## 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.

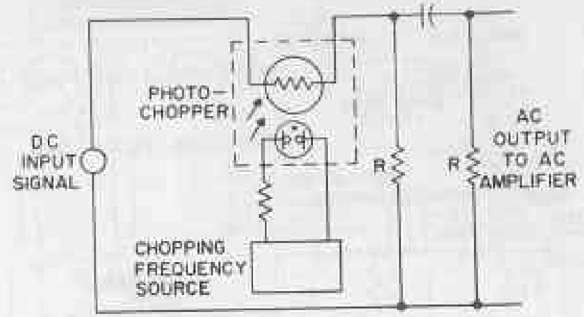
*Choppers-Modulators*

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.

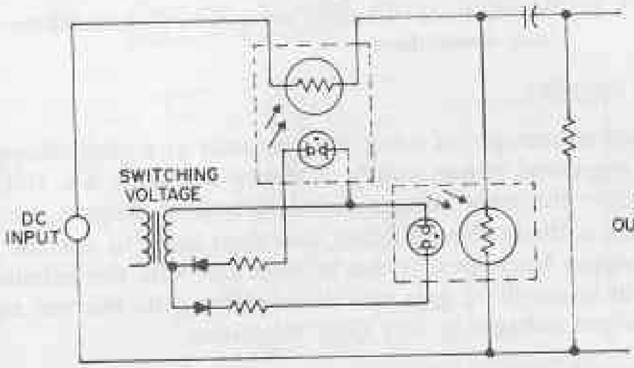
The series shunt circuit (Figure 8-2) provides a more symmetrical waveform and results in less drift in null offset under varying environmental conditions. The photochoppers must be operated 180 degrees out of phase. This is accomplished by





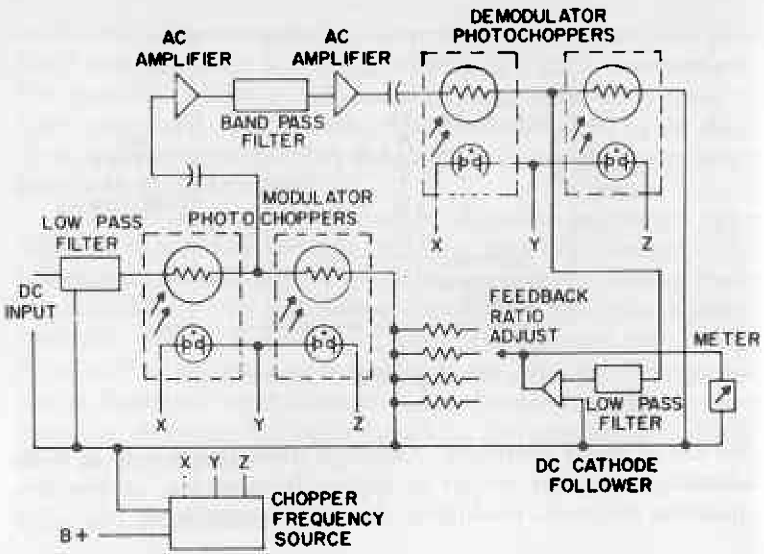

8-1 Neon-photocell series chopper

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

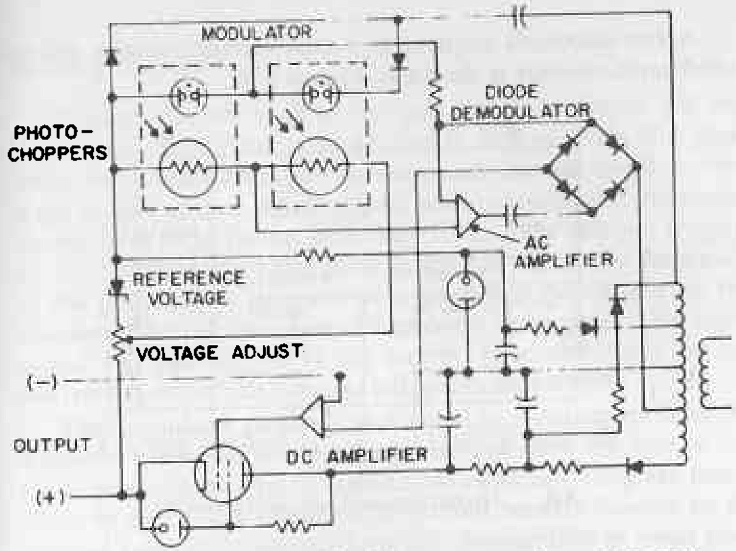
## *Power Supplies*

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.

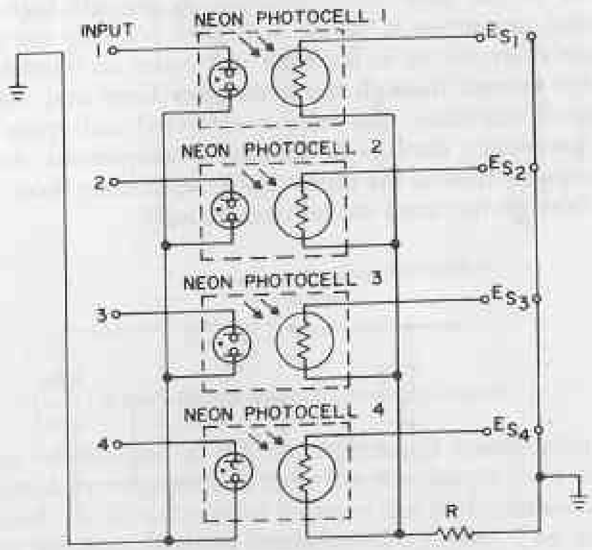
## *Low Noise Switch*

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.)



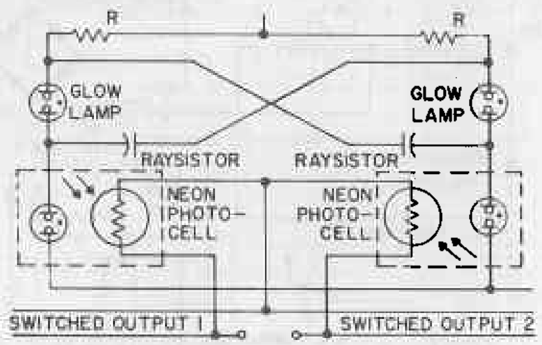



8-4 Electronic regulated power supply using neon photocell modulator




8-5 Neon-photocell low noise switch

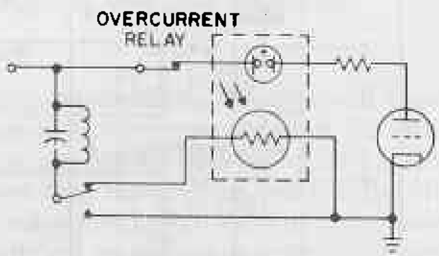
A two-photocell sequential switch circuit using a self-excited multivibrator is shown in Figure 8-6.




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.



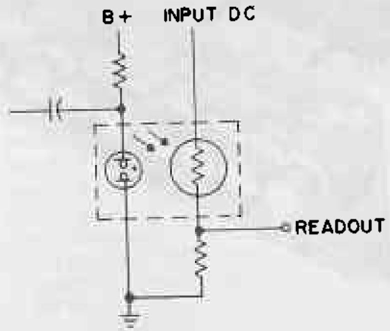

8-7 Neon-photocell overload protection



*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.

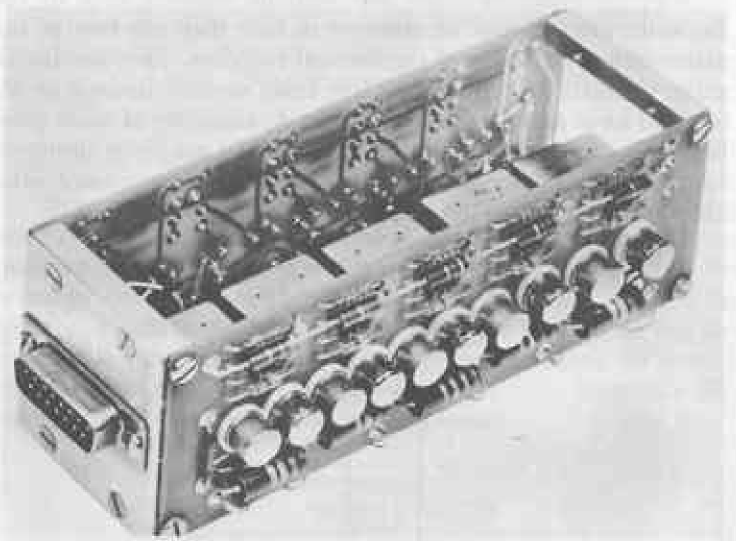
Electro-optical switches and variable resistors such as the Raysistor offer special advantages in that they are free of the maintenance problems of mechanical switches. They are insensitive to shock and vibration, free from contact bounce or jitter, and have an inherently long life. Availability of neon 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

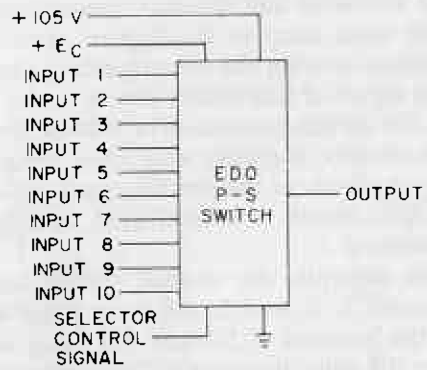
2. La Fiandra, Joseph, Senior Engineer, and Jennings, Howard, Vice President Engineering, Edo Corp., "Photoconductive Selector Circuit Uses Neon Glow Lamps," *Signalite Application News*, Vol. 2, No. 1; and *Electro Technology*, January 1964.



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.

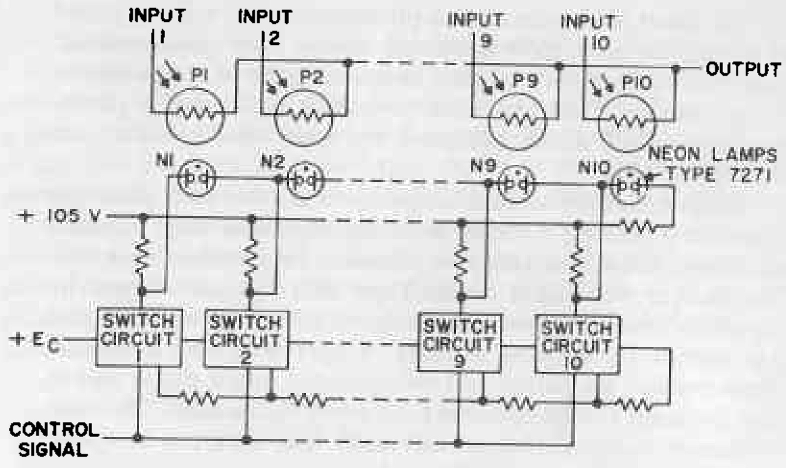
Commercially available lamps could not be used since the glow lamp striking voltages were too high, and they required additional biasing circuitry—a situation Edo wished to avoid. The answer was found in the Type 7271 lamp developed by Signalite, which has specially designed electrodes and a special 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

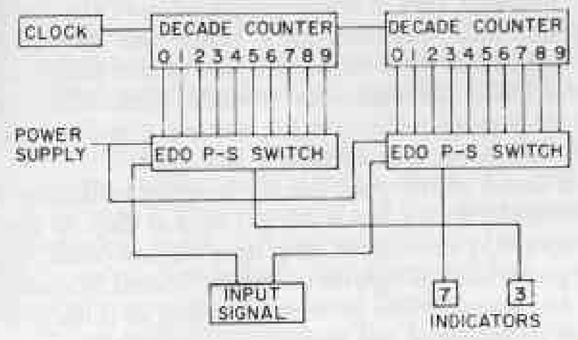
switch circuit activated and the one immediately below it in sequence. The neon lamp in the highest circuit then breaks down and ionizes, causing the corresponding photo resistor to pass the input signal of this switch circuit to the output.

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.

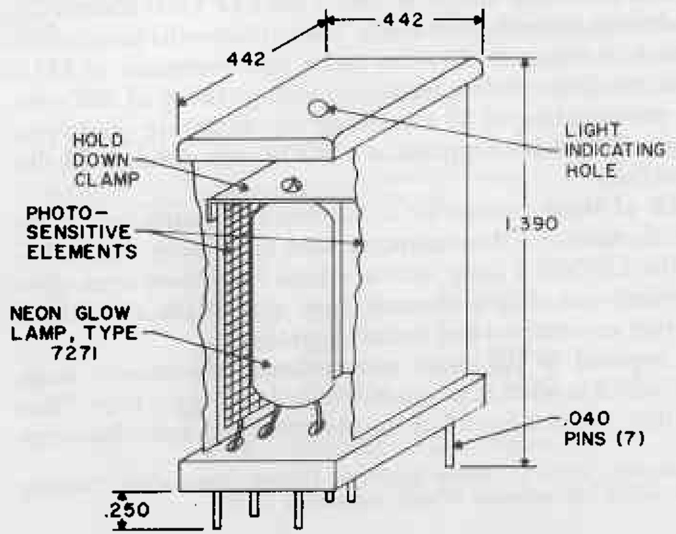





8-12 Application of photoconductive switch

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.

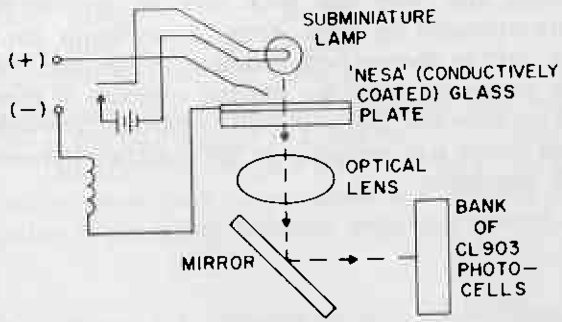
Each of these photocells is individually connected to the trigger element of a three-element neon glow lamp, type LTG-27-2. The LTG-27-2 lamp also is a high brightness neon glow lamp which was chosen because, once ignited (dc operation), it will stay on until a reset button is pushed.

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.

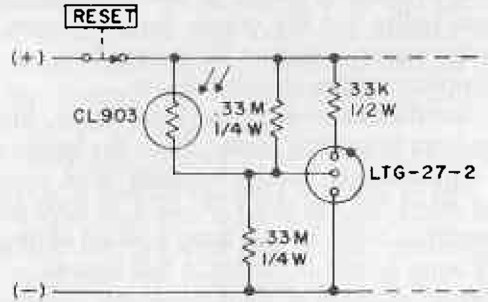
A schematic diagram of the Lite-Writer system is shown in Figure 8-14. The light source is turned on when the probe touches the conductively coated glass plate. The beam from the subminiature lamp is passed through an optical lens to a mirror where it is reflected to the bank of the CL903 photocells.




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.