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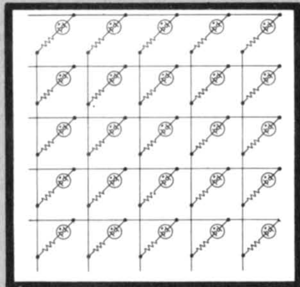

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Signalite Inc., 1933 Heck Avenue, Neptune, N J 07753

VERSATILE, LOW COST PHOTOMETER

By Michael I Distefano *Signalite*

The use of a photomultiplier tube in a photometer gives this type instrument a sensitivity and flexibility vastly different from other simple photoelectric devices. The ability to amplify low light emissions internally over a fairly wide color spectrum gives the photometer light emission characteristics similar to the human eye. As a result of internal signal amplification, the light intensity variations that are impressed onto the photomultiplier tube appear as a directly related signal output at the last stage of the tube that can be read in a very accurate manner

The only limiting factors to more widespread use of the photometer have been the relatively expensive power supply circuitry required by the multi-section tube, and the need for additional signal processing circuitry to provide a readout of the tube output signal. For a practical and economic solution to both of these problems, neon gas devices are used to provide a simple means of readout and an uncomplicated means of voltage stabilization in the power supply circuitry However, instead of using the output voltage, as is commonly done, the output current is used to charge a capacitor in a linear fashion to provide additional stability of output.

The inherent sensitivity of the photometer makes it an ideal instrument for detecting shade differences, color discrimination, or any measurement involving small light intensities. The original application of the circuitry illustrated in this story (Figure 1) is a highly sensitive instrument for accurately measuring star light intensity through a reflecting telescope that appeared in the March 1970 issue of *Sky and Telescope* magazine co-authored by Dr T E. Houck and Thomas R. Cram

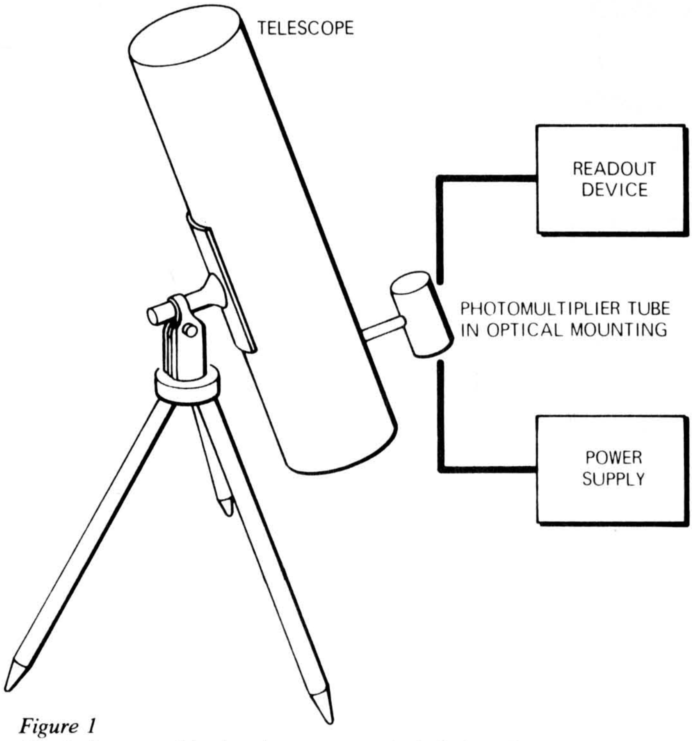

Figure 1
Block diagram of basic telescope mounted photometer.

One of the key cost factors in a photometer capable of performing starlight magnitude measurements, or to be used in any application where light differentials are very small, is the need for electronic circuitry and a readout device. A convenient means to circumvent this cost factor is the use of a simple relaxation oscillator built from a capacitor and a neon lamp. This circuit, illustrated in Figure 2, is capable of accuracies approaching 0.01 starlight magnitude in a form that offers portability as well.

The typical current output from a photomultiplier tube such as the RCA 931A is in the neighborhood of 10 microamps to 1 nanoamp (10^{-5} to 10^{-9} amps). Using the output current of the photomultiplier instead of the output voltage enables the capacitor to be charged at

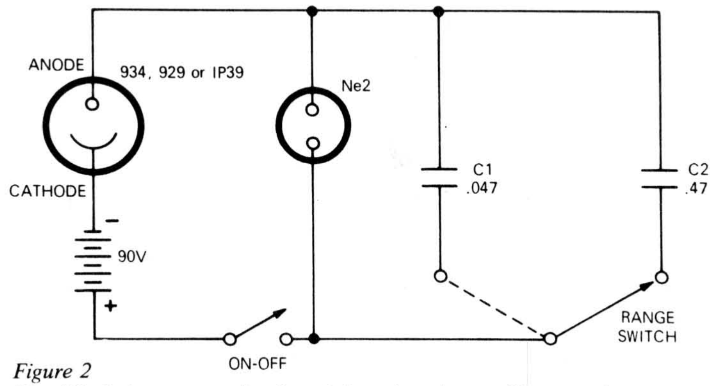

Figure 2
Simplified photometer circuit and the relaxation oscillator readout.

a linear rate which is a function of the illumination of the photomultiplier, thus increasing the accuracy of the readout device. When a capacitor is charged by the output voltage, the rate of charge vs. time tends to drop off as the capacitor nears full charge (Figure 3A). On the other hand, charging the capacitor by a constant current source, as available from the photomultiplier tube results in the charging rate shown in the positive slope of Figure 3B.

The output from the photomultiplier tube is applied across the capacitor C_1 or C_2 depending on the range desired. As the electrons are collected in the capacitor, the voltage increases, at a linear rate, to the point where the breakdown level of the A287 neon tube is reached. When the lamp ionizes and conducts, the charge stored on the capacitor is released in a few milliseconds until the voltage level drops to below the maintaining level of the tube (Figure 3B). When the tube extinguishes electrons again begin to collect in the capacitor and the process repeats itself, giving a highly stable blink rate which can be directly related to the illumination level. The voltage levels reached in this basic circuit are about 70 volts for neon tube ignition and about 40 volts for tube extinguishing.

If very high leakage resistance capacitors are chosen for the oscillator, the rate of neon lamp flash is directly proportional to the input current supplied by the photomultiplier tube. By adjusting the

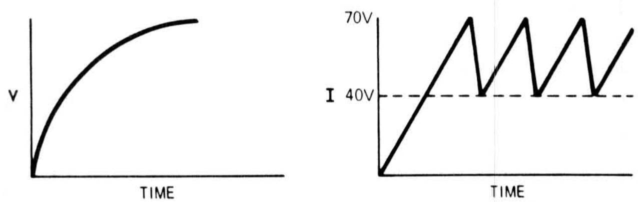

Figure 3 *Figure 3A* *Figure 3B*
Capacitor charging characteristics with respect to voltage, and in relaxation oscillator circuit.

capacitor values with a little care, this simple indicator circuit can be very accurately used over the entire current range of the tube.

To facilitate low light levels, as in determining starlight magnitude, several different value capacitors are selected by a ceramic wafer switch. In this way the timing constant of the relaxation oscillator can be readily changed to keep the neon lamp flash rate within a countable range that can be accurately counted. If a very low flash rate were to be encountered such as one blink in four minutes elapsed time, the nominal internal resistance of even the best capacitor would dissipate the photomultiplier tube current as fast as it was being supplied. At the other extreme of very high flash rates, in the neighborhood of several thousand per minute, the neon would appear to be constantly lit.

In starlight measurement applications, the photometer is optically coupled to a reflecting telescope eyepiece. The photomultiplier tube and counter are turned on and the range switch is rotated through its different positions. When a switch position is found that will yield an easily and accurately countable neon blink rate, this information is recorded. By previously measuring and recording blink rates for known magnitude stars, a blink rate conversion chart is made based on range switch position, and blink count with respect to time.

The telescope mounted version of the photometer uses a RCA 931A photomultiplier tube powered by a series-connected string of dry batteries. For more critical photometer applications, particularly where higher sensitivity and lower dark current response may be needed, another tube, the RCA 1P21, may be directly substituted for the 931A. The advantage of the 931A lies chiefly in its lower cost; the 1P21 is electronically identical and differs only in higher production standards.

The theory and operation of the photomultiplier tube is a bit more complex than the basic oscillator circuitry The photomultiplier operates in a similar manner as the simple phototube illustrated in Figure 2, that is, photon energy impinging on a photocathode causes an emission of electrons. But in the internally amplifying photomultiplier tube, these electrons are directed to a secondary emitting surface called a dynode. Impingement of any single 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 can have as many as 14 dynodes, but for the case in point, the RCA 931A tube has nine. 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 the multiple secondary emission stages (dynodes) so that the secondary electrons from one become the primary electrons of the next is done through application of a direct current at each stage. 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 in the vicinity of 70 to 100 volts.

The power supply consists of ten 90 volt dry batteries connected in series to give the instrument portability and independence from line

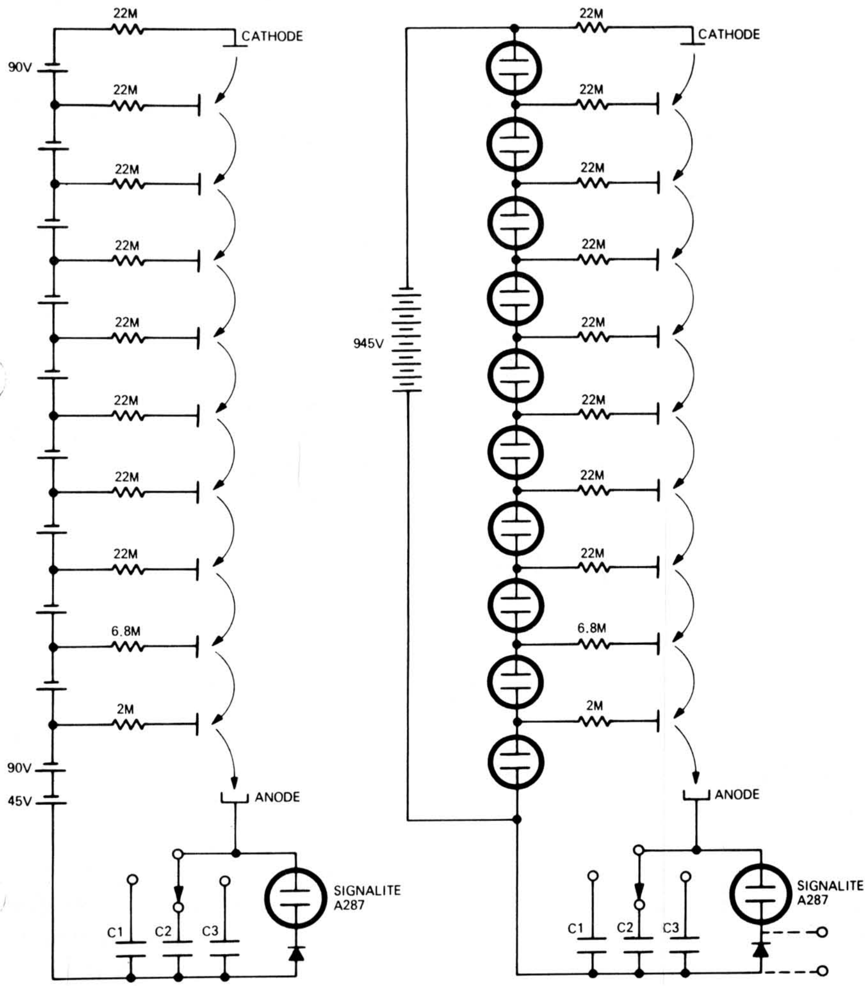

Figure 4
Individual battery power supply used in the original starlight photometer design, and the same circuit using Signalite voltage regulator tubes and a single power supply source.

voltage for remote field use as well as observatory application. In addition, the use of batteries greatly simplified the early design by eliminating the need for voltage stabilization circuitry that should be used for any AC line power supplies. Since interstage current requirements of the 931A tube are negligible for the light levels encountered in star magnitude measurements, the battery supply should last from 3 to 5 years before replacement should be necessary The 45 volt dry battery shown in Figure 4 brings the nominal 55 volt potential between the last dynode and anode of the photomultiplier tube up to a level high enough to operate the relaxation oscillator circuit.

Building the circuitry does not require any specialized electronic knowledge, but a few suggestions are in order When building the relaxation oscillator circuit, all switch surfaces and soldered joints should be thoroughly cleaned with alcohol. If high resistance paths caused by solder flux or skin oils are not removed, the resultant leakage within the circuit will have an adverse effect on overall counter accuracy The use of the Signalite A287 neon glow lamp with a leakage resistance in excess of 100 thousand megohms and good quality capacitors will give the counter an accuracy of one percent or better

The series connected batteries in the photomultiplier power supply present a potential of 945 volts through a multiconductor power cable. Because of this higher than normal voltage level, the battery container must be double insulated with strips of bakelite, dry wood, or any suitable material. Any exposed parts should be covered with a silicone potting compound to prevent accidental contact by personnel, or voltage leakage due to water condensation. Series connected resistors at each dynode stage of the photomultiplier offer additional protection against accidental operator contact, and protect the tube from high current damage from accidental exposure to excessive light.

ADAPTING THE BASIC DESIGN TO AN A.C. POWERED PHOTOMETER

A reasonable cost photometer that is AC current operated can be made by making a few basic changes in the original circuit. These changes will also provide greater accuracy and an output that can be read by a meter.

The biggest problem in powering a photometer from the AC line is regulating the instrument's power supply accurately enough that line voltage fluctuations will not interfere with measurement accuracy The problem centers around voltage changes at the individual dynodes. Any voltage variation will directly effect the gain factor of the tube, whether only one dynode or all dynodes are involved. In practice then, the amplification of the photomultiplier depends on the charac-

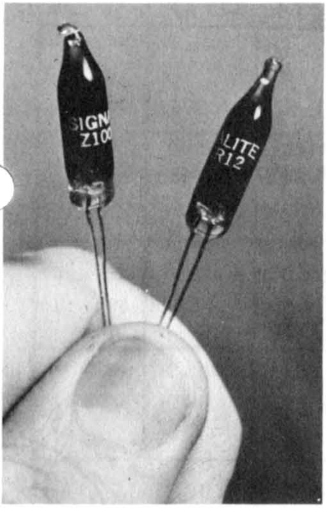

Figure 5
Cold cathode voltage regulator tubes

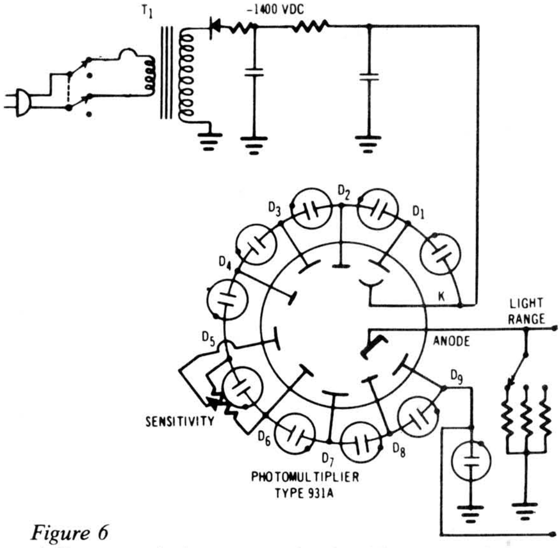

Figure 6
A.C. powered photometer circuit without a readout.

teristics of the circuit supplying the required inter-dynode operating voltages. If a simple resistive voltage divider is used, the interstage currents of the tube may alter dynode voltage distribution in such a manner as to cause limiting of the output current and consequent loss of gain. Designers try to overcome this problem by designing a very accurate (and expensive) power supply with a high current bleeded resistor They reason that by supplying a low source impedance voltage to each dynode, individual voltage changes due to current differences will be minimized.

Another possible solution involves regulating the individual voltages at each dynode. Zener diodes perform this task well, but have to be close-tolerance types that are prohibitively expensive. Large gas tube regulators will work, but are not accurate enough and are very bulky The ultimate solution lies in the use of subminiature cold cathode voltage regulators such as the Signalite Z84R2 (Figure 5). These devices offer low cost and high regulating accuracy in a small package.

A circuit for accurate voltage regulation of a photomultiplier tube using Signalite Z84R2 voltage regulator tubes is shown in Figure 6. The voltage at dynode 9 of a 931A photomultiplier tube is plotted against an unregulated input voltage in Figure 7 These regulator 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 level over a typical 0.15 to 2.0 ma operating range. Life expectancy is 30,000 hours of continuous operation, permitting them to be wired directly into the photometer circuitry

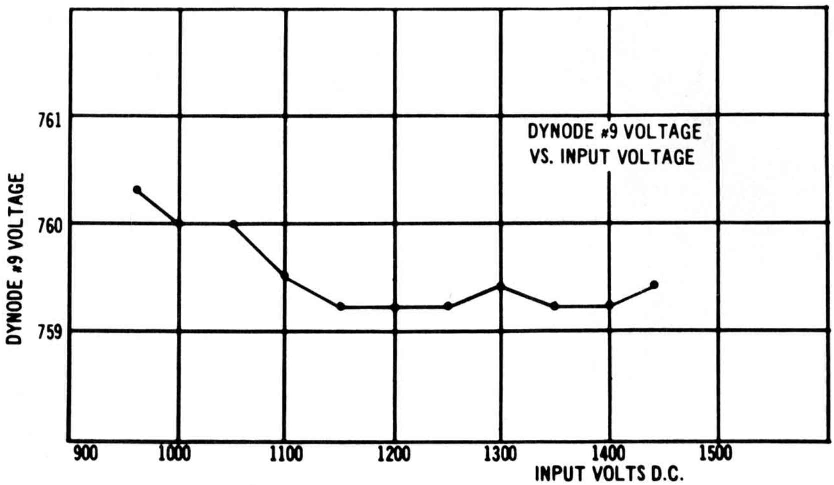

Figure 7
Dynode No.9 Voltage Vs. Input Voltage

To put these components to work in an inexpensive but very accurate photometer, add a simple 1,400 VDC power supply, a range switch, and use a vacuum tube voltmeter as an indicator After some trial and error, range switch resistors can be found that will match most commercial VTVM's. If a complete photometer with meter indication is desired, the circuit illustrated in Figure 8 can be added as well. In either case, the finished instrument is capable of accurate measurements in the micro lumen range.

Photometers are versatile devices that need not be limited to straight light intensity measurements such as the starlight magnitude instrument illustrated in this story They find usage in judgment of

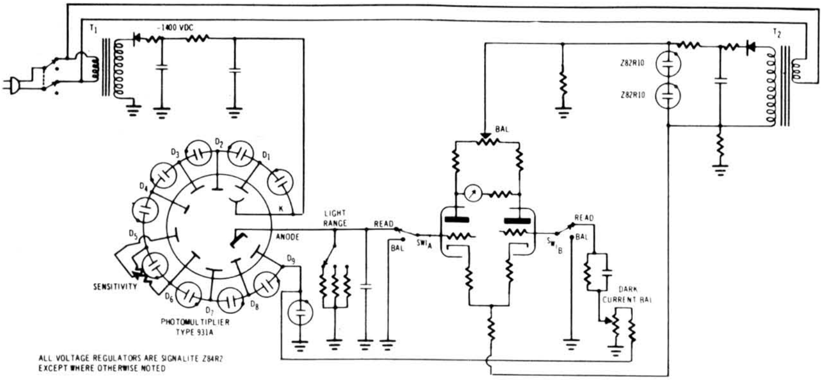

Figure 8
Complete A.C. powered photometer circuit with a sensitive vacuum tube voltmeter readout system.

color dyes, thickness of sheet plastics and textiles, and refractometer sampling in the chemical industry The low light threshold of the photomultiplier makes it useful where other higher light level photosensitive devices such as photocells would not work at all. They are useful for any detection and measurement operation that is below the visual acuity of the human eye.

When the photomultiplier tube sensitivity is combined with the accurate voltage regulation of the Signalite Z84R2 devices, entire new application areas are opened up. Instruments such as scintillation counters, gamma ray spectrometers, smoke detectors, celestial navigation devices, laser detection, and other types of spectrophotometric instruments can benefit. The photometer is a versatile device; look around and see what you can use it for

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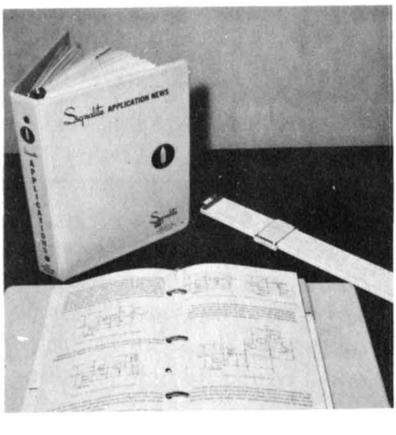

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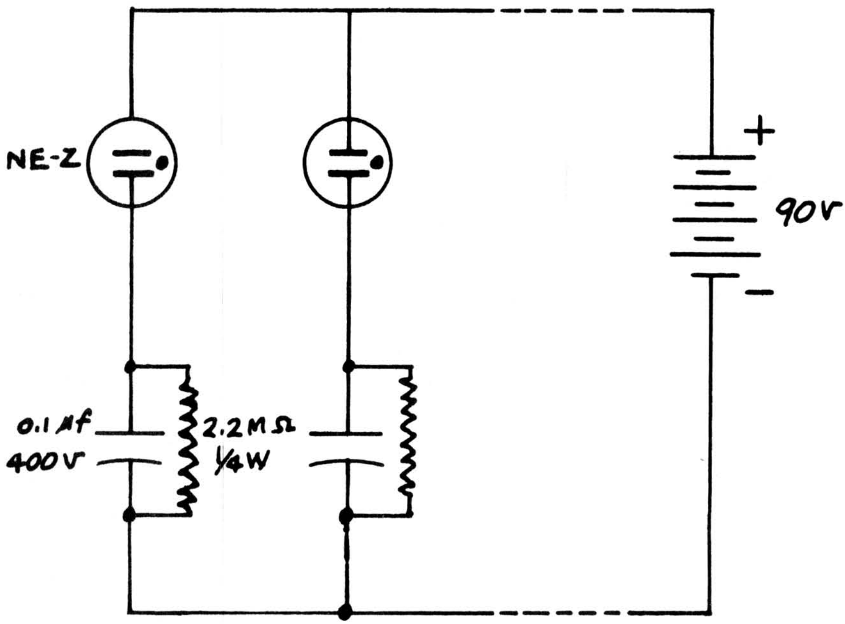
HOLIDAY GREETINGS

Gentlemen

Enclosed is neon lamp application that I display during the Christmas holiday season

I purchased a large plastic wreath and to the back of this wreath



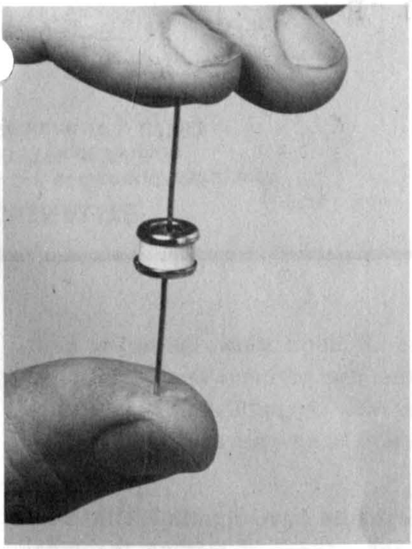
I secured fifty neon flash units (as per sketch). All of the non-polarized capacitors are 0.1 µf., 400 volts and all of the resistors are 2.2M ohms, 1/4 watt. The neon lamps do not flash at the same rate due to manufacturing tolerances of the components. The end result is a wreath with small twinkling ights flashing at different rates.

The 90-volt battery will last about 3 seasons with about 2 weeks continuous use per season.

E. Sadok

Ottawa, Ontario

SIGNALITE INTRODUCES FAST-ACTING, LOW VOLTAGE, SUBMINIATURE SURGE ARRESTER



A new line of two-electrode, gas filled surge arresters for the protection of telecommunications lines and solid state electronic circuitry has just been introduced by Signalite. These arresters, the CG series, are subminiature in size and feature low voltage operation, fast response to spurious transients, low internal capacitance, high peak current capabilities, self-extinguishing capability, long life and low price.

These arresters have been designed to suppress external surges caused by the secondary effects of lightning in telephone, microwave link, telemetry and transmission lines. In addition, they can be used to protect against internally generated surges caused by short circuits and switching of inductive components.

Response to transients is rapid. Life is guaranteed for 50 discharges under maximum load conditions with 200 discharges being typical. If failure occurs, it is typically in the fail safe direction.

Five ratings are available in the CG series. When subjected to a slowly rising DC voltage equal to or less than 100 volts per second, these ratings are 90, 230, 350, 470 and 800 volts DC. Pulse voltage breakdown (a rise of 5 kv per microsecond) occurs at 1.0, 1.5, 1.5, 2.5 and 4.0 kv maximum respectively. These devices have a rating of 10,000 amperes peak, maximum interelectrode capacitance of 2 picofarads, and insulation resistance greater than 10,000 megohms.

The arresters are ceramic to metal type gas-filled gaps which are stabilized for dark operation. All five units are .380" in diameter and .265" in length. Leads are #20 AWG wire approximately 7/8" long. The arresters may also be supplied in clip type button configuration for installation in the same manner as fuses.

The new line of arresters is low priced (under $1.00), will reduce maintenance and downtime and withstand shock and vibration. They are available for immediate delivery from Signalite.

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