# LIGHT DIMMER & POWER-TOOL CONTROL

By DONALD LANCASTER

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

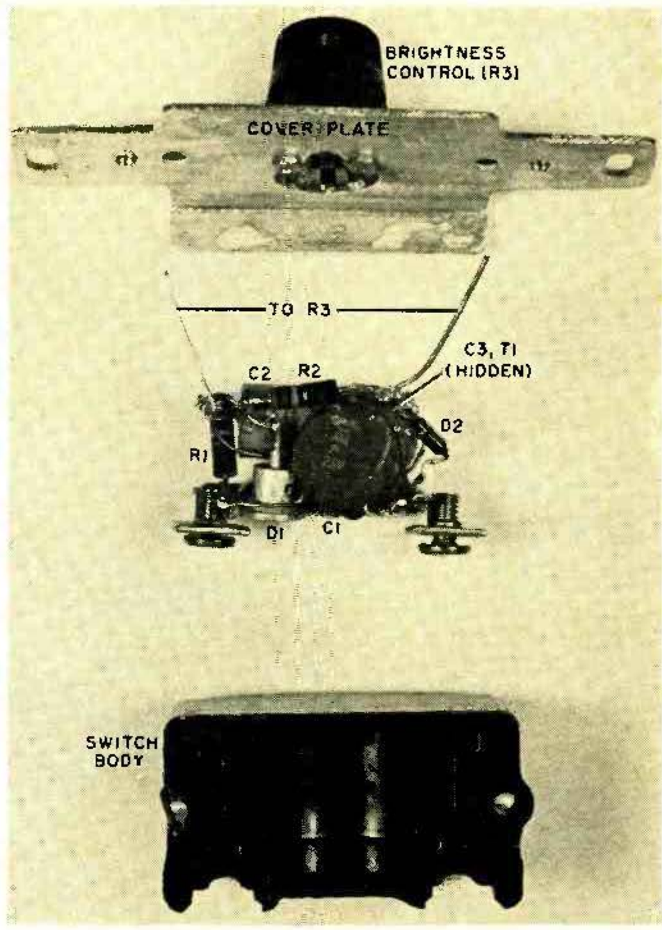
MOST readers will find the electronic control to be described useful either as a light dimmer capable of handling up to 250 watts of lighting power or as a controller for regulating the speed of an electric motor. It can be used to vary the speed of an electric drill or buffer. It can also be used to 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.

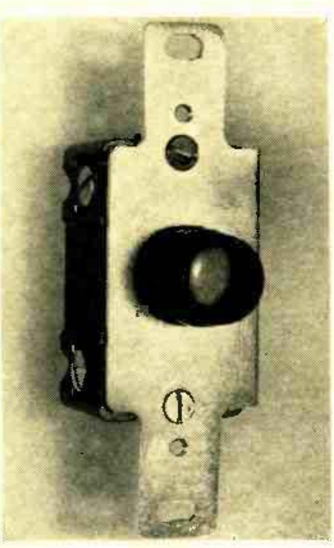
It is built into a conventional light switch and will fit the same space, providing a direct replacement for the conventional wall switch. A double box and a duplex outlet adapt the circuit for the control of power tools.

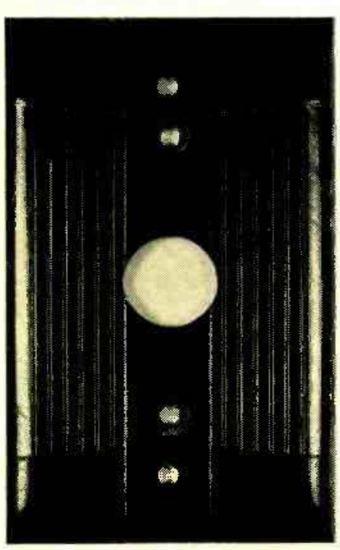
### How It Works

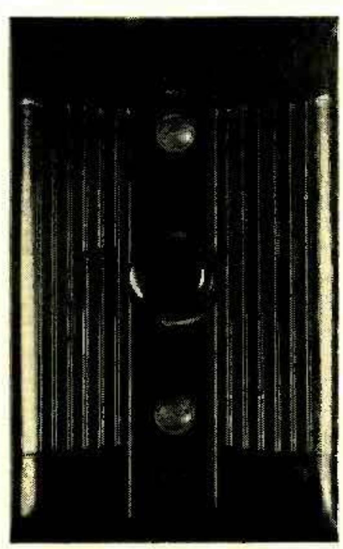
The key to the unit's operation is the relatively new semiconductor device known as a "bilateral switching diode." This device has the unique ability to control large amounts of a.c. power but, unlike silicon controlled rectifiers or thyra-



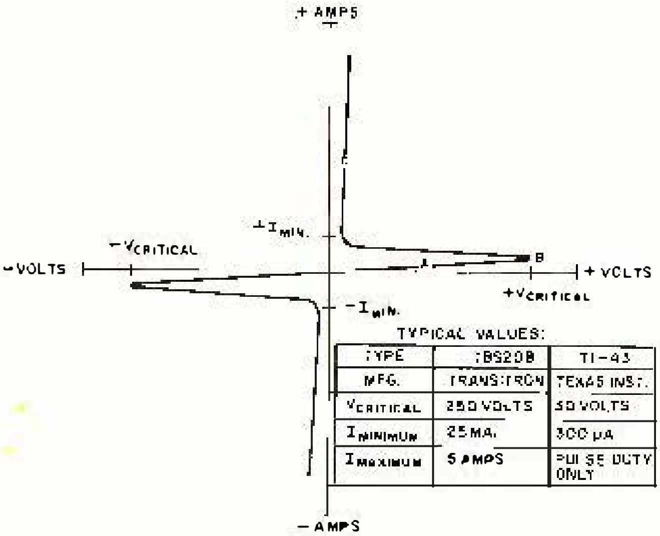

Photos showing the construction and assembly of the dimmer.







(Left) The completely assembled light dimmer uses a special cover that is screwed into a standard wall-switch housing. (Center) Modified cover-plate for the dimmer unit. (Right) Appearance of the completely installed unit.




| TYPE | BS20B | TI-43 |
|---|---|---|
| MFG. | TRANSITRON | TEXAS INST. |
| $V_{CRITICAL}$ | 250 VOLTS | 30 VOLTS |
| $I_{MINIMUM}$ | 25 MA. | 300 µA |
| $I_{MAXIMUM}$ | 5 AMPS | PULSE DUTY ONLY |

**Fig. 1. When applied voltage is less than $V_{critical}$ (A), 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 $I_{min}$. At lower currents, diode is returned to "off" state. The operation of the device at reverse voltage polarities is exactly the same.**

trons, 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 results, 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 five-layer *p-n-p-n-p* structure.

Fig. 1 shows the volt-ampere (*VI*) 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 $V_{critical}$) avalanches the diode into conduction, or "on." The diode stays "on" until the circuit current becomes nearly zero and then returns to the "off" state. Current reversals 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. This transformer must have a very low 60-cycle a.c. impedance. A high-turns-ratio transformer would allow a low voltage pulse to be stepped up to a high enough voltage value 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 timer is needed to determine when in each cycle the high-voltage pulse and diode "turn-on" is to be produced. A simple saw-tooth generator consisting of an *RC* circuit shunted by a low-voltage bilateral switching diode is used. A resistor, *R*, charges up a capacitor, *C*, until the voltage across *C* exceeds $V_{critical}$ of the diode. The diode turns "on," discharging *C*. If a high-voltage step-up transformer primary is in the discharge path, high voltage spikes will be generated. Varying *R* will vary the delay and, ultimately, the amount of power reaching the load. Further, if the *RC* circuit is itself shunted by the main bilateral switching diode (BSD), the entire operation is locked (synced) to the a.c. line. This insures 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 r.f. noise from the high-voltage spike and the fast turn-on 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*)

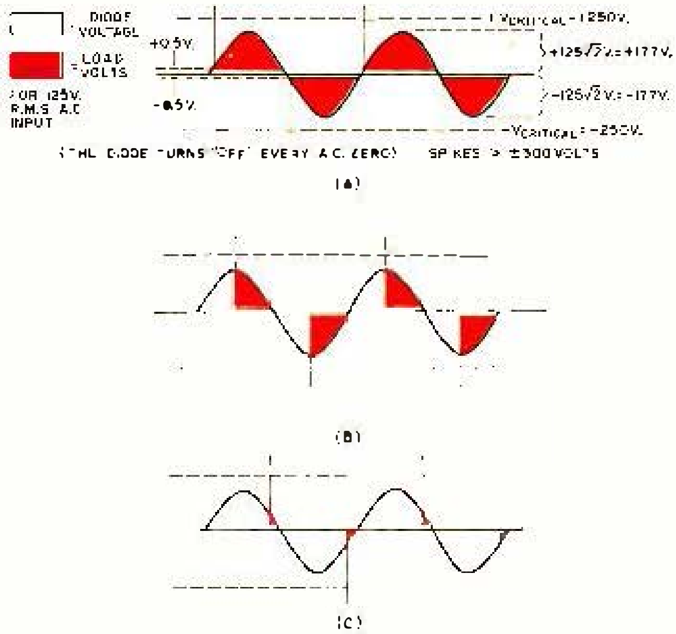
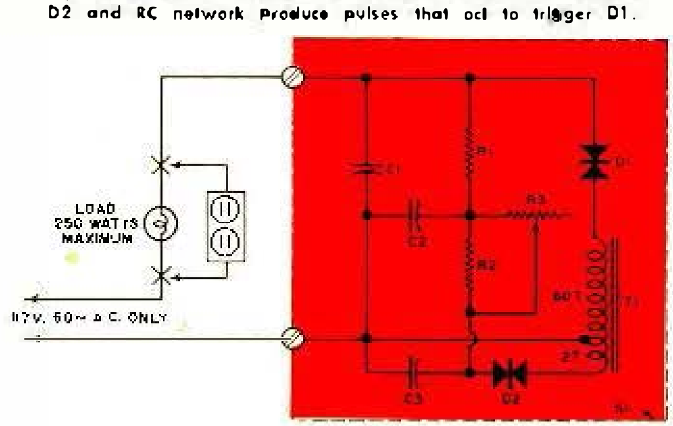



**Fig. 2. An RC network and a low-power bilateral switching diode can be used to generate a spike of voltage that can be stepped up by a transformer and used to turn on a main switching diode. With the network adjusted to produce spikes very early in each alternation (A), maximum load current flows. When spikes occur in the middle of the alternations (B), normal load voltage exists only half the time, so only half the power reaches the load. With the circuit set to trigger very late in the alternations (C), very little power reaches load.**

**Fig. 3. Circuit of dimmer. D1 determines the load current. D2 and RC network produce pulses that act to trigger D1.**




*R1—10,000 ohm, ½ w. carbon res.*
*R2—68,000 ohm, ½ w. carbon res.*
*R3—250,000 ohm miniature pot (Centralab B-16-123 or equiv. Note: Center shaft must be insulated from front plate and operator.)*
*C1—.02 µf., 200 v. disc capacitor*
*C2—.1 µf., 200 v. capacitor*
*C3—.22 µf., 50 v. flat Mylar capacitor (or two .1 µf. discs in parallel)*
*S1—S.p.s.t. 10-amp Leviton wall switch (see text)*
*T1—92 t. #22 en. wire wound on Arnold A1-500-187-114-P core, tapped at 2 t.*
*D1—5 amp, 200 v. p.i.v. "Bi-switch" (Transitron TDS-20-R. See text for other ratings.)*
*D2—30 v. silicon bilateral trigger diode (Texas Instruments TI-43 or Transitron FR-900.)*
*Note: D1, D2, and Arnold core are available as a "kit" from Kimball Electronics, 3614 N. 16 Street, Phoenix, Ariz., 85016 at $7.00 each plus postage.*

## Light Dimmer

(Continued from page 17)

to the load travels through a high-power BSD and the "secondary" of the autotransformer, *T1*, a small 30:1 toroidal transformer.

The timer consists of *C3*, *D2*, and the parallel combination of *R2* and *R3*. The low-voltage pulses generated by *D2* discharging *C3* are coupled to the "primary" of *T1*. After the 30:1 step-up, they appear as the 300- to 400-volt high-voltage spikes used to trigger *D1*. A parallel combination of *R2* and *R3* gives a much more linear brightness control action and provides an adjustment for the amount of "off" time. Resistor *R1* and capacitor *C2* comprise a dropping and phase-shifting network. This phase shift aids 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 housed in the 1½ cubic inches of space inside a conventional wall-mounted light switch so the smallest available part should be used in each instance.

*D1*, the heart of the circuit, is a *Transitron* TBS-20-B "Biswitch." It is normally rated at 5 amps at room temperature and has a p.i.v. rating of 200 volts. Since heat sinking is not provided in this circuit, current must be limited to less than 2 amperes to prevent overheating of the part. This is the reason for specifying a 250-watt maximum load. *D2* is a standard *Texas Instruments* 30-volt silicon trigger diode, the TI-43, available at jobbers.

*T1* consists of 62 turns of #22 enameled magnet wire wound on a small powdered iron core and tapped at two turns. This core is a very low-cost item 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 miniature pot with its element built inside the control knob and is thus mounted on the outside of the controller case.

The housing for the controller is the body of a *Leviton* 10-amp "house-wiring" switch. The switch selected must be of the type with the terminals out 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 redesign.

Two parts have to be modified, *S1* and the blank outlet cover plate. Start with *S1*. Drill out the two eyelets holding the Bakelite body to the front plate. Remove and discard the eyelets, the front plate, and all moving parts. This leaves the case, two screw terminals, and two fiber spacers. File or drill out any bosses, spacers, or protrusions inside the switch body. The material is fairly soft and easily removed. Make a new front plate from 1/16" soft aluminum. The lip bent down the one side adds strength to this part and should be flush with the switch body. See photos.

The brightness control, *R3*, is next mounted on the front plate. A second knob is glued on top of the original to increase the gripping area and to insulate the operator from the hot center shaft of *R3*. A ¾-inch diameter knurled 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 be sure to use spaghetti on all leads. Begin with *C2* and *R1*. Next tightly hand wind 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 *C1*, *R2*, and *C3*, added in that order, followed by the final two connections made to *R3*.

It is a good idea to test operation at this point. If the circuit is properly wired, the first ⅛ turn of the pot should leave the lamp load out completely. This is the control "dead space." From this point, the control should provide smooth, linear operation from practically zero light to full brilliance. The amount of dead space is determined by *R2*. To increase it, raise the value of *R2*; to lower it reduce the value. This compensates for high- or low-line voltage and for the type of load. Generally, less dead space is wanted in a power-tool control than in a dimmer. Five percent of available load power won't turn over an electric drill but it will cause an obvious orange glow in a light bulb that is supposed to be off. This is a case of too much dead space in one case and too little in the other.

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

This controller will only work on 60-cycle a.c., 100 to 125 volts. The load must be held to less than 250 watts and preferably below 200 watts during any long-term operation. Generally, an a.c. appliance motor with brushes will work while any a.c. motor without brushes won't—and could be damaged. Any of the motor loads should be less than ⅓ h.p., as any higher rating would draw too much current.

The circuit may be used to control 600 watts by replacing *D1* by the almost equal-cost TBS-20-BS 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 (1 h.p. motor or less) control, *D1* should be the TBS-20-AS which requires a much larger heat sink. ▲