# Fluorescent Lamp Dimming with Semiconductors

by E. E. Von Zastrow

***Application of semiconductor devices to fluorescent lamp dimming at commercial power frequencies is a logical extension of earlier application in television and theater incandescent lighting control, and more recently in residential lamp dimming control. Here are some general considerations of applying solid-state control to fluorescent lamp dimming systems. Two specific examples of actual installations serve to illustrate these considerations.***

**ARCHITECTS** and designers may look forward to the increased use of fluorescent lamp dimming in commercial as well as in residential applications. There are already systems available which combine greatly increased ease and flexibility of installation with superior performance. Key to these systems is the development of efficient and small semiconductor devices for use in dimmers which permit very smooth control over the lamp's intensity. Proper design of the total dimmer and ballast system circuitry assures smoothness of control over dimming ratios which are in excess of several hundred to one.

*Fluorescent Lamp Dimming System:* A 60-cycle fluorescent dimming system consists of essentially three parts—the lamp, the ballast, and a variable control element or dimmer. This is shown in Fig. 1 in block diagram form. The performance of the system will, therefore, depend on the characteristics of each of these parts and the degree to which these parts are matched to each other. The optimum system would represent an optimum match of the three basic components.

*Lamp:* The light output of a fluorescent lamp is proportional to the current through it. Dimming the lamp, therefore, is accomplished by varying the current through the lamp. Another requirement is that sufficient voltage must always be available to re-start the lamp even at the lowest setting of the control. If the cathodes of the lamps are preheated by a separate filament current, much like a vacuum tube, the voltage required to start the lamp is reduced. For this reason the rapid-start lamp is preferred over the instant-start lamp for 60-cycle dimming applications. Also, a ground plane or starting aid should be supplied for the lamp as specified by the lamp manufacturer. Usually a metallic plane one inch from the lamp and electrically connected to the common or "white" side of the supply line is sufficient.

*Ballast:* For dimming applications the best performance is achieved when a ballast specifically designed as a dimming ballast is employed. Most of these ballasts were originally designed to operate with some other means of control such as autotransformers or thyratron tubes. However, satisfactory operation using semiconductor-controlled rectifiers as the principal control elements can be achieved with these older ballasts provided suitable control circuitry is employed in the dimmer.

A manufacturer may, on the other hand, elect

AUTHOR: Application Engineer, Rectifier Components Dept., General Electric Co., Auburn, N. Y.

## HINTS . . . for Fluorescent Dimming of Commercial Lighting Installations

- Lamps should be operated free from drafts at 50 F to 80 F.
- Ballast case, lighting fixture and white lead should all be grounded.
- Season new lamps for at least 100 hours at full brightness.
- Do not mix F30T12 and F40T12 lamps in the same circuit. Some ballast and control combination will operate either but not when intermixed.
- Do not use high power factor ballasts on any system having high-frequency carrier signal (clocks, signaling devices, etc.).
- Be sure the system chosen is suitable for the required:
  (a) dimming range,
  (b) low-brightness starting,
  (c) maximum lamp brightness, and
  (d) uniformity of intensity of all lamps.
- Be sure the control has sufficient capacity for the number of lamps to be dimmed.
- Use lamps of the same manufacturer, the same color, manufactured at the same time, and the same age. Group replacement is the most satisfactory procedure.
- Control the type and location of the dimmer early in the planning of the installation.

to supply a ballast specifically designed for his semiconductor-controlled rectifier dimmer. The dimmer manufacturer will in any case be in the best position to recommend the optimum ballast. His recommendations should be followed if a specified performance is to be achieved.

In contrast to incandescent lighting circuits a standard "on-off" fluorescent lamp circuit does not lend itself very readily to backfitting for dimming operation unless the standard ballasts are first replaced with the proper dimming ballasts. With this in mind, it is well for the architect or engineer to consider the dimming feature for fluorescent lighting early in his planning.

*Dimmer:* The variable control element, or dimmer, is usually connected between the "hot" supply line lead (black) and the "control" lead of the ballast, as shown in Fig. 1.

The dimmer must present a variable and a symmetrical a-c impedance to the ballast voltage appearing between the "control" and "black" leads. When its electrical impedance is high the lamp will be "off;" when its electrical impedance is low the lamp will be "on." Electrically phase-controlled semiconductor-controlled rectifiers will perform this transition continuously and without steps over the entire specified dimming range.

The semiconductor-controlled rectifier (SCR) was first used in incandescent television studio and commercial lamp dimming[1, 2] soon after its

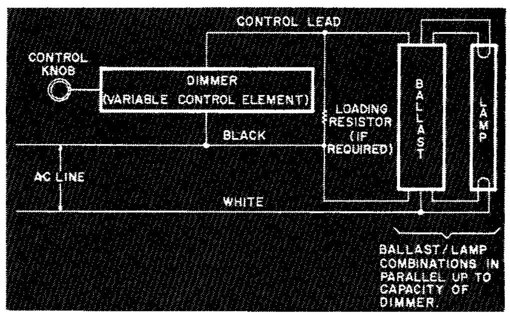



*Figure 1. A basic 60-cycle fluorescent lamp dimming system.*

introduction late in 1958. Today it has become one of the standards of the industry. SCR's are now used in a vast variety of industrial, military, and commercial application areas whenever efficient, smooth, high-performance, and economical control of electrical power is required. Most recently SCR's and related semiconductors have been applied to residential incandescent lamp dimming.[3] Several manufacturers have introduced wall-mounted dimmers for this application.

Fig. 2 shows three current types of SCR's having current ratings of 110, 7, and 25 amperes RMS, respectively. Due to the relatively large efficiency of the SCR only a very small fraction of the load power (of the order of one per cent) need be dissipated by the SCR. In order to accomplish this the manufacturer of the dimmer mounts the SCR on a so-called heatsink which in turn dissipates the losses to

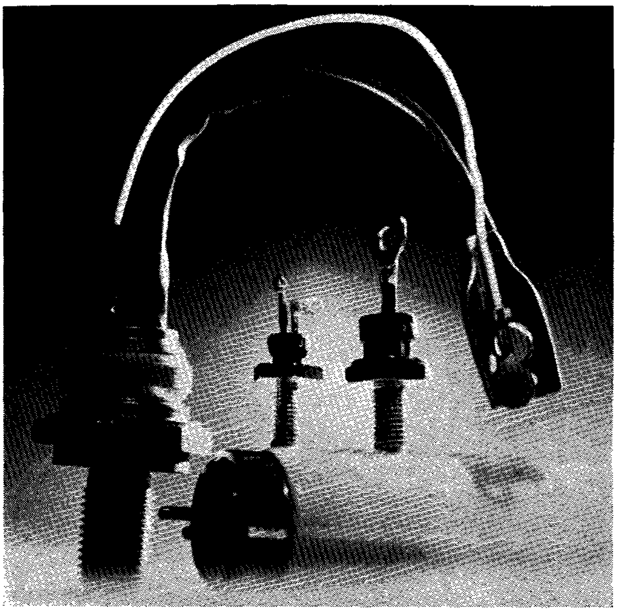


*Figure 2. Semiconductor-controlled rectifiers: high, low and medium current.*

the ambient air. Usually this heatsink takes the form of a metal mounting plate suitably integrated into the package design of the dimmer. The architect or engineer, however, should keep in mind that some provision must be made for proper ventilation of the dimmer.

Power control is achieved by the SCR by virtue of its ability to either block or pass electrical current in accordance with the control signal impressed on its third, or so-called gate, terminal. For a detailed description of the device, its theory of operation and applications, the reader is referred to Reference 4.

As far as the power circuit of the dimmer is concerned its electrical output must be symmetrical in its mode of operation relative to the alternating voltage of the a-c supply line. This is so because the ballast, which represents the electrical load on the dimmer, contains a magnetic iron core structure. Any dissymmetry of the voltage applied to the ballast introduces an average, or d-c, component of voltage which can lead to core flux saturation and attendant overheating of the ballast. It is important for the architect or engineer to keep this in mind because it explains why every "dimmer" on the market is not necessarily suitable for fluorescent lamp dimming where conventional magnetic ballasting is used. As stated previously, it is well to adhere to the recommendations of the dimmer manufacturer regarding the suitability of his dimmer for fluorescent lamp dimming.

In view of the symmetrical output required for present conventional dimming ballasts two basic SCR power circuits shown in Fig. 3 are usually employed. Fig. 3a utilizes two SCR's: one for the "positive" half-cycles of the alternating current, the other SCR for the "negative" half-cycles. When the control circuit supplies properly timed and symmetrical gating signals to the SCR's the lamp intensity can be smoothly controlled. Fig. 3b shows a basic power circuit which accomplishes the same result as the circuit of Fig. 3a. However, four conventional semiconductor rectifier diodes in conjunction with merely one SCR are used.

The dimmer manufacturer will select the power circuit best suited to the over-all requirements of the application. The reader interested in further detail and some specific control circuit approaches is referred to Reference 5.

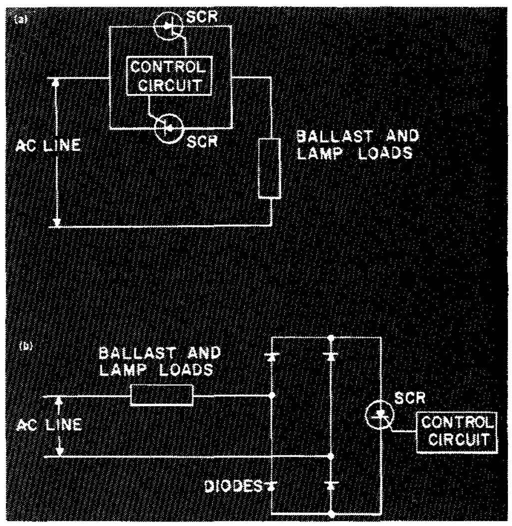



*Figure 3. Basic SCR power circuits: (a) Parallel-inverse (back-to-back) connection; (b) "SCR in bridge" connection.*

## Types of System Layout

The complete semiconductor fluorescent lamp dimming system lends itself to great installation flexibility. The SCR dimmer can be designed to be mounted in a number of different ways. This is due to the inherent relatively small size and high efficiency of the semiconductor components used. For example, the SCR dimmer can be recessed in the wall, mounted in a lamp fixture, or separately mounted in a remote location. Generally speaking, the rating of the dimmer might be 300 to 500 watts in a single-gang wall box, up to a kilowatt when mounted with the fixture, and

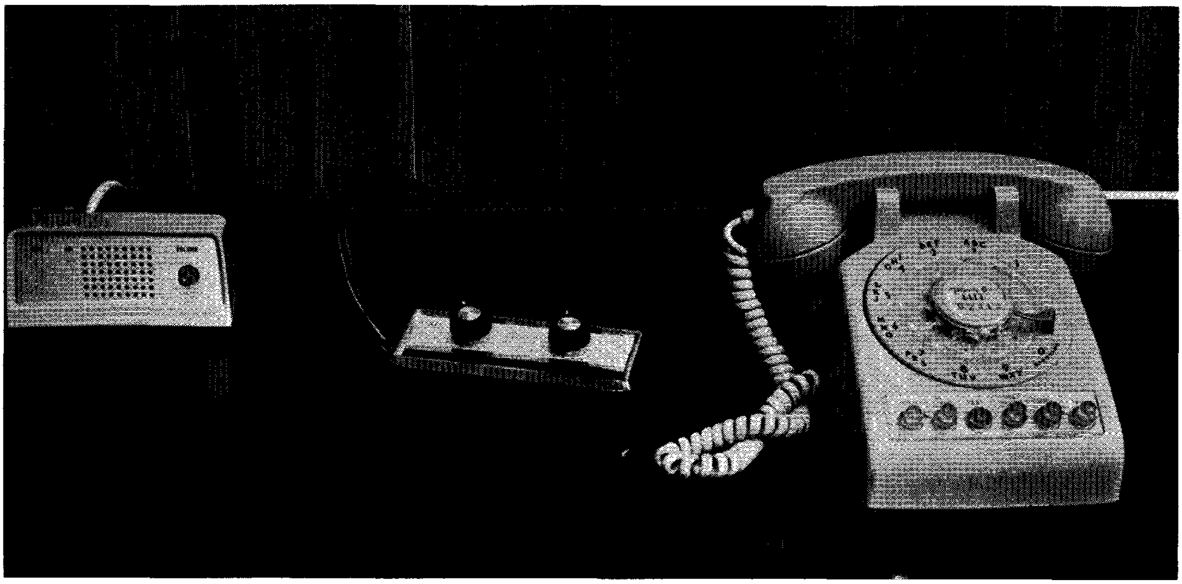


*Figure 4. Table-top remote-control units.*

arbitrarily large when the dimmer is mounted in a separate location.

In any case, control over the dimmer regardless of rating can be achieved from any arbitrary location by means of nothing more than a simple radio-type potentiometer. This is a result of the very low voltage and current required to actuate the control of the semiconductor dimmer. Typically, a circuit carrying no more than a few thousandths of an ampere of current at maybe 20 volts is sufficient to exercise complete control over a number of kilowatts of lighting load. This, for example, allows the mounting of the small control knob attached to the potentiometer in a conventional wall box or on a table top. Fig. 4 shows a prototype of such a table-top control unit, used in an executive office luminous ceiling installation. The system was split into two separately controlled circuits; hence, one knob for each circuit. In that case the dimmer units were separately mounted in a recessed wall compartment.

Remote-control operation of the lighting may also be obtained by wireless means much like the remotely controlled television receiver. Control circuitry responsive to either electromagnetic or ultrasonic energy can be used in conjunction with a suitable transmitter to provide perhaps the ultimate in control versatility!

Not only do SCR dimmers lend themselves well to remote-control manual operation but, due to the great electrical amplification that can easily be obtained in the dimmer circuitry, control over the lamps can be exercised, for example, by light-sensitive photoresistors. In this manner the lighting level can be raised or lowered in response to, say, the ambient sunlight. Also, of course, "on" or "off" control of the lights can be had by means of such a light-sensitive feature incorporated into the SCR dimmer control circuitry.

No system specification would be complete without the requirement for adequate radio-frequency interference (RFI) suppression. This is of some importance in its possible effect on AM radio reception, public address systems, and possibly telephone and intercom systems in close proximity to the dimmer installation. Also, without proper RFI suppression interaction may arise between adjacent SCR dimmers.[6, 7] These two allied phenomena arise due to the fast switching speed of the SCR's. However, it is a relatively simple matter for the dimmer manufacturer to include a suitable RFI filter in the dimmer. It is usually much simpler to provide such a small filter early in the design stages rather than as an afterthought later on.

## Applications

When the architect or engineer is preparing performance specifications for dimmable fluorescent lighting it may be well for him to also consider the dimming ratio required in terms of stable tracking performance between individual lamps. In other words, as the lighting level is raised or lowered over the specified dimming range it may be more or less important, depending on the application, that the lamps all "stay together."

Two different types of installations may serve to illustrate this point: the fluorescent ceiling *vs* the valance, cornice or cove lighting application.

*Fluorescent Ceiling Installations*

With many lamps serving a large area an "averaging" effect of all the lamps may be obtained depending somewhat on the nature of the diffusing means used. In this regard, for example, a smaller "eggcrate" pattern is generally preferable over a similar diffuser having openings through which, from some viewing angles, the face of the lamp might be visible.

Fig. 5 shows a typical fluorescent ceiling installation in a conference room. Normally, the total lighting load would be split in accordance with local code requirements. For example, in one executive office installation a total of 54, 40-watt rapid-start lamps were split into two circuits of 30 and 24 lamps, respectively. Each circuit had its own SCR dimmer using medium-current SCR's of the type shown in Fig. 2. It may be well when preparing specifications to consider the number of circuits—and dimmers—required so that proper mounting provisions may be made early in the design of the installation.

*Valance or Cove Lighting*

A residential valance lighting application is shown in Fig. 6. The valance was set at such an angle with respect to the ceiling to also allow a general level of illumination. The control knob was located on a conventional single-gang wall box plate at the opposite end of the room. The remote mounting of the control allows adjustment of lighting level from a convenient vantage point to achieve the most pleasing balance with various incandescent light sources for the desired level of lighting.

The dimmer used for this installation is shown in Fig. 7. It was an experimental type larger than required, housed in an aluminum box 6 by 4½ by 3½ inches. Using low-current SCR's of the type shown in Fig. 2 and one conventional dimming ballast for each 40-watt rapid-start lamp, this size dimmer in an ambient air temperature not in excess of 86 F can handle 17 such ballast-lamp combinations. However, for the four 40-watt lamps used in the application shown in Fig. 6, the entire dimmer could be built to fit directly into a conventional single-gang wall box.

This dimmer has been in operation for almost

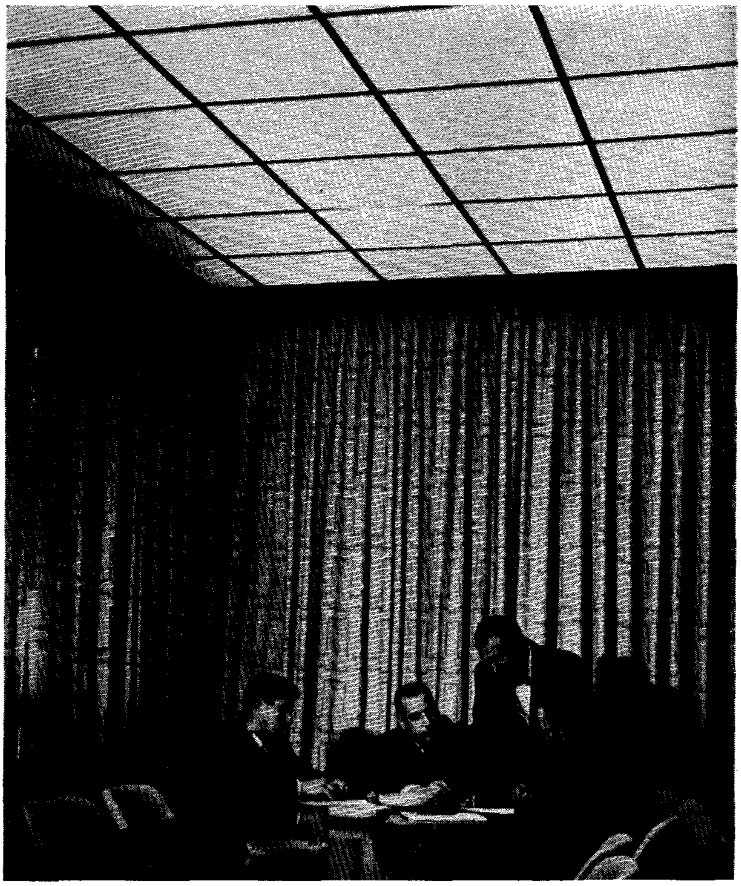
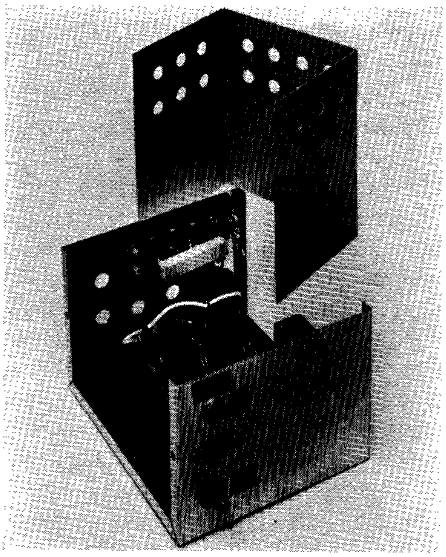


*Figure 5. Conference room with fluorescent ceiling lighting installation.*

▲ *Figure 6. Residential valance lighting.*

*Figure 7. Prototype SCR fluorescent lamp dimmer with trimmer adjustments for critical applications.* ▶



two years without any malfunction. A ceiling installation has likewise been in operation since November of 1959 using prototype SCR dimmers without any semiconductor failures.

In contrast to the ceiling installation with suitable diffusers, the valance lighting application generally requires closer tracking of the lamps over the entire dimming range. Since each lamp illuminates a discrete portion of the area adjacent to it, poor tracking performance is very noticeable. For this reason the dimmer used in the application shown in Fig. 6 has trim adjustments that allow adjustment of its output to conform to the changes in lamp characteristics as the lamps age slightly in service. In this manner optimum performance with regard to both dimming ratio and tracking performance can be assured.

## References


1. Daugherty, C. S.: "Problems Encountered in Applying the Silicon-Controlled Rectifier to Control Tungsten Lamp Loads," *AIEE Transactions* 61-182 (February 1961).
2. Von Zastrow, E. E.: "The Silicon-Controlled Rectifier in Lamp Dimming and Heating Control Service," Application Note 200.14. General Electric Co., Rectifier Components Dept., Auburn, N. Y. Available on request.
3. Von Zastrow, E. E.: "Semiconductor Dimming in Architectural Lighting," *Lighting* (April 1962).
4. *Silicon Control Rectifier Manual,* 2nd Edition, General Electric Co., Rectifier Components Dept., Auburn, N. Y.
5. Von Zastrow, E. E.: "Fluorescent Lamp Dimming with SCR's and Associated Semiconductors," Application Note No. 200.18, General Electric Co., Rectifier Components Dept., Auburn, N. Y. Available on request.
6. Von Zastrow, E. E.: "Coping with RFI and Interaction in Silicon-Controlled Rectifier Circuits," *Electronic Design* (March 1962).
7. Chapter 13 of Reference 4.