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-
A presence of diode into circuit current becomes voltage pulse.

There is a shunt ed by a very low (i.e., cycle) impedance.

A primary is introduced in the 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 61)

Fig. 1. When applied voltage is less than $V_{critical}$, the diode draws little current; circuit is "off." At higher voltages $V_{critical}$ avalanche conduction causes diode to conduct heavily. Current is now limited only by load. 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.

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.

Fig. 3

$R_1 = 10,000$ ohms, $1/2$ w. carbon res.

$R_2 = 68,000$ ohms, $1/2$ w. carbon res.

$R_3 = 250,000$ ohms miniature pot (Centralab B-16-123 or equiv. Note: Center shaft must be insulated from front plate and operator.)

$C_1 = .02$ µf, 200 v. disc capacitor

$i _2 =.1$ µf, 200 v. capacitor

$i _3 = 2$ µf, $50$ v. flat core are in parallel

$I T 1 = 42$ c. 223 ev. wire wound on Arnold A1-500-187-H 1-P core, tapped at 2

$I T 2 = 5$ amp, 200 v. p.i.s. "Bias-tick" (Transition TBS-208. See text for other varieties.)

$I T 3 = 5$ amp, silicon bilateral trigger diode (Texas Instruments T1-43 or Transition ER-800.)

Note: D1, D2, and Arnold cores are for type A, 1 µf discs in parallel available as a "kit" from Kimball Electronics. 3614 N. 16 Street, Phoenix, Ariz., AS10 7-7900 each plus postage.

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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 15 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 Transistor TB5-20-B "Biwitch." It is normally rated at 5 amp at room temperature and has a p.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 parts. This is the reason for specifying a 250-watt maximum load. R2 is a standard Texas Instruments 30-volt silicon trigger diode, the T1-3.2, available at jobbers.

T1 consists of 62 turns of #22 enamelled magnet wire wound on a small powdered iron core and tapped at 2 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 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 switch type 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 spaces. 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 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 3/8-inch 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 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 1/4 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 240 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 5 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 TB5-20-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 TB5-20-AS which requires a much larger heat sink.