LIGHT DIMMER & POWER-TOOL CONTROL

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Construction of 250-watt dimmer using bilateral switching diode. Can be built into light switch.

MOST readers will find the electronic control to be described useful either as a light dimmer capable of handling up to 250 watts of lighting power or as a controller for regulating the speed of an electric motor. It can be used to vary the speed of an electric drill or buffer. It can also be used to vary the heat of a small drying oven or other heat source, the temperature of a soldering iron or gun to allow both fine and heavy work from one iron; or the speed of a kitchen mixer or blender.

Unlike some similar devices, this low-cost, 250-watt unit is a full-wave proportional a.c. controller that will give a smooth, continuously variable control of power from zero to full load with a single turn of the control knob. The device is built from standard parts and can be assembled in a few evenings work.

It is built into a conventional light switch and will fit the same space, providing a direct replacement for the conventional wall switch. A double box and a duplex outlet adapt the circuit for the control of power tools.

How It Works

The key to the unit's operation is the relatively new semiconductor device known as a "bilateral switching diode." This device has the unique ability to control large amounts of a.c. power but, unlike silicon controlled rectifiers or thyra-

Photos showing the construction and assembly of the dimmer.
Fig. 1. When applied voltage is less than \( V_r \) (approximately 1\( \text{V} \)), the diode draws little current, circuit is "off." At higher voltages \( B \) avalanche conduction causes diode to conduct heavily. Current is now limited only by load \( C \). Diode continues to conduct as long as current is at least \( I_h \). At lower currents, diode is returned to "off" state. The operation of the device at reverse voltage polarities is exactly the same.

trans, does it equally well in either current direction. This new switching diode is similar to two silicon controlled rectifiers that have been connected in parallel and in opposite directions.

There are two ways of turning an SCR on—the common one of pulsing the gate and the less familiar method of exceeding the forward breakover voltage and avalanching the SCR into conduction. Either method achieves the same result, the SCR turns on and stays on until the anode current reverses direction or is turned off. But this only works in one current direction. A second SCR is needed for bilateral avalanche operation. This is what the bilateral switching diode does. Actually, this device is less complicated than the two-SCR combination and consists of a single 4-layer p-n-p-n structure.

Fig. 1 shows the volt-ampere (V-I) characteristics of a bilateral switching diode and details diode operation. Basically, we have a device that is in an "off" state until a high-voltage pulse (in excess of the diode’s \( V_r \)) avalanches the diode into conduction, or "on." The diode stays "on" until the current becomes nearly zero and then returns to the "off" state. Current reverses every a.c. zero will always return the diode to the "off" state. Since the circuit is "off" during the presence of the high-voltage pulse, very little pulse power is required to trigger the diode. This high-voltage pulse can be introduced by adding a transformer secondary in series with the diode and the load. The transformer must have a very low 60-cycle a.c. impedance. A high-breakdown transformer would allow a low-voltage pulse to be stepped up to a high enough voltage to trigger the bilateral switching diode.

By controlling the point in each a.c. half cycle when this pulse occurs, load power may be varied from zero to full power. This is detailed in the waveforms that are illustrated in Fig. 2.

A variable time is needed to determine when in each cycle the high-voltage pulse and diode "turn on." This is achieved by the RC network shown in Fig. 2. The RG circuit is self-started by the main bilateral switching diode \( (B) \), and the entire operation is locked (synchronized) to the ac line. This ensures that each delay time will start exactly as the a.c. input swings through zero, and that the delay will occur after every a.c. zero. Except for a capacitor filter to eliminate any d.c. noise from the high-voltage spike and the fast turn-off of the main diode, this is all there is to the dimmer-controller circuit which is to be described below.

**Practical Circuit**

With this design plan, the actual circuit of the unit in Fig. 3 is simple. The a.c. power (Continued on page 81)

[Diagram of circuit shown]
Light Dimmer

(Continued from page 17)

to the lead travels through a high-power B51 and the "stabilizer" of the auto-transformer, T1, a small 3Bl1 wound transformer.

The inner consists of C5, D2, and the parallel combination of R2 and R5. The low-voltage pulses produced by D2 discharging C1 are coupled to the "primary" of T1. After the 100m volt capacitor, they appear at the 500 to 1000m volt high-voltage spikes used to trigger D1. A parallel combination of R2 and R5 gives a much more linear brightness control action and provides an alteration in the amount of "off" time between R1 and capacitor C2 comprising a damping and phase-shifting network. This phase shift adds brightness control linearity near maximum brightness. Capacitor C1 is the r-f interference filter and completes the controller circuit.

Parts size is somewhat critical if all the components are to be located in the 15 cubic inches of space inside a conventional wall-mounted switch box, so the smallest available part should be used in each position.

D1, the heart of the circuit, is a Transistor THS-200 "B" diode. It is normally rated at 5 amps at room temperature and has a P.D. rating of 200 volts. Since heat sinking is not involved in the circuit, current must be limited to less than 2 amps to prevent overheating of the part. This is the reason for specifying a 250-watt maximum load. D2 is a standard Texas Instruments 500-volt silicon transistor diode, the T1-43, available at jubilee.

The capacitors of D2 form a 52,000-pf capacitor with 1/2-watt yellow band ceramic caps and tapped at two turns. This core is a very low-cost core and is a factory stock item. Actually, any small toroidal core of suitable material will work as well in this application.

Because of the limited space, R3 is a snap-in potentiometer with its element built inside the control knob and is then mounted on the outside of the controller case.

The housing for the controller is the body of a Lecon 10-gap "low-rising" switch. The switch selected must be of the type with the terminals on the side of the case and with a simple riveted-on mounting plate that covers the entire front of the Bakelite case. Any other type switch might not come apart as easily and might require mechanical alignment.

Two parts must be modified: S1 and the blank outlet cover plate. Start with S1. Drill out the two cutouts, building the Bakelite body to the front plate. Remove and discard the gaskets, the front plate, and all covering parts. This leaves the case, two crew terminals, and two terminal

spaces. File or drill out any bosses, spacers, or protrusions inside the switch body. The material is fairly soft and fairly easy to work with. Make a new front plate from 1/16" soft aluminum. The lip bent down on the side adds strength to this part and should be flush with the switch body. See photo.

The brightness control, R3, is next mounted on the front plate. A second knob is slid in top of the original to increase the diameter and to actuate the operator from the front center shaft of R3. A 5/16" diameter ground black knob fits nicely.

The disassembled unit shown in the photo illustrates the construction technique used. There are two layers of parts. Start with the bottom layer and place these cubed on all leads. Begin with C2 and R1. Next, take the lead of the transformer and wedge it (lightly) in front of C2. Diode D1 is next followed by D2. Wiring follows the schematic diagram of Fig. 3. The top layer consists of R1, C2, and C3, added in that order, followed by the last two connections made to R3.

It is a good idea to test operation at this point. If the circuit is properly wired, the first 4 v. out of the pot should light the lamp load. If complete, this is the "control" ideal point. From this point, the controller should provide smooth, linear operation from practically zero to full brilliance. The amount of dead space is determined by R2. To increase it, raise the value of R2, to lower it replace the value of R2. To increase the value of R2, to lower it remove the value of R2. To increase the value of R2, to lower it replace the value of R2. To increase the value of R2, to lower it replace the value of R2. To increase the value of R2, to lower it replace the value of R2. To increase the value of R2, to lower it replace the value of R2. To increase the value of R2, to lower it replace the value of R2. To increase the value of R2, to lower it replace the value of R2. To increase the value of R2, to lower it replace the value of R2. To increase the value of R2, to lower it replace the value of R2. To increase the value of R2, to lower it replace the value of R2.

Complete the assembly with 4-40 screws and nuts where the clamps used to be in S1. The coverplate, as modified, is then mounted with its own hardware.

This controller will only work on 60-cycle, 100 to 125 volts. The load must be held in less than 3.50 watts and preferably below 200 watts during any long-term operation. Generally, an a.c. appliance motor with brushes will work only on a.c. motors or a.c. motors on a.c. motors and could be damaged. Any of the motor brushes should be less than 2,500, as any higher rating would draw too much current.

The circuit may be used to control 600 watts by replacing D1 by the almost identical THS-200s if the new D1 is bolted to a heat sink. With this unit, however, the circuit will no longer fit into the switch plate. For 1000-watt 110-volt or less control D1 should be a much larger heat sink.

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