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Electronic Light Intensity Control to Simulate Dusk and Dawn Conditions[1]

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ABSTRACT Simulation of sunrise and sunset light conditions is achieved with an electronic light intensity control using DC- or AC-powered incandescent lamps. The duration of the sunrise and sunset is easily adjusted and the photoperiod is controlled with a standard 24-h timer. The light intensity control is especially useful for behavioral studies of crepuscular insects.

Most studies of the effects of photoperiods on insect behavior and physiology have utilized instant on/off light control (Lipton and Sutherland 1970, Leppla and Spangler 1971, Ball and Chaudhury 1973, Roberts 1974, Truman 1974, Chabora and Shukis 1979, Leppla et al. 1979). However, simulation of dusk and dawn light intensity changes may be required to properly observe insect activity rhythms in the laboratory. Several devices have been described that gradually change the light intensity during the circadian period. Unfortunately, the control systems were mechanically complicated and consisted of such parts as timing motors (Moody et al. 1973), "light shutters" (Turner et al. 1977a,b), solenoid, clutch plates and springs (Sparks 1973) or gears, cams and rubber bands (Eaton 1980).

Most environmental chambers use AC current to power the incandescent and fluorescent lights. Shields (1980) found that activity levels and turning rates of females of the minute pirate bug, *Orius tristicolor* (White), (Hemiptera: Anthocoridae) were higher under DC powered incandescent light than under flickering AC light (120 c/sec). Therefore, an electronic device with variable dusk and dawn dimming periods controlled by a standard 24-h on-off timer is described that can provide power to lights with either DC or AC current.

Materials and Methods

The light intensity control device (Fig. 1) uses a standard 24-h timer (or electronic timer, Byers 1981) to actuate a 120 volt DPST relay which either allows charging or discharging of C_1 through a 2 MΩ linear potentiometer (R_1) during the period of light intensity change. Independent control of the dusk and dawn periods can be achieved by adding a second 2 MΩ potentiometer to Fig. 1. One potentiometer would be connected to +12 V and the other to ground. The DPST relay would switch pin 2/C_1 to either potentiometer. C_1 may consist of several smaller value capacitors connected in parallel. The voltage of C_1 determines the output voltage of the 741 op amp (pin 6), which ranges from about 0.5 to 5 volts. The diode in parallel with C_1 is used to prevent pin 6 from going above about 6.7 V. The diodes between pin 6 and the transistors, or "to Fig 2" (see Fig. 1) are used to assure that the lamps (DC or AC) turn off when output becomes low. The diodes can be any type with a reverse breakdown greater than 15 V (IN4001, IN4002).

The number of 6-volt DC lamps (6 c.p.) that can be driven depends on the output current capabilities of the particular 12-volt power supply. The power transistors, Q_1, (2N3055 or similar) must be heat sinked. If a large number of 6-volt lamps are needed, the 741 op amp may not provide enough current to drive the transistors. In this case, the op amp could drive the base of a npn transistor (2N2222 or power) with its emitter (see arrows, Fig. 2) connected to the bases of all the power transistors, as in Fig. 1.

In Fig. 2, the output of the op amp drives a red LED. The LED and a CNS photoresistor (Radio Shack #276-116, 0.5 MΩ resistance in dark) are wrapped together with opaque electrical tape to prevent ambient light from reaching the photoresistor. The light from the LED, adjusted via the 50 KΩ potentiometer, that impinges on the photoresistor effects the unijunction transistor, Q_3 (Sylvania ECG6401), which varies its firing rate and causes the triac, Q_6, to vary the light intensity of AC powered lamps. The triac can be any type that is rated for the voltage and amperage for the requirements of the particular 120 V lamps. The remainder of the circuit (Fig. 2) has been modified from Marston (1973). Transistor Q_2 can be any low-power pnp type (2N3702) and transistors Q_4 and Q_5 can be any low-power npn type (2N2222). The power transistors (Fig. 1) and the triac(s) must be heat sinked and separated from the other electrical components so radiant heat does not affect operation of the control circuits.

Discussion

The duration of the "sunrise" and "sunset" period (Δt in sec), adjusted by the potentiometer R_1, is determined by the following equation: $\Delta t = R_1C_1\ \Delta V/6$ V. Where R_1 is in ohms, C_1 in μf, and $\Delta V = V_{max}$ op amp output minus V_{min} op amp output (ΔV typically 4.5 volts). The values of R_1 and C_1 shown in Fig. 1 will cause this transition period to range from a few seconds up to about 66 min. The lamps will extinguish at the end of the dim-off period, however, a second group of lamps of constant intensity could set the minimum level of light. The brightness of this second group of lamps could be regulated by npn power transistors similar to those in Fig. 1, but instead of their bases connected to the diode they would be connected through a 100 KΩ potentiometer to the positive supply voltage. Thus, this

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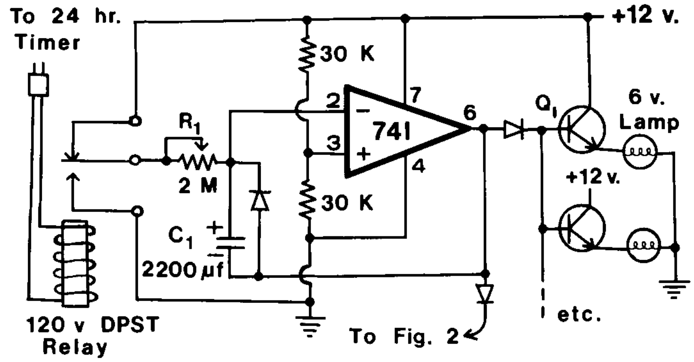

FIG. 1. Light intensity control for DC lamps. List of components—Resistors, ¼ watt: (2) 30 KΩ; Potentiometers: (1) 2 MΩ; Capacitor: (1) 2200 µf electrolytic 16 V; Transistors: (one per lamp) npn 2N3055 heat-sinked; Diodes: (3) IN4001; Integrated Circuit: (1) LM741; Lamps: 6 volt, 6 candlepower; Timer: (1) standard 24-h; Relay: (1) DPST 120 V.

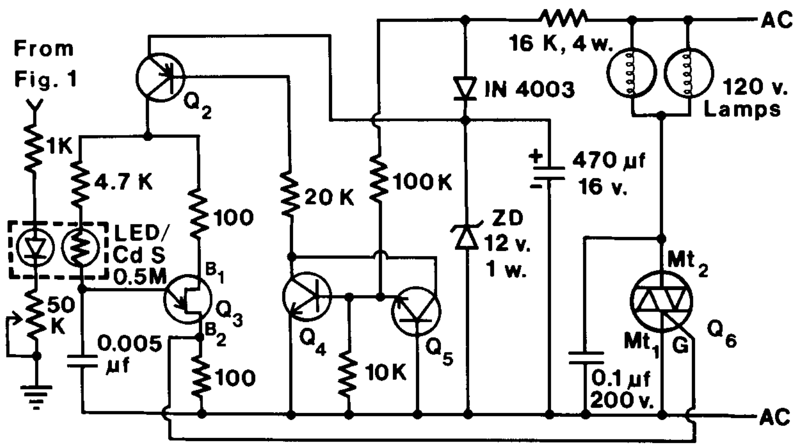

FIG. 2. Dimming circuit for AC lamps controlled by light intensity control (Fig. 1). List of components—Resistors, ¼ watt: (2) 100Ω, (1) 1 KΩ, (1) 4.7 KΩ, (1) 10 KΩ, (1) 16 KΩ, 4 watt, (1) 20 KΩ, (1) 100 KΩ; Potentiometers: (1) 50 KΩ; Capacitors: (1) 0.0047 or 0.005 µf, (1) 0.1 µf, 200 V, (1) 470 µf, 16 V; Transistors: Q_2, 2N3702, Q_3, Sylvania ECG6401, $Q_{4\text{-}5}$, 2N2222, Q_6, triac, 10 A, 200-400 V; Diodes: (1) IN4003, red LED, 12 V zener, 1 watt; Lamps: 120 V, 100 watt; Photoresistor: CdS, Radio Shack #276-116, 0.5 MΩ dark.

would allow insects which may need a certain minimal amount of light to exhibit normal behavior, as for example the response of male moths to pheromones (Bartell 1977).

The change in current supplied to the lamps is approximately linear over the period, although the wavelength of light emission from incandescent bulbs shifts toward the infrared as the intensity decreases. However, the spectrum of natural light similarly shifts toward the red during sunset and inversely at sunrise due to refraction of shorter wavelengths.

Generally, we do not believe that AC lamps should be used in behavioral studies designed to simulate natural environments because of the possibility that light flickering may affect the insect. It is well known that the flicker fusion frequency of diurnal flying insects is usually above 120 c/sec (Wigglesworth 1972). The control of DC lamps (Fig. 1) would simulate natural conditions more closely than AC lamps, providing the voltage supply was well filtered with large capacitors (at least 1,000 µf/ampere current, 16 V). However, our AC and DC circuits provide the experimenter with the option of comparing the behavioral effects of these two types of illumination. In any case, the AC circuit would be useful for control of heaters, motors, and other devices.

The dimmer control circuit is inexpensive to build and easy to adjust for various dimming periods. The device should make it practical to study the behavior of many crepuscular insects.

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