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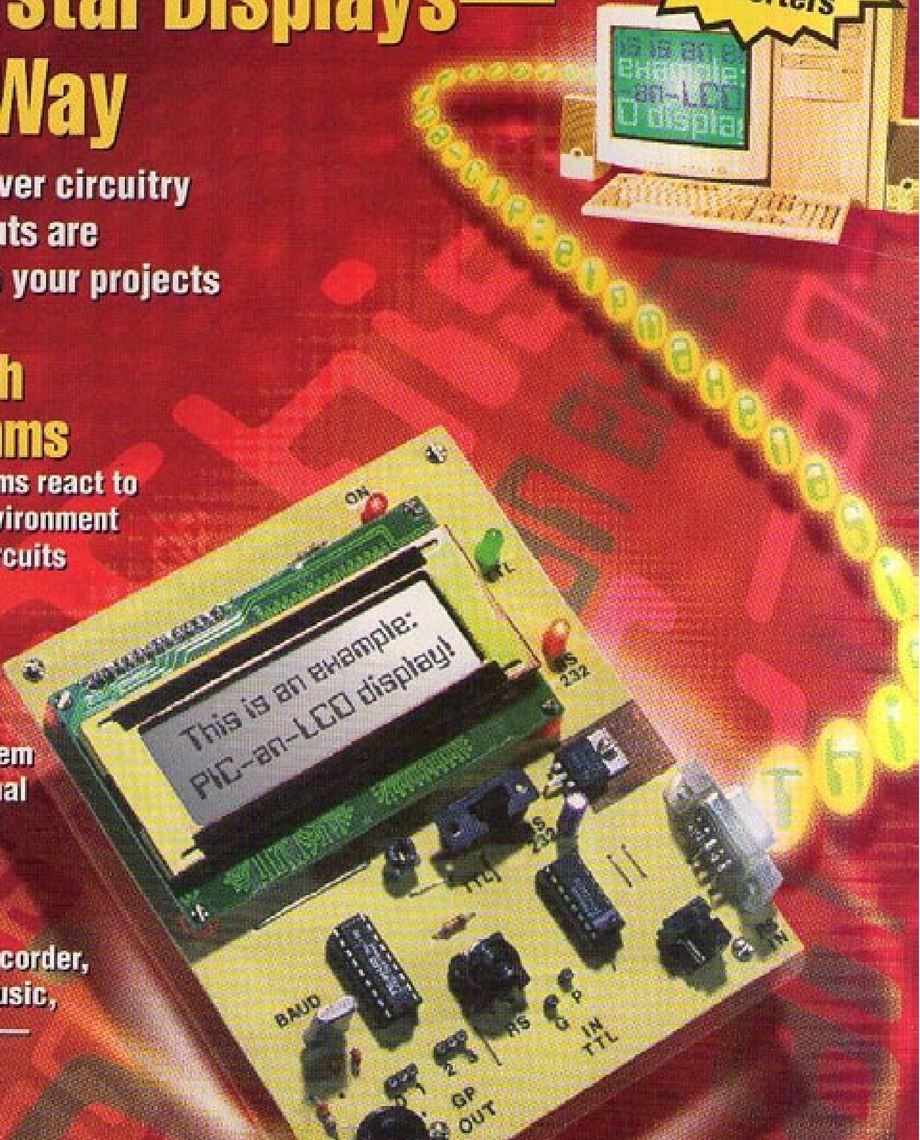

Adventures With Circadian Rhythms

Observe how living organisms react to changes in their normal environment with these easy-to-build circuits

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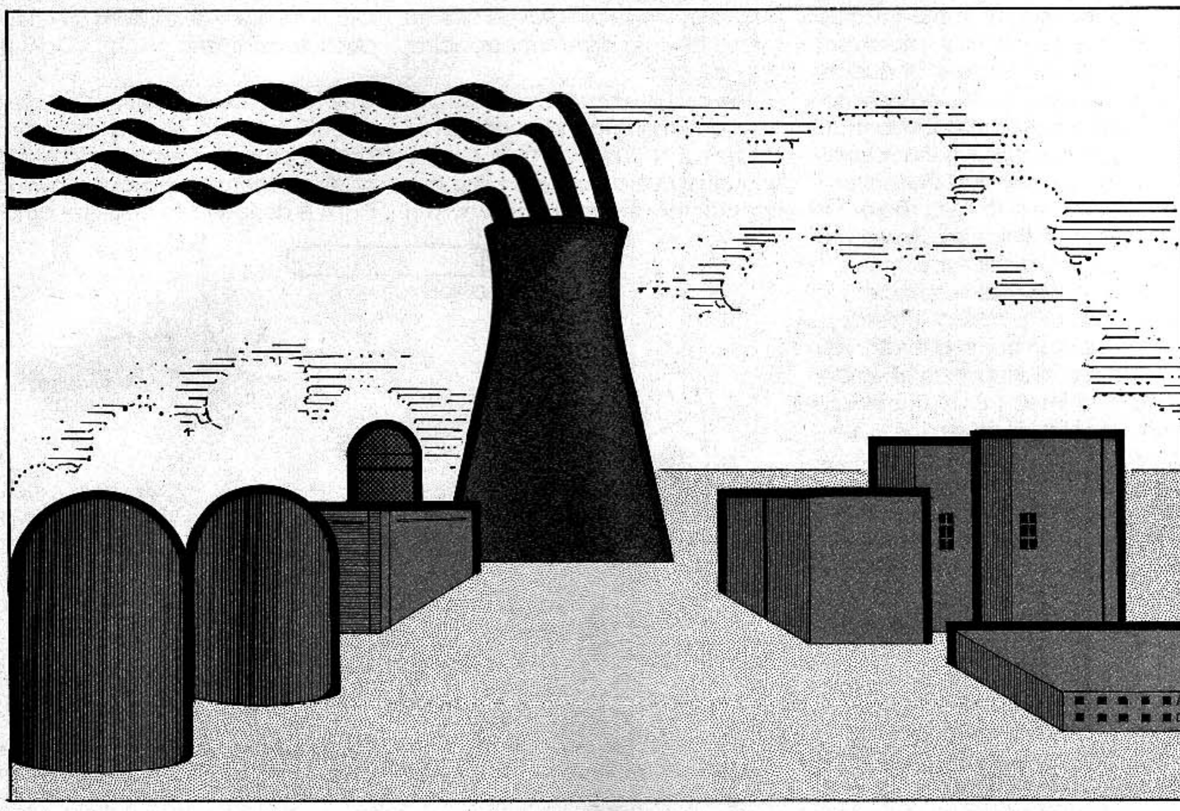
Adventures With CIRCADIAN RHYTHMS



Ever wonder how living organisms react to changes in their normal environment? Whether you're an amateur scientist, a student, or just have a healthy scientific curiosity, you can investigate the realm of circadian rhythms with any of the easy-to-build circuits presented here.

NEWTON C. BRAGA

Circadian rhythms, the study of the internal biological clocks of various living organisms, have been the subject of scientific research for some time now. Studies have shown the internal clocks of living organisms to be sensitive to light, as well as to other forms of external stimuli (such as ultraviolet, infrared, and nuclear radiation, magnetic and electric fields, *etc.*) that can affect hormonal levels and other physiological functions (see Fig. 1). Thus, it follows that by subjecting living organisms to various forms of external stimuli and observing their reactions, scientists can extrapolate how various external forces can affect changes in growth, physiology, reproductive functions, *etc.*

Such scientific inquiry needn't involve elaborate, high-tech (read high-priced) laboratory equipment, facilities, and conditions. Such studies can be pursued using common, fast-growing, domestic vegetation (such as tomatoes, beans, corn, flowers, *etc.*) as subjects. A dark room or a cardboard box can be used as a controlled environment, wherein the subject (in this case a plant) can be bombarded with various forms of artificial stimuli, as shown in Fig. 2. For example, a coil fashioned on a cardboard form can be used to produce magnetic fields with which to conduct radiation experiments. Exposing several plants to different sources and levels of radiation allows the researcher to gain an understanding of how growth and development are influenced by external forces.

Of course, in order to get meaningful results, the researcher must use two subject groups for the experiments. One group—serving as the control group—can be exposed to the light following the normal day/night cycle. The second group might be exposed to different forms of radiation (modulated light, ultraviolet, infrared modulated, pulsed light sources), or the usual day/night cycle might even be reversed. The researcher then can compare the growth and development of the two groups.

Experimentally Yours. As all of the experiments outlined herein are conducted using common, readily available subjects and equipment (such as incandescent or fluorescent lamps), the experimenter needs no special background in behavioral studies to perform this scientific research. In addition, the subjects can be exposed to light, radiation, and magnetic fields simultaneously to perform complex experiments.

For our studies, we've selected an assortment of practical electronic circuits that can be used to discover how the circadian rhythms of various plants and insects are affected by environmental changes. The selected circuits can produce light, ultraviolet radiation, and magnetic fields in several patterns that can be adjusted to various operating conditions. The circuits can be used to study the effects of external forces on plants or other living organisms, such as insects or even humans (with specialized aid). Of course, we're certainly not advocating that you put a human being in a coil and crank up the "juice" to observe what happens when a magnetic field is produced. But, a trial that involves stress would certainly make an interesting experiment in psychology.

For example, you might put several volunteers in a darkened room with a pulsed light to cause stress, and then measure respiration, heart rate, and blood pressure. (Sessions of about 10 minutes are sufficient.) By repeating the experiment (with the same group), you can determine if the subjects become more or less affected by unusual ambient conditions.

Now let's take a look at a few circuits that can be used in your quest for knowledge.

Stroboscopic Lamp. Our first circuit, see Fig. 3, is a simple arrangement that's comprised of four 1-amp 400-PIV rectifier diodes (D1–D4), four resistors (three fixed and one variable), a capacitor (C1), an incandescent lamp (I1), and an SCR. The pulse rate of the circuit can be adjusted (via R1) over a wide frequency range, from about four pulses per second (4 Hz) to one pulse every five seconds (approx. 0.2 Hz). A single capacitor, C1, sets the overall operating-frequency range of the circuit. The range of frequencies produced by the circuit can be altered by substituting different capacitor values for C1.

The circuit, which can be used to drive common incandescent lamps rated up to 100 watts, is simple enough to be assembled using any construction technique with which you are most comfortable. When assembling the circuit, the SCR should be mounted to a heatsink to dissipate heat generated by the SCR during operation. When mounting the circuit in an enclosure, take care that any exposed parts of the circuit are kept away from any conductive surface.

Day/Night Conditioner. Our next circuit takes a slightly different approach to the exploration of circadian rhythms. The circuit shown in Fig. 4 is designed to help the ama-

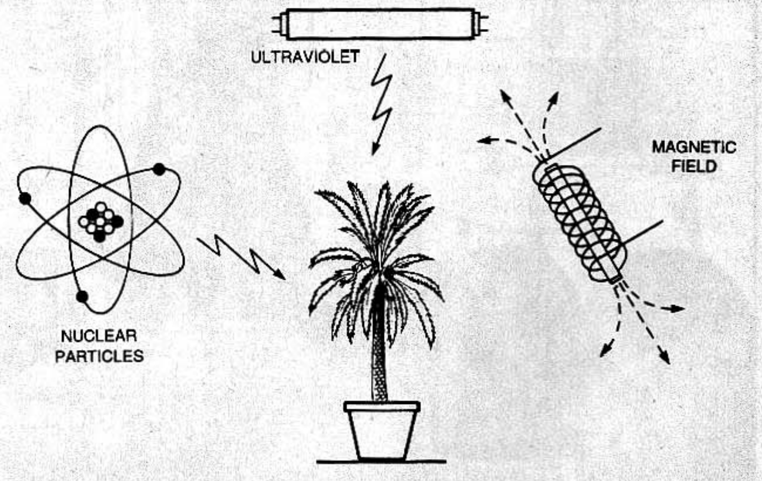


Fig. 1. All living organisms exhibit hormonal levels and/or other physiological functions that are "governed" by the day/night cycle and/or other external influences, including ultraviolet and infrared radiation, magnetic and electric fields, nuclear radiation, etc.

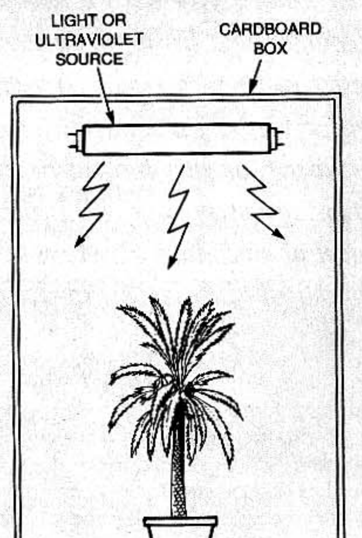


Fig. 2. A dark room or a cardboard box can be used as a controlled environment, wherein a plant or other subject can be exposed to various forms of artificial stimuli.

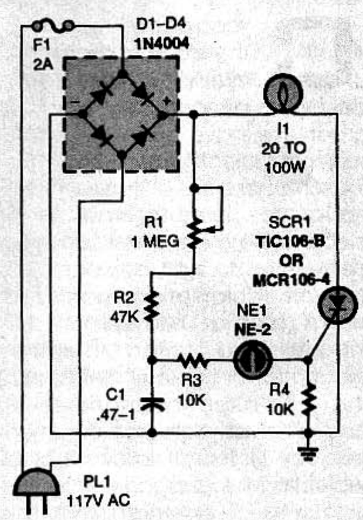


Fig. 3. The Stroboscopic Lamp—comprised of four 1-amp 400-PIV rectifier diodes (D1–D4), four resistors (three fixed and one variable), a capacitor (C1), an incandescent lamp (I1), and an SCR—is designed to produce short light pulses.

teur researcher ascertain the effects of artificially altering the test subject's 24-hour (day/night) cycle using a common low-voltage incandescent lamp. The circuit, built around a 555 oscillator/timer (IC1), a 4520 dual synchronous up counter (IC2), TIP120 Darlington transistor (Q1), and an assortment of support components, can be set for a flash rate ranging from several minutes to more than 24 hours.

In the Day/Night conditioner, the 555 (IC1) is configured as an astable multivibrator (or oscillator), the frequency of which is determined by R1, R2, R3, and C1. Potentiometer R1, a 2.2-megohm unit, allows the oscillator output to be adjusted over a wide range of the frequencies. The output of the oscillator is fed to the ENABLE input of up counter IC2 (only half of which is used in this application) at pin 2, while IC2's CLOCK input (at pin 1) is tied low. The output of the counter is fed through a 10k resistor (R4) to the base of Q1. Each time the counter output goes high, the Darlington transistor (Q1) turns on, completing I1's ground return path, causing the lamp to light. During negative excursions of the output waveform, I1 is cut off.

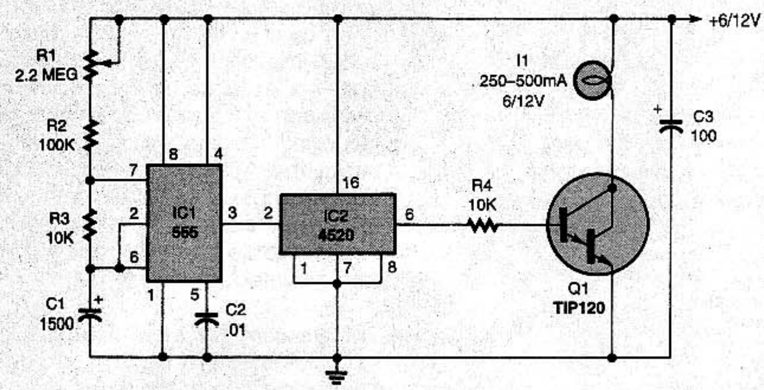


Fig. 4. The Day/Night Conditioner, taking a slightly different approach to the exploration of circadian rhythms, is designed to help ascertain the effects of artificially altering the test subject's 24-hour (day/night) cycle.

When assembling the circuit, Q1 should be mounted to a heatsink. The Darlington transistor can be replaced by a power-FET, such as the IRF640, without any additional alteration in the circuit. The circuit can be powered from a 6- or 12-volt power source. The lamp (I1) can be a 6- or 12-volt incandescent unit depending on the supply voltage selected. The lamps can be placed in a cardboard box along with the subject (plant or insects) to be studied.

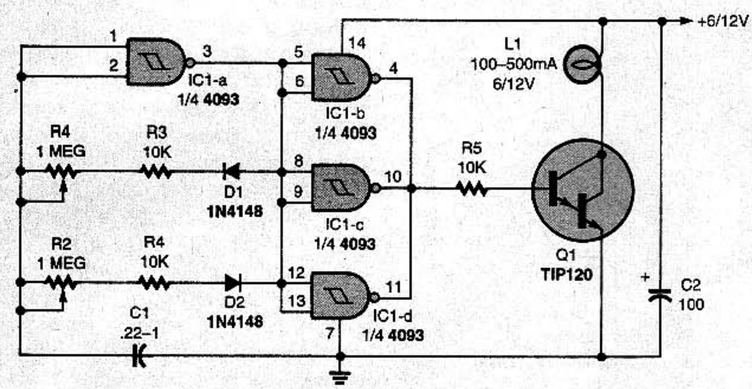


Fig. 5. This circuit, with its controlled duty-cycle, is built around a 4093 quad two-input NAND Schmitt trigger. One gate of the NAND Schmitt trigger, IC1-a, is configured as an astable oscillator, with a duty-cycle that can be adjusted via R1 and R2.

Controlled Duty-Cycle Light-Source. Figure 5 shows another circuit that can be used for circadian-rhythm experiments. The circuit, built around a 4093 quad two-input NAND Schmitt trigger, allows both on-time and off-time periods to be controlled. In that circuit, one gate from IC1 (IC1-a) is configured as an astable oscillator, whose duty-cycle can be adjusted via R1 and R2. The setting of potentiometer R1, along with the fixed-resistor value of R3, determines the charge period of C1 and, by extension, the time that IC1-a's output is at logic high. The setting of potentiometer R2, along with the value of fixed-resistor R4, combine to determine the discharge period of C1. It also determines, in an analogous way, the time the transistor—as well as the lamp—is on.

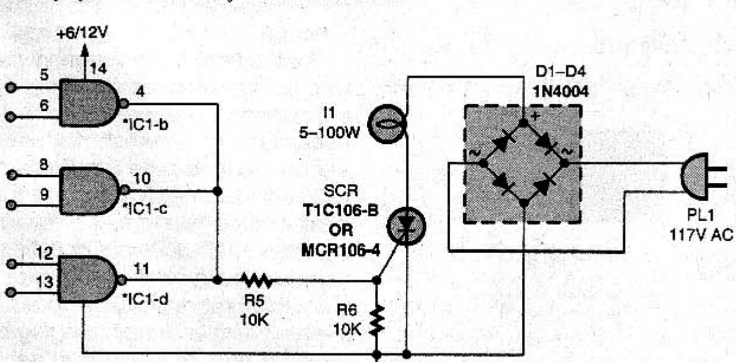


Fig. 6. The previous circuit (see Fig. 5) can be altered, as shown here, allowing the reconstituted circuit to control AC-line-powered lamps up to 100 watts through SCR1.

The other three gates (IC1-b, IC1-c, and IC1-d), which are connected in parallel, are used to boost the output drive current of the oscillator, while inverting the signal. That means that when the output of IC1-a is high, the combined outputs of IC1-b, IC1-c, and IC1-d are at logic low. That logic-low output, which is applied to the base of transistor Q1, holds the transistor at

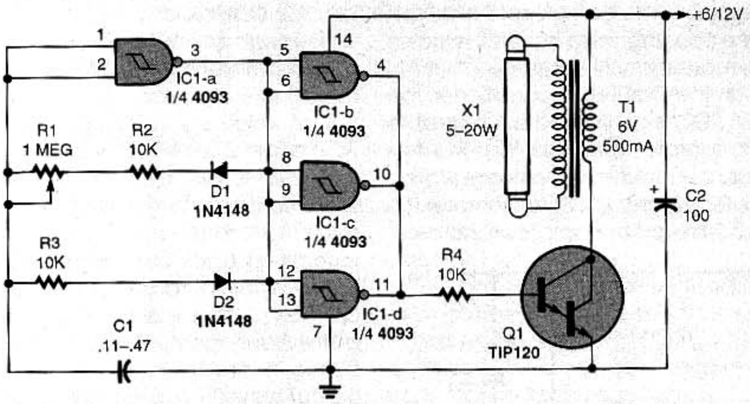


Fig. 7. The Fluorescent UV Light-Source, although nearly identical to the circuit in Fig. 5, is designed to produce short pulses of visible light or ultraviolet radiation.

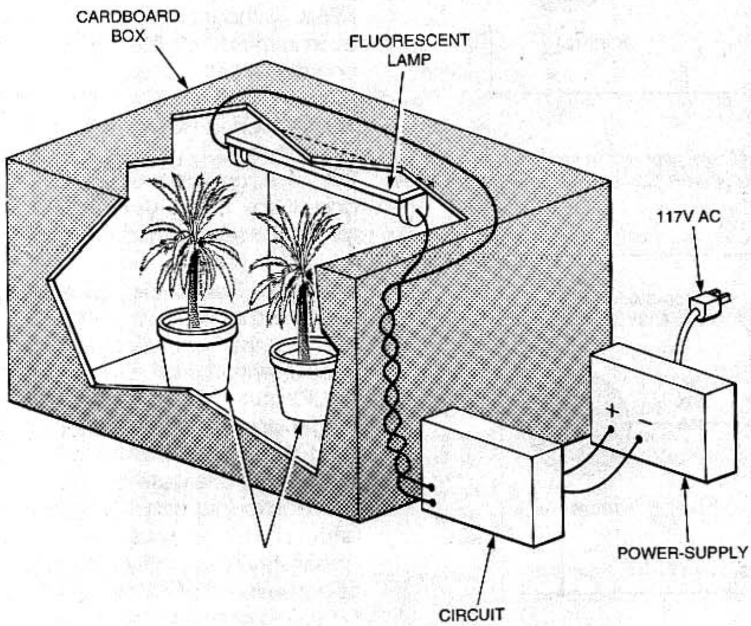


Fig. 8. Ultraviolet experiments, as illustrated here, should be performed with the ultraviolet light source enclosed in a cardboard box.

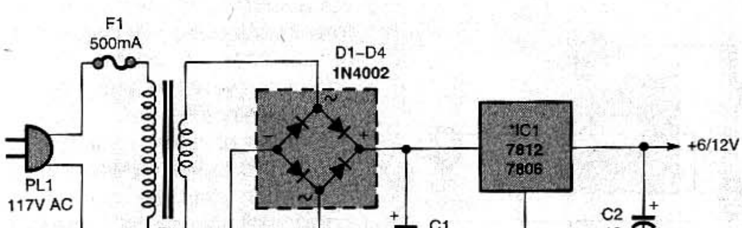


Fig. 9. This Power Supply circuit can be used to operate all of the circuits presented in this article. Note: IC1 can be a 12- (7812) or 6- (7806) volt regulator, depending on how your circuit is configured and what parts are used in the circuit.

cutoff, so the lamp does not light. However, when the output of the oscillator swings low, the combined output of the three parallel NAND Schmitt triggers (IC1-b, IC1-c, and IC1-d) goes positive. That positive output causes Q1 to turn on, illuminating I1.

The circuit—which is capable of driving lamps up to 600 mA—can be powered from 6- or 12-volt supplies. The circuit in Fig. 5 can be altered, as illustrated in Fig. 6, thereby allowing the reconstituted circuit to control a lamp that's powered from the AC line. The circuit can drive lamps up to 100 watts. As the SCR may be required to dissipate considerable heat, that unit should be mounted to a heatsink.

Fluorescent UV Light-Source. Our next circuit (see Fig. 7), although nearly identical to the circuit in Fig. 5, is designed to produce short pulses of visible light or ultraviolet radiation. The only difference between this circuit and the one in Fig. 5 is that instead of directly driving a fluorescent lamp, the output of the transistor is used to drive a step-up transformer (T1), which, in turn, provides sufficient voltage to light a fluorescent lamp (FL1).

The lamp's flash rate is determined by the RC time constant established by R1 and C1. The flash rate can be altered by varying the value of C1 within the range indicated in Fig. 6. Transformer T1 is a common power transformer, whose primary winding (rated at 117 volts AC) is connected as the secondary and its secondary winding (which can be either 6 or 12 volts at 800 mA) is connected as the primary winding.

That allows T1 to function as a step-up transformer, boosting the low-voltage pulses produced by the circuit to a level that's strong enough to ionize the gas inside the fluorescent lamp. The high-voltage output of the transformer, pulses that can reach up 400 volts, is sufficient to cause even very weak lamps to glow. Common white, colored, or even ultraviolet lamps (ranging between 6 and 25 watts) can be driven by the circuit in Fig. 7.

When experimenting with ultravi-

(Continued on page 65)

BUILD THE SENTINEL

(continued from page 48)

measure the resistance between the positive and negative sides of the battery connector to be sure there is no short-circuiting in the wiring. You should get a reading of 20k or more. If you get a reading of zero or some low resistance, troubleshoot the circuit and correct the fault before proceeding. Pay particular attention to C1 and all other polarized components, and check the circuit board for any possible solder bridging.

If all seems OK, proceed to the next phase of the test. Snap a fresh 9-volt battery into the battery clip. The piezo buzzer should immediately emit a series of $1/2$-second tone bursts. If the buzzer remains silent, check battery polarity and voltage under load to be sure it is at least $8^1/_2$ volts. Then check the wiring to the piezo buzzer to be sure its polarity is correct. Also check D2 and D3. If everything looks normal, check all components associated with IC1. Measure the voltage from pin 4 or pin 8 to ground to be sure the chip is receiving at least $8^1/_2$ volts. If so, try a new chip.

If IC1 is not receiving battery voltage at pins 4 and 8, check Q1, Q2, and all associated components. Check the part numbers for the transistors to be sure the parts are properly wired into the circuit. Measure the voltage across R3 to be sure that Q1 is conducting current. You should read about 8 volts. If not, replace Q1. If Q1 is conducting and Q2 is not, replace Q2. With the fault corrected and tones emanating from the piezo buzzer, continue with the test.

Connect the DC power supply, set to 20 volts or more, to the telephone input terminals, "+" and "–," as shown in Fig. 4. The piezo buzzer should become silent. If the 20-volt DC potential does not silence the buzzer, find out if it's properly polarized. Troubleshoot the circuit by verifying that the gate-to-source voltage of Q1 is at least –4 volts, with the gate negative with respect to the source. Check R1, R2, D1, Q1, and Q2. Try new transistors. When the 20-volt DC potential is present, the voltage at pins 4 and 8 of IC1 must fall to zero, silencing the buzzer.

The battery-monitor circuit can be checked by using a variable DC power supply in place of the battery or by inserting a worn but not exhausted battery (about 7.7 volts or less terminal voltage) onto the clip. With the battery source voltage at 7.7 volts or less and the 20-volt DC power supply connected to the telephone line terminals, the piezo buzzer should emit a short tone every 15 or 20 seconds. If not, troubleshoot the circuit composed of IC2, IC3, and Q3.

Verify that the gate voltage of Q3 is zero with respect to circuit common. If not, check IC3 and D5. Then check IC2 pins 4 and 8 to be sure there is about 4 or 5 volts DC potential there. If not, check Q3 and, if necessary, try a new transistor. With DC power present at pins 4 and 8, IC2 should oscillate at a repetition rate of about 1 pulse every 15 or 20 seconds as indicated by a short positive pulse appearing at pin 3. Check D3, D4, and all components associated with IC2. Try a new chip.

Once the fault has been corrected and the circuit detects a low-battery condition, the checkout procedure has been completed. Remove the exhausted battery and disconnect the DC power supply.

Optional Relay Circuit. Provision has been made on the Sentinel's printed-circuit board for a single-pole, single-throw miniature relay with normally-open (form A) contacts. The relay contacts can be used to activate any other alarm system, such as a wailing siren, should the phone line be cut. The relay's contact rating is $1/2$ amp, which should be sufficient to activate most commercial alarm systems. If a higher current is necessary, use the contacts of RY1 to drive the coil of a high-power relay, which would then carry load current. If the optional relay is not required, simply omit RY1 from the board.

Installation. If the unit is not going to be installed immediately, remove the 9-volt battery. Otherwise, install a new battery and plug the Sentinel into an appropriate telephone jack to monitor the status of the line. Your bedroom is a good choice. Once the telephone's line cord is connected to the jack, the piezo buzzer should be silent. If not, check telephone-line polarity.

Simulate a telephone-line failure by disconnecting the modular plug from its receptacle. The piezo buzzer should respond with a series of tones. Reconnect the modular plug to silence the buzzer. The Sentinel requires no attention as long as it is connected to a working telephone receptacle. ■

CIRCADIAN RHYTHMS

(continued from page 44)

olet radiation, **do not** look directly at the lamp! The radiation can seriously damage your vision. Ultraviolet experiments should be performed with the lamp enclosed in a cardboard box, as illustrated in Fig. 8.

Caution: The high voltage produced by the transformer can cause severe shock. Make sure that the transformer is isolated from all conductive surfaces when mounted into its enclosure.

Power Supply. All the circuits, intended for long operation periods, should be powered from power supplies and not batteries that can be drained in a short time. Figure 9 shows a power supply that can be used to power 6- or 12-volt projects that need currents up to 1 amp.

The IC should be mounted on a heatsink. The transformer should have a secondary wounding rated at 1 amp. The reader should take care when mounting the transformer, as its primary winding is connected directly to the AC power line. An accidental touch when in operation can cause severe shocks. ■

"Of course I know what I'm making, or I will when it's finished."