A "SMART" GREENHOUSE LIGHT CONTROLLER

Grow temperamental plants with artificial light when the sunlight goes away

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WITH their controllable growing conditions, greenhouses and hot frames can make possible the cultivation of plants too delicate to survive the rigors of the natural environment in many parts of the north Temperate Zone. Well-established technologies for the control of temperature and humidity exist, but photoperiod (the time for which the plant is exposed to light) and the intensity of light in its duration are also important, if not critical, to plant growth. Lamps whose spectral output is consistent with plant needs exist; the problem is how to control them.

To allow the lamps to run for a fixed period of time regardless of whether the sun is hidden or not is unacceptable. For one thing, some plants would be subject to excessive illumination, and, for another, heat build-up could stress the temperature-control system. Turning the lamps on when the sun is hidden and off when it reappears would be an improvement, but this too is subject to difficulties. One is that temporary occultations of the sun, as by passing clouds, birds, or aircraft, would cause an excessive number of on-off cycles and adversely affect lamp life.

An acceptable controller would give positive control of the duration of the photoperiod, turn on the lamps if the sun were to disappear for any significant length of time, and ignore short-term solar "dropouts." The system described in this article has these attributes.

Overall operation of the controller is shown in Fig. 1. The photoresistor monitors the sun's light and produces a voltage drop across its associated series resistor that is compared against a value set by the sensitivity control. If the light intensity, hence the voltage applied to the comparator noninverting input, is too low, the comparator will trigger timer 1. This timer will delay for a preset interval (up to 10 minutes or so) to determine if the light intensity remains low. Thus, momentary blockages of the sun won't cause the lamps to turn on. If allowed to time out, timer 1 will trigger timer 2, which will turn on the lamps for some minimum time (for example, 30 minutes), but will also keep the lights on as long as the sun remains hidden.

If it has finished timing-out, when the sunlight returns, timer 2 will trigger timer 3. This timer will keep the lamps on for some period (15-20 minutes) to make sure that the sun is back to stay. If it is, the lamps will turn off when timer 3 times out. If not, the comparator will trigger timer 1, and the whole cycle starts again. (If timer 1's delay is sufficiently less than that of timer 3, the lamps will stay on after the timer 3 period times out if the sun is hidden again.)

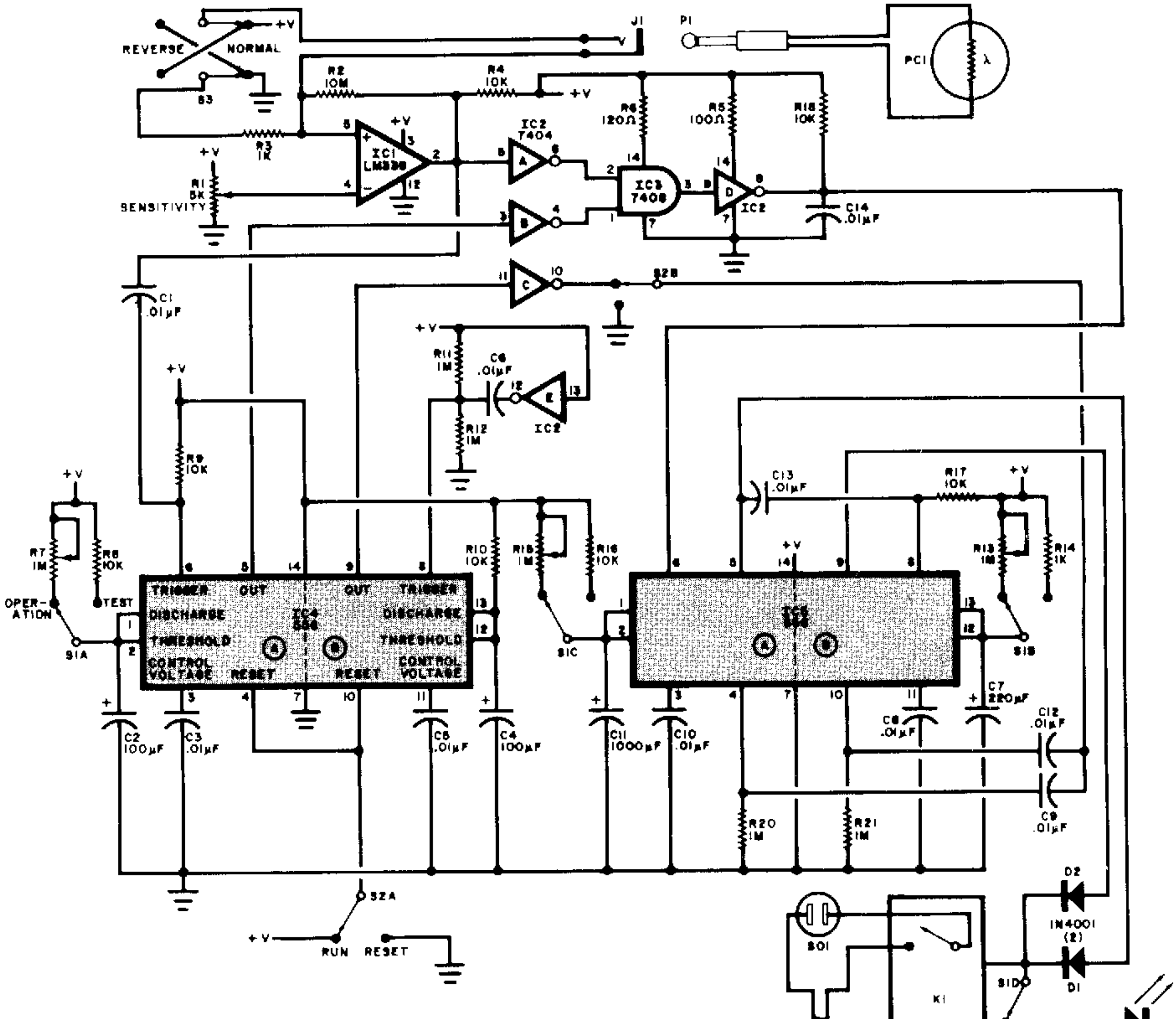
Circuit Operation. The complete circuit is shown in Fig. 2. Photoresistor *PC1's* resistance can range from a few hundred to 100,000 ohms or more depending on how much light falls on it. However, only 20 to 50 ohms difference was found when a bright sunny day was compared to an overcast day. To detect such a very small difference, comparator *IC1* is used. With *S3* in its normal position, the voltage drop across *R3* is compared against that set by sensitivity control *R1*. When the light is relatively dim, the *IC1* output at pin 2 goes low, thus triggering timer 1 (*IC4A*) via *C1*. The *IC1* output is inverted by *IC2A* and applied to one input of AND gate *IC3*. Resistor *R2* acts as feedback to improve the *IC1* switching action.

Timer 1 (*IC4A*) is one-half of a 556 operating in its one-shot mode. When it times out, its output at pin 5 is inverted by *IC2B* and fed to the other input of AND gate *IC3*. When both inputs to *IC3* are high, the gate triggers timer 2 (*IC5A*), via inverter *IC2D*. Thus, two conditions are necessary to trigger timer 2—low ambient light and the timing-out of timer 1.

Timer 2 (*IC5A*) will turn on for a

minimum period determined by *R15-C11*. However, this timer will stay on indefinitely as long as the light impinging on *PC1* is low, since the *IC1* output will remain low, and as long as it is low, timer 1 (*IC4A*) will not be released from its timing cycle. Capacitor *C14* will keep timer 2 on even after it has timed out for as long as timer 2 is in its "on" state, it will energize relay *K1* via *D1* which, in turn, supplies ac power to lamp socket *SO1*.

After timer 2 turns off, it triggers *IC5B* timer 3 via *C13*. This timer remains on for a period determined by



PARTS LIST

C1,C3,C5,C6,C8,C9,C10,C12,C13,C14—0.01-µF disc capacitor
C2,C4—100-µF electrolytic
C7—220-µF electrolytic
C11—1000-µF electrolytic
D1,D2—1N4001 diode
IC1—LM339 quad comparator
IC2—7404 hex inverter
IC3—7408 AND gate
IC4,IC5—556 dual timer
J1—2-conductor jack
K1—Solid-state relay (Radio Shack 275-236)
LED1—20-mA light-emitting diode
PC1—CdS photoresistor (Radio Shack 276-116)
Following are ½-W, 10% resistors unless otherwise specified
R1—5-kΩ potentiometer
R2—10 MΩ
R3,R14—1 kΩ
R4,R8,R9,R10,R16,R17,R18—10 kΩ
R5—100 Ω
R6—120 Ω
R7,R13,R15—1-MΩ mini-potentiometer (Radio Shack 271-229)
R11,R12,R20,R21—1 MΩ
R19—270 Ω
S1—4-pole, 2-position rotary switch (Radio Shack 275-1384)
S2,S3—Dpdt miniature toggle switch (Radio Shack 275-620)
Misc.—Sockets for ac, IC mounting sockets, case (Radio Shack 270-627), pc board, wire, solder, 6-volt battery eliminator, etc.

Fig. 2. Schematic diagram of the complete timer circuit. Points marked +V can be connected to a 6-volt battery eliminator or a separate 6-volt supply can be built and mounted in the enclosure.

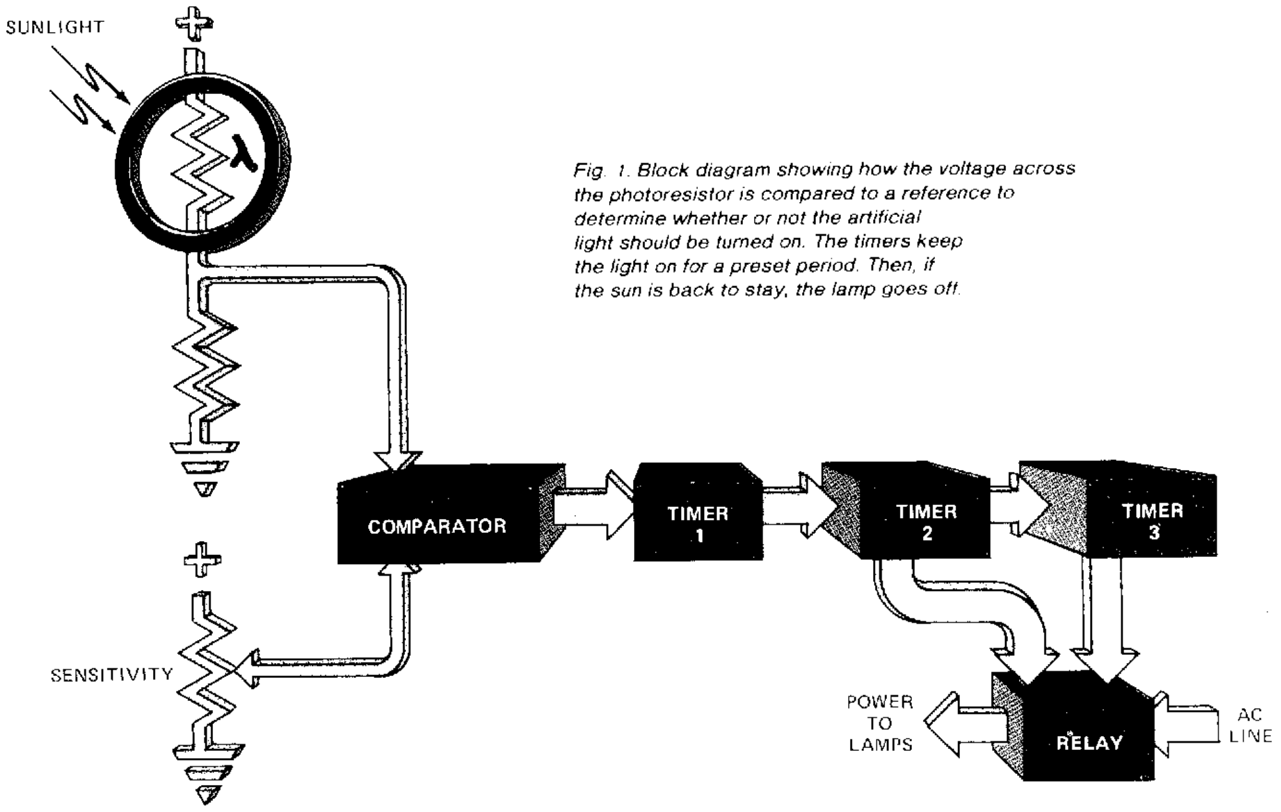


Fig. 1. Block diagram showing how the voltage across the photoresistor is compared to a reference to determine whether or not the artificial light should be turned on. The timers keep the light on for a preset period. Then, if the sun is back to stay, the lamp goes off.

R13-C7. Timer 3 also energizes the relay via *D2*.

When timer 3 times out, relay *K1* is de-energized if the *IC1* output went high since timer 3 started. However, if the low light condition returned and *IC1* went low again, timer 1 will turn on again, and the cycle starts over. If timer 1's delay is sufficiently less than timer 3's, timer 2 will turn on before timer 3 can time out and the relay will remain energized.

IC4B is used as a switch debouncer, and prevents timers 2 and 3 from being triggered when the power is first applied. This timer is used to momentarily reset both halves of *IC5* (via *C9* and *C12*) during the one second or so period just after the power is applied to the circuit.

A conventional 6-volt battery eliminator can be used to supply the 45 or 70 mA needed by the circuit. A 24-hour clock timer can then be used to power the battery eliminator so that the light controller operates only during daylight hours.

Switch *S1* places the controller into either TEST or OPERATION status. The only difference between these two conditions is that the timer delays are only a few seconds in the TEST mode. This latter mode is used mainly to adjust sensitivity control *R1*. *LED1* will glow in TEST so the lamps do not have to be connected to *SO1*. When the unit is not in the test mode, the LED will not operate.

Switch *S3* permits the unit to be used for much more than just a light controller. For initial testing as a light controller, *S3* should be positioned as shown with *R3* grounded.

Construction. The controller can be built on perf board, or a pc board can be fabricated. Sockets can be used for the ICs if desired. Once built, the circuit can be mounted within a selected enclosure with only the three switches, *R1*, *J1*, *LED1*, and lamp power socket *SO1*, mounted on an outside surface. A 6-volt power supply can also be mounted within the enclosure. The ac power line can exit via a grometted hole at the rear.

Adjustment. Plug the photoresistor into *J1*, and place it so that its light-sensitive surface is receiving direct sunlight. Place *S1* in the TEST position, then *S2* to RESET, then RUN. Adjust *R1* in small steps until a small amount of shade caused by your hand (12 or more inches away from *PC1*) causes *LED1* to turn on. Allow sufficient time between each *R1* adjustment for timer 1 to time out. If it does not time out, place *S2* in RESET, back *R1* off, and try again.

When you have adjusted *R1* to your satisfaction, place *S1* in the OPERATION position and connect the lamps to *SO1*. Control *R1* may have to be readjusted under actual overcast conditions. Note that a little hysteresis is present in *IC1* and if *R1* is adjusted "too tight", the controller will not turn the lamps off even when full sunlight appears.

While it was designed primarily as a light controller, the unit can be used to control other ac loads depending on the type of sensor plugged into *J1*. For example, replacing *PC1* with a temperature sensor, the controller could be used to turn on heating elements after ignoring momentary *high* temperatures. Using the same probe but placing *S3* in the REVERSE position, which switches the relative positions of *R3* and the external probe in their voltage divider configuration the controller can be used to turn on exhaust fans while ignoring sudden *low* temperatures.

It is possible that some user modification of potentiometer *R1* and *R3* might be necessary if probes having different resistance characteristics from those of *PC1* are used. Also, if even the small amount of hysteresis present in *IC1* cannot be tolerated, experiment with different valued resistors for feedback resistor *R2*.