ray oscilloscopes where capacitors were switched for frequency range changing and the resistor was varied for "fine" adjustment. The high level of output voltage simplified the horizontal deflection amplifier requirements and was one of the important advantages that the neon glow lamp offered for this early application. Another advantage was the ease and simplicity of synchronizing the oscillator frequency to input signal frequency.

This circuit was, in time, replaced by the "hard tube" and later by transistorized sweep circuits, as cathode ray instrumentation became more advanced. It is interesting to note, however, that in these days of highly sophisticated components, the neon glow lamp relaxation oscillator is being "re-discovered" as a time function generator, especially where time bases of up to an hour or more are required.

The neon glow lamp is a cold cathode diode with bistable characteristics. In its non-conducting state it comprises a very high resistance until its ignition, or breakdown, voltage is reached. At this point it rapidly becomes a low resistance path and maintains this condition until the voltage across the lamp drops below its extinguishing voltage. When this occurs, the lamp abruptly ceases to conduct and again becomes a high resistance element. This ability to stay "off" until a critical voltage point is reached, and to stay "on" until another, lower critical voltage point is reached, makes it uniquely well suited for use as the "switching" component in an oscillator circuit.

With no resonant circuit, a minimum number of components, and its elementary simplicity, the neon glow lamp relaxation oscillator circuit constitutes an approach of outstanding practicality, economy, and reliability. The advent of "tight tolerance" neon glow lamps, which might more properly be referred to as cold cathode diodes rather than lamps, has permitted a new degree of reliability and control in this particular circuit configuration.

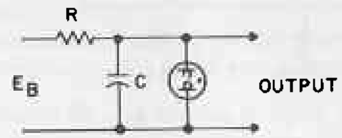
Consequently, we find that oscillator circuits utilizing these units are being widely used in a variety of circuit applications. In the electronic organ, for example, the basic circuitry consists of cold cathode diode relaxation oscillators and frequency dividers. (See Chapter III) The ability to construct oscillators with time bases that range from less than 0.0005 cps to over 20,000 cps has resulted in their use in many oscillators and time delay applications. (See Chapter IV) In addition they have been used in a variety of audible and visual alarms, plus a host of different applications too numerous to cover here.

*Theory of Operation*

The basic circuit for a relaxation oscillator is shown in Figure 2-1. As mentioned above, when the supply voltage $E_B$, is applied to the RC network, C begins charging until the voltage reaches the ionization voltage of the neon glow lamp. At ionization, the glow lamp abruptly switches from a high resistance to a low resistance, discharging C rapidly through the lamp. When the voltage across the lamp decreases to the extinguishing point of the lamp the lamp extinguishes and reassumes its high resistance characteristic. The capacitor, C, again charges through



R toward the $E_B$ potential, repeating the cycle, thus producing oscillations which continue as long as $E_B$ is maintained.




**2-1 Basic circuit for relaxation oscillator**

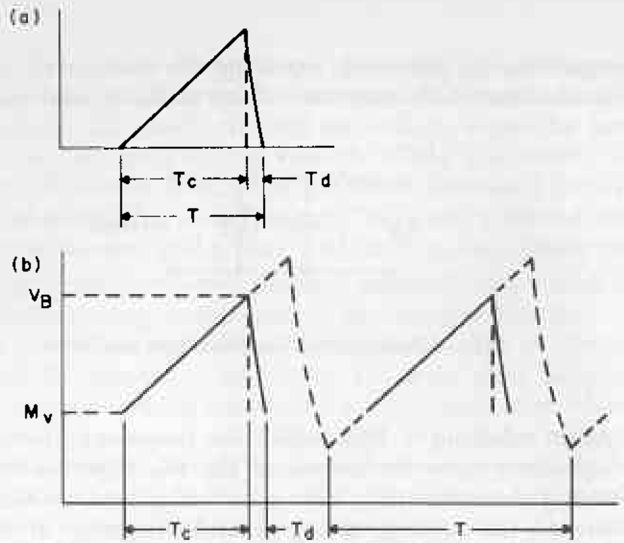
Again referring to Figure 2-1, the frequency of oscillation is dependent upon the values of the RC time constant, the operating characteristics of the glow lamp (i.e. specific breakdown and maintaining voltages) and the value of $E_B$. The peak-to-peak output level will be the difference between the glow lamp's breakdown and maintaining voltages.

The primary limitation on the high-frequency capabilities of such a relaxation oscillator lies in the finite ionization and deionization times of the particular neon glow lamp. This limitation restricts the use of a glow lamp to a practical maximum of about 20 kilocycles per second. Only the leakage of the capacitor in the RC network, the neon lamp and the associated circuitry, restrict the low-frequency capability of the circuit.

*Circuit Design Considerations*

In the design of a relaxation oscillator in which the output characteristics are not particularly critical, elaborate computation is not really necessary. The output level is established by the selection of the particular type of glow lamp (ignition voltage minus the maintaining voltage approximate the peak-to-peak output amplitude). As for determining frequency a familiarity with the principles outlined below will enable the designer to create a circuit having the desired general characteristics.

In instances where the frequency is more critical a number of factors must be taken into consideration.




2-2 Period of cycle in oscillator

*The solid curve is the calculated frequency. The broken line represents the actual frequency attained because of ionization and deionization time factors.*

As shown in Figure 2-2, the period of a cycle T in a relaxation oscillator's output is equal to the total charge, $T_C$, and discharge times, $T_D$. For low frequency oscillators (below approximately 20 cps) the discharge time is such an insignificant portion of the cycle that it can normally be ignored. At higher frequencies, however, the discharge time, in addition to the ionization and deionization times of the glow lamp, become factors to be reckoned with.

*Low-Frequency (<20 cps) Design*

In oscillators intended for use below approximately 20 cps, the resistance and capacitance required for the desired frequency may be determined as follows:

Determine $K_1$ from the following expression. $K_1$ should be 0.63 or less for optimum stability.



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

Where $E_B$ = Supply voltage
$M_V$ = Maintaining voltage of the glow lamp
$V_B$ = Breakdown voltage of the glow lamp

If $K_1$ is greater than 0.63 and the $E_B$ is fixed, then another neon lamp must be chosen whose $V_B$ and $M_V$ will yield a $K_1$ of 0.63 or less. If $E_B$ is not fixed, then increase $E_B$ until $K_1$ is equal to 0.63 or less. Then from the graph of Figure 2-3, determine $K_2$.

Then the value of the RC time constant is determined from the expression:

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

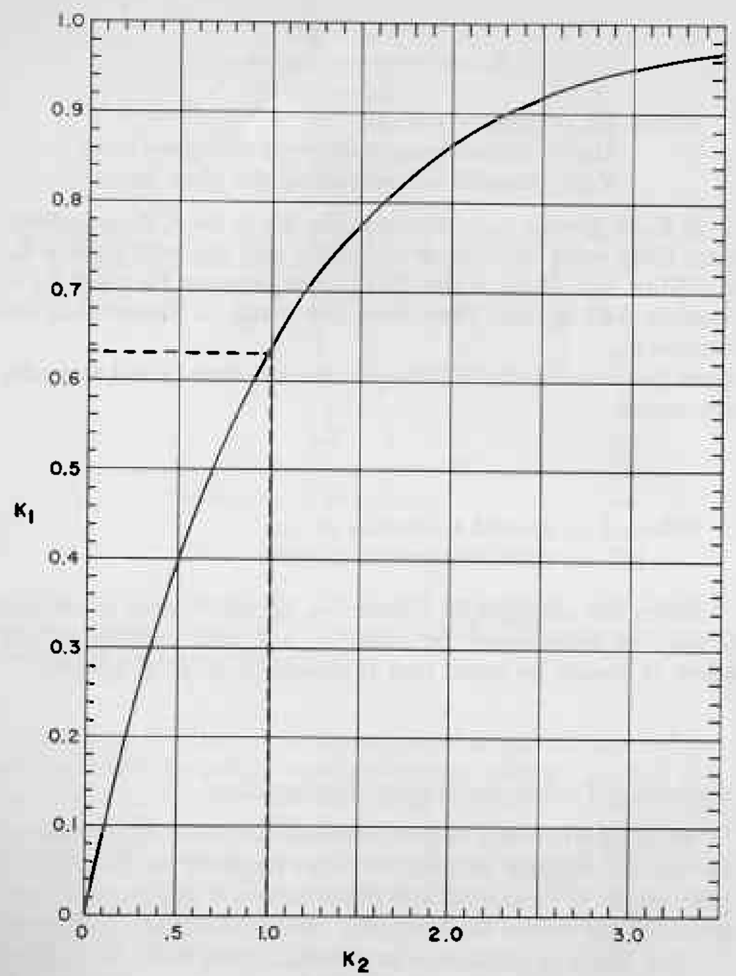
Where f = desired frequency in cps
RC = time constant in seconds

From the nomograph, Figure 2-4, specific values for R and C may be determined by selecting one and reading off the other. It should be noted that R should be 470K or greater.

*Correction Factors for Higher Frequencies*

In cases where the output frequency is above approximately 20 cps, and is fairly critical, the times required for the physical phenomena of ionization and deionization of gas must be compensated for before the foregoing computations are performed.

The effect of ionization and deionization times is to lower the frequency from that computed from theoretical values. As can be seen from Figure 2-2b, the times required for the firing and extinguishing of the lamp add to the total period of the cycle. The higher the frequency, the greater a portion of the total cycle these time lags occupy. In addition, the non-linearity in the fall-time similarly assumes increasing importance as it ($T_D$) becomes a significant portion of the total cycle.




2-3 $K_1$ versus $K_2$

It is also obvious from Figure 2-2b, that overshoot effects resulting from the ionization and deionization times of the gas result in the oscillator's operating at a somewhat higher output level than that calculated from the difference between the firing and maintaining voltage of the particular neon glow lamp.



Example:

*Let us assume we wish to construct an oscillator whose frequency is .5 cycles per second. The supply voltage, E , is 90 volts and the neon lamp is the close tolerance AO 59-6 with a breakdown voltage, V , of 70 volts and a maintaining voltage of 56-57 volts.*

*Substituting these values in the formula:*

$$K_1 = \frac{B_V - M_V}{E_B - M_V}$$

$$K_1 = \frac{70 - 56.5}{90 - 56.5}$$

$$K_1 = .4$$

*Since this is less than 0.63 we then refer to the chart in Figure 2-3, where we find that a factor of $K_1 = .4$ yields a value of .5 for $K_2$. Inserting these values in the formula:*

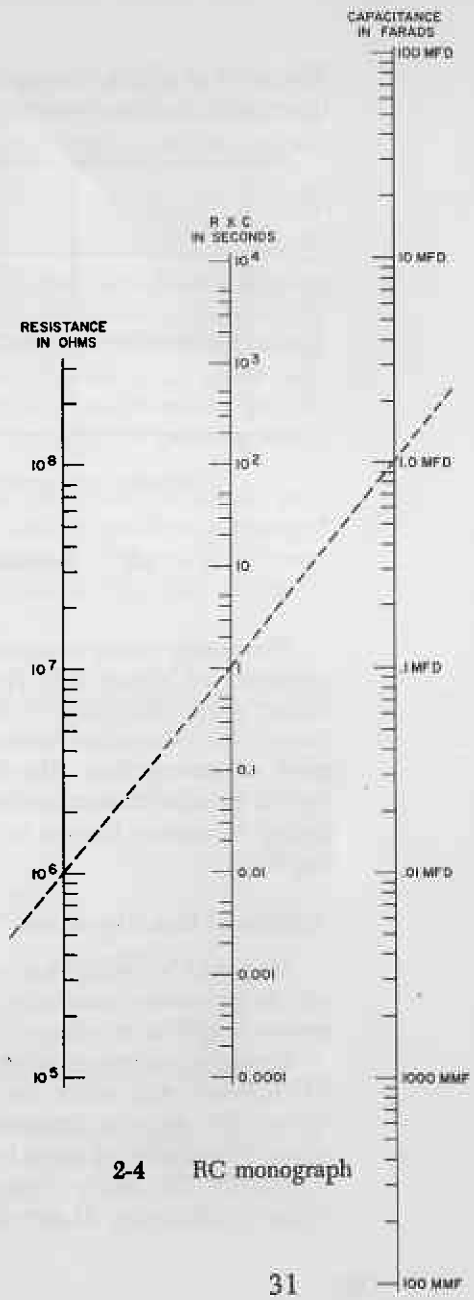
$$RC = \frac{K_2}{f}$$

$$RC = \frac{.5}{.5}$$

$$RC = 1$$

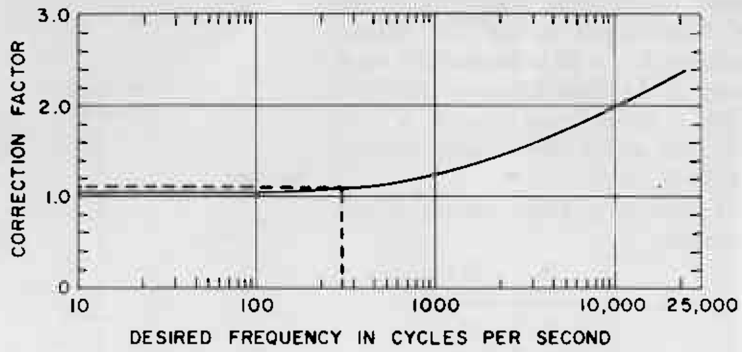
*From the nomograph, Figure 2-4, we can then determine values for the resistor and capacitor. Thus our components in this low frequency oscillator are:*

*R = 1 megohm*
*and C = 1 microfarad*




2-4 RC monograph

The point at which the capacitor begins to recharge is similarly lowered by this phenomenon.




2-5 Frequency correction factor

Frequency compensation may be easily accomplished by reference to Figure 2-5. To locate the appropriate correction factor read vertically from the desired frequency to the curve. The correction factor then read horizontally from this point of intersection. The desired frequency should be multiplied by this correction factor in order to obtain the "calculating" frequency for use in the above expression for determining RC.

*Additional Considerations*

It should be noted that variations in supply voltage will result in frequency instability. If this is of concern, a regulated power supply or a voltage regulator should be used.

Similarly variations in the resistance and capacitance of the RC network will affect the frequency. Therefore components having low or zero temperature and voltage coefficient characteristics should be used for optimum frequency stability.

Finally, the active element, the cold cathode diode, is of critical importance. It should be recognized that a glow lamp



intended primarily for indicator applications does not provide the type of reliable performance required in a precision switching device used in an oscillator having critical output characteristics.

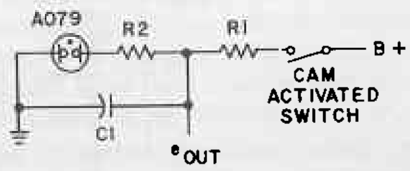
*Circuit Examples*

The variety of individual circuits that have been designed using neon glow lamps for relaxation oscillator applications is virtually unlimited. A few typical examples are included here to demonstrate some of the variations possible. A quick perusal of these circuits shows that minor modifications can be made to the basic oscillator circuit in order to perform many different tasks.

The addition of a cam activated switch and a resistor to a relaxation oscillator circuit can be used to produce a triangular waveform. (Figure 2-6) The symmetry of the output is seen if we let F equal the rotational speed of the cam activated switch.

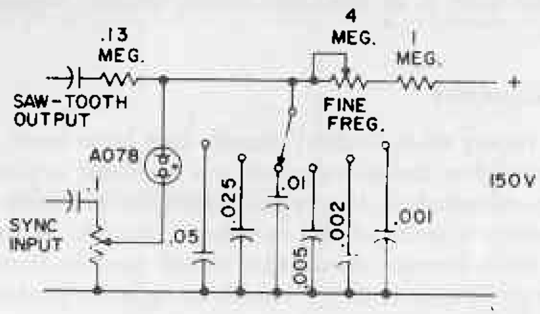
Then, $F = \dfrac{1}{T}$ where $R_1C_1$ and $C_1R_2$ are equal to T. The

switch could readily be replaced by any gating circuits such as multivibrators, phantastrons, and so forth. The lamp is our AO 79.



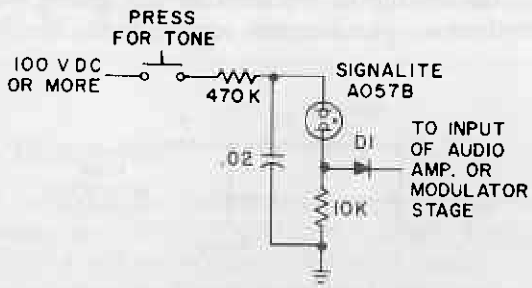

2-6 Circuit for symmetrical triangular waveform

A circuit producing a sawtooth waveform ideally suited for inexpensive, moderately linear time bases is shown in Figure 2-7. This specific circuit has been used as a source of time base voltage for the horizontal sweep of a small oscilloscope. With the components given, the frequency range is from about 5 cps to over 1,500 cps, which is well suited for oscilloscopes.




2-7 Circuit for inexpensive, moderately linear time base

Many variations on this circuit are possible and most of the parts are not critical. Changing the resistance or the capacitance, for example, would change the oscillator frequency. If only a small range of frequency is to be covered, a single capacitor could be used across the AO 78 neon lamp. If no synchronization is desired, the sync control could be left out, and the neon lamp connected to ground.

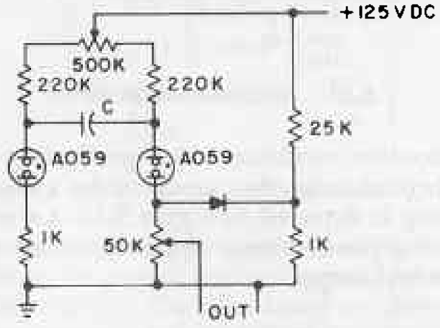



2-8 Simple tone generator

While neon lamp relaxation oscillators have been widely used as tone generators in electric organs, the circuit in Figure 2-8 shows a simple and inexpensive tone generator which could



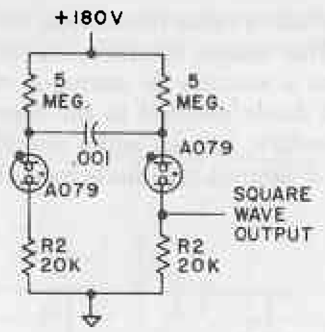
be incorporated into a radio transmitter for fast on-the-air tone identification. This simple oscillator easily may obtain operating power from a suitable dc source in the transmitter. The audio output is diode coupled to the input of the modulator stage, or if necessary, into an audio amplifier stage preceding the modulator. If desired, the diode may also be replaced by a capacitor.




2-9 Low frequency oscillator

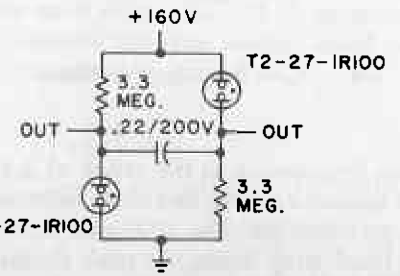
For very low frequencies in the range of 1-10 cps, the circuit shown in Figure 2-9, using two close tolerance AO 59 type lamps, does an excellent job. The 1000 ohm resistor in the cathode of the left hand lamp limits the peak discharge of the capacitor, C. The right hand lamp is adequately protected via the 50K resistor and the clamping diode with the 1K resistor.

Another dual relaxation oscillator, which operates as a multi-vibrator type oscillator, is shown in Figure 2-10. It can be used as a sequence flasher or as a source for square wave output. Output is obtained across resistor $R_2$. The positive peak is slightly curved, but with a diode clipper across $R_2$ the output is near a perfect square wave. With the components shown, the frequency is approximately 300 cps, but this can be changed by altering either the resistance or the capacitance.




2-10 Multivibrator oscillator

A dual relaxation oscillator which produces a differential saw-tooth voltage of twice that produced by a circuit using a single neon lamp is depicted in Figure 2-11. An advantage of this circuit is that power supply ripple and noise are reduced by the symmetrical output.

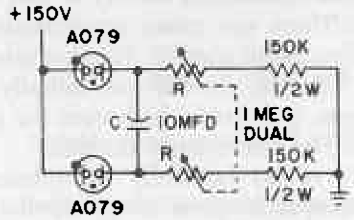



2-11 Dual relaxation oscillator

Another approach to generating a triangular waveform is produced with a dual neon astable oscillator as shown in Figure 2-12. The voltage across C closely approximates a linear triangular waveform. With the values shown the frequency is variable from approximately 0.005 cps to 0.5 cps, providing an extremely low frequency oscillator. The upper frequency limit is set by the ionization time of the neon glow lamps. The lower

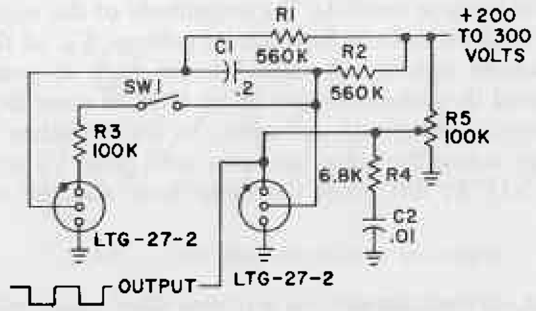


frequency is limited mainly by the leakage resistance of capacitor, C, which should be a high quality paper or mylar capacitor. Using type AO 79 neon lamps the circuit operates reliably over a range of at least three decades with a single control. Capacitor, C, may be switched to obtain a very wide range circuit.




2-12 Dual astable oscillator

The circuit in Figure 2-13 is an interesting variation on the oscillator theme for several reasons. It produces a square wave output at about 50 cps. The neon lamps are three-element cold cathode tubes instead of the standard two-element type. (For a discussion of three-element lamps, see Chapter V). The cycle is self-completing when the switch SW1 is closed. Should neon #2 be in conduction when switch SW1 is closed, neon #2 will continue to time out and turn on neon #1. Neon #1 will then inhibit neon #2, thus preventing the beginning of the next cycle.




2-13 3-element lamp oscillator

## Chapter III

## GLOW LAMPS AS FREQUENCY DIVIDERS

The basic characteristics of the neon glow lamp relaxation oscillators also lend themselves ideally to the function of frequency dividing. There are many applications in electronics for this classic glow lamp circuit. To illustrate how the glow lamp serves this function, we will use, initially a discussion of the electronic organ, a system which uses the glow lamp both as an oscillator and as a frequency divider.[1]

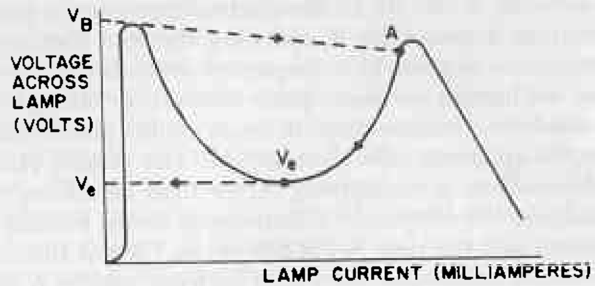
The electronic organ faithfully reproduces a variety of waveforms at different frequencies to simulate electronically the range of tones characteristic of other instruments, creating the same effect as is accomplished in a modern pipe organ. The frequency dividers have a division ratio of 2 to 1, so that the tone outputs are always one octave below the preceding stage. The sawtooth output waveform is rich in harmonic output, so that with proper filtering the tone characteristics of other instruments can be simulated.

When used as a relaxation oscillator in the organ, advantage is taken of the bistable characteristics of the glow lamp. That is, when it is off, it will stay off until a critical voltage is exceeded, then turn on. When it is on, it will stay on until the lamp current is reduced below a minimum current.

For the lamp to oscillate, the magnitude of the supply voltage, $E_B$, must exceed the breakdown voltage, $V_B$, of the lamp. For maximum stability, it should be as high as practicable. The value of the resistance should be 470K or more depending on the supply voltage. In operation, as the capacitor charges, the voltage across the lamp increases until point $V_B$ is reached. (Figure 3-1) At this point the lamp fires, and the capacitor

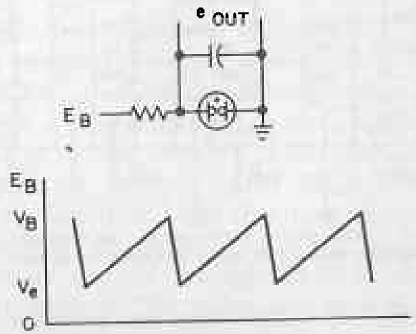
1. Bauman, Edward, Signalite Inc. — "Neon Glow Lamps as Oscillators and Stable Frequency Dividers," *Signalite Application News*, Vol. 2, No. 3, and "Neon Glow Lamps: Stable Oscillators and Frequency Dividers." *Systems Design*, June 1965.






3-1 Bistable characteristics of glow lamps

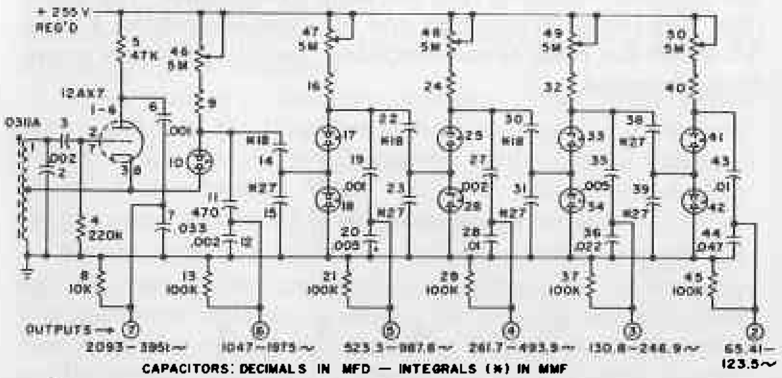
discharges through the lamp, increasing lamp current to point A. As the capacitor discharges rapidly, voltage and current follow the curve until point $V_e$ is reached. At this point, since the current flowing from $E_B$ through the resistor R is below the critical current of the neon lamps and there is no other means available for the voltage to rise, the lamp extinguishes. The capacitor then begins to recharge, and the cycle is repeated. Figure 3-2 shows the basic circuit simplified, and the sawtooth waveform generated.




3-2 Oscillator circuit and waveform

A refinement of this circuit is used to produce the frequency dividers which create additional octaves. Frequency dividers of this nature have worked successfully in divisions of any integral between 2 and 10. In the electric organ one is primarily interested in divisions by 2, reducing the tone frequency in each stage one octave. This frequency division must be exact because the human ear hears pitch intervals or changes in the same non-linear fashion that it hears audio power changes. That is, the apparent difference between two pitches (frequencies) depends on a multiplying rather than an adding factor. For example, the frequency difference between middle A (at 440 cycles) and the next A (at 880 cycles) seems the same to the ear as the interval of difference between middle A and the next lower A (at 220 cycles). Therefore, to create the next lower octave, once a stable frequency has been established, all that has to be done is to divide the frequency exactly in half.

In Figure 3-3 is shown a schematic diagram of a tone generator. One triode tube, half of a 12AX7, is used as the master oscillator for stability. This circuit is one whose stability has been proved for many years.




3-3 Electronic organ tone generator

A typical stage is one producing output 5 (523.3 cycles, C above middle C.) This consists of a classical neon lamp relaxation oscillator comprising a resistance (16 and 47 in series) in series with a neon lamp (actually two lamps in series) between



$E_B$ and ground, with a capacitor (19 and 20 in series) across the lamps. The frequency of free-running oscillation for a given $E_B$ voltage and lamp type is determined by the values of R and C and will be slightly lower than 523.3 cycles. The lamp used throughout is the circuit component, type AO 78, with a breakdown voltage of 66 to 74 vdc, and a maintaining voltage of 52 to 59 vdc. Its leakage resistance is extremely critical in this circuitry since variations in it would entail special selections of the timing resistor, R. Specifications call for a minimum leakage resistance of 8,000 megohms, and the average of the lamps obtained is about 20,000 megohms, giving a comfortable margin to work with.

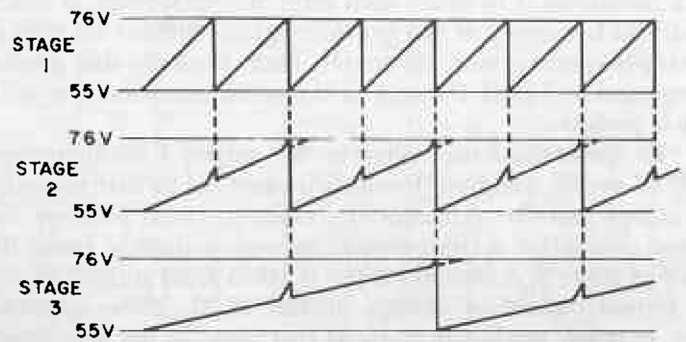
Output from this stage is taken through a capacitive voltage divider 19-20, which also acts as an impedance transformer. The output of terminal 5 is a low impedance output, therefore minimizing the loading effect on the relaxation oscillator.

In the specific circuit employed there are some significant deviations from the standard neon oscillator. The purpose of the deviations is to cause each stage to synchronize at exactly half the frequency of the previous stage, without causing the lower-frequency tone to couple back through the previous stage and be heard. Because of the synchronization, the stability is perfect.

To understand this, refer to the output 4 oscillator stage (261.7 cycles, middle C), which is identical to that for output 5 except that the values of the capacitors and resistors have been chosen for a free-running frequency slightly lower than half of stage 5. A second output is taken from stage 5 through a second capacitive voltage divider 22-23. These capacitors are so much smaller than 19-20 that they do not significantly affect the frequency of oscillator 5. When lamps 17-18 fire, a negative pulse is applied through 22-23 to the junction of lamps 25-26 in stage 4. This pulse voltage is divided approximately in two through capacitors 22-23.

Operation is as follows: the $E_B$ voltage being applied to stage 4 starts the standard neon oscillator build up. When the negative pulse is injected from stage 5, this voltage plus the voltage across the lamp at the time is not great enough to fire the lamp. (See Figure 3-3) When the second pulse is injected the voltage across the lamp has built up to a point close to breakdown voltage of the lamp. The summation of the pulse peak voltage from stage 5 plus the existing voltage is sufficient to cause the lamp to break down. This transmits positive voltage to lamp 26 which also fires. Thus, the lamps fire on every alternate firing of the previous stage and at the point when the condenser is almost charged, thereby dividing the frequency exactly in half. This produces a tone one octave below stage 5. The same action takes place with every following stage.

The principle of frequency division in the tone generator is shown in a simplified form in Figure 3-4. Assuming breakdown voltage is 76 volts and maintaining voltage is 55 volts, the glow lamps in Stage 1 fire on each cycle, creating the sawtooth waveform indicated. The pulse from the lamp firing each cycle is injected to the following stage, increasing the voltage across




3-4 How frequency dividing is accomplished

the lamps by the incremental peak. The second pulse increases the voltage across the lamps to the breakdown voltage and the lamps fire. (Note that this must occur before the voltage build-up in the capacitor reaches the breakdown voltage of the lamp, as indicated by the continuation of the dashed line beyond the incremental peak, otherwise all synchronization would be lost.)



As shown here, stage 2 creates the same effect on stage 3, again dividing the frequency exactly in half. This process continues through the desired number of octaves in the organ.

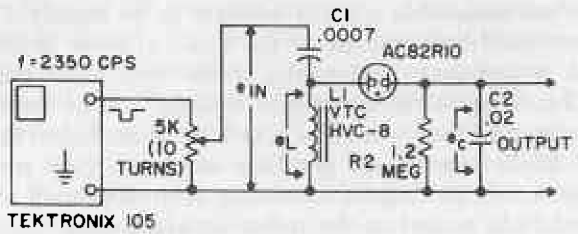
A special point about this circuit is important. It is most undesirable when playing a particular tone to hear anything of the tone an octave lower. While something of a higher octave tone is not noticeable since it appears to be merely a part of the harmonic development of the tone, a lower octave component is extremely noticeable. If the sync-pulse path from stage 5 to stage 4 could conduct equally well in the back direction, stage 4 tone would be heard in output 5. But for pulses at the 25-26 junction to get into output 5, they must pass through a voltage divider consisting of a very small capacitor (22 and 19 in series) as the series leg and a very much larger capacitor, 20, as the shunt leg. The voltage division is 5,000/22. Thus, the backfed tone is inaudible.

This organ is completely an electronic device. There are 12 tone generators of the type described above, one for each of the 12 notes of the chromatic scale. Through the use of a basic oscillator and five frequency dividers as described, it is possible to cover six complete octaves. The use of glow lamps as sawtooth oscillators and stable frequency dividers provides stable operation where, if there were variations in performance, the results would be noticeable and very unpleasant. This high reliability is obtained with a relatively inexpensive component. This application can be used in many other areas of operation, such as dividing a frequency standard, or as a source of accurate timing signals.

Very often in electronic systems, a need arises for an audio voltage to be divided into equal steps. Staircase generators normally used for this purpose generally involve 1 or 2 transistors and perhaps a dozen other components. It is possible through the use of neon glow lamps to reduce the number of components and produce a circuit which serves a double purpose—a staircase generator and a frequency divider.[2] When function-

2. Cistola, A. B., IBM Space Guidance Center, "A Unique Frequency Divider and Staircase Generator," *Signalite Application News*, Vol. 3, No. 4.

ing as a frequency divider the circuit separates out the odd number of pulses, for instance, 3's, 5's, 7's, etc. Thus the circuit eliminates the need for decoding logic usually associated with binary systems in order to separate out odd counts.



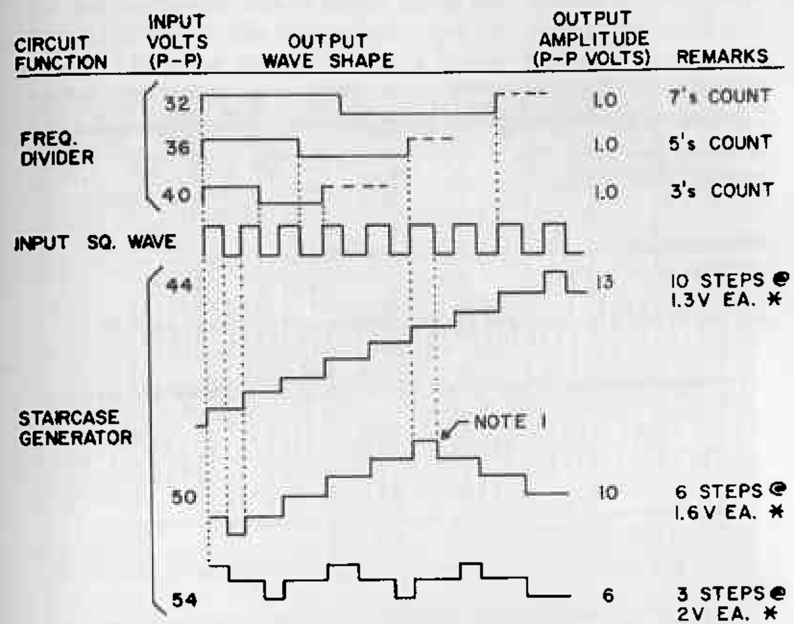

3-5 Staircase generator

The basic circuit is shown in figure 3-5. The input potentiometer R1 is a 10 turn pot controlled by a vernier dial. Its purpose is to supply a variable amplitude of the input square wave voltage to the series-resonant L1, C1 combination. The inductor L1 should have a high "Q" factor since the voltage which is developed across L1 must be high enough to fire the neon lamp. The combination of R2 and C2 serve as an integrator, aside from the normal duty of R2 as a current limiter.

The circuit is capable of operating in two distinctive modes: namely, as a frequency divider and as a staircase voltage generator. The mode of operation is determined by the range of the input voltage (See Figure 3-6)

When a square wave voltage on the order of 54 volts or so is applied to resonant circuit L1, C1 the voltage across L1 is sufficiently high to cause current pulses to flow through R2 due to the firing of the neon lamp. Capacitor C2 will accumulate a charge of such polarity that it will be series-opposing the input voltage of breakdown to occur in the one direction, but series-aiding the input voltage for breakdown to occur in the opposite direction.

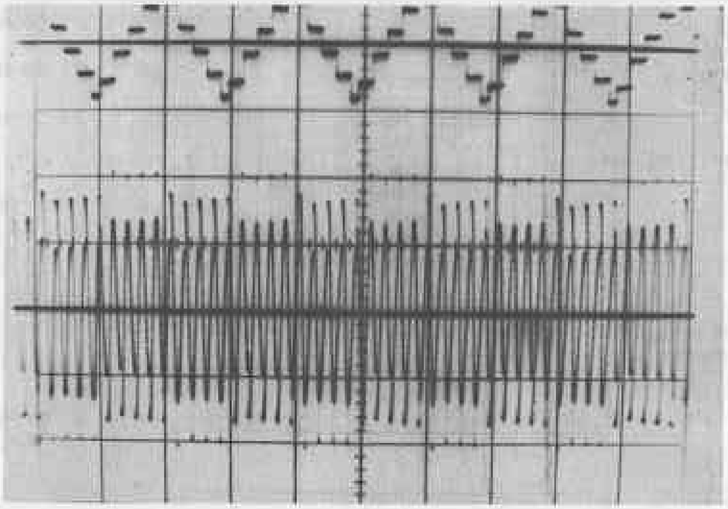





3-6 Mode of operation – Staircase Generator

Assuming that breakdown is occurring on the *positive going* pulses, the immediate result is that no current will flow through the lamp on negative going pulses. (See Figure 3-7) For every positive going input pulse an additional charge will accumulate on C2 until the voltage across C2 in series-aiding with the *negative going* voltage across L1 is enough to cause a discharge through the lamp in the opposite direction. When this happens all the negative going input pulses will reduce the accumulation of positive charges on C2, go through a zero level and build up in the negative direction until a point is reached where C2 will again discharge through the lamp, with the series-aiding *positive going pulses.* (See Figure 3-8)

This cycle will recur at a definite time interval. The number of step levels in a staircase is changed by changing the pot



3-7 Oscilloscope trace – positive going pulses

setting in *small* increments. (See Figure 3-6) As the input voltage is reduced various staircases of increasing step levels and peak-to-peak amplitudes will be generated. A point will be reached, however, where a further decrease of input voltage will not be sufficient to cause lamp current to flow on every positive or negative going cycle. This is the voltage at which the circuit will start operating in the frequency divider mode. (See Figure 3-9)

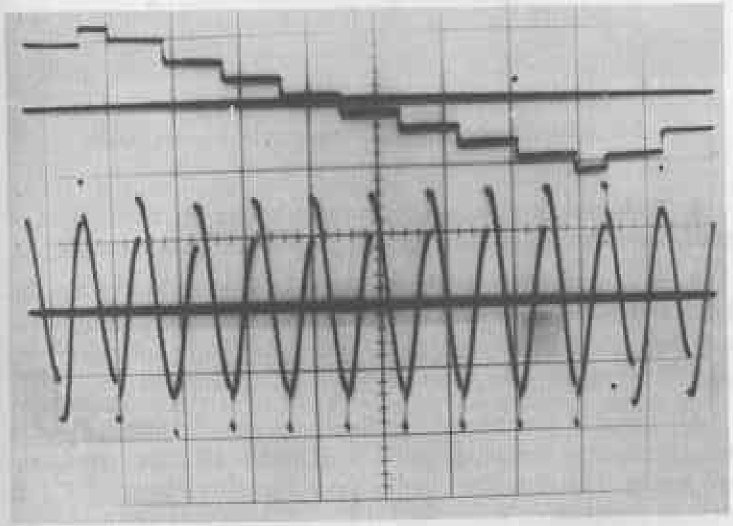
When the input voltage across L1 and C1 is in the order of 40 volts, the voltage across L1 will take a number of cycles to build up to a sufficient level to fire the lamp. The L-C circuit acts as a heavy load immediately upon application of the input signal and requires some time constant to build up. After about 1-1/2 input cycles have occurred the voltage across C2 will be sufficient to fire the lamp. A charge will develop across



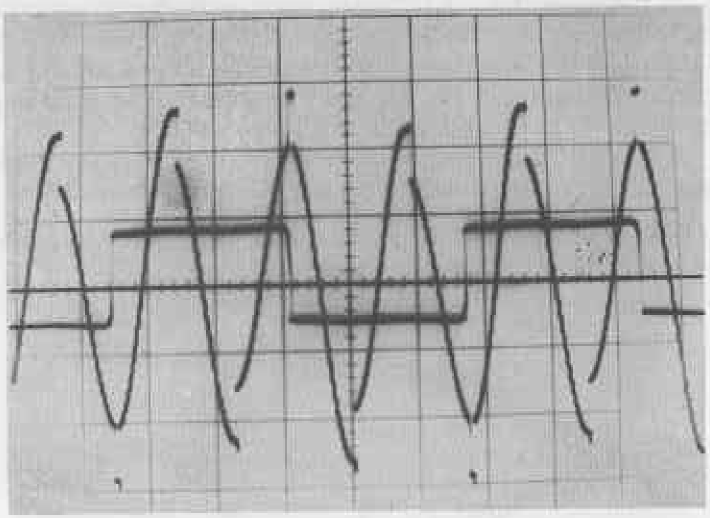
C2 due to current flow through R2, in the order of 1 volt (peak-to-peak). When the lamp discharges the voltage across L1 is lowered to some voltage which is below the maintaining voltage of the lamp. After 1-1/2 more input cycles have occurred again, the lamp will fire in the opposite direction causing a 3 to 1 count of the input square wave to be developed across C2. Frequency division by 5's, 7's, and 9's is obtained by reducing the input voltage through R1 in small increments.

In order to insure proper operation of this circuit the neon lamp characteristics should meet the following specifications:

1. It should have a large difference between breakdown and maintaining voltages.



3-8 Oscilloscope trace – generation of staircase



3-9 Oscilloscope trace – frequency divider mode

2. It should be checked on a curve tracer for cleanliness of breakdown curve. (It should not display an erratic curve.)

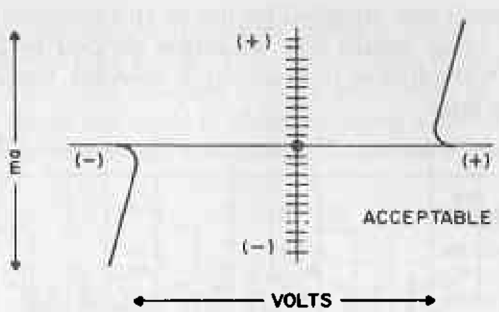
3. It should have as close tolerance as possible on breakdown and maintaining voltage levels in both positive and negative directions. Otherwise there will be a slight misalignment between positive going and negative going step levels.

All three of the above specifications can be checked on a transistor curve tracer. Figures 3-10 and 3-11 show good and bad traces. The inductor should have a quality factor ("Q") as high as possible.

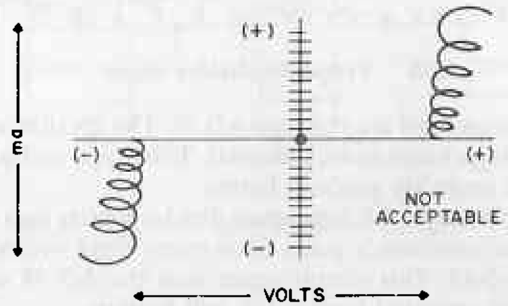
The signal generator should have a sufficient amount of drive to be able to handle loading of circuit.

An interesting variation on the conventional frequency dividers used in electronic organs uses transistors for coupling






3-10 Transistor curve trace – acceptable

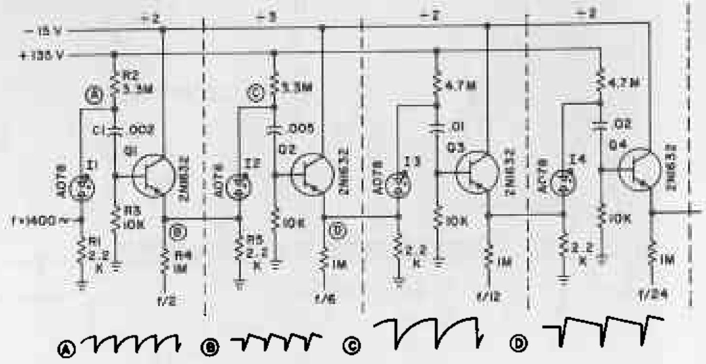



3-11 Transistor curve trace – unacceptable

the signals from one stage to the next and also for supplying an isolated output signal. (Figure 3-12) The first stage, a relaxation oscillator, has its natural frequency determined by $R_2$ and $C_1$. The familiar sawtooth waveform is shown at A. The synchronizing sine wave is a low impedance generator in series with $I_1$. The sine wave synchronizes the first stage by advancing or retarding the discharge of $I_1$ because it adds or subtracts itself to the ionizing potential.

Succeeding stages have natural frequencies lower than their synchronized frequencies because the negative pulse at B supplies an increased voltage to $I_2$, firing it prematurely.

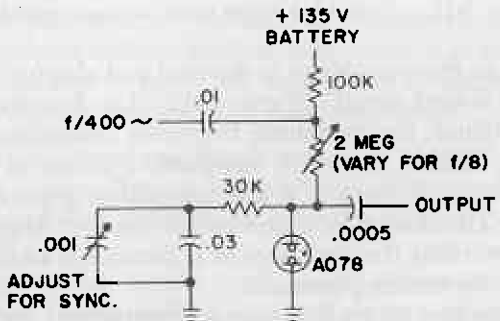
The circuit was intended for use as an electronic organ tone generator which would have all stages divided by 2. The second stage was adjusted to divide by 3, however, simply to prove it could be done.




3-12 Frequency divider circuit

The lamps used are the type AO 78. The 2N1632 was selected for its high breakdown potential. Tube-type cathode followers would probably perform better.

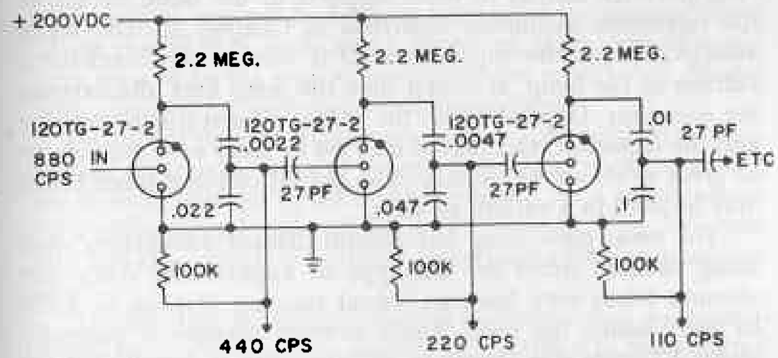
A simple scale-of-8 frequency divider which uses a 400 cps source and produces a pulse once every eight cycles is shown in Figure 3-13. This circuit again uses the AO 78 neon lamp and can be operated from a 135 volt battery.




3-13 Scale-of-8 frequency divider



Another approach to frequency dividers using a 3-element trigger tube, the type 120TG-27-2 cold cathode triode, is shown in Figure 3-14. (See Chapter V for a discussion of 3-element lamps.) A linear sawtooth is obtained using a 200 vdc power supply which powers the master oscillator and other auxiliary circuits.




3-14 3-element lamp frequency divider

## 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.

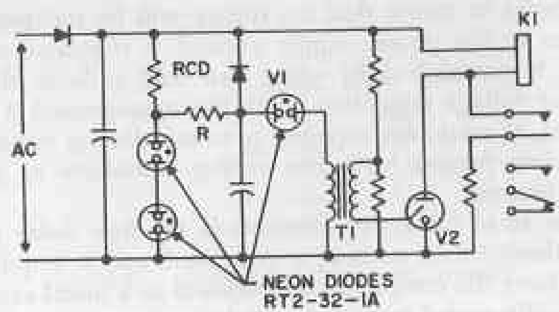
With the availability of radioactive isotope additives, cold cathode tubes are now available with stable characteristis regardless of incident illumination in a great variety of electrical characteristics. Cold cathode triodes (See Chapter V) are also available for control applications such as timers, 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.

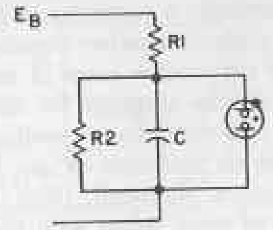
The time delay relay is not affected by voltage transients, is not damaged by current surges caused by turning it off and on, is not affected by temperatures in the range of 40 to 120 degrees Fahrenheit, and provides time delays in the range of .02 to 300 seconds for a selling price of $20.00 or less.

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:

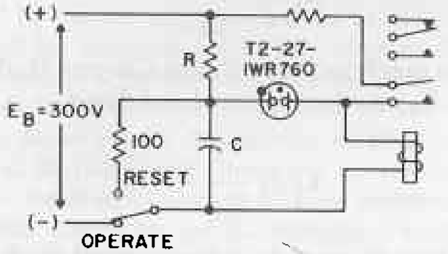
$$RC = \frac{T}{K_2}$$

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.

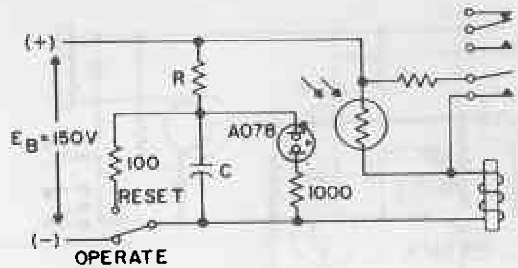



4-3 Use of neon-timer output to operate relay

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, $E_B$.

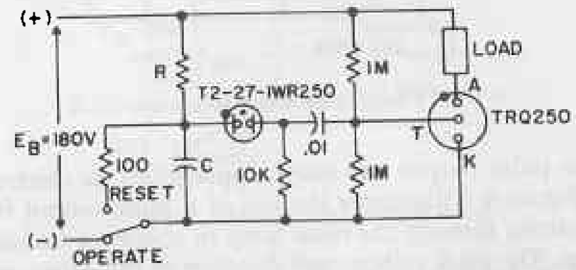
Use of the light output of the timer neon lamp with a cadmium sulfide or cadmium selenide photocell is shown in Figure 4-4. When the lamp ignites, its light falling on the photocell reduces the resistance, permitting the applied voltage to operate the relay. As above a contact on the energized relay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






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

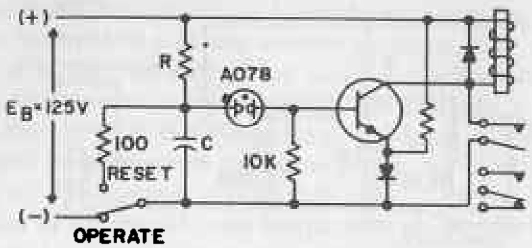
The voltage output of the timer neon lamp can operate a subminiature thyratron or three-element neon lamp as shown in Figure 4-5. The output pulse of the neon lamp is coupled to the trigger electrode of the thyratron causing it to turn on. Once the thyratron is ignited, it will stay on. With the components 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

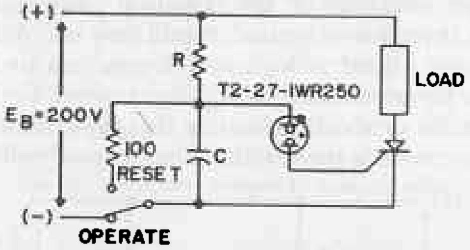
Operation of a transistor directly from the output of the neon lamp is diagrammed in Figure 4-6. The transistor is used to pull in the relay.

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.

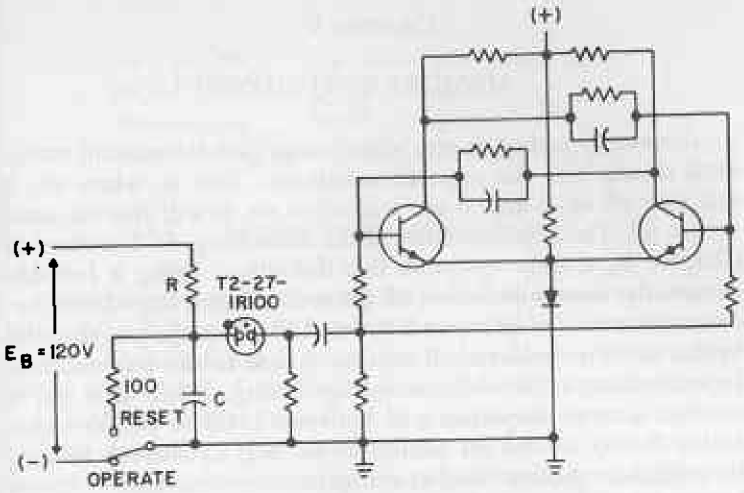



4-7 Use of neon-timer to operate SCR

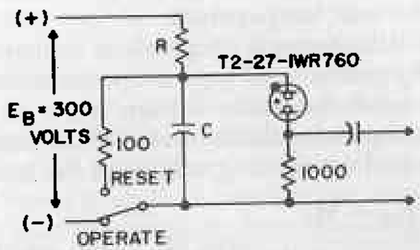
The pulse output has many applications in electronic design. Figure 4-8 illustrates the use of a pulse output from the timer circuit through the neon lamp to operate a transistorized flip-flop. The peak voltage and duration of the driver pulse are determined by the selection of the capacitor between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

## Chapter V

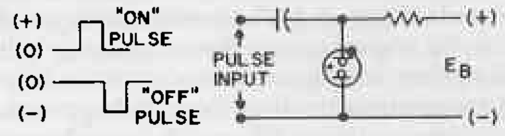
## MEMORY SWITCHES

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.

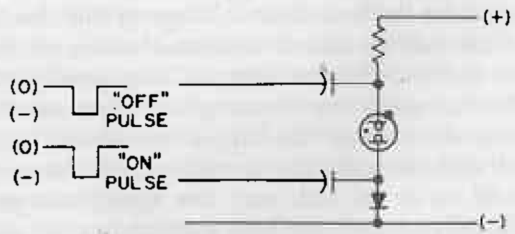





5-1 Memory switch with single input

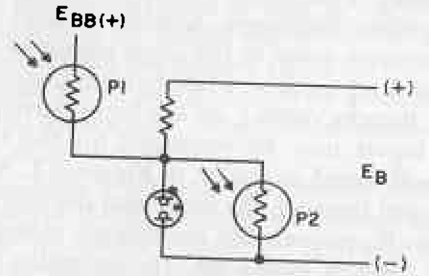
This memory switch can be turned off in a variety of ways, all of which have a common purpose. This is to reduce the current flowing through the lamp below the critical current rating of the lamp, I . The simplest method to accomplish this is to turn off the source voltage, $E_B$, or remove it from the 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.

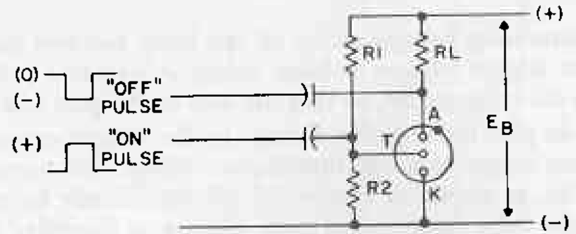



5-3 Operation of memory switch by photocells

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).

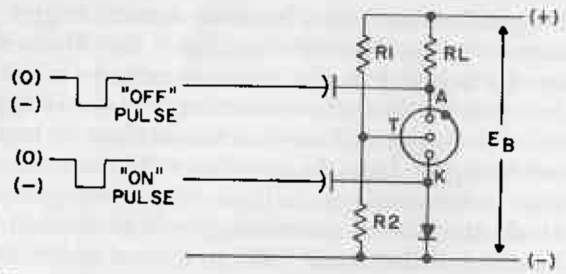



5-4 Trigger-driven 3-element lamp memory switch

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.

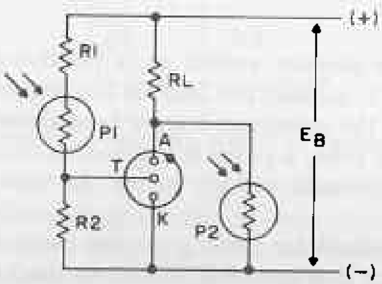
Another method for turning on the three-element memory switch is shown in Figure 5-5. In this method a negative pulse is applied to the cathode so that the sum of the positive bias on the trigger electrode plus the negative pulse to the cathode exceeds the maximum breakdown voltage rating of the trigger 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-



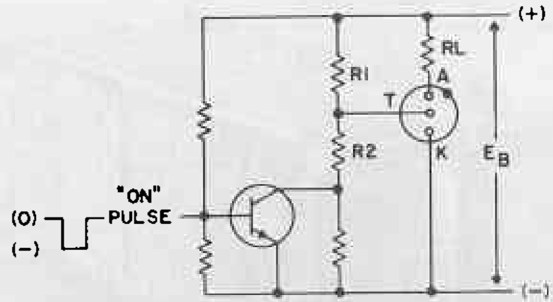

5-5 Cathode-driven 3-element lamp memory switch

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 applied 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, $E_B$.

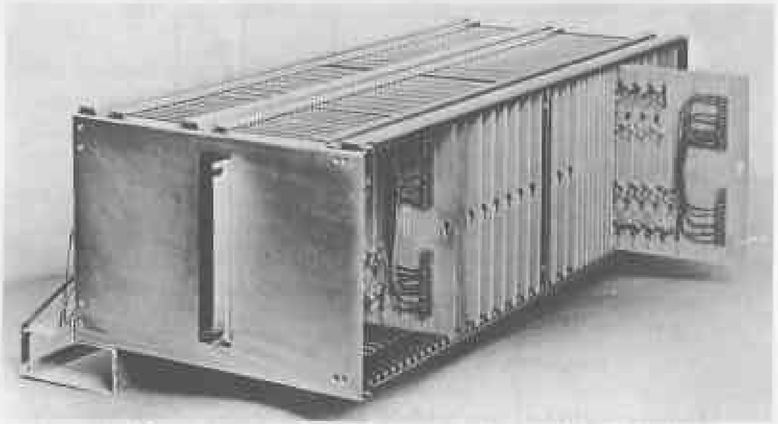



5-7 Operation of 3-element lamp memory switch by transistors

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.

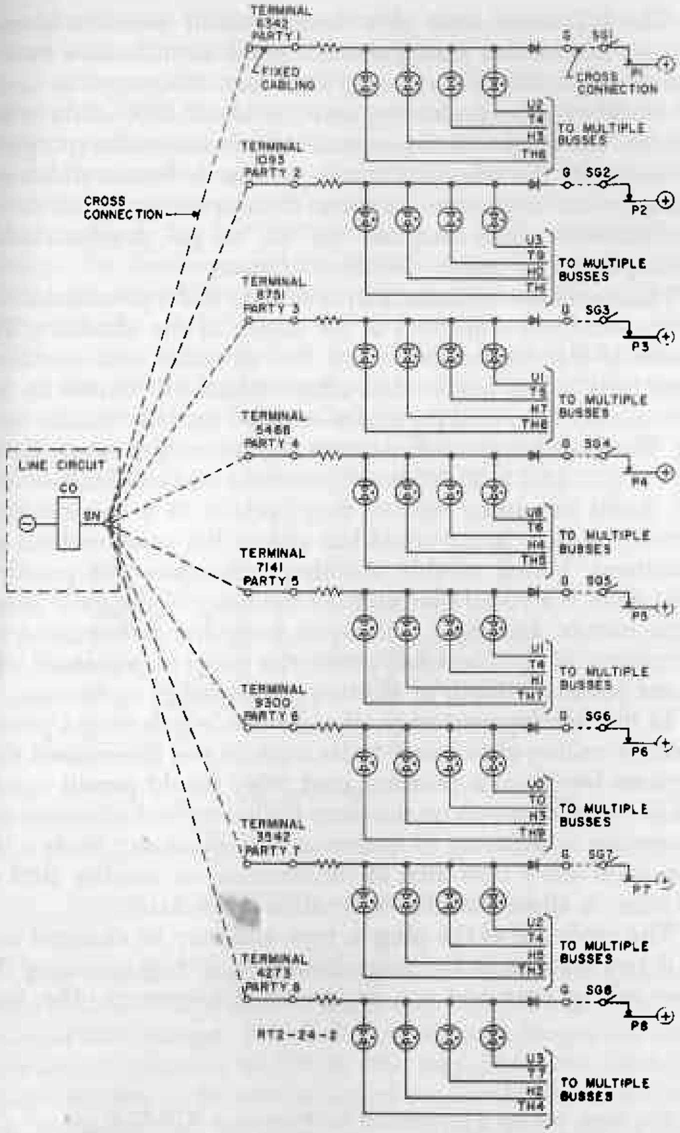
The identification principle employed is based upon a matrix (Figure 5-8) in which standard neon glow lamps are used as gating elements. A pulse of positive potential is applied via the originating switch train sleeve to the originating line circuit and connector terminal, and thence to an associated 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

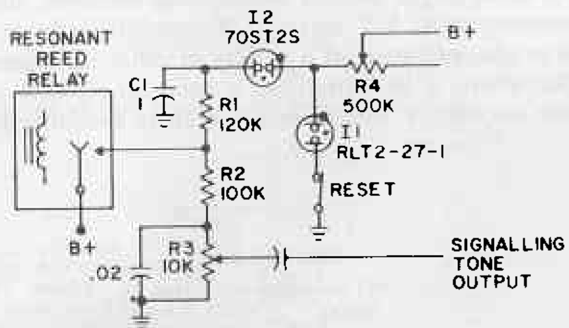
2. This lamp has been superceded by Signalite's RT2-27-1.
3. Childs, Gailand, E. F. Johnson, Inc., "Call Alert for Two-Way Radio," *Electronics World*, July, 1965.



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)

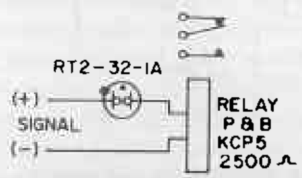



5-10 Station call memory circuit

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



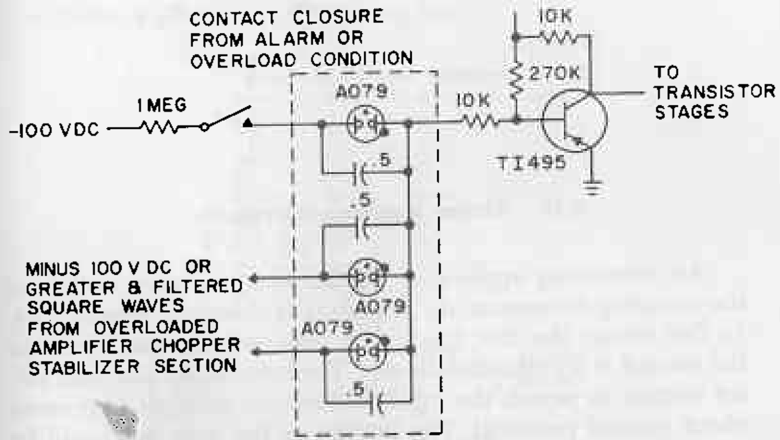

5-11 Relay with close pull-in and drop-out characteristics

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.

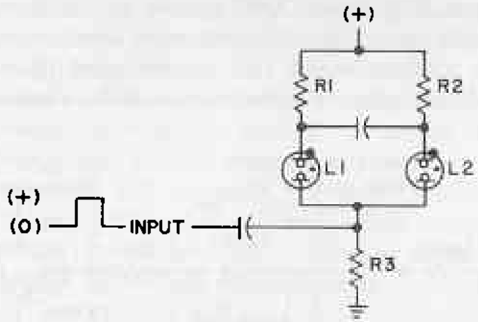
Many possibilities exist for using neon memory switches as computer logic circuit elements such as "OR" gates or "AND" gates. Figure 5-12 is an "OR" circuit application where the lamps provide visual identification as to which equipment in a system has malfunctioned and at the same time energize a transistor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

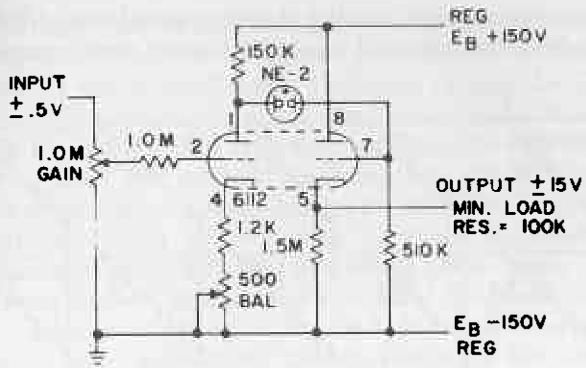



5-13 Driven bistable multivibrator

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.

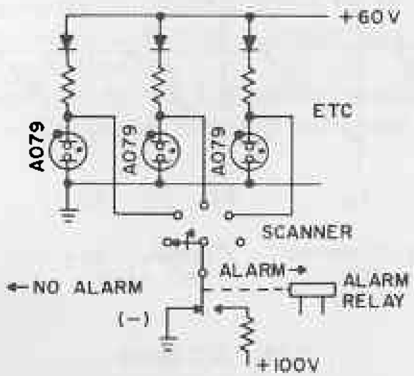
In the scanning annunciator, Figure 5-15, the position of the alarm—no alarm relay determines whether the lamp should be lit or extinguished as the scanner selects each alarm annunciation lamp. The diode in each lamp circuit prevents the 100 volt alarm-no voltage from raising the voltage on the 60 volt





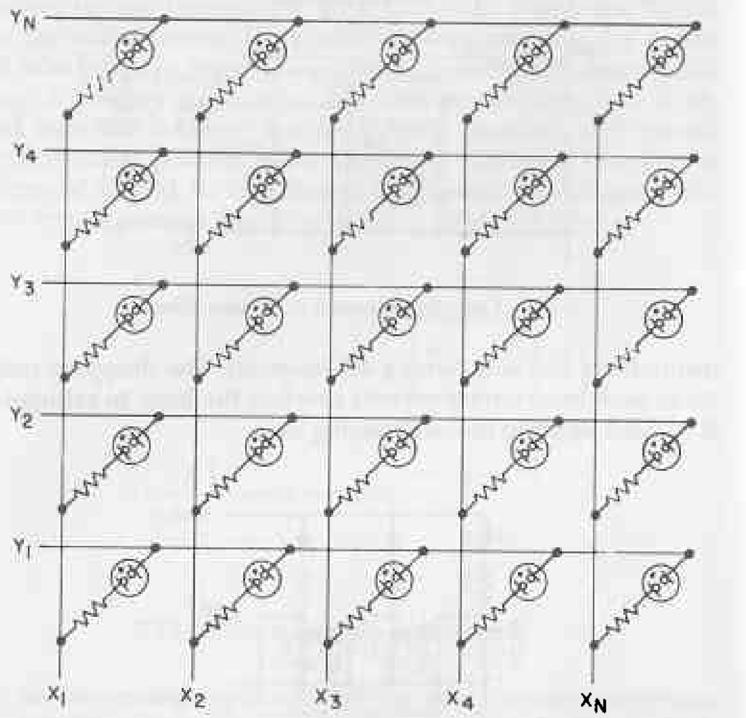

5-14 Coupling element in dc amplifiers

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.

## CHAPTER VI

## VOLTAGE REGULATION AND REFERENCE

Most electronic systems being designed today use some form of voltage regulation to ensure circuit stability regardless of changes in load current or supply voltage. In addition to being a requisite for proper circuit operation, many times the circuit design can be simplified with resultant cost reductions if it is based on using a regulated supply. The degree of accuracy that the voltage regulator must provide varies considerably with the function performed by the electronics. As a result there are many different methods for providing the regulation available to the designer.

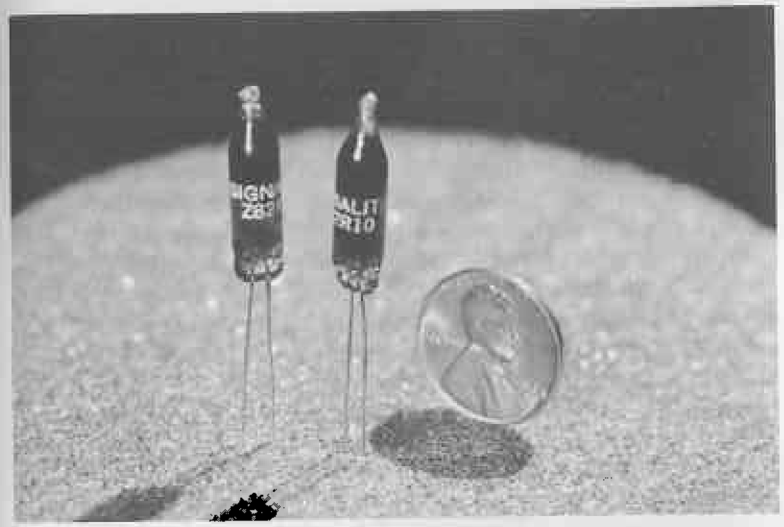
For many years neon glow lamps have been used to provide voltage regulation. This is because the characteristic maintaining voltage of these gas discharge tubes remains fairly constant over a relatively wide range of operating currents. Thus, they can absorb any reasonable voltage or current fluctuations occurring in normal operation, keeping the load voltage fairly constant.

For many applications, however, the degree of control required by the system and its components is so close that standard neon glow lamps, originally designed for indicator use, can not be used. Consequently, where regulation of voltage has to be held within limits less than ±5 volts, it has been necessary in the past to use other means such as complex circuitry for regulating the power supply itself or installing large gas tube regulators or zener diodes, all of which are fairly expensive.

Recently, a major improvement was made in the design and manufacture of cold cathode tubes by Signalite whereby the breakdown and maintaining voltage characteristics could be held to extremely close tolerances. As a result a new family of cold cathode voltage regulators was evolved which could be used to provide regulation, predictably and reliably, to within ±0.5 volts. Compared to other methods for regulating voltage, these tubes are small, inexpensive, simple to install, rugged,

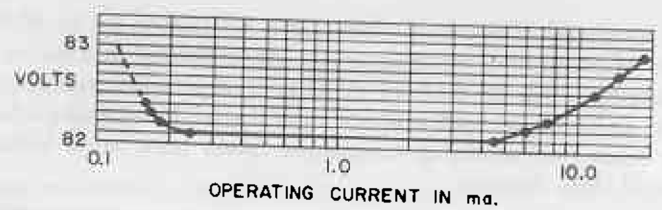


and longlived. They hold their close tolerances up to 30,000 hours of continuous operation, and are relatively insensitive to vibration, shock or thermal cycling. Temperature coefficients range as low as minus 2 millivolts per degree Centigrade which is at least two orders of magnitude lower than same voltage in solid state devices.



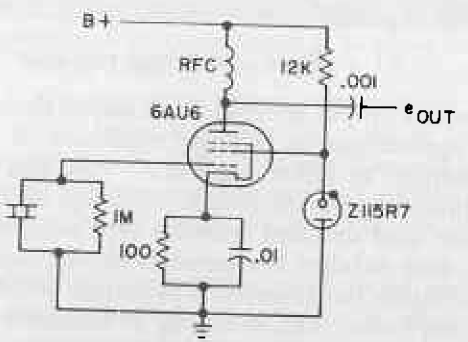
6-1 Photo neon voltage regulators

The precise output of these tubes makes them equally suitable for applications as voltage regulators or for reference voltage sources. In either application they can be depended upon to provide accurate output. Although in the past many people have used standard indicator type neon lamps for these purposes, their stability, low current carrying capacity, and degree of variation has imposed a limitation which has necessitated a compromise with precision or reliability. It should be noted that the tubes discussed in this chapter are not standard indicator lamps. The tubes under consideration here represent a whole new class of component which should be compared to the highest quality gas tube regulators, zener diodes and other methods for achieving close regulation. (See Figure 6-2)




6-2 Typical regulation curve for cold cathode voltage regulator

Many circuits in today's electronic equipment require the maintenance of precise voltage levels for proper operation. Variations in the $E_B$ voltages can cause shifts in amplifier gain or can produce significant distortion. These changes in power supply voltage can result in malfunction of the equipment in less serious cases, or in catastrophic failure in the more severe cases. Lack of proper regulation in the screen voltage of a crystal oscillator, for example, can cause the frequency to drift in spite of the crystal control and can change the output level. A typical application for neon cold cathode voltage regulators for this application is shown in Figure 6-3.




6-3 Voltage regulation for crystal oscillator

One of the more common devices that is particularly sensitive to the stability of the power supply voltage is the photo-



multiplier.[1] Development in recent years of semiconductors and solid state technology has precipitated an unparalleled progress in photosensitive cathodes. This is because the semiconductor materials have a quantum efficiency in the visible spectrum that exceeds that of the metals by a significantly higher ratio, up to 30 percent for semiconductors versus up to 0.1 percent for metals.

Although photoelectric emission is a relatively efficient process on a per quantum basis, the primary photocurrent for low light levels is so small that secondary electron emission is necessary to provide current amplification high enough to be useful. In the photomultiplier tube photon energy impinging on a photocathode causes an emission of electrons. These are directed to a secondary emitting surface called a dynode. Impingement of the primary electron on the dynode causes 3 to 6 secondary electrons to be emitted per primary electron. These secondary electrons are directed to a second dynode where the process is repeated. Photomultiplier tubes may have as many as 14 dynodes. The last dynode in any case is followed by an anode which collects the electrons and provides the output signal.

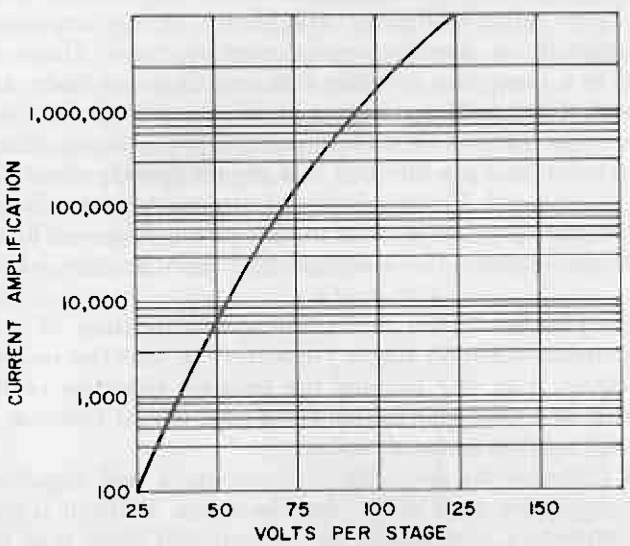
In the photomultiplier the coupling and focusing of multiple secondary-emission stages (dynodes) so that the secondary electrons from one become the primary electrons of the next result in a total gain which is an exponential function of the voltage applied to the dynodes.

This indicates the necessity of providing a well regulated voltage supply for each of the dynode stages. While it is possible to operate a photomultiplier so that each stage is at the voltage required for maximum secondary emission, such a condition would require in the vicinity of 500 volts per stage. The more conventional and practical approach is to operate each dynode at the voltage which produces the maximum gain per volt. While this voltage varies from tube to tube, it is generally

1. Bauman, Edward, Signalite Inc. — "A New Method for Precise Voltage Regulation for Use With Photomultipliers," *Signalite Application News*, Vol. 3, No. 2, and "Precise Voltage Regulation for Photomultipliers," *Electronic Industries*, February 1966.

in the vicinity of 70 to 100 volts. Thus, we see the need for closely regulated voltage supplies.

Depending on the method by which electrons are directed from dynode to dynode, photomultiplier structures may be classified as unfocused, electrostatically focused, and electromagnetically focused. In unfocused structures such as the grid, Venetian-blind and box types, electrons are simply accelerated from dynode to dynode by means of grids. In electrostatically focused photomultipliers a portion of each dynode serves to




**6-4 Variation of amplification factor with voltage per stage**

shape the electric field between dynodes in such a manner that secondary emission from one dynode is focused upon the optimum area of the following dynode. Mutually perpendicular electric and magnetic fields provide similar focusing of secondary electrons in electromagnetically focused photomultipliers.



A typical electrostatically focused photomultiplier with nine dynode stages before the collector anode may result in an overall gain of approximately one million at 100 volts per dynode stage. Variation of the amplification factor with the voltage per stage is shown in Figure 6-4 for a typical 931-A tube.

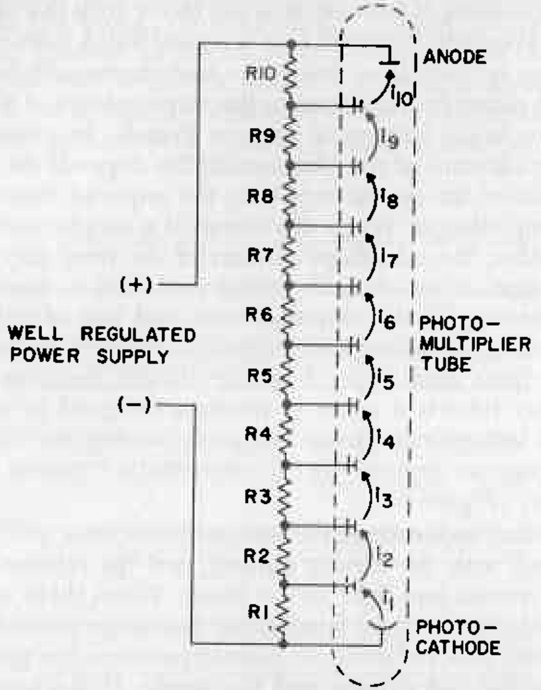
It can be seen from this curve that photomultiplier gain is affected either by variations in the stage voltage of all the dynodes, or in the voltage of just one dynode. In practice, then, the amplification of the photomultiplier depends on the characteristics of the circuit supplying the required inter-electrode operating voltages. When this circuit is a simple resistive voltage divider, the interstage currents of the tube may alter the distribution of the dynode voltages in such a manner as to cause limiting of the output current and loss of gain due to electrostatic defocusing and electron skipping of dynode stages.

The most usual type of voltage divider used for a photomultiplier tube is a series of resistors designed to divide the applied voltage equally or unequally among the various dynode stages as required by the electrostatic focusing system of the tube. (Figure 6-5)

In some applications the interstage currents are negligible compared with the divider current, and the relation between output current and light flux is linear. When there are significant variations in light level, these interstage currents are not negligible. This reduction in current produces the greatest loss between the last dynode and the anode. If the total applied voltage is maintained constant, the voltage lost in the output stages is redistributed among the preceding stages in a nonuniform manner. This causes unequal changes in the gain of the affected stages and may cause electrostatic defocusing, electron skipping of stages, and other effects.

Regulation of the voltage applied to the dynodes may be accomplished by either of the two following methods. One of these is to have a very tightly regulated power supply in the 1000 to 1500 volt class, and to have a high current bleeder so as to supply a low source impedance voltage to each dynode. The disadvantage of this method is that for most applications it is complex, costly and may present a severe maintenance problem.

The second method is to regulate the voltage at each dynode. Several methods have been proposed and used to accomplish this. One is to use zener diodes, which exhibit good

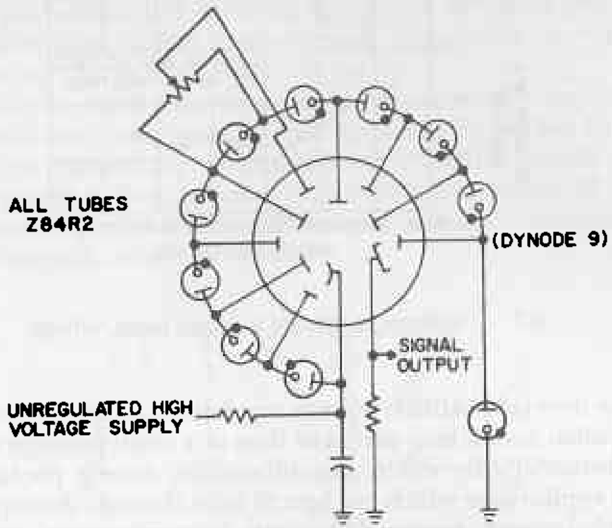



**6-5 Resistive-type voltage divider for photomultiplier**

characteristics in regulation. However, they can only be used in applications where they will not be adversely affected by their poor temperature coefficients. Cost is also a factor in their selection because high voltage, close tolerance zeners tend to be prohibitively expensive.

The use of large gas tube regulators for each dynode also tends to be expensive. Frequently, they do not exhibit a close enough regulation to maintain the dynode voltage within tight limits. Occasionally, they exhibit jump voltage characteristics. In some applications their size prohibits their use.

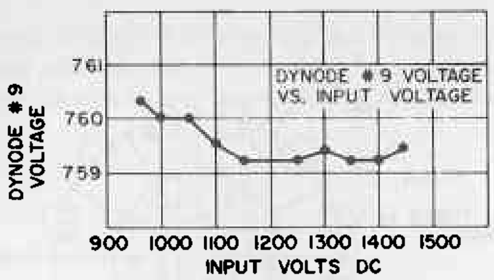





**6-6 Cold cathode voltage regulators with photomultiplier tube**

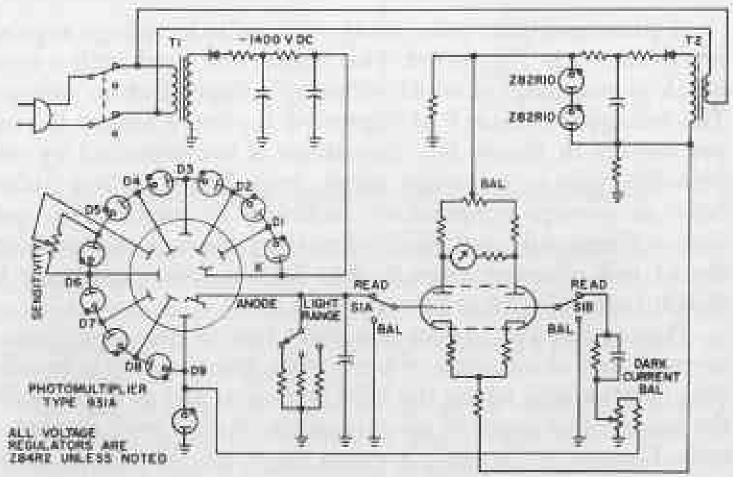
A photomultiplier tube using cold cathode voltage regulators is shown in Figure 6-6. This circuit was used with a type 931-A photomultiplier which is critically dependent on voltage. The voltage at dynode 9 of Figure 6-6 is plotted against the input voltage in Figure 6-7. Regulation is accomplished by ten Signalite voltage reference tubes, type Z84R2. These tubes have an average temperature coefficient of minus 2 mv per degree Centigrade and exhibit less than one volt change from the 84 volt reference from 0.15 to 2.0 ma. Life expectancy is 30,000 hours of continuous operation.

Photomultipliers are an important tool in detection, measurement and observation where human visual acuity is insufficient, particularly where the light level is so low as to preclude the use of other types of photosensitive devices such as photocells. Because in these applications the effects of noise or transit time can materially affect the required results, accurate regulation of voltages to the dynodes is of critical importance.




6-7 Voltage at dynode 9 versus input voltage

These new cold cathode voltage regulators can provide reliable regulation over a long period of time in a small package and at a substantially favorable cost differential. Among photomultiplier applications which can benefit from this new development are photometry, spectrophotometric instrumentation, scintillation counters, gamma ray spectrometers, Cerenkov radiation measurement, particle size measurement, smoke detectors, ce-

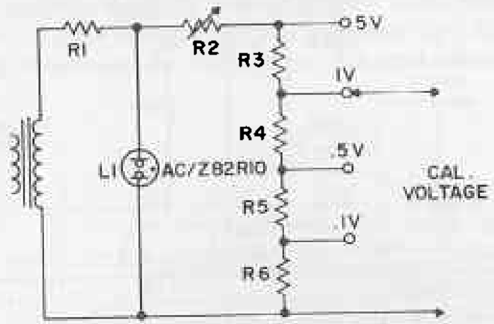



6-9 Calibrator circuit



lestial navigation, star tracking, flying-spot television pick-up, laser detection, timing measurement, and others. A typical photometer circuit is shown in Figure 6-8.

A circuit which uses these cold cathode voltage regulators for a calibrator in an oscilloscope is shown in Figure 6-9. In this circuit the maintaining voltage of the AC/Z82R10 tube is used as the reference line. Accuracy is maintained to within .2% over an extended period of time. The output voltage is specified as a peak-to-peak reference voltage.




6-8 Typical photometer circuit

$R_1$, $L_1$ and $R_2$ are mounted internally. $R_2$ is adjusted once initially to match the voltage regulator being used. Recalibration is not necessary since these voltage regulator tubes maintain their close tolerances for an extremely long time.

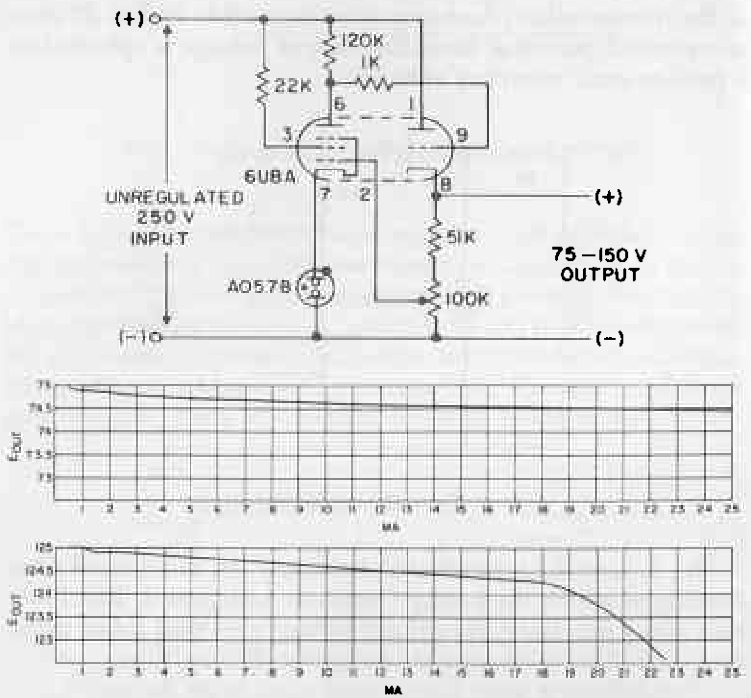
The following procedure is used to calibrate the unit:

1. Connect a calibrated oscilloscope to the highest reference voltage tap, that is, the junction of $R_2$ and $R_3$.

2. Adjust $R_2$ until the oscilloscope reads exactly 5 volts peak-to-peak. Then, if the resistors ($R_3$, $R_4$, $R_5$ and $R_6$) are accurate, the output voltages should be as specified.

This circuit may be used with ac voltage or dc voltage simply by choosing the appropriate voltage regulator tube.

A simple method for regulating the voltage of low-power power supplies used in electronic equipment is shown in Figure 6-10. The potentiometer permits output voltage to be set at any value between 75 and 150 volts. The neon tube is used to set the reference level, and its maintaining voltage establishes the lower limit for voltage regulation.



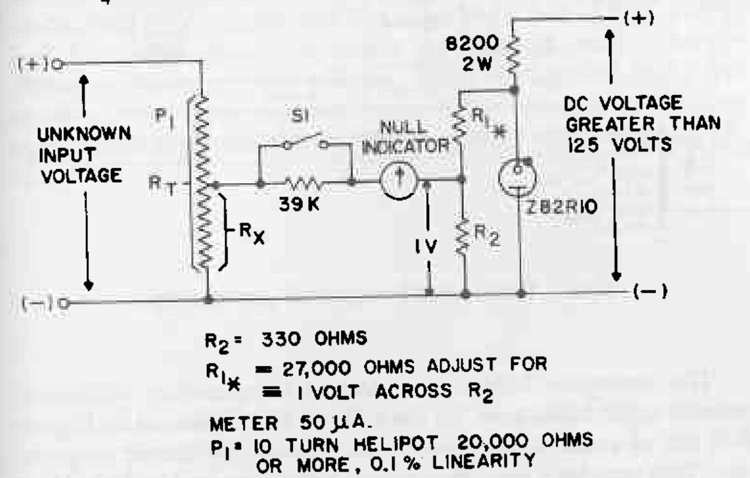

6-10 Power supply regulation

Use of the neon cold cathode voltage regulator tube as a stable voltage reference source for comparison purposes is shown in Figure 6-11. While this example indicates a simple digital voltmeter, a similar approach may also be used to make a suppressed zero meter.



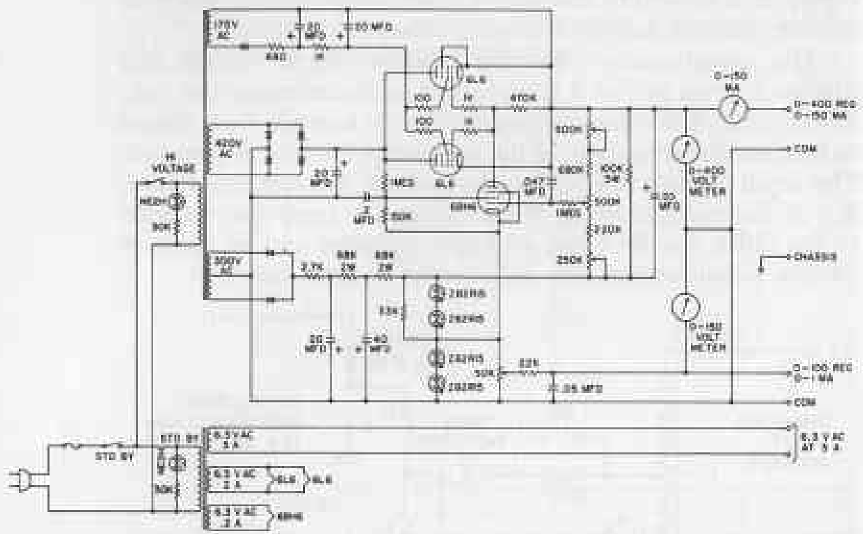
This circuit uses a precision Z82R10 voltage regulator for supplying an accurate 82 volts, and permits this value to be divided down to an absolute 1 volt. The accuracy of the voltage regulator is to within one volt. Consequently, the accuracy of the one volt will hold to .012 volts versus line conditions.

The potentiometer takes the unknown input voltage and divides it down so that it is compared to the reference one volt. As the ratio of the division comes close to balance, $S_1$ is closed to increase the sensitivity of the null meter for final adjustment. The input voltage is equal to the ratio of the total resistance, $R_T$, of the potentiometer to the resistance from the common to the slider, $R_X$. By using a 10-turn indicator and an accurate 10-turn potentiometer, the voltage can be read directly.




6-11 Potentiometer bridge voltmeter

Another example of a regulated power supply is shown in Figure 6-12. This is an electronically regulated power supply which uses the subminiature Z82R10 voltage regulators for a reference source. The output voltage is zero to 400 volts, regulated, up to 125 ma. Bias is zero to 100 volts. Output impedance is less than 10 ohms.



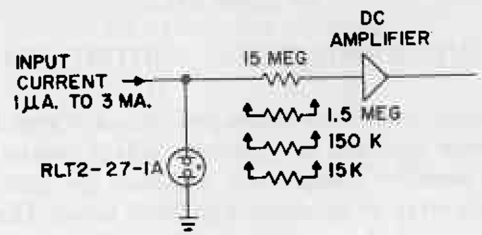
6-12 Electronically regulated power supply

The aerospace field is accustomed to operating within extremely tight tolerances. In the critical circuit shown in Figure 6-13 use of zener diodes would have made the circuit inoperative. This was for a sounding rocket nose cone and included five cold cathode ionization gauges. The microamp signal from the gauges was amplified in a dc amplifier as shown in Figure 6-13.

For low currents the input resistance of the amplifier was 15 megohms. But for higher currents an automatic range switching circuit inserted 1.5 megohms or 150K or 15K as required in place of the original 15 megohm input resistor.

In this program if the input current changed abruptly to a high value, for example 3 ma, when the 15 megohm resistor was on the input, the input voltage would be 3 times 15, or






6-13 Voltage limiter circuit

45 KV. To prevent this, a voltage limiter was required. Zener diodes had been considered but their high leakage at +85°C (<0.1 μa) introduced too much input signal error. Leakage current of the neon tube was low, firing voltage was high, and input voltage clamping was assured by using a neon lamp which has a high breakdown voltage rating, such as the RLT2-27-1A.

## CHAPTER VII

# SURGE AND SIGNAL PROTECTORS

Neon lamps frequently find applications where it is necessary to prevent transient or recurrent voltage pulses from damaging more sensitive components or where the circuit must be isolated from stray or spurious signals or noise. Three characteristics are essential to this application. First, the component must remain open-circuited until the applied voltage or pulse exceeds a predetermined ignition point. Second, it must be able to conduct moderately high currents without damage to itself. And third, it must have a finite and known extinguishing point high enough so that circuit operation may continue uninterrupted. All of these characteristics, as has been discussed earlier, are inherent in the neon glow lamp.

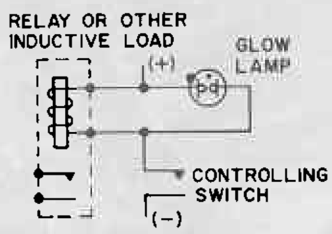
Among the many applications in this area is the prolonging of life for switch contacts used with relays and other inductive devices.

When the current flowing through an inductive load is suddenly stopped, a counter electromotive force is developed which theoretically may reach an infinitely high voltage at the instant of switching. In normal practice, the limitations imposed by leakage resistance and capacitance will prevent this voltage from exceeding 10,000 volts. This voltage is sufficient, however, to break down across the air gap between the open contacts, creating an arc which tears away some of the metal and shortens the contact life.

This problem has been eliminated in many cases by the addition of a simple neon glow lamp to the circuit. The lamp is placed across the relay coil as shown in Figure 7-1. When nonconducting, it does not affect normal circuit operation.

Under the build up of the counter emf as the contacts are opened, the lamp is ionized. The stored energy in the coil then discharges very rapidly through the lamp. The voltage across the coil is held to the maintaining voltage of the lamp until such time as the coil counter emf falls below this maintaining voltage. At that point the lamp will extinguish.






7-1 Protection of relay contacts from counter emf

When the lamp is operating, the voltage is maintained at a sufficiently low level to prevent arcing across the open contacts of a relay.

The effect of the current surges on lamp life and lamp characteristics is a function of the amplitude and rate of the surges. Under normal conditions in circuits with relay switches the duration of the surge is of such a short time that extremely high amplitudes can easily be tolerated without serious detriment to the life of the lamp.

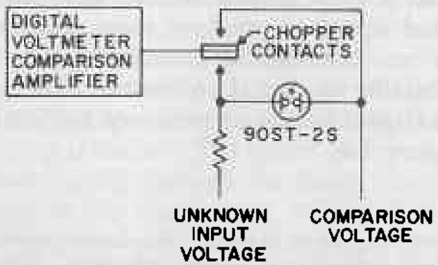
Choice of the specific neon glow lamp to be used in this type of application will depend on the inductance, the operating voltage and the current of the relay in the circuit. It is important to remember, however, that the maintaining voltage of the lamp must be higher than the relay operating voltage. Currently available lamp types have been designed with maintaining voltages from 50 to 150 volts dc. Initial breakdown voltages range from about 65 to 250 volts dc.

A specific use of glow lamps to absorb momentary surges to isolate unwanted signals or spurious noise, and to operate as off-on switches was described by Leonard M. Scholl in his discussion on reliability in digital voltmeters.[1] The product was the Model 484 Digital Voltmeter produced by Non-Linear Systems Inc. (Figure 7-2)

1. Scholl, Leonard M., Project Manager, Non-Linear Systems Inc., "Providing Low Cost Reliability in Digital Voltmeters," *Signalite Application News,* Vol. 2, No. 5.

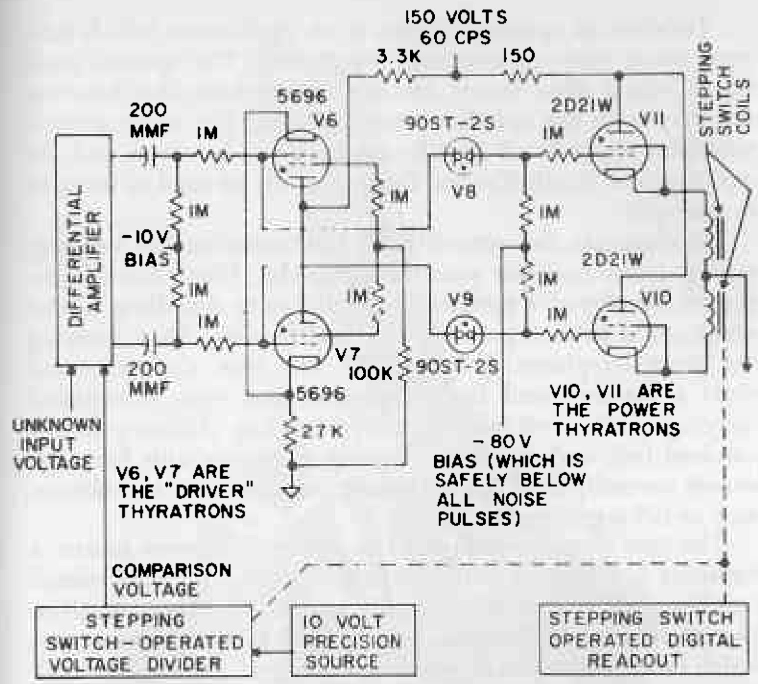
7-2 Photo digital voltmeter

The neon lamps were used in two separate circuits in the voltmeter. In a circuit similar to that shown in Figure 7-1, the neon lamp was used for chopper contact protection. This circuit was part of the differential amplifier and provides a bypass for high voltages around chopper contacts. During range switching in digital voltmeters, momentary high voltages are often applied to chopper contacts which would cause arcing if not protected. The lamps do not affect digital voltmeter operation during normal measurements because they are effectively open-circuited when extinguished. (Figure 7-3)




7-3 Protection of chopper contacts from momentary high voltage






7-4 Neon lamps as a coupling network

The second application for neon glow lamps in the voltmeter was to provide for reliable firing of the thyratrons to pulse stepping switches. The driver thyratrons are set to be fired by an input of 1 millivolt to the amplifier. When the driver thyratrons are ignited, they cause the neon lamps to switch on and ignite the power thyratrons. The power thyratrons are biased off by a high negative voltage to avoid being fired by noise pulses created by pulsing the stepping switches. Since the 90ST2S lamps are such effective on-off switches, they greatly simplify using a high negative bias voltage. The neon lamps very effectively isolate the driver thyratrons and the amplifier from these noise pulses.

Isolation of spurious signals is an application which concerns many types of electronic equipment. The specific manner in which glow lamps are used to perform this function will vary with the specific circuit at hand. The same general principles apply to all specific applications, however, and the experience of North Electric Company can be used to serve as an example.[2]

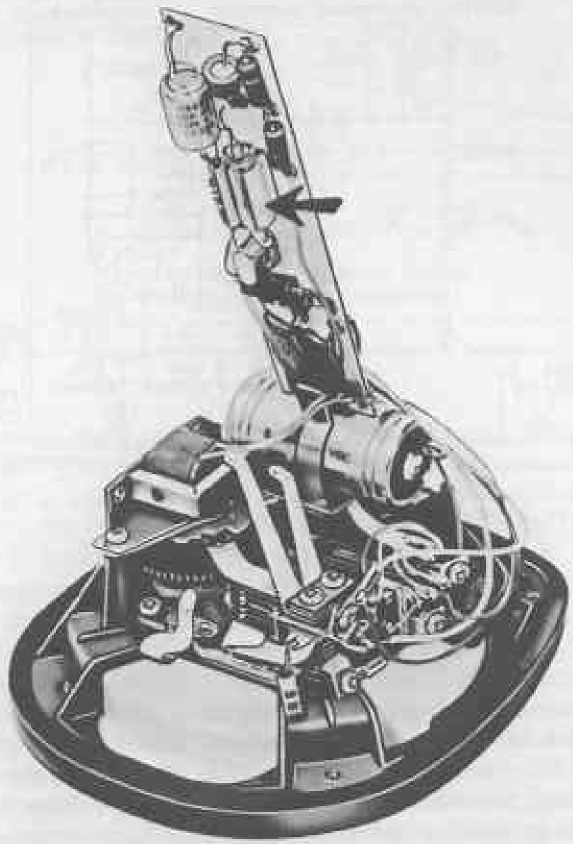
To eliminate the conventional electromechanical bell signalling device used for years in telephones, North Electric engineers developed a miniaturized solid state signalling device which could be incorporated into the Ericofon (TM) standing one piece telephone. (Figure 7-5) The new electronic unit emits a pleasant and highly efficient tone with exceptional carrying quality, without the nerve jangling stridency of the standard bell, and one that is readily distinguishable from the sounds normally heard in the vicinity of telephone substations, such as talking or music.

The tone ringer is comprised basically of a power source, a transistor blocking oscillator circuit, and a tank circuit which together couple actuating signals to the telephone receiver. The 20 cycle ringing signals are coupled to the power source which in turn provides a pulsating dc output causing the oscillator to operate. The oscillator operates at the mechanical resonant frequency of the receiver. The power source includes series resistance connected between the terminals.

A rectifier is placed in parallel with a resistor to provide unidirectional current flow in the direction indicated. A network including a first branch capacitor connected in parallel with a resistor, and a second branch including a series-connected capacitor, resistor and type RT2-32-1A glow lamp connected in parallel with a capacitor, provide the signal output for controlling the operation of the blocking oscillator circuit. The oscil-

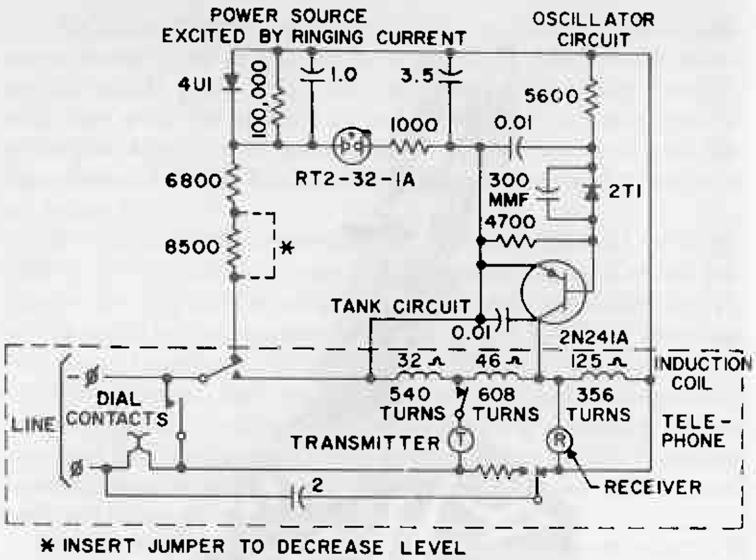
2. Pickett, Robert, Director Technical Marketing, North Electric Co. and Bauman, Edward, Signalite Inc., "Glow Lamp Prevents Operation By Transient Signals," *Signalite Application News*, Vol. 3, No. 1; and Bauman, Edward, "Glow Lamp Prevents Telephone Dial Tapping," *Electronic Design*, December 21, 1964.





7-5 Photo telephone tone signalling device

lator circuit includes a conventional P-N-P transistor and produces sine wave output signals of variable amplitude which cause the diaphragm of the receiver to vibrate, generating the melodious tone call signal. The tank circuit is connected to the collector circuit and includes two of the induction coil windings for positive feedback, a third being wound in the opposite direction.

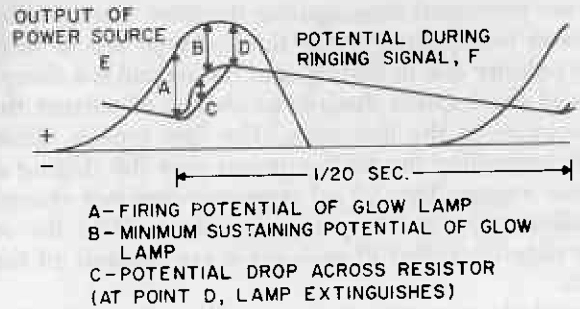



7-6 Electronic tone ringer circuit

In operation the ringing voltage across the telephone line is of sufficient value, when rectified and filtered, to be greater than the firing voltage of the glow lamp. This causes the lamp to ignite and immediately settle to its sustaining voltage, allowing a voltage buildup across the capacitor. This voltage is applied to the tone oscillator circuit. As the ringing voltage across the line decreases to a value less than the sustaining voltage of the lamp, the lamp goes out and the capacitor discharges through the tone oscillator. (See Figure 7-7)

This is shown graphically in Figure 7-7. Curve F, indicated as Potential During Ringing Signal, represents the potential which appears across the capacitor connected in parallel with the glow lamp. Curve E, indicated as Output of Power Source, represents the voltage which appears across the capacitor (3.5 mf) connected in series with the glow lamp, and is the voltage






7-7 Voltage and current relationships in electronic tone ringer

applied to the oscillator circuit. During ringing, the incoming voltage is rectified and filtered by the power source. The dc voltage is stored in the 1 mf condenser. When this voltage reaches the firing potential of the neon glow lamp (A on the curve), the lamp will ignite and begin to conduct to complete a charging circuit through the 3.5 mf condenser. During this time the potential difference between the 1 mf and 3.5 capacitor consists of the maintaining potential of the lamp, which is a constant, and the potential drop across the 100 ohm resistor, which is a variable represented by C on the curve. As the 3.5 mf capacitor becomes fully charged, the potential drop across the lamp and resistor decreases until it is below the maintaining potential of the glow lamp, which then extinguishes. The 3.5 mf capacitor supplies power to the oscillator circuit.

From curve E it can be seen that, if the capacitor (3.5 mf) is chosen so that it never becomes completely discharged between ringing frequency cycles, the potential will gradually drop between positive half cycles to a low value, and rise again to a maximum value during the next half-cycle in a continuous manner. This introduces variation in amplitude, or a "warble," into the tone, producing a melodious and pleasant sounding signal.

To guard against spurious signals on the telephone line passing into the circuit and affecting the electronic tone signalling device, the device is connected so that transient pulses on the line are prevented from igniting the glow lamp. These transients are of two distinct types: the first type is a 48 volt peak of either polarity due to dialing, and the second is a sharp spike or series of short spikes due to the change of current through the inductance of the line relay. The first type is eliminated simply by extending the dialing pulses over the ringing circuit and power source. The 1.0 mf capacitor does not charge to a value sufficient to fire the neon glow lamp. With the second type the negative spikes of each cycle are shunted off through the diode.

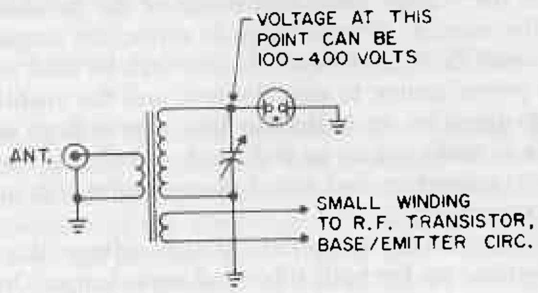
To preclude operation of the signalling device by the positive short spikes, the 1 mf capacitor and 6800 ohm resistor are selected for a value that provides a time constant of such duration that the capacitor cannot charge to a value sufficient to fire the glow lamp. Thus, the lower frequency spikes of shorter duration are shunted through the diode, and the higher value spikes of short duration are accumulated momentarily by the capacitor and then discharged through the 100 K resistor without operating the signalling device.

Breakdown voltage of the neon glow lamp is critical and must be held within narrow limits to prevent dial tapping throughout the life of the telephone.

The RT2-32-1A lamp used in this circuit handles 18 milliamps, an unusually large amount of current for a lamp of this size. Its reliability and long life were proven at North Electric during a test program which produced the equivalent traffic of a busy telephone for 40 years of operation.

Various transistorized communication receivers, particularly mobile and marine, are often subjected to severe overloads at their antenna terminals. The voltage levels which can be created at the receiver's input by the high powered transmitter on an adjacent vehicle are often able to destroy the tuned circuits immediately connected thereto. The resonant rise of voltage of such circuits is conveniently limited to 50 volts or so by the use of a low voltage glow lamp, and this fact, coupled with the typical 10 or 12 to 1 step-down at the transistor input terminals of such an input coil, is sufficient to protect typical R.F. transistors.





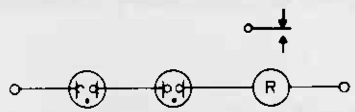

7-8 Transistor input protection

At first glance, it appears that damage could be done to the transistor during the instant immediately following the beginning of a dangerous power burst before the lamp had a chance to light. Two factors, however, are in our favor at this point.

1. The transistor input diode is generally of sufficient thermal capacity that we can safely wait until the glow lamp would normally be expected to light.

2. The glow lamp in fact ignites much more rapidly with R.F. voltage than it does with a dc step function.

During the design of special test equipment it is often necessary to protect either the tested unit or the test equipment, or both from higher than normal voltages. These high voltages can be caused by misconnection of the equipment or of the tested unit. One way to provide this protection is to put neon glow lamps in series with a sensitive relay across the terminals to be protected as shown in Figure 7-9.




7-9 Relay isolation network

When the voltage exceeds the sum of the breakdown voltages of the number of neon lamps in series, the lamps will ionize and cause the relay to operate. This can be used to de-energize the power source to stop the test, and the visible glow of the lamps provides an indication that over-voltage is present. This idea is usable on ac as well as dc circuits. It can be used to protect voltmeters and transformers under test against incorrect connections.

Depending on the magnitude of over-voltage, this can be a severe application for both relay and neon lamps. One advantage, however, is that the relay is isolated from the circuit by 500 megohms until the overvoltage appears. If the relay is used to turn off the power source, a reasonable number of operations is expected.

## Chapter VIII

# USING NEONS WITH PHOTOCELLS

An interesting variety of applications are being developed for electro-optical components which consist of a neon glow lamp assembled in a light-tight casing with a photoconductive device. Because of the advantages of economy, long life, low maintenance and low noise, this type of unit is finding increasing use in electronic circuitry as a switch or as a variable resistance.

The spectral distribution light output of certain neon glow lamps is compatible with photosensitive polycrystalline semiconductors such as cadmium selenide and cadmium sulphide. For many applications the low power consumption and speed of response of a neon glow lamp makes it the ideal light source for use with the photocell.

Basically, these devices operate on the principle that any variation of the input current to the neon lamp alters the illumination incident on the photocell and changes its resistance. As a result the voltage across a fixed resistance in series with a signal voltage and the photocell can be changed by altering the input current to the light source.

The speed of the photocells is governed by their turn-on response and their turn-off response. In the neon lamp-photocell devices, the speed of response is limited to that of the photocell since the glow lamps are capable of faster reaction times than the photocells.

Among the Raysistors, developed and produced by Raytheon Company,[1] are neon glow lamp-photocell combinations which are designed to be used as a single component to perform a specific function. Working closely with Signalite, three primary requirements for performance of the glow lamps were

1. Whateley, D., Raytheon Company, "Some Uses For Neon-Photocell Units," *Signalite Application News*, Vol. 2, No. 2; and *Electronic Industries*, July 1964.

established. Because the Raysistor is enclosed in an encapsulated unit, the lamp has to fire reliably in a dark environment. For practical usage, a high ratio of conversion of current to light is required. And because replacement of parts in the Raysistor is not compatible with its design purpose, the lamps must have a long effective life.

The special lamp developed by Signalite engineers, type A240954, is based on use of some of the recent technological developments in the design of gas discharge devices. Among these are included special radioactive elements, a new gas mixture, electrode design, and others. These developments have made it possible to establish new standards for neon glow lamps for use as electronic circuit components, standards which are not based on adapting indicator lamps to performance for which they are not suited.

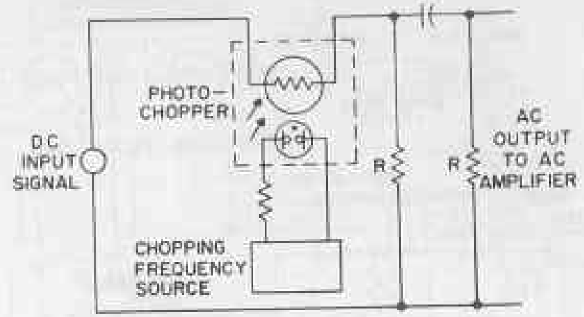
*Choppers-Modulators*

Choppers or modulators using photoconducting cells and modulated light sources offer the equipment designer several unique advantages. The purely ohmic behavior of the photoconducting cell, and the ease with which the cell may be shielded from induced emf's at the chopping frequency tend to eliminate the more common sources of null offset. Contact bounce and malfunctions are eliminated entirely. Since there is no voltage present at the cell except that due to the dc source being measured, there is no critical balance to be upset as in the case of solid state devices using barrier junctions.

As a series modulator (Figure 8-1) at low chopping frequencies from 30 to 60 cps, the output waveform is nearly squarewave so that the results are comparable to other types of choppers. At high frequencies the output waveform becomes more nearly sinusoidal, and it becomes necessary to consider amplifier and detector characteristics before comparing relative efficiencies.

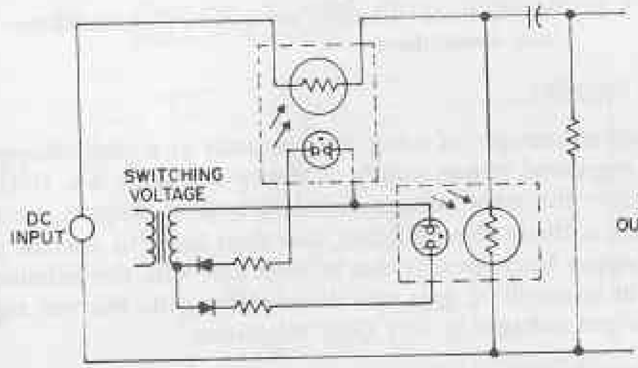
The series shunt circuit (Figure 8-2) provides a more symmetrical waveform and results in less drift in null offset under varying environmental conditions. The photochoppers must be operated 180 degrees out of phase. This is accomplished by





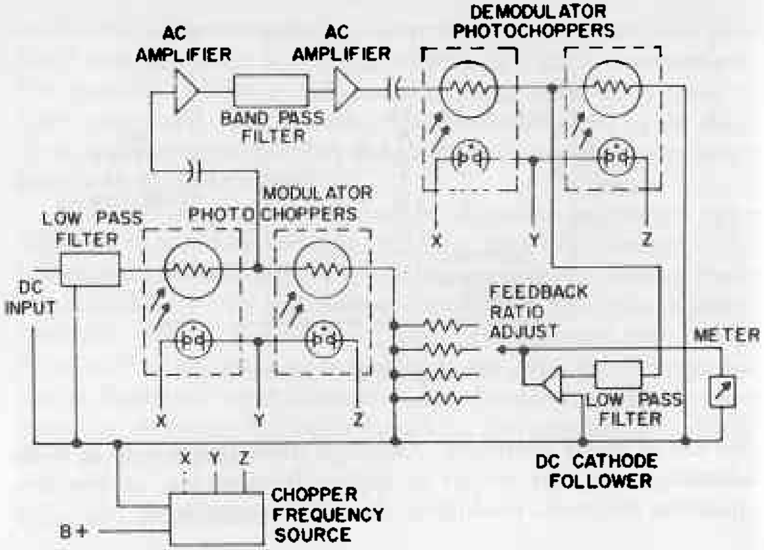

8-1 Neon-photocell series chopper

the use of diode switching. Although there may be up to 6 db advantages in this circuit at higher frequencies, at low frequencies the series modulator should be considered.




8-2 Neon-photocell series shunt chopper

For the ultimate in low drift or minimum null offset in dc amplifiers, the photochoppers can be used for both the modulator and demodulator. This is accomplished by the constant phase relationship between modulator and demodulator shown in Figure 8-3.




8-3 dc electronic voltmeter using neon photomodulator and demodulator

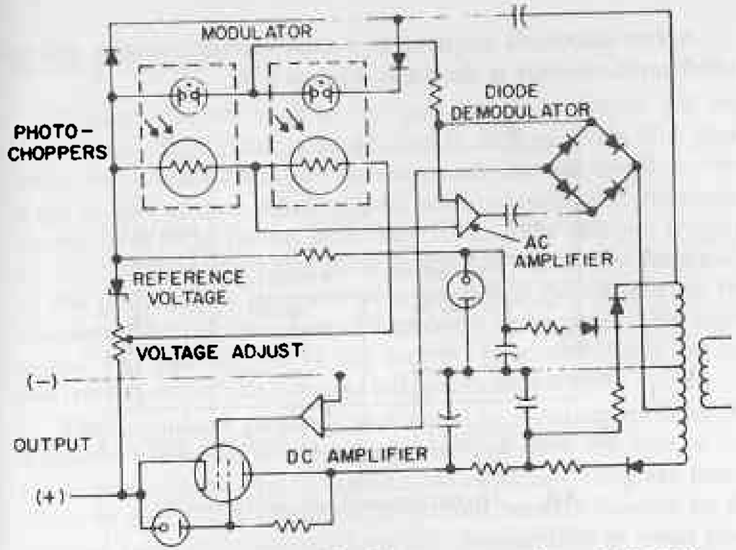
*Power Supplies*

Another example of using the Raysistor as a photochopper is in a regulated power supply as shown in Figure 8-4. In this application the error voltage is fed through a chopper, an ac amplifier, a diode demodulator, and then back to control its own chopper frequency. It can be seen that with the judicious choice of ac amplifier gain and dc amplifier gain, this can regulate output voltages to very close tolerances.

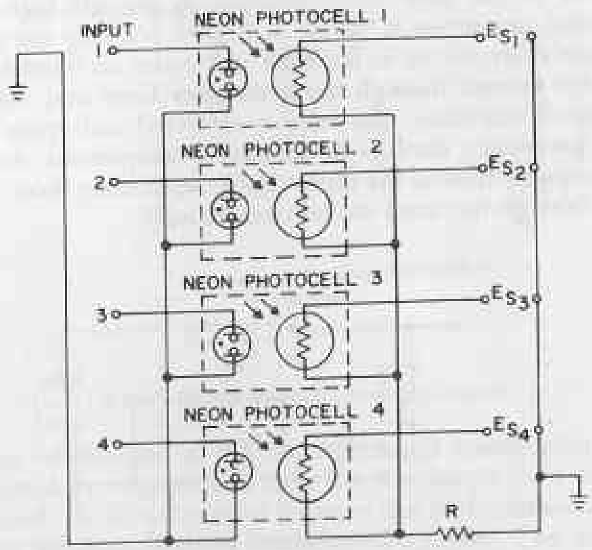
*Low Noise Switch*

The glow lamp-photocell combination will provide a low noise switch, free of transients or pedestals, for switching low level signals. It is a relatively slow speed device. The off time is normally slower than the on time, and it is the off time that determines the maximum switching rate. Any number of devices can be switched in succession provided a means of sequentially switching the control circuits is provided. (Figure 8-5.)



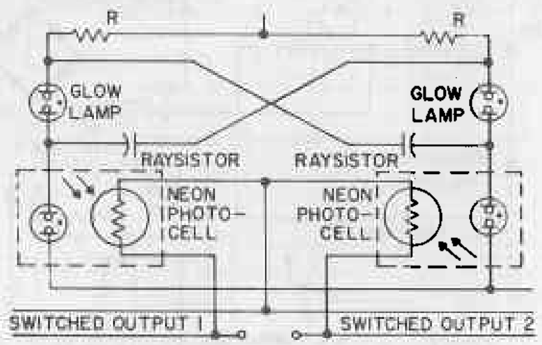



8-4 Electronic regulated power supply using neon photocell modulator




8-5 Neon-photocell low noise switch

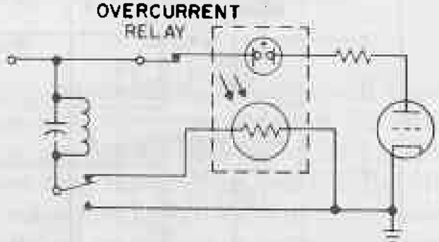
A two-photocell sequential switch circuit using a self-excited multivibrator is shown in Figure 8-6.




8-6 Neon-photocell sequential switch

*Overload Protection*

Use of the glow lamp-photocell to provide high voltage overload protection is shown in Figure 8-7. Any arc or intermittent short circuit in the tube will cause an increase in the average current through the neon glow lamp and reduce the photocell resistance. The relay is activated and opens the circuit, preventing damage to the circuit components. As shown, the response time of the unit is quite rapid since there is a current through the lamp circuit continuously.



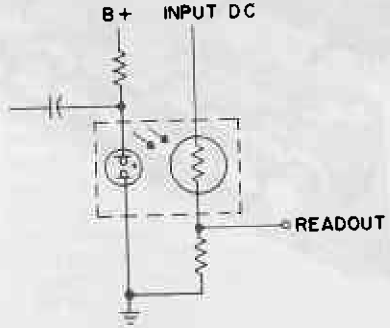

8-7 Neon-photocell overload protection



*Memory Circuits*

Memory circuits such as the one shown in Figure 8-8 can utilize the neon glow lamp-photocell device. With the glow lamp non-conducting, the resistance of the photocell is very large and any input signal will be attenuated by the photoconductor by a large factor. However, if the glow lamp is triggered on, the light from the glow lamp will cause the resistance of the photocell to decrease to a low value depending on the characteristics of the photocell and the lamp used. The input signal will now appear at the output, attenuated only by the low resistance of the illuminated photoconductor.

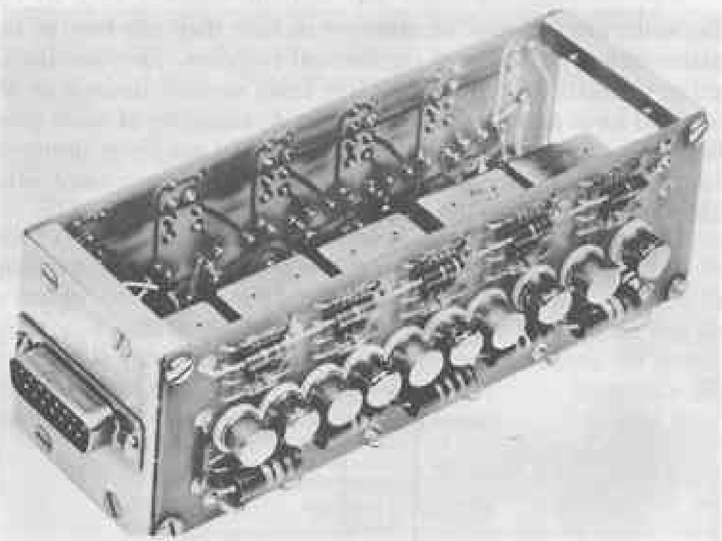
Electro-optical switches and variable resistors such as the Raysistor offer special advantages in that they are free of the maintenance problems of mechanical switches. They are insensitive to shock and vibration, free from contact bounce or jitter, and have an inherently long life. Availability of neon glow lamps to extremely precise parameters and specially designed for use with photocells makes this component even more valuable to the design engineer.




8-8 Neon-photocell memory circuit

The advantages of the neon-photocell combination were recognized by engineers of Edo Corporation in their continuing search for techniques to improve the performance and reliability of their airborne Loran A/C systems. The circuitry they developed allowed them to avoid the use of mechanical relays.[2] Since this circuit has no moving parts, it permits selection of any one of the number of outputs by means of a single wire control. The company has recently filed an application for a patent on this Photoconductive Selector Circuit as embodied in the Edo P-S Switch. A prototype model of the P-S Switch, developed by Edo Commercial Corporation is shown in Figure

The unit has ten switching circuits based on photoconductive cells, each composed of a neon glow lamp and a solid state photo resistor. The Edo P-S Switch is an outgrowth of Edo's product improvement program on the Model 345A Airborne Loran A/C system.



8-9 Photo Photoconductive Selector Switch assembly

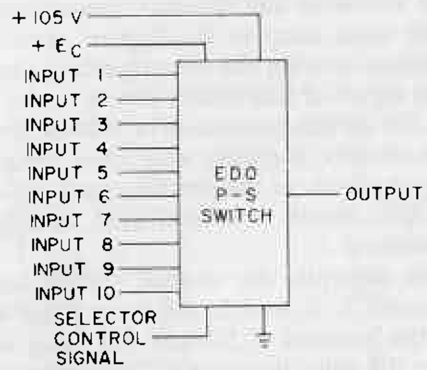
2. La Fiandra, Joseph, Senior Engineer, and Jennings, Howard, Vice President Engineering, Edo Corp., "Photoconductive Selector Circuit Uses Neon Glow Lamps," *Signalite Application News*, Vol. 2, No. 1; and *Electro Technology*, January 1964.



The heart of the circuit is a photoconductive cell composed of a long life neon glow lamp and a solid state photo resistor. Based on the property of glow lamps to ignite at the predetermined voltage, Edo engineers preceded to develop a photoconductive cell which exhibited optimum characteristics for this application.

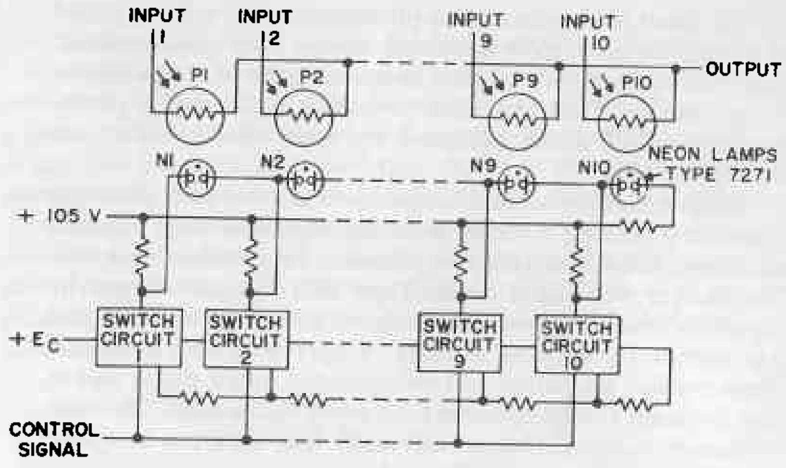
Commercially available lamps could not be used since the glow lamp striking voltages were too high, and they required additional biasing circuitry—a situation Edo wished to avoid. The answer was found in the Type 7271 lamp developed by Signalite, which has specially designed electrodes and a special gas mixture for extreme stability of operation. The lamp and photo resistor are potted and encapsulated into a single unit so that the lamp always operates completely in the dark. The close tolerances required that an extremely low variation in operating characteristics be maintained.

The circuit developed by Edo may be shown functionally as in Figure 8-10. A simplified schematic is shown in Figure 8-11.




8-10 Functional schematic photoconductive switch

The control signal voltage activates a number of switch circuits as a function of the amplitude of the signal. The neon lamp string is grounded to the junction between the highest




8-11 Photoconductive switch circuit

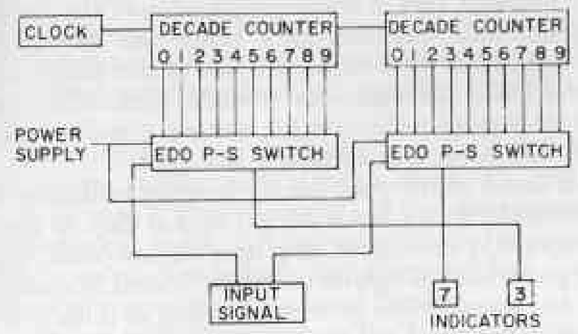
switch circuit activated and the one immediately below it in sequence. The neon lamp in the highest circuit then breaks down and ionizes, causing the corresponding photo resistor to pass the input signal of this switch circuit to the output.

Basically, the switch consists of a voltage divider, a number of switch circuits, Signalite neon glow lamps, and photoresistors. The amplitude of the control signal will determine the number of switch circuits to be activated, starting in sequence with circuit number 1.

Should, for example, the control voltage activate switch circuits numbered 1, 2, and 3, the neon lamp string will be grounded to the junction of N2 and N3. Only neon lamp N3 will then have 105 volts dc across it. This lamp will light, causing photo resistor P3 to decrease its resistance to allow input signal number 3 to be present at the output.

The selecting function is achieved by causing the boundary condition to be shifted with each change in control signal. The boundary is the point below which all stages are on, and above which all stages are off. Variation of the control signal amplitude will cause different input signals to be passed.

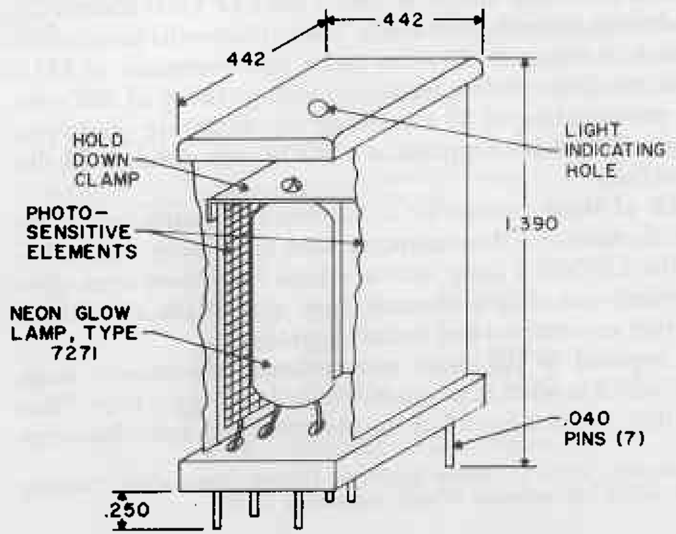





8-12 Application of photoconductive switch

This circuit may also be used in configurations where there are *n* output terminals corresponding to the *n* input signals. In any case, the input and output terminals are effectively isolated from each other until switched, as well as from the control circuit.

A typical application of the Edo P-S Switch is shown in Figure 8-12.




8-13 Physical diagram of neon-photocell housing

In quite a different vein, a unique application of the use of solid state photo cells and neon glow lamps was developed by Clairex Corporation[3] to demonstrate one of the many uses for cadmium sulfide and cadmium selenide photocells. The device is an interesting technique for writing a semi-permanent message with nothing more than a flashlight.

The unit is based on the principle of changing resistance in individual photocells with a beam of light so that they, in turn, ignite a corresponding neon glow lamp on a display panel. The lamps on the panel remain lighted until it is desired to change the message. Any message can be written as long as it fits within the physical geometry of the panel.

The system may also be used to project repetitive messages simply by cutting a perforated stencil which is laid over the writing plate. Light from the lamp over the stencil would be projected through the holes to the proper photocells which again would light the corresponding neon lamps. A moving message could be projected in the same manner with a minor modification in the circuit.

The Lite-Writer was developed by Clairex not as a product, but rather, as a demonstration tool showing the versatility of photocells and neon lamps. It uses a bank of 1,000 Clairex CL 903 cadmium selenide photocells. These photocells have a dark resistance in excess of $10^9$ ohms and a light resistance of 133 K ohms at two foot-candles, maximum voltage rating of 250 volts, and a power rating of 50 mw. They are miniature photo-conductive cells and are supplied in a TO-18 case which is .21 dia. x .15 inches.

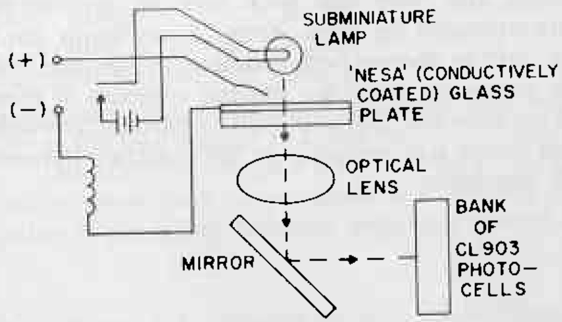
Each of these photocells is individually connected to the trigger element of a three-element neon glow lamp, type LTG-27-2. The LTG-27-2 lamp also is a high brightness neon glow lamp which was chosen because, once ignited (dc operation), it will stay on until a reset button is pushed.

As opposed to the more conventional two-element lamp, the LTG-27-2 is what is commonly called a "trigger tube." This means that, while it has all of the electrical and light characteristics of two-element lamps, it has an auxiliary trigger so it can be turned on by a circuit not necessarily connected to the circuit which supplies power for operating the lamp. (See Chapter V)

Another reason for the selection of neon glow lamps is their low power requirements. Design current for the LTG-27-2 is only 3.0 ma. A previous model of this demonstrator had used incandescent bulbs, but the power drain for even a relatively short message was so high that the power line was overloaded, repeatedly operating the circuit breaker.

For an installation such as the Lite-Writer, lifetime of the neon lamps is an important factor. Since the lamps are soldered in place, replacements would be both time consuming and costly. The rated life for the LTG-27-2 is 5000 hours of continuous operation. Since no one lamp is on all of the time, actual life for any lamp is well in excess of this figure.

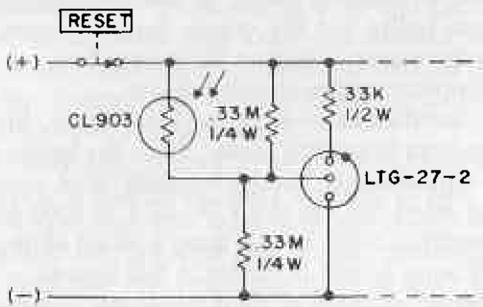
A schematic diagram of the Lite-Writer system is shown in Figure 8-14. The light source is turned on when the probe touches the conductively coated glass plate. The beam from the subminiature lamp is passed through an optical lens to a mirror where it is reflected to the bank of the CL903 photocells.




8-14 Schematic of Lite-Writer

3. Rabinowitz, Jacob G., Chief Engineer, Clairex Corporation, "Writing With Light," *Electronics World*, November 1965.

Output from each photocell is taken through the circuit shown in Figure 8-15 to the corresponding glow lamp on the display panel. Each neon lamp so activated will remain on until the reset button is pushed which extinguishes all lamps at once. The power source is 140 to 145 volts.




8-15 Lite-Writer Circuit

The Lite Writer is but one of many interesting devices which utilize solid state photocells to perform a variety of tasks. They have been used, as has been described here, to light neon lamps, and have also been used in applications where they are activated by neon lamps. Neon lamps are a good source of light to operate both cadmium sulfide and cadmium selenide photocells since the spectral response of these materials peaks at between 5150 and 7350 Angstroms. The light from neon glow lamps falls primarily in the spectrum between 5200 and 7500 Angstroms.

## CHAPTER IX

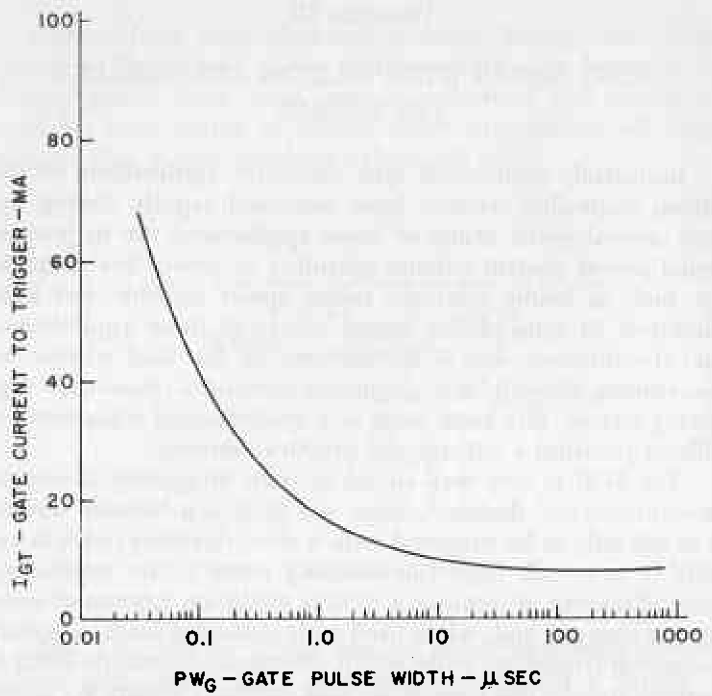
# USING NEONS WITH SILICON CONTROLLED RECTIFIERS

Industrial, commercial and consumer applications of the silicon controlled rectifier have increased rapidly during the past several years. Many of these applications are in proportional power control circuits operating at power-line frequency, such as heater controls, motor speed controls and light dimmers. In spite of the varied nature of these applications, and the different size SCR's dictated by the load current requirements, they all have a common need for a phase-shift triggering circuit. The neon lamp in a synchronized relaxation oscillator provides a natural and practical answer.[1]

The SCR is very well suited to pulse triggering, if certain precautions are observed. Since the SCR is a bistable device, it needs only to be triggered with a short duration pulse to enable it to switch from the blocking state to the conducting state. However, it requires a certain minimum amount of energy (or charge) and, when used with inductive loads, a certain minimum triggering pulse width (dependent upon its latch-in current and the rise time of the load current.) Figure 9-1 shows a typical curve for $I_{GT}$ vs PW for the Texas Instruments TI 40A2 industrial type SCR. This curve assumes a resistive load. The curve shows that a pulse width greater than 10$\mu$sec should normally be used. But when inductive loads are controlled, the triggering pulse width must be longer than the time required for anode load current to reach the anode latch-in-current.

The AO 57B neon glow lamp is designed to operate with a 75 ma recurrent peak surge current at a 10% duty cycle, and is capable of providing sufficient triggering energy for all but the

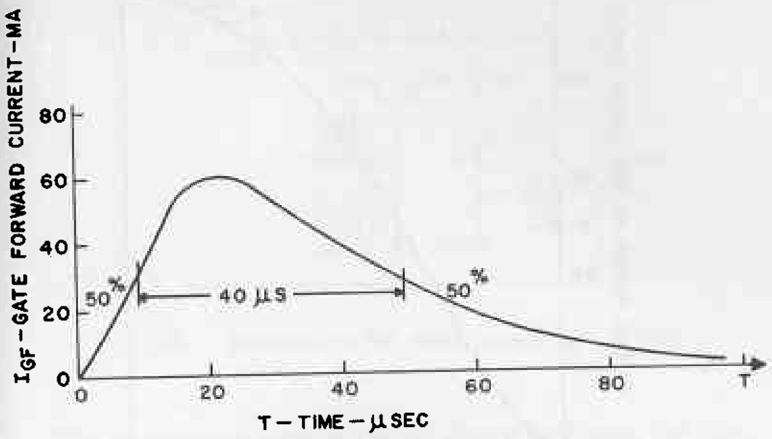
1. McKenna, R. G., Manager of Power Device Characterization, Texas Instruments, Inc., "Neon Lamp Triggering of SCR's in Proportional Power Control Applications," *Signalite Application News*, Vol. 2, No. 4; and McKenna, Robert, Texas Instruments, Inc., and Bauman Edward, Signalite Inc., "Neon Lamp Triggering of SCR's," *Electro-Technology*, March 1965.




9-1 Typical gate current to trigger SCR vs gate pulse width

largest SCR's. Figure 9-2 shows the current wave shape into an SCR gate when a 0.1 μfd capacitor is discharged through the AO 57B. The 20-μsec pulse width is sufficient to trigger TI 40A2 series SCR's controlling resistive, capacitive, and most inductive loads. Such loads include universal motors used in most small hand tools and appliances. If more highly inductive loads must be controlled, a larger value capacitor may be used if care is taken to add limiting resistance in series with the neon lamp to limit its peak current to 75 ma.

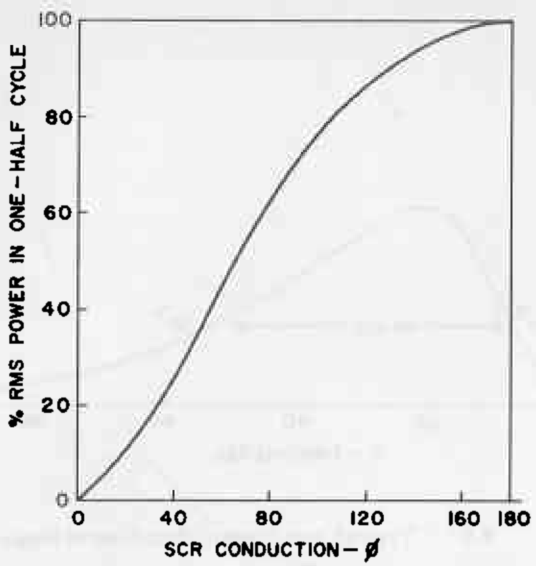





9-2 Typical gate trigger circuit wave shape

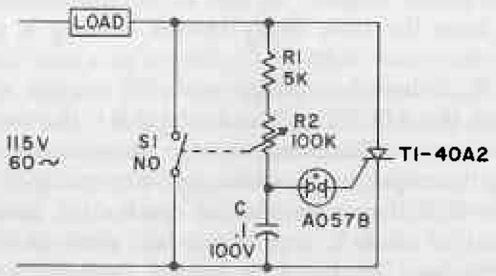
Figure 9-3 shows the RMS power supplied to a load by an SCR triggered by a phase shift circuit of the kind shown in Figure 9-4. This basic proportional power control circuit is capable of providing a minimum conduction angle of approximately 40°, and a maximum conduction angle of about 150° This is a range of from 24% to 95% available power in a half-wave circuit supplied to the load.

In operation, resistors $R_1$ and $R_2$ in combination with capacitor C form the time delay circuit. During a positive half-cycle of sine wave voltage, C charges at a rate determined by $R_1$ plus $R_2$. When the voltage across C reaches the breakover voltage of the AO 57B (75 volts typical), the neon lamp will break back to a maintaining voltage of approximately 53 volts, allowing the capacitor to discharge into the gate of the SCR. Since the SCR is only capable of conduction in one direction, it can only be made to supply one-half cycle of sine wave current to the load. Switch $S_1$ is ganged to the potentiometer, so that it closes at the end of the clock-wise rotation of the pot, applying full power to the load.



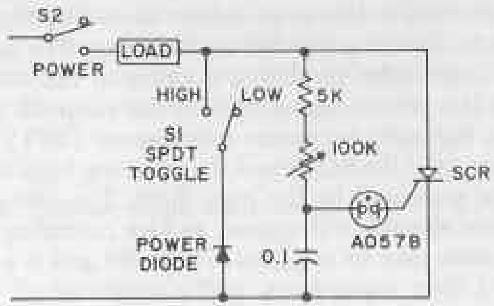

9-3 Percent RMS power in 1/2 cycle vs SCR conduction angle

A very simple way to modify the half wave control in Figure 9-4 into an inexpensive 360° full wave control is shown in Figure 9-5. This is accomplished merely by the addition of the power diode and the SPDT toggle switch. All other components are the same.



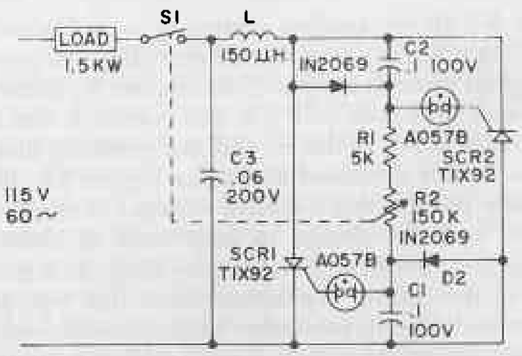

9-4 Half wave proportional power control






9-5 Inexpensive full wave proportional control

The symmetrical control circuit shown in Figure 9-6 uses two RC circuits with a common R to control the firing point of the two AO 57B's triggering the two SCR's. Diode $D_1$ shunts $C_2$ to supply the charging current to $R_1$ $R_2$ $C_1$ on the positive half-cycle, while $D_2$ performs a similar function on the negative half-cycle. When this circuit is used for an incandescent light dimmer, it may cause a small amount of flicker at initial stages of conduction at low light levels. This is due to variation in values of $C_1$ and $C_2$, as well as in the break-over voltages of the AO 57B's.




9-6 Direct coupled full wave power control

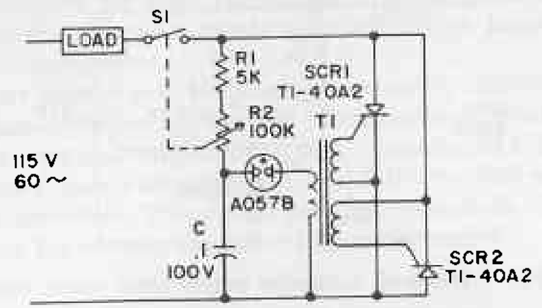
A solution to this is to reduce the value that allows minimum conduction angle before flickering. The lamp may then be dimmed to this level, and $S_1$ opens at full counterclockwise turn of the potentiometer to turn the lamp off. The $LC_3$ filter reduces the radio frequency interference (RFI) caused by the fast turn-on of the SCR's and the resulting high-frequency components generated by the high di/dt. The 150 $\mu$h shown is a minimum effective inductance, and for critical applications, 500 $\mu$h or more may be required. The 0.068 $\mu$fd is a good nominal value of filter capacitance, and a maximum of about 0.1 $\mu$fd could be used to prevent unnecessarily high surge currents through the SCR at turn-on.

A simple filter such as this is sufficient for proportional power control circuits used for home light dimmers and appliance controls. Proportional power controls used to control such inductive loads as universal motors do not need the filter, as the motor provides the inductance. (Usually, the RFI from the brushes is substantially higher than that from the SCR, so the RFI from the di/dt is insignificant.)

When a motor is controlled, it is wise to make $R_1$ an adjustable resistor, so that the maximum resistance in the timing circuit may be set to provide a minimum conduction angle for the SCR's. This allows the minimum speed of the motor to be set above the speed where it begins to "cog", or run with bursts of power.

Figure 9-7 shows another version of a symmetrical power control using a single timing circuit providing 120 pps pulses to the SCR gates through the pulse transformer $T_1$. Since the same timing circuit fires both SCR's in this circuit, it eliminates the unsymmetrical firing problem, and the resulting flicker of incandescent lamps discussed above for Figure 9-6. Because of the alternate positive and negative voltages to which capacitor C charges, and the change in magnitude of these voltages before and after the AO 57B neon tube fires, there is a hysteresis effect in the control characteristics of this type circuit. As $R_2$ is decreased from its maximum value, C is allowed to charge to a higher voltage on each half-cycle. When it charges to the firing voltage of the AO 57B, the SCR is turned on, shorting the control circuit voltage so that on the next half-cycle the capacitor starts charging from a low voltage and will charge to the neon tube firing voltage at an earlier firing angle. The potentiometer resistance may now be increased to phase back the SCR firing angle, giving a hysteresis effect.

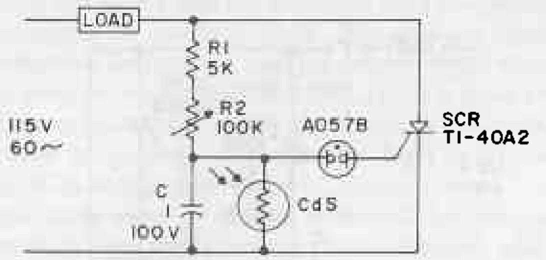





9-7 Transformer coupled full wave power control

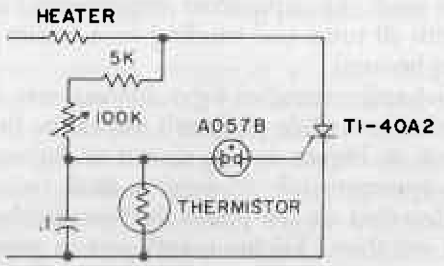
The transformer $T_1$ is not critical. The Sprague 31Z286, which is a 1:1:1 with $L_p \approx 10\mu$h designed for SCR triggering, may be used. An equivalent transformer, such as a simple 1:1:1 with 40 turns per winding on a ferrite or soft iron core, may also be used.

A photocell-controlled light dimmer may be made by adding a cadmium sulfide photocell across the timing capacitor of the circuit in Figure 9-4, as shown in Figure 9-8. The photocell has approximately 1 megohm dark resistance, which has very little effect on the phase shift circuit, but the light resistance of less than 1 kilohm is sufficient to prevent the capacitor from charging to the neon lamp firing voltage. This results in an out-of-phase light-controlled light dimmer. The light level may be set manually with $R_2$ when the CdS cell is dark, and the light will be dimmed below that level as the CdS cell is exposed to light, until the light is "dimmed off" completely. Variations in the component values may be made to set the light sensitivity level of the circuit. To reduce the sensitivity, a photocell with a higher light resistance range may be used, or a resistor may be added in series with it, or the capacitor value may be increased (with appropriate changes in $R_1$ and $R_2$). The opposite changes will tend to increase the circuit sensitivity.




9-8 Photocell controlled proportional power control

Substituting a thermistor for the cadmium sulfide photocell in Figure 9-8 results in a temperature controller. (Figure 9-9) A high resistance thermistor is mounted inside the area to be temperature-controlled. The 100K potentiometer can then be set to maintain a specific temperature.



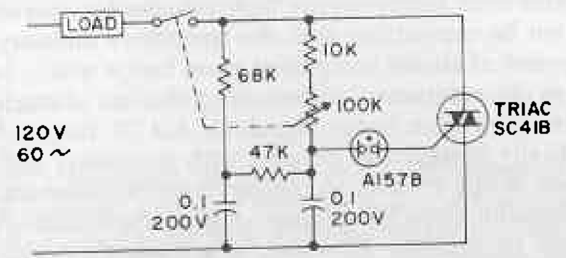

9-9 SCR temperature controller

Circuit possibilities are endless. Transistors may be introduced into the timing circuit to permit electronic control and feedback control circuits. However, in circuits of this type, the



stability of the firing angle becomes more critical. Since this is directly dependent upon the stability of the neon tube, it becomes a critical component. Lamps to meet such requirements with breakdown voltages held to within ± 3 volts are produced by Signalite as circuit components. The AO 57B is one of these and is designed for high current-pulse applications in electronic circuitry where a standard indicator-type lamp would be totally inadequate.

In some cases it may be possible to simplify full wave proportional circuits through the use of bidirectional triode semiconductor switches, such as the recently introduced G.E. Triac and others. Figure 9-10 shows a typical full wave 600 watt proportional controller. This circuit performs essentially the same function as the circuits shown in Figures 9-6 and 9-7.




9-10 Full wave proportional control using bidirectional semi-conductor switch

The semiconductor switch, being bidirectional, can be fired from either direction. Therefore, it is imperative that the breakdown voltage of the triggering neon lamp be the same in either direction. If the breakdown voltage in one direction differs from the breakdown voltage in the other direction, it can be seen that, when the phase angle is retarded for minimum power to the load, the power being delivered to the load will have a tendency to vary in a random fashion.

The A157B tube shown in this circuit was designed specifically to have symmetrical characteristics in this regard to within 5%. It will handle peak currents as high as 80 milliamperes and average currents of 2 milliamperes, well within the requirements imposed by the semiconductor switch.

## Chapter X

# USING NEONS WITH TRANSISTORS

Transistors are basically low power, long life devices which offer many advantages to the design engineer. However, when they are used in circuitry that has associated light output, the high current requirements of incandescent lamps imposes limitations on the transistor, requiring the use of auxiliary circuitry simply to handle the higher power.

Replacing the incandescent lamp with a properly designed neon glow lamp can in most cases eliminate the problem. The characteristics of the neon lamp (low current requirements, absence of generated heat and extremely long life) make them a favored choice for use in transistor circuitry. However, most indicator neon lamps require high voltages for operation which may not be compatible with the transistor's circuitry. The development of circuit component neon lamps which have lower voltage characteristics is overcoming this last obstacle.

One such neon lamp, Signalite's AO 79, has, in fact, been specifically designed to be used with transistors and is shown in three of the circuits accompanying this discussion.

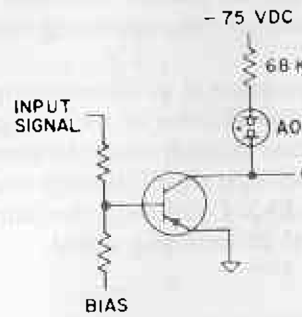
Normally, neon glow lamps require approximately 70 volts or more for ignition. However, in a transistor circuit, such as shown in Figure 10-1, it is possible to trigger the lamp with extremely low signal voltages. In this case the transistor acts as a current amplifier. Input signals in the order of .3 volts or currents of .1 ma can operate the neon lamp through the transistor.

In this circuit the reverse bias applied to the base of the transistor in the absence of an incoming signal keeps the transistor in a cut-off condition. As a result, no emitter to collector current flows. Because the AO 79 is also non-conducting, the 75 vdc is prevented from being applied to the transistor. When an appropriate input signal is applied, the transistor will change its condition from cut-off to saturation. This allows current to flow from the emitter to the collector with only approximately a .6 volt drop. The AO 79 lamp is now on. The corresponding voltage drop of 55 volts is the maintaining voltage of the lamp.



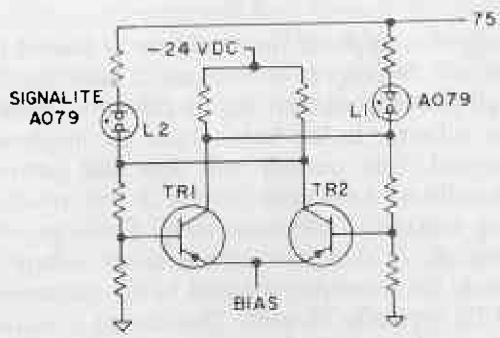
The remainder of the voltage, 19.4 volts, appears across the resistor. This means that .3 ma is flowing through the lamp.

The maximum voltage that will ever appear across the collector to base of the transistor is less than 20 volts, and this occurs only at the instant of cut-off.




10-1 Neon lamp controlled by transistor

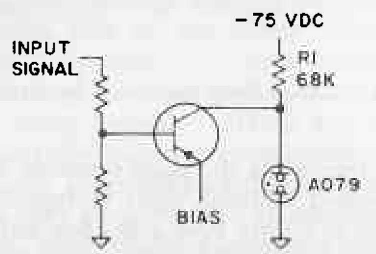
Figure 10-1 represents the most common arrangement for a transistor operated indicator light. A typical application of this use is shown in Figure 10-2, a flip-flop status indicator. In this circuit it can be seen that when transistor $TR_1$ is on, or




10-2 Flip-flop status indicator

saturated, indicator light $L_1$ is also on. At this time transistor $TR_2$ is off. Its collector voltage is approximately 24 volts. The resulting 51 volts (75 volts B+ minus the 24 volts collector voltage) is below the 55 volts maintaining voltage of the AO 79 lamp. Hence, lamp $L_2$ is off. When the flip-flop changes its condition by virtue of an external signal, $TR_2$ turns on and lamp $L_2$ turns on also through the process described above. $TR_1$ is then cut off, and with only 51 volts appearing across lamp $L_1$, it will go off.

In many cases the presence of an incoming signal represents a prime condition and the absence of such a signal represents the O or failure condition. In such cases the neon lamp can be turned on by the absence of a signal through transistor circuitry as shown in Figure 10-3. Conversely, the lamp can be turned off in the presence of an incoming signal.

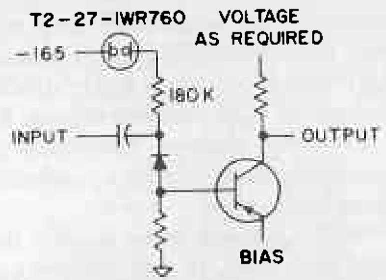



10-3 Neon lamp controlled using shunt transistor

When no signal is applied, the transistor is biased beyond cut-off and the AO 79 lamp is on because it *sees* the 75 volts applied through the 68K resistor, $R_2$. At this time 55 volts appears from the collector to the base. Upon the application of an incoming signal, base current will flow and saturate the transistor. The collector to emitter drop is .6 volt, much below the maintaining voltage of the neon lamp. Consequently, the neon lamp turns off. In this case the maximum voltage which can appear across the transistor is equal to the ionization voltage of the AO 79, typically 70 volts. This circuit is common in logic applications where an indication is required of absence of a signal.



It is also possible to combine the bistable electrical characteristics of the neon lamp and its light generating characteristics with a transistor to perform the function of a memory with a low output impedance plus a status indicator lamp. A number of variations on this basic function, such as relaxation timers, etc., are possible.




10-4 Transistor – neon memory circuit

In Figure 10-4 under normal circumstances, with no information stored, the neon lamp is off, no current flowing, and the transistor is biased beyond cut-off. The output voltage is equal to approximately the collector supply voltage. When a positive going pulse of 5 volts or more is applied to the input, it will cause the T2-27-1WR760 lamp to ignite and stay on. At this point 2 ma current will flow through the base circuit causing the transistor to saturate. The entire circuit is now in the primed condition. The neon lamp glows, indicating information is stored, and the output voltage is very low, .6 volts above bias.

## Chapter XI

# GLOW LAMPS IN DECODING LOGIC

### Binary to Decimal Coverters and Digital to Binary Converters

Electronic counters are extensively used to make accuratc frequency, period, time interval and ratio measurements. Many of the indicating readout devices in today's solid state counters require high voltage or high current inputs. For reasons discussed in the preceding chapter, transistors can not coveniently be used to supply the drive for a readout matrix and still perform reliably at high speed.

The conventional approach is to decode the binary information to decimal and, then, to add sufficient gain to the signal in order to drive the decimal indicators. This generally results in a fairly complex system consisting of a diode or resistive matrix plus ten amplifiers for each decade.

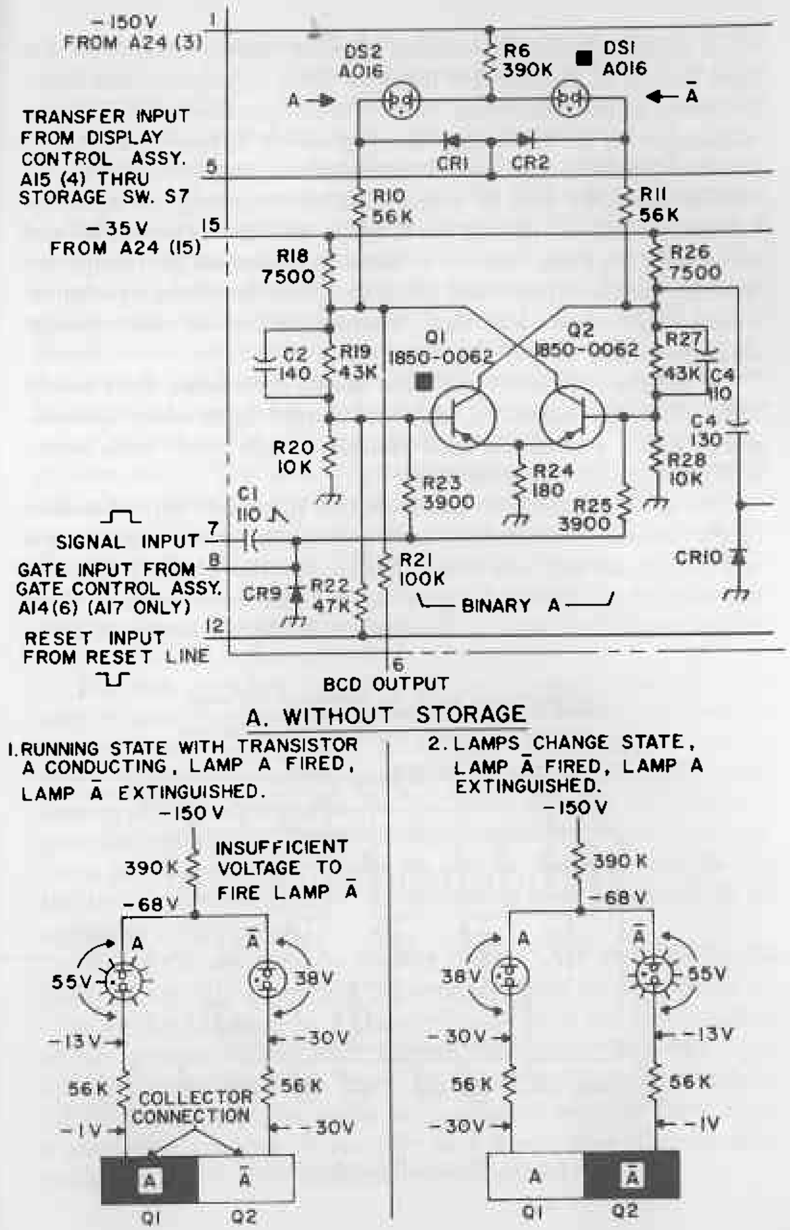
Hewlett-Packard has recently developed a technique in which neon glow lamps and solid state photoconductor elements provide the necessary gain and perform the decoding logic.[1] This system also has the advantage of having a memory by which the readout display remains undisturbed while the next counting operation continues.

Counting is accomplished by using a modified binary number system. It is binary in that each counting stage consists of four of these binaries interconnected in such a way that the circuit will cycle in 10 counts instead of the normal 16 counts.

Once the counter has accumulated the desired information it must be put in a format acceptable to people; i.e., the binary coded decimal information in which the counter has been operating must be converted to decimal information which will operate a visual display. This is where the neon lamps come into the picture.

1. Willrodt, Marvin, Hewlett-Packard Co. — "Binary To Decimal Decoding System Using Neon Lamps And A Photoconductor Matrix," *Signalite Application News*, Vol. 3, No. 3.



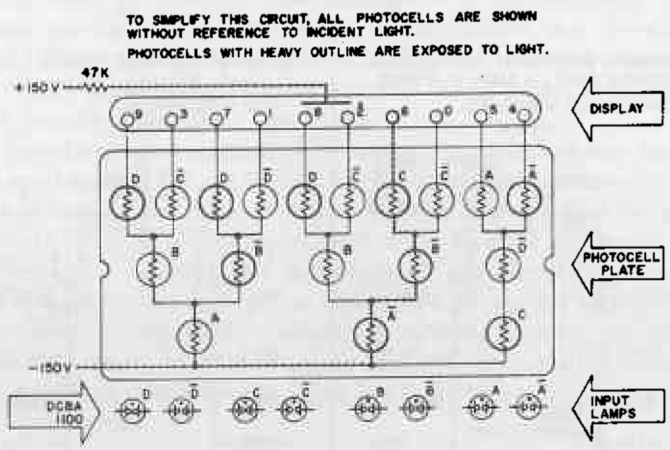



11-1 Schematic of one stage of a binary counter

A counting decade consists of four binary circuits of the kind shown in Figure 11-1 together with appropriate interconnections. Each binary has two neon lamps, DS1 and DS2, associated with it. The lamps are Signalite's Type AO 16 which can be provided for specific breakdown voltages within ±1 volt between 64 and 80 volts. Their maintaining voltages are held to within ±1/2 volt for a value selected between 52 and 60 volts. This close control is necessary because the lamps are used in matched pairs and reliable operation of the system requires that *their electrical characteristics do not change throughout the life of the instrument.*

If diodes CR1 and CR2 were not in the circuit, DS1 would light when Q1 conducts, and DS2 would light when Q2 conducts. Since a common load resistor, R6, is used, both neons will not light at the same time.

Neon lamps are also connected to the other three binaries of the decade so that four, and only four, of the eight lamps will be on at any one time. These are the INPUT LAMPS shown at the bottom of Figure 11-2. Light from each of these lamps can fall on two, or in some cases three, photoconductor




11-2 Photocell display matrix



elements on the photocell plate, which is shown schematically on Figure 11-2. Since this whole assembly is in a light-tight plastic mounting, photoconductor elements are illuminated only when the associated neon lamp is turned on.

These photoconductive elements behave electrically as resistors which have a resistance of under 10K when illuminated and above 10 megohms when in the dark. They behave as if they were light activated switches which turn on when illuminated and are off when dark. By interconnecting 18 of these photoconductive elements as in Figure 11-2 a circuit is produced which always has three photoconductive cells in series between B– and each numerical electrode. Of the sixteen combinations of four lamps on and four lamps off, there are only ten that are used that permit only one path at a time in order to have each of the three photoconductor elements illuminated. All other paths have at least one element that is not illuminated. The illuminated photocell path has low resistance all the way from the common, –150 volts, and can carry current to deflect a meter, light a gas display tube, light another neon lamp or operate some other readout system. In Figure 11-2 the path to the "6" is the one which is complete.

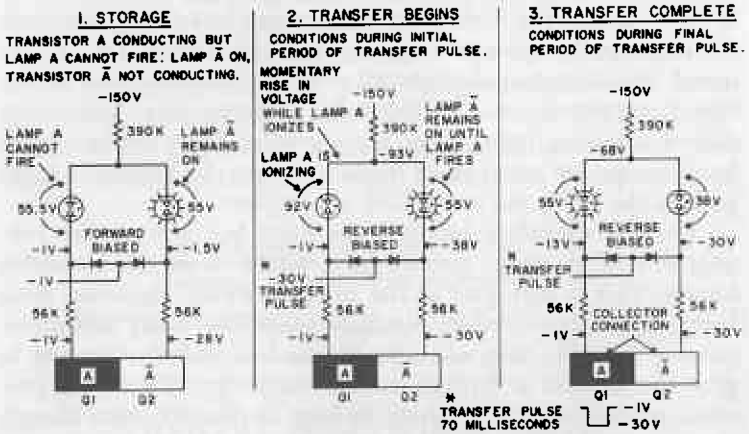
For this decoding function the neon lamps must fire reliably in total darkness at voltages available from the transistor binary. This is only part of the story, however. By using neon lamps which have stable, carefully controlled firing and maintaining voltages, they can also be used as circuit elements to give the counter a display storage capability. That is, a previous reading can be retained as long as desired, even though the transistor binary might be switching back and forth to accumulate a new count.

Storage is achieved by adding diodes CR1 and CR2 to the basic binary. To enter new information into storage, these diodes are back biased by a transfer pulse from the logic section of the counter. When back biased, the diodes look like open circuits; therefore, neon lamp DS1 will light when transistor Q1 conducts, and vice versa as mentioned earlier. To achieve a maximum number of samples in a given time, this transfer pulse should be kept as narrow as possible.

Storage is achieved by keeping these diodes in a conducting state. When conducting, these diodes tie one end of DS1 and one end of DS2 effectively to ground, thus the switching of the transistors will not cause the neon lamps to change state.

Figure 11-3 indicates the voltage during the "transfer" and "store" cycle. Requirements which the neon lamps must meet to make this feature reliable are:

1. Rapid firing in complete darkness with a narrow pulse;
2. Carefully controlled firing and maintaining voltages, not only initially but throughout the life of the lamp. Life expectancy of the neon lamps is good—in excess of 40,000 hours.

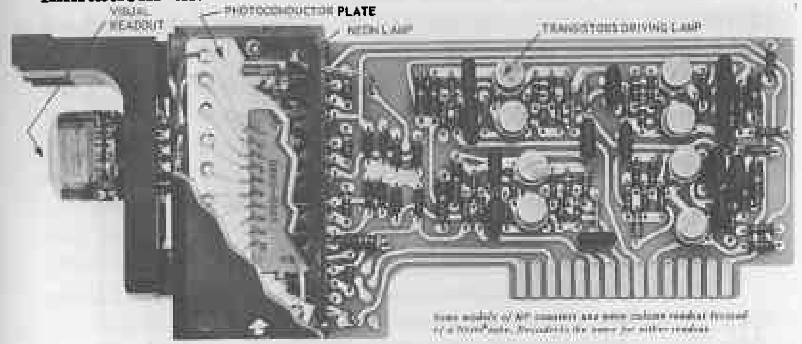



11-3 Lamp control in storage modes

The speed of switching in this circuit is a function of the photoconductor since the neon lamp is capable of considerably faster response than is the photoconductor. Through the proper use of materials and construction, response speed in the 300 $\mu$sec. region could be obtained. Since the parameters that affect switching speed also effect other characteristics, a switching



time of a few milliseconds produces good resistance stability and good lifetime expectancy. Speed in this range is completely adequate for visual display since the eye itself has greater limitations than this.




11-4 Photo Decimal Counting Assembly

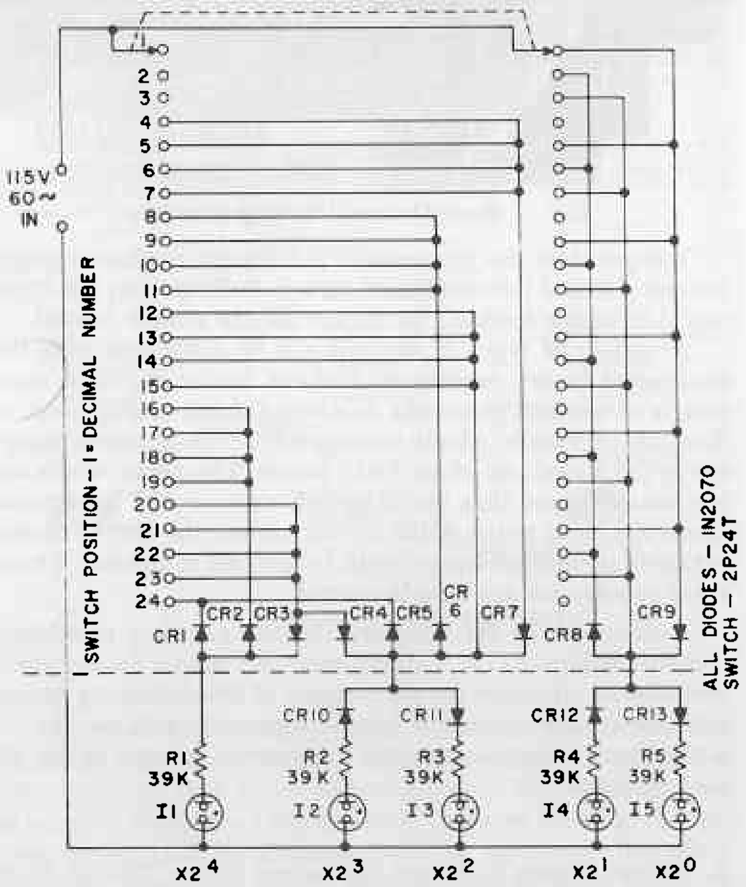
It is possible, also, to use neon glow lamps in circuits which convert decimal information to binary. Such circuits are quite useful in simple methods for supervisory or remote control.

A variety of types of readout can be associated with the decimal to binary translation. Perhaps one of the most common is to connect photocells in a series shunt arrangement so that the photocells which correspond to the actuated lamps are in the series arm of an AND circuit. The neons which are not actuated, and thus are in the off state, would be shunted across the input to the AND. In this manner the proper combination of on and off lamps could be utilized to operate a transistor or relay for any simple control.

A circuit which illustrates the decimal to binary translation is shown in Figure 11-5. This is a relatively simple device which was created originally for the purpose of demonstrating binary arithmetic.[2] The readout is housed separately and may be remote. Four conductors connect the decimal selector to the binary readout.

2. Ashburn, Claude W., Physics International Co. — "Decimal To Binary Translation," *Signalite Application News*, Vol. 3, No. 3.

The decimal selector in this example is essentially a two-pole, twenty-four throw rotary switch. This was selected for convenience, not because of a limitation of the circuit. A three-pole, sixty-four position switch would enable sixty-four bits of information to be transmitted over the four conductors instead of the twenty-four shown here. If the readout is to be through photocells, as discussed above, high brightness neon glow lamps such as Signalite's AO 72 should be used.




11-5 24-Bit Decimal to Binary Translator



Chapter XII

## SOME INTERESTING INDICATOR APPLICATIONS

When the neon glow lamp was first developed commercially over 40 years ago, it found immediate application as a pilot light in appliances and as a location indicator. While light output is relatively low compared to the incandescent lamps it replaced, it was sufficient for the purposes to which it was put, and it offered many other advantages.

Since the neon lamp has no filament to burn out, the lamp has an extremely long life, generally much longer than the appliance in which it is installed. This characteristic permits the neon lamp to be wired into the circuitry permanently.

Power requirements for neon lamps are extremely low. Standard lamps running on 115 volts ac with the 100K resistor dissipate only 1/10 watt. They draw only .6 milliamperes. Thus, they may be run continuously at an insignificant cost. This means, also, that they may be operated directly from line voltage without the necessity for a step-down transformer.

The neon lamp is one of the most rugged components made. It is virtually unaffected by average shock and vibration. Thermal shock, such a major factor in the life of an incandescent lamp, does not exist with the neon lamp. Consequently, repeated on-off cycling has virtually no effect on its lifetime. The neon lamp runs at a relatively low temperature, averaging perhaps 120°F in ambient temperatures of 70°F, so that under normal conditions it feels only warm to the touch and is not detrimental to temperature sensitive devices in close proximity to it.

Light output is generally confined to the bright orange range, a color that historically has been associated with warning devices and, thus, commands attention. The light level of a standard brightness lamp is sufficient in applications which are related to darkness, such as night lights and electric blankets. Where a higher degree of light is desired, the high brightness neon lamps provide an indication which can readily be seen under normal ambient lighting conditions. These lamps

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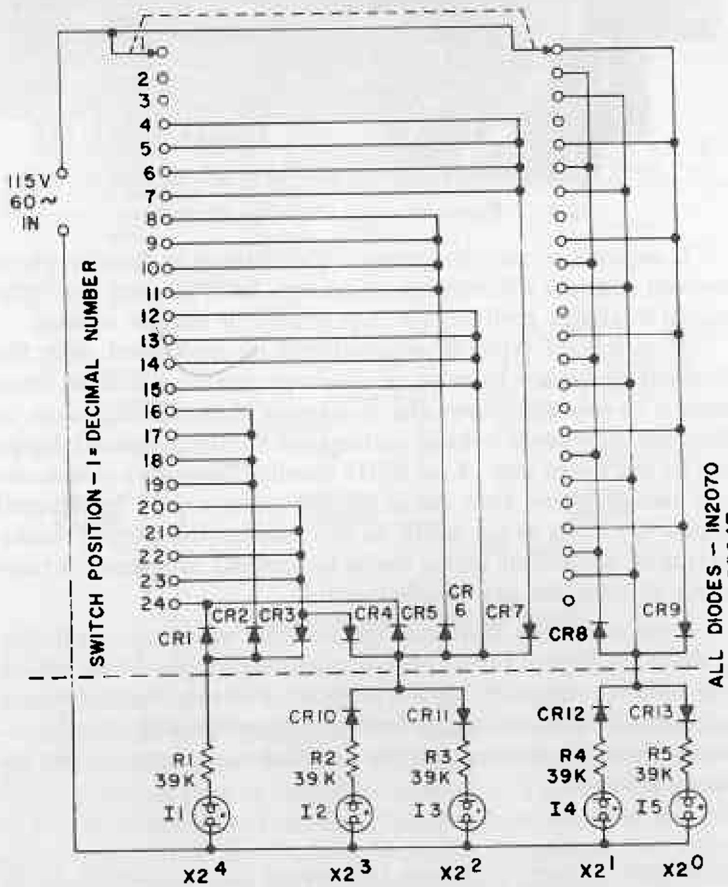


11-5 24-Bit Decimal to Binary Translator

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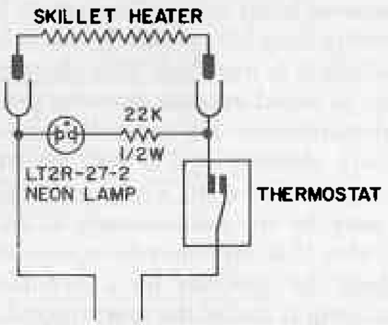
The basic use of the neon indicator lamp is to indicate that power is on or available for the device with which it is associated. Generally, this is a 115 volt or 230 volt pilot light, used on either alternating or direct current. Most common pilot light household uses include freezers, electric ovens, radio-photographs, electric blankets, escutcheon lighting for dials, circuit testers, blenders and mixers and many others.



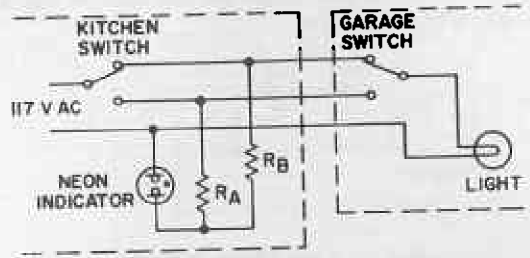

12-1 Indicator for electric heating appliances

Because of their low current characteristics, neon lamps are frequently wired across the thermostat in electric heating devices. In this type of circuit the neon lamp is off until the preset temperature is reached at which point it lights. They are thus used to indicate the temperature condition without causing the heating element to draw current. The neon lamp may also be wired across the heating element as shown in Figure 12-1 to indicate that the heating element is on. They are found on electric frying pans, deep fat friers, coffee pots, electric range ovens, waffle irons, and many common household appliances.

Neon lamps are also used to indicate the condition of an electrical circuit, either directly or remotely. For example, a

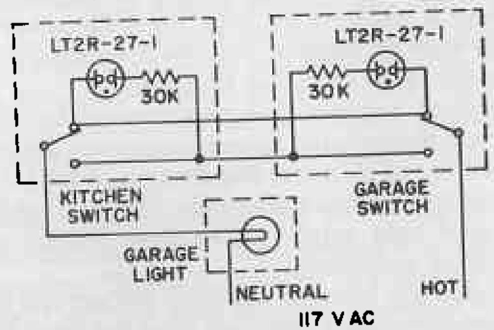


three-way switch which operates a remote circuit may be wired as shown in Figure 12-2. This approach indicates when the remote circuit is energized. The two resistors, $R_A$ and $R_B$, are equal to each other and equal to the normal series resistance for the neon lamp. With both switches on the same line, both the neon lamp and the remote circuit are on. With the switches on opposing lines, the two resistors form a voltage divider and thereby reduce the voltage across the lamp to less than its ignition potential. Consequently, the lamp and the remote circuit are both off.



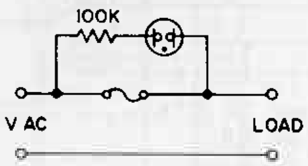

12-2 Local on-off status indicator for remote circuit controlled by 3-way switches

It might be noted that should the lamp on the remote circuit burn out or be removed the neon lamp will not extinguish. This can be used as positive indication that the lamp in the re-




12-3 On-off status indicator for remote circuit controlled by 3-way switches mote circuit is inoperative. A method for indicating the opposite condition, that is, indicating when the remote circuit is de-energized, is shown in Figure 12-3. This circuit provides an indicator lamp at each switch position. However, only one resistor is required for each neon lamp instead of the two in Figure 12-2.

In fuse boxes and circuit breaker panels the neon lamp can be used to indicate a failed fuse or a "popped" circuit breaker. (Figure 12-4) In this arrangement the lamp comes on when the circuit is broken. The current that flows through the lamp is sufficiently low that it can cause no damage on the load side of the fuse or circuit breaker.



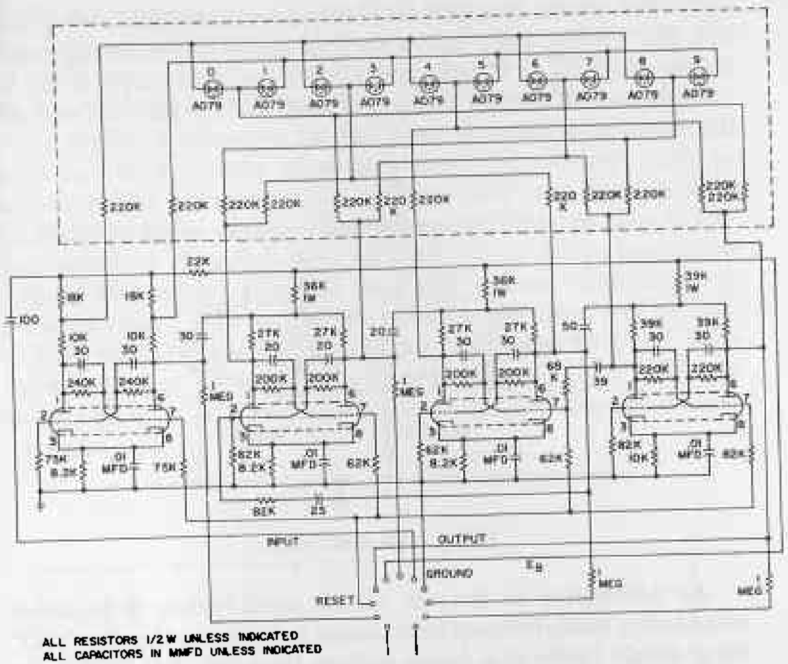

12-4 Fuse failure indicator

In numerical displays neon lamps are used frequently to illuminate the digits screened on the front panel of the unit as shown in Figure 12-5. The sharp differentiation of the neon lamp between when it is on and when it is off is a major advantage here. An incandescent lamp in the same application would have a tendency to "slur" over the numerical display simply because its filament requires a noticeable time to illuminate and a noticeable time to go out.

High speed reaction time requirements for the lamps are evident from the fact that these counters are designed for high speed counting of electrical impulses up to 1.2 Mc and separations of as little as 0.8 microseconds. The high brightness lamps provide good light output for accurate reading under all external lighting conditions.

The difference between the firing voltage and the maintaining voltage of the neon lamp can form the basis for a compact and inexpensive harness tester which will continuously monitor

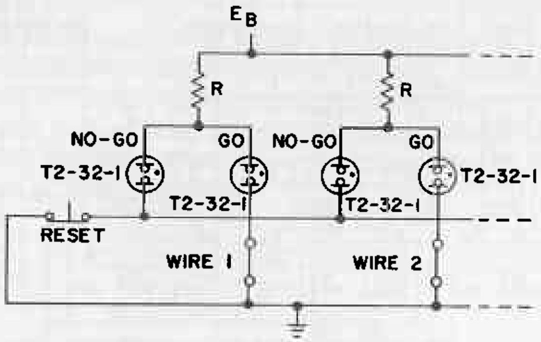





12-5 Numerical display for binary counters

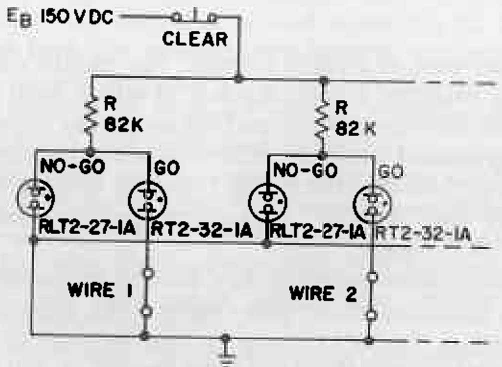
each individual wire in a cable harness. The circuit shown in Figure 12-6 is basically a neon flip-flop in which each wire is associated with two neon lamps and resistors. One terminal of each wire is grounded while the other completes the circuit for the "GO" lamp. Initially, the RESET button is used to open the circuit for the "NO-GO" lamps, extinguishing them and lighting the "GO" lamps.

A momentary open circuit in any wire in the harness will extinguish its associated "GO" lamp causing the voltage across the corresponding "NO-GO" lamp to rise beyond its breakdown voltage. Once this lamp has been ignited, it will stay on until the RESET button is pushed, enabling the operator to determine which, if any, wires have open-circuited during the test. The T2-32-1 lamp can be used in any of the following combinations: if $E_B$ is 90 vdc and all R's are 33K-1/2W, if $E_B$ is 135 vdc and all R's are 82K-1/2W, and if $E_B$ is 250 vdc and all R's are 220K-1/2W.




12-6 Harness tester

An alternative to the use of the reset button is to select neon lamps with different breakdown voltages so that the "GO" lamp would ignite at a lower voltage than the "NO-GO" lamp as shown in Figure 12-7. When the circuit is energized, all

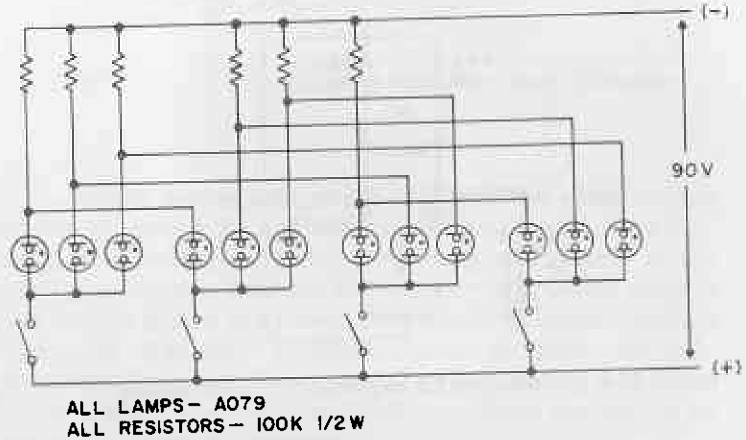



12-7 "Go-No Go" cable tester



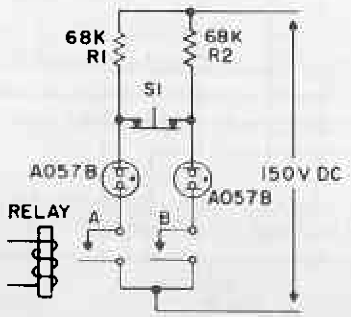
"GO" lamps ignite and stay on if all wires are good. If there is an open or momentarily open circuit in the series wire, the voltage rises to 150 vdc which causes the "NO-GO" lamp to fire, staying on and blocking the "GO" lamp from reigniting.

A similar application for the neon lamp is to indicate the sequence of operation of various electrical devices, such as switches. The circuit shown in Figure 12-8 was developed to indicate the order in which four micro-switches are closed. The first switch to close will light all three of the lamps associated with it. The second switch to close will find one of its lamps in a circuit shared with an already lit lamp, and thus, will be able to light only two of the three lamps associated with it. The third switch to close will likewise be able to light only one lamp, and there will be no lamps to be lit by the fourth switch when it closes.



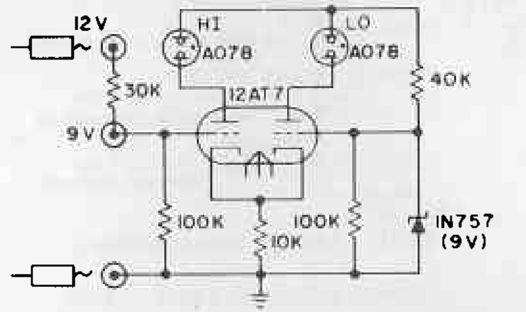

12-8 Sequence of operation indicator

Another sequence tester is shown in Figure 12-9 where it was necessary to know which contact closed first. It was vital in this application that contacts A make slightly ahead of contacts B. The test is performed in the following manner. When switch $S_1$ is closed and the relay energized, both neon indicator lights should come on indicating a continuity through both sets of contacts. Then, switch $S_1$ is opened and the relay is again energized. This time neon lamp A should indicate if the relay is properly adjusted. Only one lamp will come on since the maintaining voltage of either lamp is below the breakdown voltage of the other. If both A and B neon lamps fail to come on, this merely indicates that A and B contacts have closed simultaneously. If neon lamp B only comes on, it means that contact B is closing ahead of contact A. It is also possible to use this circuit in vibration testing. Because of the low current requirements of the neon lamps, flickering of the lights under subdued light during the test would give positive visual indication of poor contact in the relay being tested.




12-9 Indicator for sequence of contact closing

The range of uses for neon lamps in various industrial operations is limited only by the ingenuity of the engineer. In Figure 12-10 a GO-NO-GO test apparatus for balancing two voltage divider points in production by unskilled workers is shown. Sensitivity is such that a variance of 200 mv in either direction shows up as a distinct variation in illumination level of the two lamps. Increase in illumination level of the input side indicates a voltage higher than desired, and conversely for the fixed side. Although nine volts is used as the reference level in this circuit, any voltage from zero up to the limits of the dissipation level of the tube can be used. If the apparatus is to be used to test high impedance circuits, grid resistors would have to be increased.




12-10 Vacuum tube voltmeter with neon lamp indication

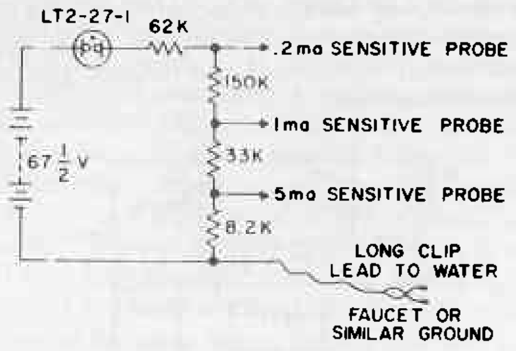
The circuit shown in Figure 12-11 is a device which detects whether any part of an appliance or machine would allow current to flow through a person touching it and ground at the same time. Electric toasters, for example, frequently allow a small current to flow if a person touches the metal case and the kitchen sink. Current is detected because the insulation leakages involved are usually very small approximating a constant current source. Safety ratings which have been established by Consumers' Union can be used:

If the current is less than 0.1 ma rms, it is acceptable.

If the current is less than 1 ma rms, there will be a slight shock.

If the current is less than 5 ma rms, it may be considered a borderline case.

And if the current is greater than 5 ma rms, it is definitely unacceptable. This level could be dangerous and above the "let go" current.



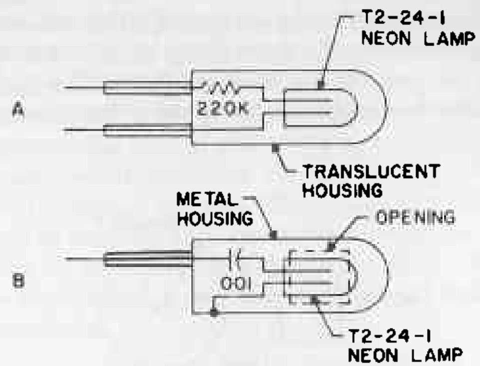

12-11 Leakage current indicator

The unit has a long ground lead and three pointed probes coming from one end. The lamp is installed in a visible location. In use the ground wire is clipped to a convenient ground point and devices such as machine tools, toasters, washers, mixers, electric drills, wiring, conduit, etc. are touched with the various probes to determine the leakage current.

On the subject of probes, Figure 12-12 shows schematics of two neon lamp probes which can be used to test the household circuitry. In Figure 12-12A the lamp is enclosed in a transparent or translucent housing and connected to the insulated leads through a 220K resistor. Both probes are touched to wires in the circuit to be tested. It may be used on either 115 or 230 volts ac, and the intensity of light output will show what the voltage is. Figure 12-12B is a single probe detector which can be used to determine when 115 or 230 volts is available. The lamp in this case is enclosed in a metal housing with a window or opening through which the light output can be seen. One lead is attached to the housing, and the other is connected to the insulated probe through a 0.001$\mu$ fd, 400 volt capacitor. The

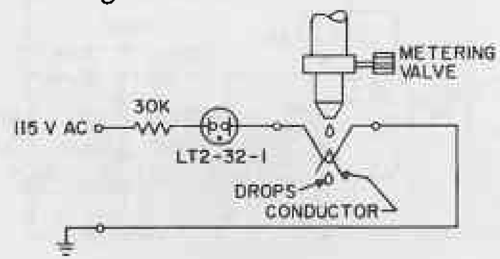


lamp will light when the probe is touched to the hot side and will not light when touching the ground or neutral side. The metal housing must be in contact with the human body.



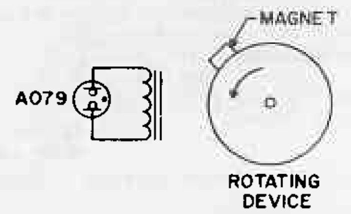

12-12 Power line testing probes

Neon lamps are frequently used to provide remote indication of the condition, status, or progress of a process. In Figure 12-13 the flow of an electrically conductive liquid, such as aqueous ammonia is monitored. As drops of the solution are released, they fall and form a conductive path between the two corrosion resistant wires which are in a series circuit with the neon lamp. A suitable voltage source such as 115 volts ac is used to flash the light.



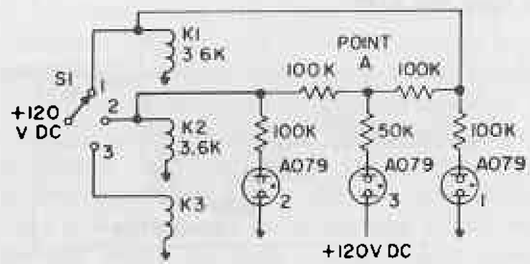

12-13 Flow indicator

In Figure 12-14 the neon lamp is used to provide positive remote indication that a rotating device is running. The lamp is connected across the coil of an inductor with a moderately high turns ratio, such as the coil from a 10,000 ohm relay. Each time the magnetic material goes through the coil it will induce a counter emf causing the neon lamp to glow momentarily. It would also be possible to place a photocell adjacent to the lamp and have the reaction of the photocell activate a rotational counter.




12-15 Status of relay indicator

The circuit shown in Figure 12-15 was developed to indicate the status of three relays, $K_1$, $K_2$ and $K_3$, through a visual means. Since the relays were operated on 120 volts dc, it would have been a simple matter except for the fact that only the terminals on $K_1$ and $K_2$ were accessible. The other components were completely not reachable without considerable modification.

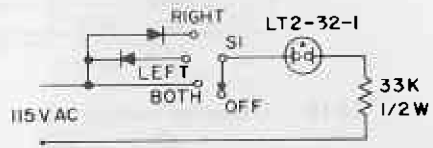



12-14 Indicator for rotating device



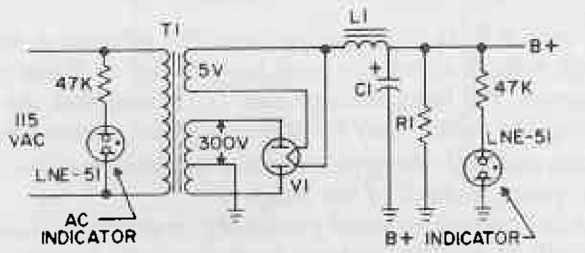
When $S_1$ selects relay $K_1$, lamp number 1 lights. Point A goes to 60 volts holding off lamp number 3. When $S_1$ selects relay $K_2$, lamp number 2 lights while Point A still holds off lamp number 3. When $S_1$ selects $K_3$, however, Point A is no longer at 60 volts dc and lamp number 3 finds a return through $K_1$ and $K_2$ (3.6K ohms each). Lamp number 3, it should be noted, is connected to 120 volts.

It is characteristic of neon glow lamps that when operated on direct current the area of glow will be centered around one electrode, and when operated on alternating current, both electrodes will appear to glow. This characteristic is used in Figure 12-16 to indicate four conditions using one glow lamp. By switching $S_1$ as indicated, either right electrode, left electrode, or both electrodes may be activated, as well as neither in the off condition.



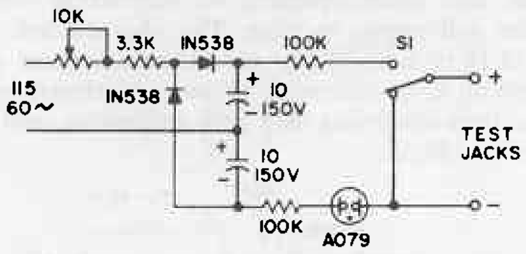

12-16 4-condition indicator

In the representative power supply schematic shown in Figure 12-17, a glowing neon lamp indicates the presence of a charge stored in capacitor $C_1$ due to failure of the bleeder resistor $R_1$. In trouble shooting equipment associated with this




12-17 Power supply showing ac and dc condition supply, the neon lamp not glowing would immediately point out the absence of $E_B$ indicating trouble in $T_1$, $V_1$, $L_1$, or associated circuitry.

A method of using a neon glow lamp to help locate a leaky capacitor is shown in Figure 12-18. This is essentially a voltage doubler. The actual voltage is controlled by $R_1$. Closing switch $S_1$ applies voltage to the test item. The resultant blinking of the neon lamp is an indication of the leakage of the capacitor.

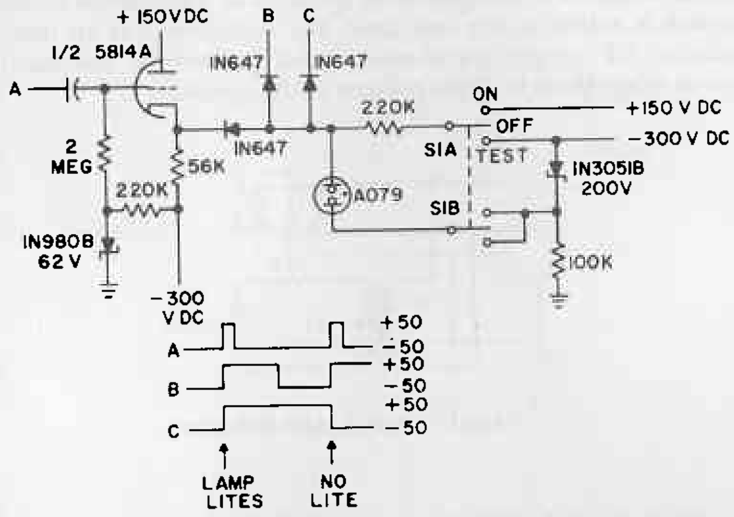



12-18 Capacitor leakage tester

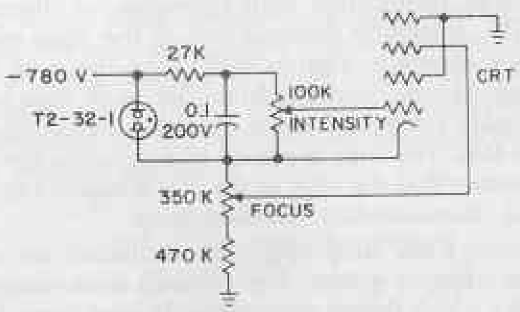
There are many different jobs that can be performed in the indication area. For example, the circuit in Figure 12-19 was designed to give a visual indication whenever three pulses appear simultaneously. The signals at B and C are gates of 100 volt amplitude from –50 to +50. When a pulse appears at A, its dc level is changed so that it appears about –50 to +50 vdc also.

If switch $S_1$ is in the on position, the pulse at A will cause enough voltage across the neon lamp to fire it. When the pulse disappears, the lamp extinguishes. To insure that the lamp is working, the switch may be pressed against a spring loaded on position and 200 vdc appears across the lamp and the 220K resistor, giving a check of the lamp.

As has been mentioned previously, many times a neon glow lamp will be used to perform more than one function, usually combining its use as a circuit component with the fact that it is a light producing component. In the circuit in Figure 12-20 the glow lamp serves as an equipment pilot light indicating that power is available and as a bias regulator for grid 1 of the cathode ray tube.

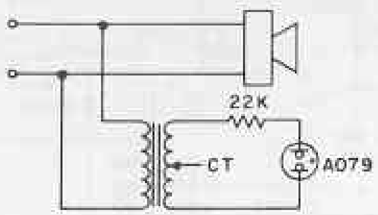



12-19 Indicator for simultaneous pulses




12-20 Pilot light and bias regulator

There are times when a multiplicity of circuits are used and it is desirable, or necessary, to know which one is energized. Such a condition is typical of annunciator applications. Another, shown in Figure 12-21, is similar in that it is used to indicate which of a multiplicity of speakers in a communications system is active at any one time. The transformer is an inexpensive A.F. output transformer wired backwards. The lamp glows when there is audio present at the speaker.



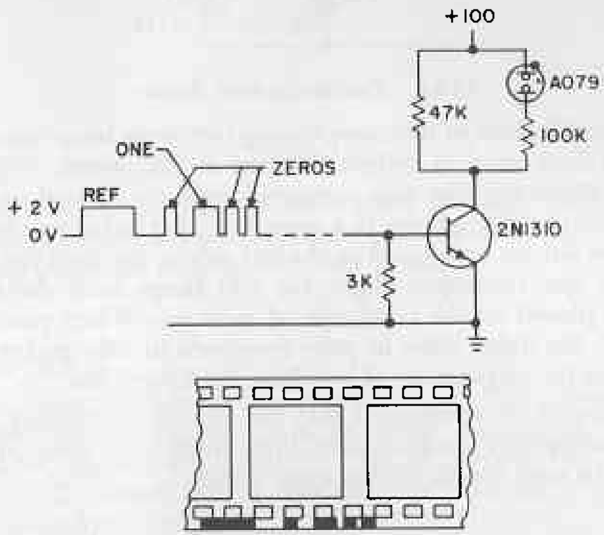

12-21 Annunciator indicator

While the light output from neon lamps, as has been discussed earlier, does not recommend them for many applications where high luminosity is required, there are certain applications where the light output will perform certain tasks. Some of these are in conjunction with photocells as discussed in Chapter VIII. A slightly different use of the light output of neon lamps is shown in Figure 12-22. Here the neon lamp is used to mark 35 mm instrumentation film with time information. The binary time code and a transistor driven glow lamp perform the task. The lamp is placed in a rig inside the camera in such a manner that the edge of the film is exposed through a pin size hole illuminated by the neon lamp.

Many times neon lamp relaxation oscillators are used as blinkers and attention-getters. Figure 12-23 is an example of a simple flasher which flashes approximately once every five seconds. The time interval in this type of blinker can be varied but the time the lamp is on is moderately short.

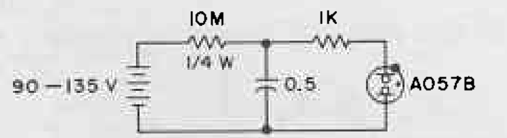


Another type of blinker which is generally more effective because the lamp is on longer and because the light oscillates from side to side is shown in Figure 12-24. In this circuit lamp $L_1$ will light when power is applied. The condenser will then

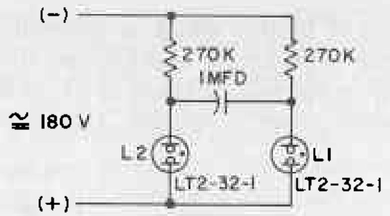



12-22 Film marker

begin to charge to the breakdown voltage potential of the other lamp, $L_2$. When $L_2$ fires, a pulse is transferred to $L_1$, driving it off. $L_2$ will then stay on while the condenser charges in the other direction toward the breakdown potential of $L_1$. When $L_1$ breaks down, $L_2$ will be driven off. The cycle is repeated as long as power is applied.



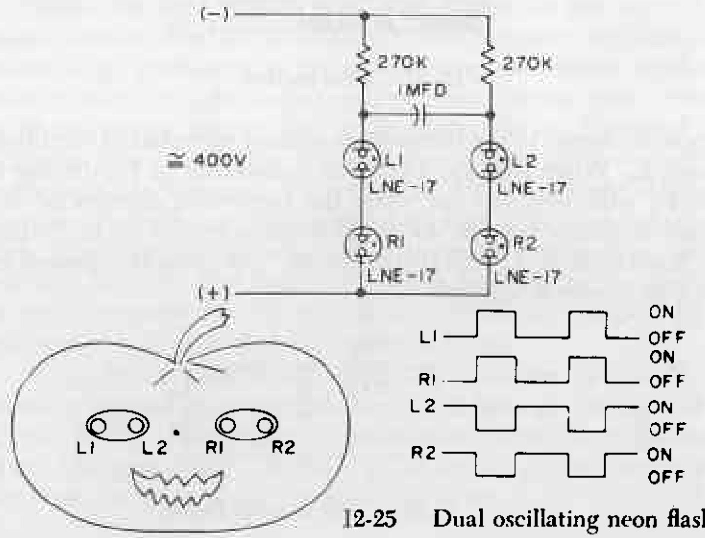

12-23 Simple neon flasher




12-24 Oscillating neon flasher

A modification of this circuit using two neon lamps on each leg has been used to delight children at Halloween. (Figure 12-25) Physically, the two common lamps are located on the same side of different eyes in a pumpkin. That is, the two lamps from the left leg are placed on the left side of the right eye and the left eye. Correspondingly, the two lamps from the right leg are placed on the right side of each eye. When power is applied, the lights blink in pairs from side to side, giving the pumpkin the appearance of watching for hobgoblins.

It should be understood that for maximum visibility and most satisfactory performance, high brightness neon lamps should be used for all blinker applications.




12-25 Dual oscillating neon flasher



## CREDITS

In addition to the references cited in each chapter, the author gratefully acknowledges the contributions from the following people in making this book possible.

CHAPTER II

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CHAPTER V

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CHAPTER VI

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CHAPTER IX

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CHAPTER XII

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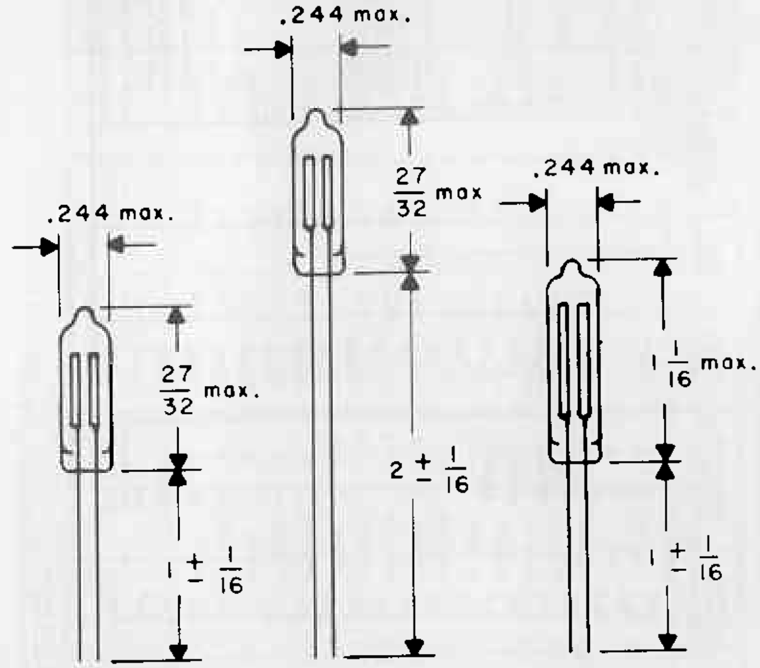
# APPENDIX

## PHYSICAL AND ELECTRICAL CHARACTERISTICS OF NEON GLOW LAMPS DISCUSSED IN THIS BOOK

DIMENSIONS:




(Drawing "A") (Drawing "B") (Drawing "C")

ELECTRICAL:

Electrical characteristics are listed on the following pages. Unless otherwise specified, electrical measurements for all lamps are taken at +20°C, 40% relative humidity, and in normal lighting (5 foot-candles minimum).

SOME TYPICAL CIRCUIT COMPONENT NEON LAMPS [1]

| Type No. | Breakdown Voltage vdc | Maintaining Voltage vdc | Design Current (average) ma | Extinguishing Voltage vdc | Average Life Hours | Oper. Temp. | Dims. (Ref: Dwgs. Page 157) | Remarks |
|---|---|---|---|---|---|---|---|---|
| AO 74 | 85(max)[2] | 50-60 | 0.3 | 48 | 10,000 | OPERATING TEMPERATURE RANGE FOR ALL LAMPS IS — 55° To +90° C | A | Designed for photocell operation |
| AO 83 | 105(max)[2] | 60-70 | 2.0 | 58 | 5,000 | | A | Designed for photocell operation |
| T2-27-1R100 | 66-74[2] | 52-59 | 0.5 | 50 | 10,000 | | A | For trigger applications; Designed for operation in total darkness |
| T2-27-1WR250 | 100-120[2] | 60-70 | 2.5 | 55(min) | 5,000 | | A | |
| T2-27-1WR350 | 115-140[2] | 60-70 | 2.5 | 55(min) | 5,000 | | A | |
| T2-27-1WR500 | 140-160[2] | 60-70 | 3.0 | 55(min) | 5,000 | | A | |
| T2-27-1WR760 | 170-200[2] | 60-70 | 3.0 | 55(min) | 5,000 | | A | |
| AO 59-2 | 65-75 | 52-53 | 0.3 | | 7,500 | | A | Close maintaining voltage series - use in simple voltage regulator or voltage reference applications or where maintaining voltage must be held to within ±.5 volts |
| AO 59-3 | 65-75 | 53-54 | 0.3 | | 7,500 | | A | |
| AO 59-4 | 65-75 | 54-55 | 0.3 | | 7,500 | | A | |
| AO 59-5 | 65-75 | 55-56 | 0.3 | | 7,500 | | A | |
| AO 59-6 | 65-75 | 56-57 | 0.3 | | 7,500 | | A | |
| AO 59-7 | 65-75 | 57-58 | 0.3 | | 7,500 | | A | |
| AO 59-8 | 65-75 | 58-59 | 0.3 | | 7,500 | | A | |
| AO 59-9 | 65-75 | 59-60 | 0.3 | | 7,500 | | A | |
| AO 57B | 85(max)[2] | 60(max) | 2 [3] | | 10,000 | | C | SCR Trigger |
| RT 2-32-1A | 70-90[2] | 50-65 | 6.0 | 50 | 5,000 | | C | High Current Glow Lamp |
| AO 79 | 70(max) | 58 | 0.3 | 47 | 7,500 | | A | Tansistor Applications |
| AO 78 | 70±4[2] | 55±5 | 0.3 | 48(min) | 10,000 | | A | For timing circuits leakage resistance is 10,000 megohms min. |
| AO 51 | 205-250 | Not Specified | —[4] | Not Applicable | —[4] | | A | Arc suppression of 115 NAC circuits |
| RLT 2-27-1 | 115-210 | 55-80 | 2.0 | 55 | 5,000 | | A | For memory circuits |

Notes: 1. Close Tolerance Lamps Designed and Manufactured Specifically for use in Electronic Circuitry.
2. In Total Darkness
3. Peak Current 80 ma.
4. Depends on Energy Switched and Application.

VOLTAGE REGULATOR AND REFERENCE TUBES

| Type No. | Breakdown Voltage vdc | | Reference Voltage | Meas. At | Regulation[1] Current Limits | Temp. Coeff. | Operative Current ma | | | Life Expectancy | Typical Variations at 250 hrs | Dimensions (Ref:Dwgs. Page 157) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Max. | Typical | vdc | ma | ma | mv/°C | Max[2] | Min as Shunt reg | Min Parallel with capacitor | Hours | % | |
| Z82R7 | 110 | 102 | 82±1 | 2.0 | 0.25-7.0 | -2 | 10.0 | 0.25 | 0.45 | 30,000 | <0.2 | Dimensions for all voltage regulator and voltage reference tubes shown on Drawing C |
| Z82R10 | 115 | 105 | 82±1 | 2.0 | 0.3-10.0 | -2 | 14.0 | 0.3 | 0.7 | 30,000 | <0.3 | |
| Z82R15 | 118 | 107 | 82±1 | 2.0 | 0.5-15 | -2 | 17.0 | 0.5 | 0.9 | 30,000 | <0.5 | |
| Z83R4 | 110 | 100 | 83±1 | 1.5 | 0.25-4.2 | -2 | 6,0 | 0.25 | 0.4 | 30,000 | <0.2 | |
| Z84R2 | 110 | 100 | 84±1 | 1.0 | 0.15-2.0 | -2 | 3.0 | 0.15 | 0.35 | 30,000 | <0.2 | |
| Z91R2 | 118 | 110 | 91±1 | 1.0 | 0.1-2.0 | -3.5 | 3.0 | 0.1 | 0.3 | 30,000 | <0.3 | |
| Z91R4 | 120 | 111 | 91±1 | 1.5 | 0.2-4.0 | -3.5 | 6.0 | 0.2 | 0.35 | 30,000 | <0.3 | |
| Z91R7 | 130 | 120 | 91±1 | 1.5 | 0.25-7.0 | -3.5 | 10.0 | 0.25 | 0.4 | 30,000 | <0.3 | |
| Z91R10 | 135 | 122 | 91±1 | 1.5 | 0.25-10 | -3.5 | 12.0 | 0.25 | 0.5 | 25,000 | <0.3 | |
| Z100R12 | 150 | 140 | 100±1 | 3.0 | 0.6-12.0 | -9 | 14.0 | 0.6 | 1.8 | 30,000 | <0.6 | |
| Z103R2 | 130 | 115 | 103±1 | 0.8 | 0.2-2.0 | -4.5 | 3.0 | 0.2 | 0.25 | 20,000 | <0.4 | |
| Z103R4 | 130 | 120 | 103±1 | 1.0 | 0.2-4.0 | -4.5 | 5.0 | 0.2 | 0.25 | 20,000 | <0.6 | |
| Z105R7 | 160 | 150 | 105±1 | 2.5 | 0.6-7.0 | -9 | 10.0 | 0.6 | 1.3 | 30,000 | <0.6 | |
| Z110R4 | 165 | 155 | 110±1 | 1.5 | 0.5-4.0 | -9 | 6.0 | 0.5 | 0.95 | 30,000 | <0.4 | |
| Z115R4 | 150 | 140 | 115±1 | 0.8 | 0.15-4.0 | 15 | 6.0 | 0.15 | 0.3 | 20,000 | <0.3 | |
| Z115R7 | 155 | 145 | 115±1 | 1.5 | 0.5-7.0 | 15 | 9.0 | 0.5 | 2.0 | 20,000 | <0.3 | |
| Z116R2 | 145 | 138 | 116±1 | 0.6 | 0.12-2.0 | 15 | 3.0 | 0.12 | 0.3 | 20,000 | <0.3 | |
| Z139R1.9 | 185 | 175 | 139±3 | 0.5 | 0.3-1.9 | -10 | 3.0 | 0.3 | 0.6 | 20,000 | <0.35 | |
| Z143R1.9 | 220 | 195 | 143±3 | 0.5 | 0.3-1.9 | -10 | 3.0 | 0.3 | 0.6 | 20,000 | <0.2 | |

Notes:
1. Limits for less than one volt variation.
2. Maximum continuous current without permanent damage to tube.

## THREE-ELEMENT TRIGGER TUBES

| Type Number | Anode to Cathode[1] | | | | | Trigger to Cathode[2] | | | | | | Trigger to Anode[3] | | Life | Dimensions |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Maximum Stand-off Voltage vdc | Breakdown voltage vdc | Maintaining Voltage ± vdc | Measured at ma | Operating Current ma | Breakdown Voltage vdc | Turn-on Current (max) | Maintaining Voltage vdc | Measured at ma | Max. Current ma | Stand-off Voltage vdc | Breakdown Voltage vdc | Hours | (Ref. Dwgs Page 157) |
| TRJ 250 | 149 | 150-185 | 96±2 | 2 | 0.1 TO 4 | 163±5 | 1μa | 83±2 | 2 | 4 | 114 | 115-165 | 25,000 | DWG C |
| TRQ 250[4] | 189 | 190-230 | 100±2 | 2 | 1 TO 6 | 116±6 | 1μa | 91±2 | 2 | 6 | 129 | 130-180 | 25,000 | DWG C |
| 120TG-27-2 | 95 | 96-120 | 65-77 | 0.5 | 0.5 | 65-82 | <1μa | 60-72 | 0.5 | 0.5 | Not Specified | Not Specified | 5,000 | DWG B |
| 180TG-27-1 | 164 | 165-200 | 70-80 | 2 | 2 | 80-102 | 1μa | 51-67 | 2 | 2 | " | " | 4,000 | DWG A |
| LTG-27-2 | 159 | 160-180 | 70-90 | 2 | 2 | 90-114 | 1μa | 60-84 | 2 | 2 | " | " | 5,000 | DWG B |

Notes:

1. Anode Positive, Cathode Negative, Trigger Floating.
2. Anode Floating, Cathode Negative, Trigger Positive.
3. Anode Positive, Cathode Floating, Trigger Negative.
4. Electrically Interchangeable with NE-77.