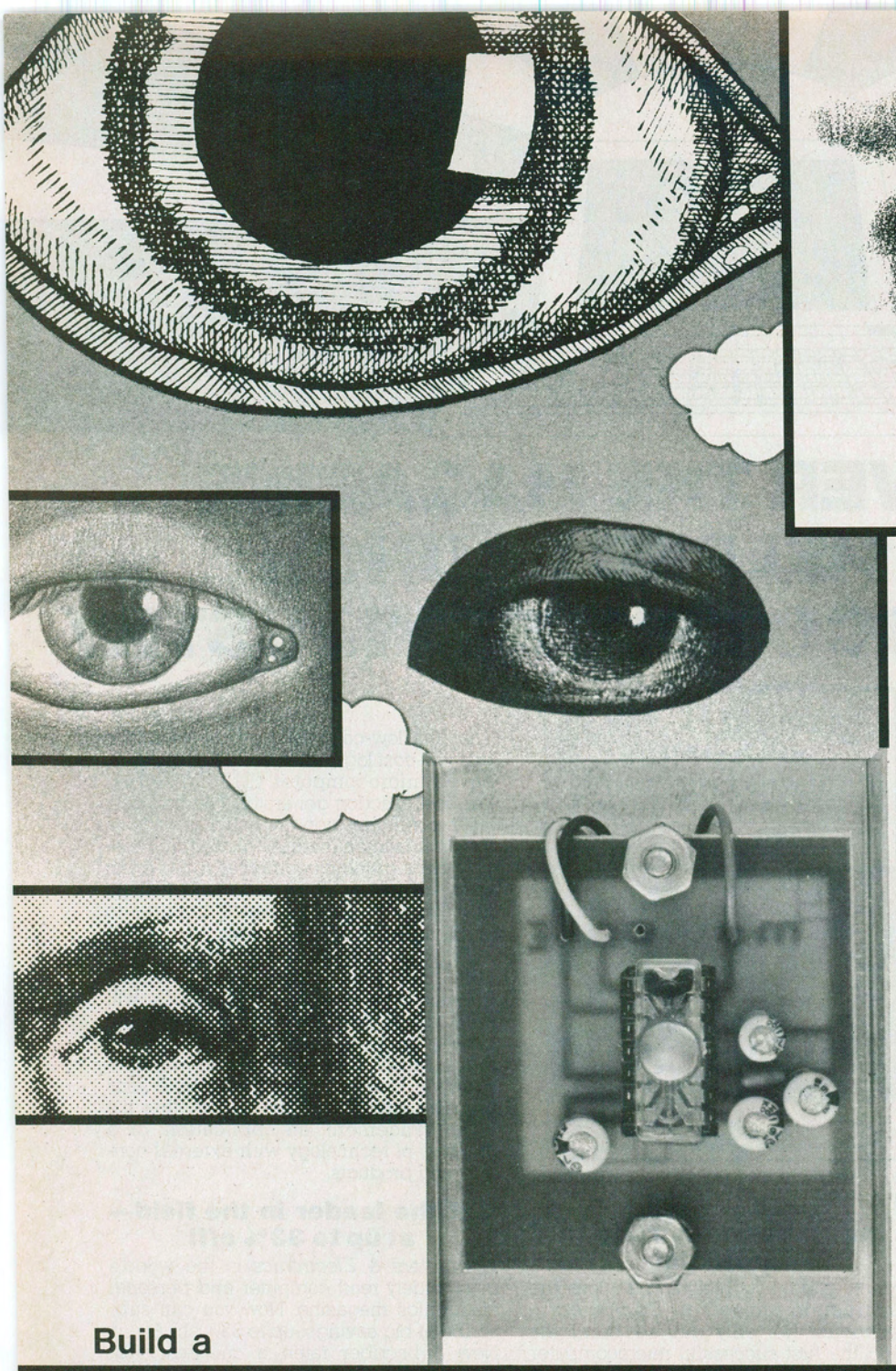


Build a

MOTION-DETECTOR ALARM

- Many-Eyed Modular System
- Low-Cost IC
- Responds to Light Changes

BY WALTER GONTOWSKI, JR.

INTRUSION alarm systems are increasingly popular today owing to the growing incidence of crime. A new security system based on an IC motion detector developed by the Sprague Electric Company doesn't have the limitations of other types while sharing some of their advantages. Called the Optical Detector Modular alarm system (Opdec), the system presented here may be likened to a many-eyed optical device that detects movements through light changes, but is much lower in cost than an ultrasonic-type alarm and is resistant to false alarms.

Other characteristics of the Opdec include modular construction, provisions for timed exit and entry, and input terminals for optional closed-loop wiring that can yield added protection. Finally, Opdec can also function as a fire/smoke detector at the same time that it is on the lookout for intruders.

The Motion Sensor. The heart of the Opdec system is Sprague's ULN-2232A Integrated Optical Motion Detector. Un-

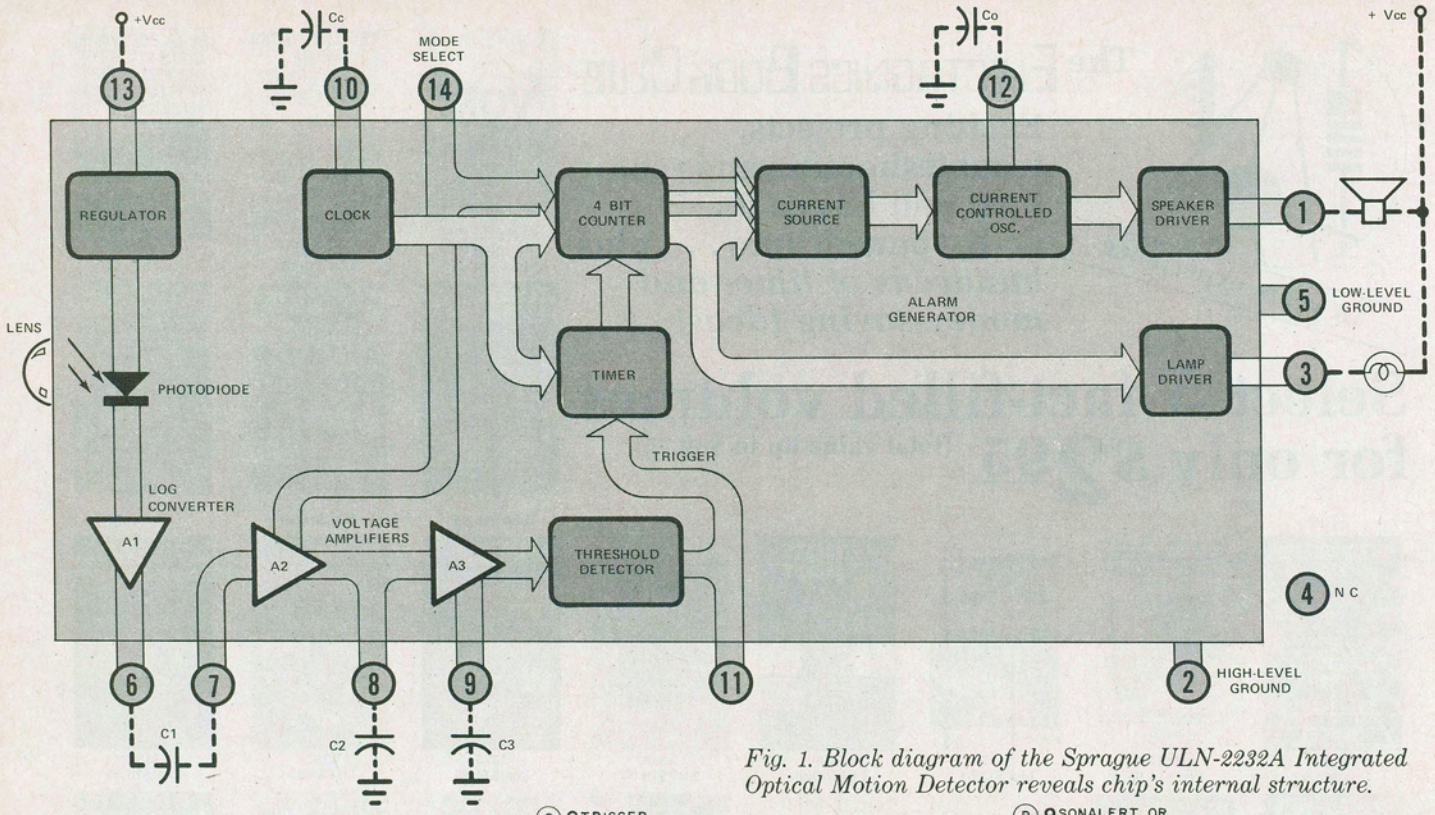


Fig. 1. Block diagram of the Sprague ULN-2232A Integrated Optical Motion Detector reveals chip's internal structure.

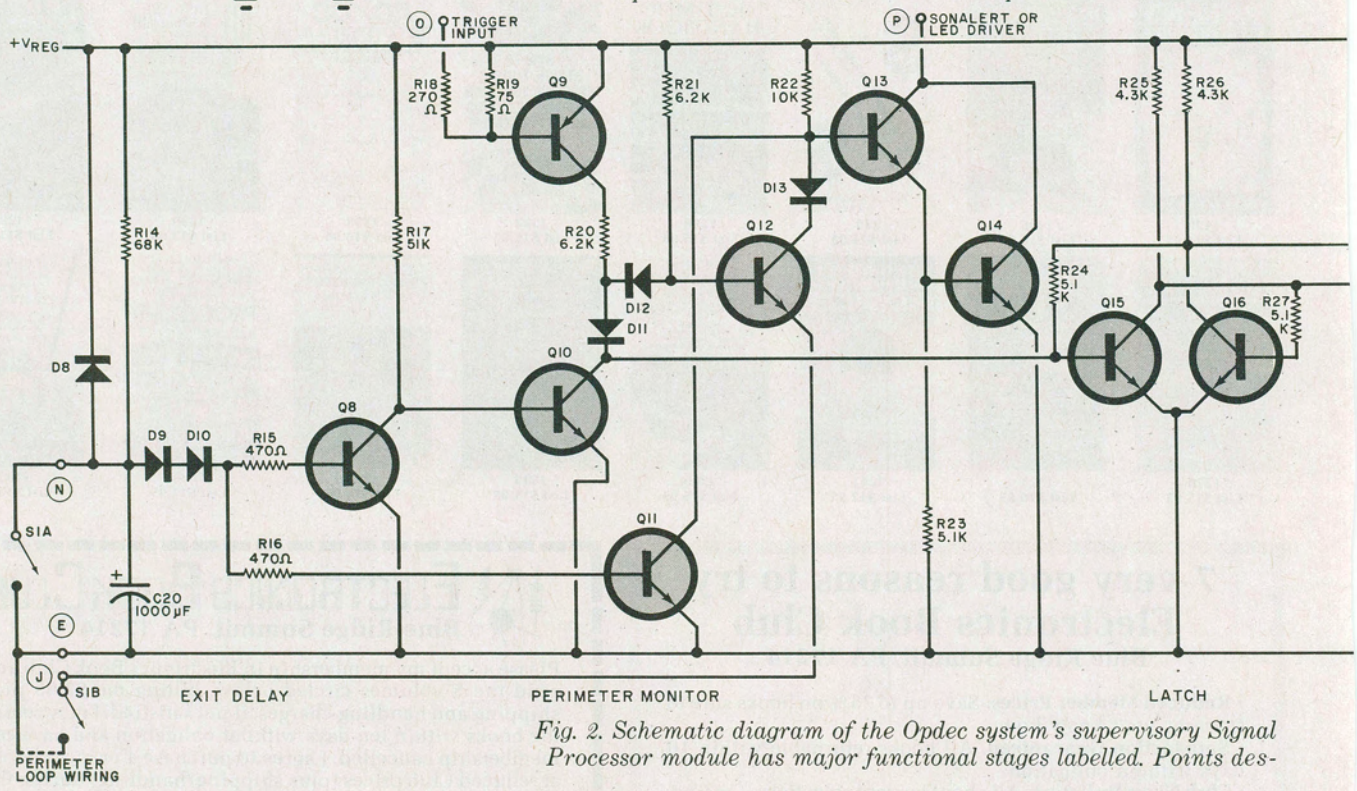


Fig. 2. Schematic diagram of the Opdec system's supervisory Signal Processor module has major functional stages labelled. Points des-

like a conventional optoelectronic alarm sensor (usually a CdS photocell) that triggers the alarm when the path between a light source and the sensor is interrupted, this novel IC senses the presence of an intruder by detecting changes in the amount of ambient light reaching it. As the intruder enters the room or moves around in it, the amount of light reflected to the sensor IC will vary. The sensor has been designed to respond to this change in light level.

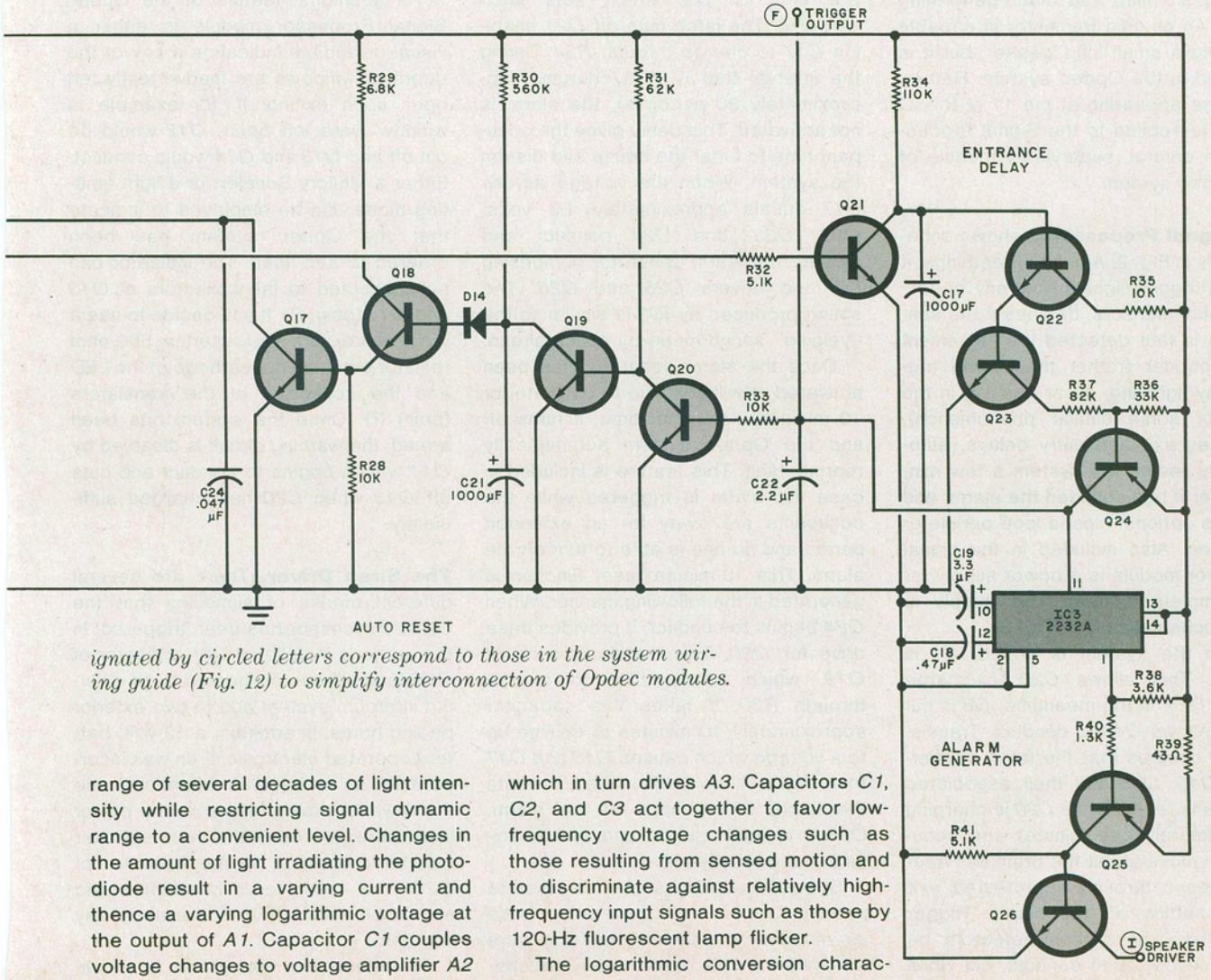
A block diagram of the ULN-2232A IC sensor is shown in Fig. 1. The chip contains, among other things, a photodiode, a logarithmic converter, a voltage amplifier, a threshold detector and an alarm generator. Sensor operation is as follows.

The photodiode generates a small electric current when it is irradiated by light energy. This photocurrent is processed into a voltage by logarithmic converter *A1*. Taking the log of the current allows sensor operation over a

PARTS LIST FOR SIGNAL PROCESSOR MODULE (including System Power Supply)

C1—10,000-μF, 25-volt electrolytic
C17,C20,C21—1000-μF, 6-volt electrolytic
C18—0.47-μF, 6-volt tantalum
C19—3.3-μF, 6-volt tantalum
C22—2.2-μF, 6-volt tantalum
C24—0.047-μF, disc ceramic
D1,D2—3-ampere, 100-PIV rectifier
D8 through D14—1N4001 rectifier
D15—4.7-volt, 1-watt zener diode (1N3825 or equivalent)
F1—½-ampere fast-blow fuse
IC3—ULN-2232A Sprague Integrated Motion Detector
Q1,Q26—2N4921 npn silicon transistor (or equivalent)
Q8,Q10 through Q23—Sprague RT108 npn silicon transistor (or equivalent)
Q9,Q24,Q25—Sprague RT106 pnp silicon transistor (or equivalent)
The following are 5%-tolerance, ¼-watt carbon-composition resistors, unless otherwise specified.
R1—100 ohms, 2 watts, 10% tolerance
R13—43 ohms, 4 watts, 10% tolerance
R14—68,000 ohms
R15,R16—470 ohms
R17—51,000 ohms
R18—270 ohms
R19—75 ohms
R20,R21—6200 ohms
R22,R28,R33,R35—10,000 ohms
R23,R24,R27,R32,R41—5100 ohms
R25,R26—4300 ohms
R29—6800 ohms
R30—560,000 ohms
R31—62,000 ohms
R34—110,000 ohms
R36—33,000 ohms
R37—82,000 ohms
R38—3600 ohms
R39—43 ohms
R40—1300 ohms
S1—Dpst switch
T1—24-volt, 2-ampere center-tapped transformer (Stancor P-8662 or similar)
Misc.—Mallory SC-628 Sonalert or LED, 8-ohm dynamic speaker (if Siren Driver module is omitted), printed circuit board, standoff insulators, snap-on heat sinks for *Q1* and *Q26* (Wakefield 291.80ABC2 or similar), silicone thermal compound, suitable enclosure measuring approximately 10″ × 5″ × 3¼″ or 25.4 cm × 12.7 cm × 8.3 cm (Bud RC11100 or similar), barrier block terminal strip, hookup wire, solder, hardware, etc.

NOTE-*The Sprague ULN-2232A Integrated Optical Motion Detector can be purchased for $3.71 (plus postage and handling) from Poly Paks, P.O. Box 942, So. Lynnfield, MA 01940. Specify part No. K5870.*



ignated by circled letters correspond to those in the system wiring guide (Fig. 12) to simplify interconnection of Opdec modules.

range of several decades of light intensity while restricting signal dynamic range to a convenient level. Changes in the amount of light irradiating the photodiode result in a varying current and thence a varying logarithmic voltage at the output of *A1*. Capacitor *C1* couples voltage changes to voltage amplifier *A2* which in turn drives *A3*. Capacitors *C1*, *C2*, and *C3* act together to favor low-frequency voltage changes such as those resulting from sensed motion and to discriminate against relatively high-frequency input signals such as those by 120-Hz fluorescent lamp flicker.

The logarithmic conversion charac-

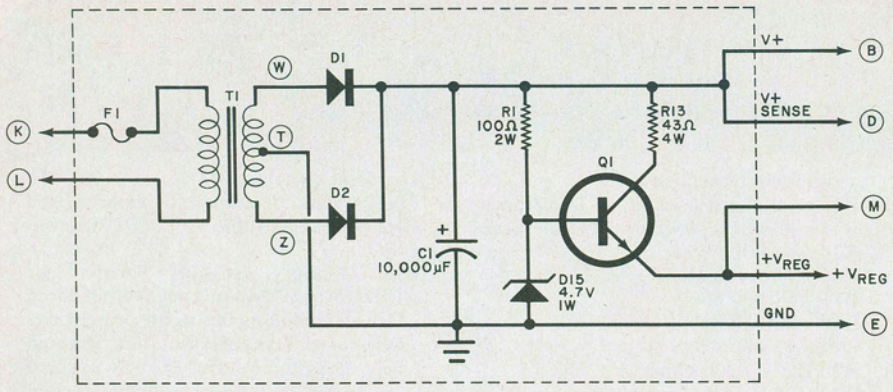


Fig. 3. This power supply can satisfy current demand of a complete Opdec system. Most of it fits on the Signal Processor's pc board.

teristic of *A1* and the gains of *A2* and *A3* are chosen so that the threshold detector is triggered when the change in light level exceeds ±5% during a relatively short period of time (about one second). When the threshold detector is triggered, a pulse is routed to pin 11 of the IC and to a four-bit counter that is part of the chip's timing and alarm-generating circuit. An on-chip transistor is capable of driving a small loudspeaker, but it is not used in the Opdec system. Rather, the pulse appearing at pin 11 of the IC sensor is applied to the Signal Processor, the central, supervisory module of the Opdec system.

The Signal Processor is shown schematically in Fig. 2. Among other things, it detects trigger signals from any of several motion sensors, decides if the sensor has in fact detected the movement of an intruder (rather than being triggered by lightning, a car passing in the night, or some similar phenomenon), generates exit and entry delays, automatically resets the system a few minutes after it has sounded the alarm, and provides optional closed-loop perimeter protection. Also included in the signal processor module is a power supply for the complete system. This supply is shown schematically in Fig. 3.

When the system is armed, *S1* is opened. This allows *C20* to charge through *R14*. In the meantime, *Q8* is cut off and allows *Q10* to conduct. Transistor *Q10* ensures that the latch consisting of *Q15*, *Q16* and their associated resistors is reset. While *C20* is charging (approximately one minute), the occupant can move about the premises freely and leave through a protected exit without setting off the alarm. Trigger pulses from the motion detectors he passes cause *Q9* to conduct, but while *C20* is charging, the pulses appearing at the collector of *Q9* are shunted to ground by *Q10*. When the voltage across *C20* increases to approximately 2.1 volts, *Q8* conducts and cuts off *Q10*. The Opdec system is now armed.

If light-level changes such as those caused by motion are detected, pulses are sent to *Q9*, which sets latch *Q15Q16*. The latch cuts off *Q21* enabling *C17* to charge through *R34*. During the interval that *C17* is charging (approximately 30 seconds), the alarm is not activated. This delay gives the occupant time to enter the house and disarm the system. When the voltage across *C17* equals approximately 1.3 volts, *Q22*, *Q23*, and *Q24* conduct and actuate the alarm generator comprising *IC3* and drivers *Q25* and *Q26*. The sound produced by *IC3* is similar to the "yelping" sound made by police sirens.

Once the alarm generator has been activated, it will continue to oscillate for 10 minutes. After that time, it turns off and the Opdec system automatically rearms itself. This feature is included in case the alarm is triggered while the occupants are away for an extended period and no one is able to turn off the alarm. This 10-minute reset function is generated in the following manner. When *Q24* begins to conduct, it provides base drive for *Q20*. This transistor cuts off *Q19*, which allows *C21* to charge through *R30*. It takes this capacitor approximately 10 minutes to charge up to a voltage which causes *Q18* and *Q17* to conduct. When *Q17* turns on, it resets the latch, which turns off the alarm. Opdec is again armed and awaits any further trigger signals.

Special precautions must be taken to prevent Opdec from generating false alarms due to lightning, passing cars with glowing headlights, etc. One specially constructed detector module (more on this later) should be mounted in a window and aimed at the sky. When a lightning flash occurs, this detector will momentarily disarm the system and then automatically rearm it. This module should not be mounted in such a way that any swaying trees, moving cars, or similar objects are in its field of view.

If you would like to incorporate the additional protection of a closed-loop system, magnetic reed door switches (normally closed) and metallic foil tape for glass can be connected to the signal processor. These items can be purchased at most electronics stores and are simple to install. The switches and tape are all wired in series and connected to point J and ground (point E). If any of the protected doors are opened or a foiled window is broken, the closed-loop circuit is opened. This cuts off *Q12*, which in turn allows the latch to be set by means of *R21*, *D11*, and *D12*. After the 30-second entry delay interval, the alarm is activated.

An additional feature of the Opdec Signal Processor module is either a visual or audible indication if any of the doors or windows are inadvertently left open upon exiting. If, for example, a window were left open, *Q12* would be cut off and *Q13* and *Q14* would conduct. Either a Mallory Sonalert or a light emitting diode can be employed to indicate that the Opdec system has been ordered to arm itself. The indicator can be connected to the collectors of *Q13* and *Q14* (point P). If you decide to use a LED, make sure you insert a 560-ohm resistor between the cathode of the LED and the collectors of the transistors (point P). Once the system has been armed, the warning circuit is disabled by *Q11*, which begins to conduct and cuts off *Q13* when *C20* has charged sufficiently.

The Siren Driver. There are several different means of signalling that the Signal Processor has been triggered. In the author's installation, the collector of *Q26* (point I) was connected to an existing intercom system and to two exterior paging horns. In addition, a 12-volt, battery-operated electronic siren was incorporated as a back-up alarm in case there was a power failure, or the power lines were cut. An 8-ohm horn speaker can be connected to the collector of *Q26*. The resulting *loud* alarm sound should be sufficient to scare away any intruder.

The electronic siren driver is shown

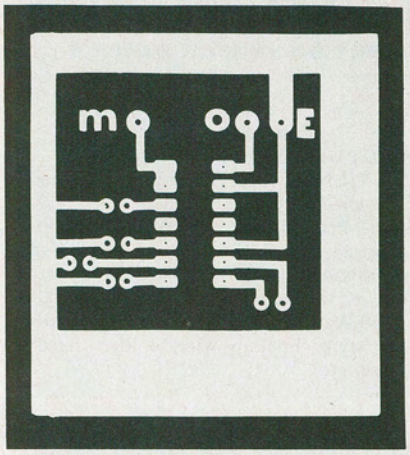


Fig. 4. Etching and drilling guide for motion and lightning sensor pc boards (shown above.)

Fig. 5. Etching and drilling guide for Signal Processor module pc board (shown below).

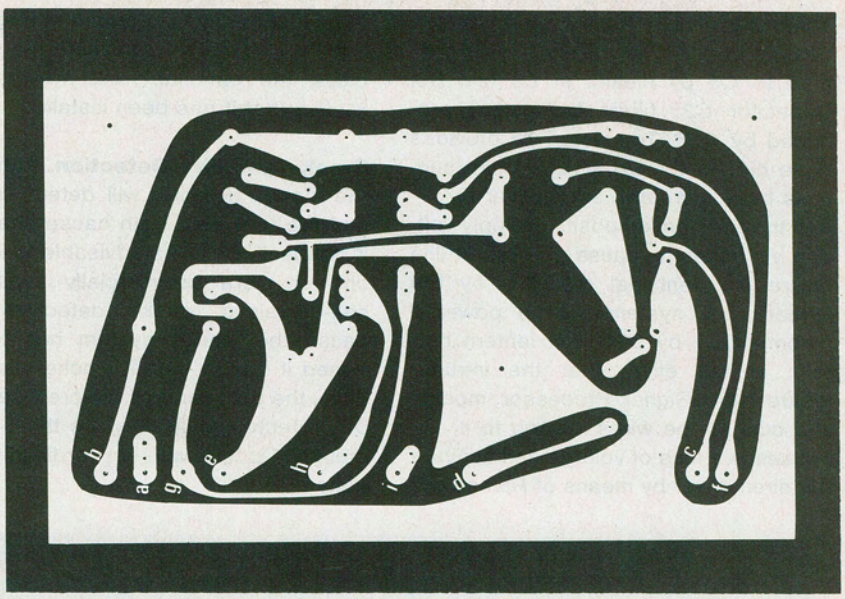
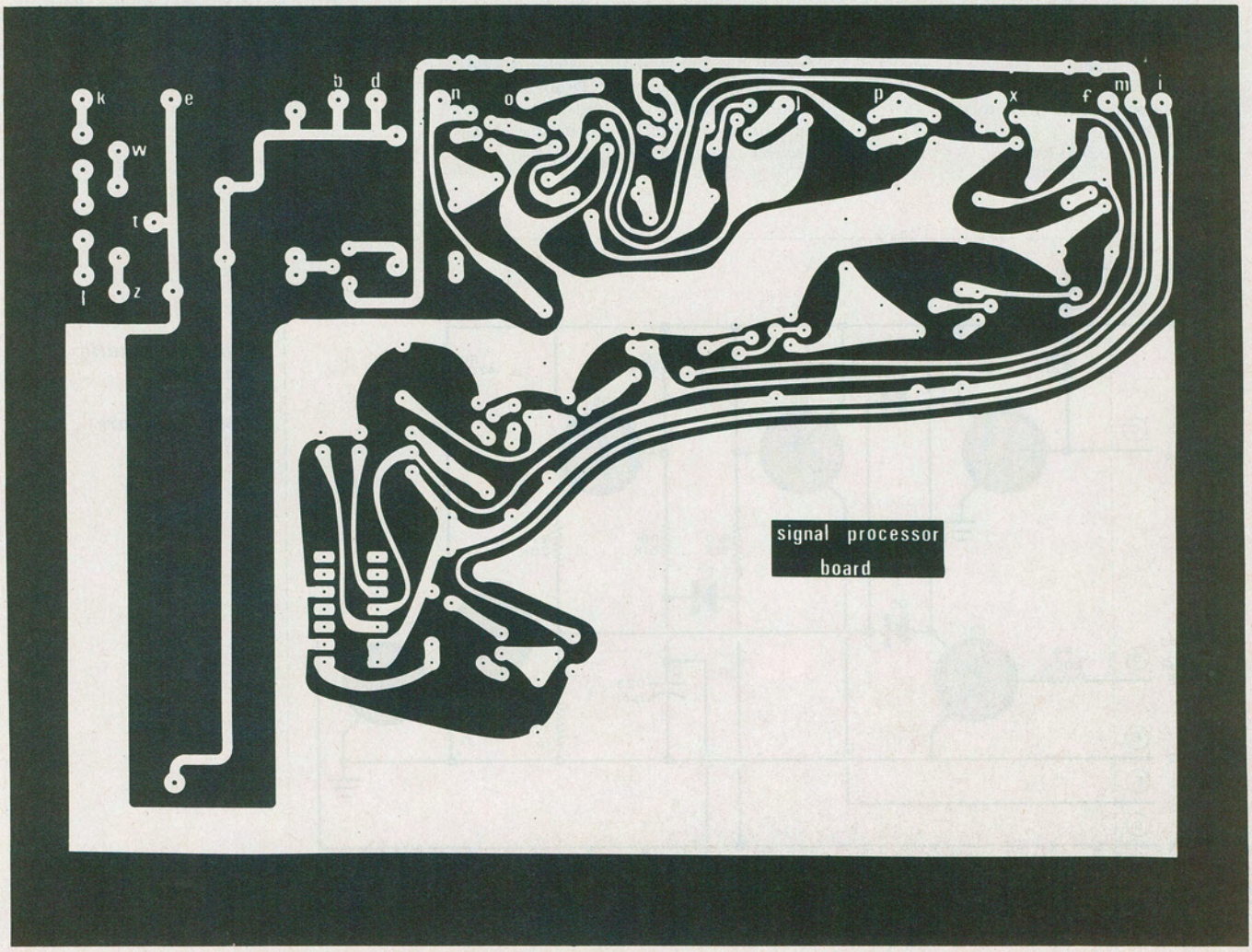


Fig. 6. Etching and drilling guide for the Siren Driver module's printed circuit board is shown above. Artwork for this and the other two pc boards on this page appears full-size.



schematically in Fig. 7. Signals appearing at the collector of *Q26* are coupled to *Q5* by means of *D6* and *R8*. Capacitor *C23* filters the pulses produced by *Q26*. Transistor *Q5* provides base current for *Q6* which in turn supplies base current to siren driver *Q7*.

If the line-derived positive supply voltage V+ is lost because of a power-line failure or intentional disabling by the intruder, the system will be powered automatically by a 12-volt lantern battery. In the event that the intruder locates the Signal Processor module and cuts all the wires leading to it, *Q3* will sense a loss of voltage and activate the siren driver by means of *R5* and *D5*.

Finally, if because of some emergency you want to instantly activate the siren, close the optional, PANIC switch, assuming that it has been installed.

Smoke and Fire Detection. Although the motion detector will detect smoke and fire (because both cause changes in ambient light), it is advisable to install one or more commercially available, self-contained smoke detectors because the Opdec system has to be armed if it is to detect smoke and fire. Thus, the occupants of the premises will be protected while they are there even though Opdec will not ordinarily be armed.

PARTS LIST FOR SIREN DRIVER MODULE

C23—1-μF, 25-volt electrolytic
D3—3-ampere, 100-PIV rectifier
D4 through D7—1N4001 rectifier
Q2,Q3,Q6—Sprague RT108 npn silicon transistor or equivalent
Q4,Q5—Sprague RT106 pnp silicon transistor or equivalent
Q7—Sprague RT114 npn silicon transistor or equivalent
The following are 5%-tolerance, ¼-watt, carbon-composition resistors.
R2—10,000 ohms
R3,R5,R9—20,000 ohms
R4—200,000 ohms
R6,R7—75,000 ohms
R8,R10—51,000 ohms
R11—30,000 ohms
R12—470 ohms
R42—360 ohms
Misc.—Siren (Vexon 160, Radio Shack 275-488 or equivalent), printed circuit board, standoff insulators, snap-on heat sink for Q7 (Wakefield 296040AB or similar), silicone thermal compound, suitable enclosure, 12-volt battery, barrier block terminal strip, etc.

PARTS LIST FOR MOTION SENSOR MODULE

C2,C5,C6—47-μF, 6-volt electrolytic
C3—0.22-μF, 6-volt tantalum
C4—0.01-μF, 50-volt disc ceramic
IC1—ULN-2232A Sprague Integrated Motion Detector
Misc.—Printed circuit board, standoff insulators, suitable enclosure measuring approximately 2¾" × 2⅛" × 1⅝" or 7 cm × 5.4 cm × 4.1 cm (Bud CU-2100-A or similar), barrier block terminal strip, hookup wire, solder, hardware, etc.

PARTS LIST FOR LIGHTNING SENSOR MODULE

C7,C10—47-μF, 6-volt electrolytic
C8—0.22-μF, 6-volt tantalum
C9,C11—4.7-μF, 6-volt tantalum
IC2—ULN-2232A Sprague Integrated Motion Detector
Misc.—Printed circuit board, standoff insulators, suitable enclosure measuring approximately 2¾" × 2⅛" × 1⅝" or 7 cm × 5.4 cm × 4.1 cm (Bud CU-2100-A or similar), barrier block terminal strip, hookup wire, solder, hardware, etc.

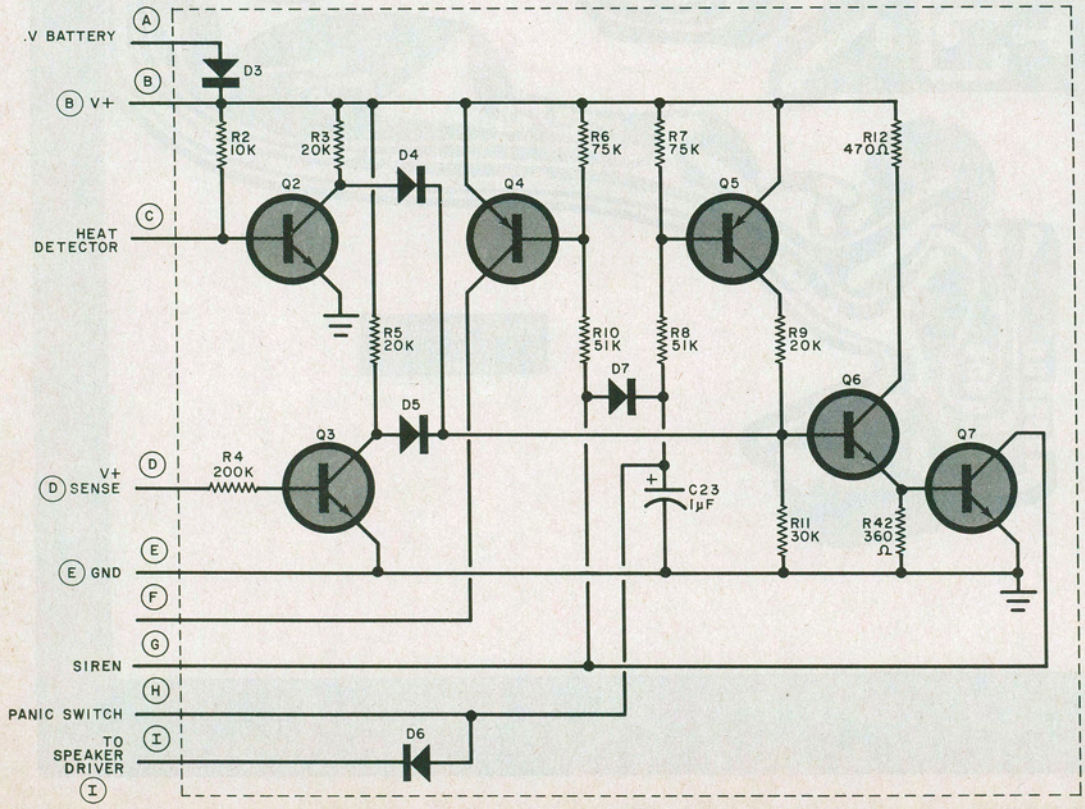
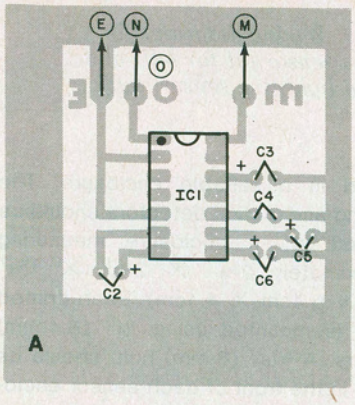


Fig. 7. Schematic diagram of Siren Driver module appears at left.



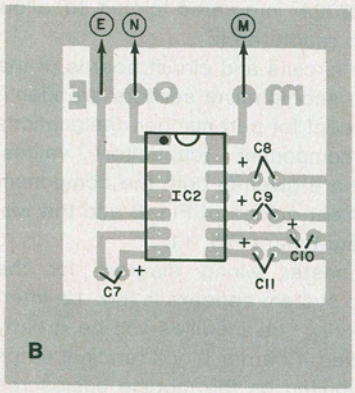


Fig. 8. Component placement guides for motion (A) and lightning sensor modules (B) appear above left. Also see Fig. 11.

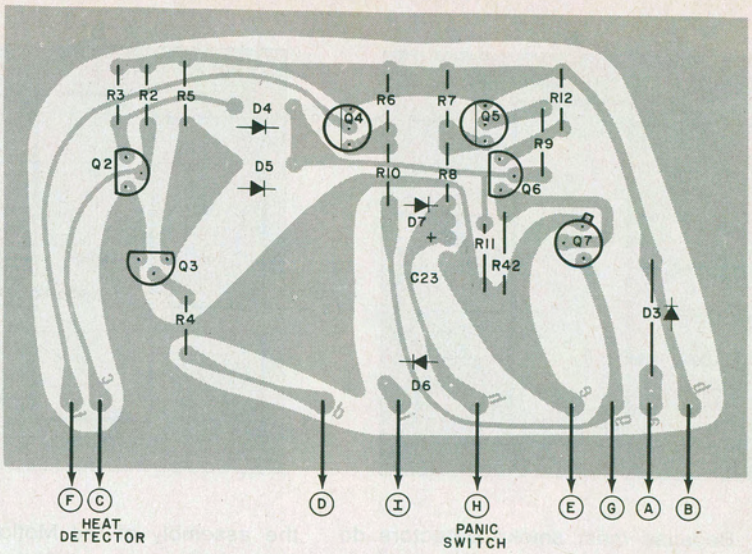
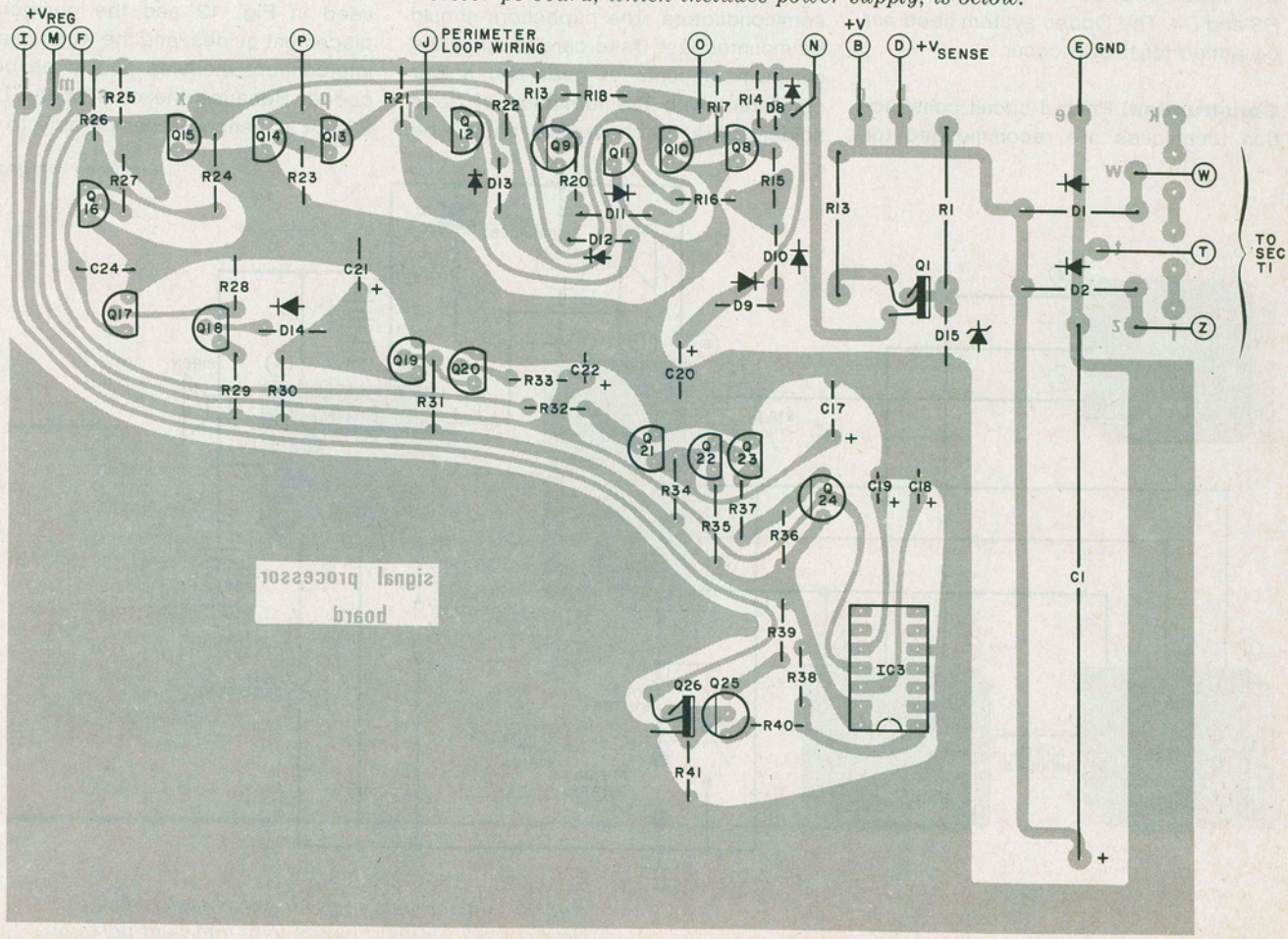


Fig. 10. Shown above is the component placement guide for Opdec system's Siren Driver module printed circuit board.

Fig. 9. Component placement guide for the Signal Processor pc board, which includes power supply, is below.



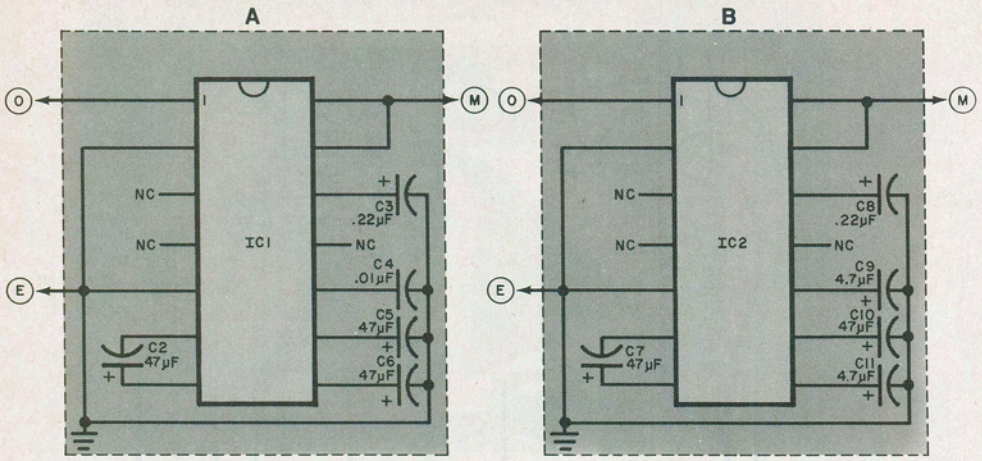


Fig. 11. Wiring diagrams for motion sensor (at far left) and special lightning sensor (left).

Because most smoke detectors do not detect fire, it is also wise to install heat detectors (available at most electrical supply houses) in areas where instant flare-ups could occur (i.e. furnace rooms, areas where paint and thinner are stored, etc.). These detectors, which behave like normally open switches, can be wired in parallel to point C of the Siren Driver module and ground. Whenever a heat detector attains a certain temperature, it behaves like a closed switch. It will then cut off *Q2*, which enables the siren driver via *R3* and *D4*. The Opdec system need *not* be armed for this to occur.

Construction. Printed circuit construction techniques are recommended for the assembly of the Motion Detector, Signal Processor, and Siren Driver modules. Full-size etching and drilling guides for printed-circuit boards for these modules are shown in Figs. 4, 5, and 6. The corresponding component placement guides appear in Figs. 8, 9, and 10. Note that there are two component placement guides in Fig. 8. The first (Fig. 8A) is the guide for the standard motion sensor, and the second (Fig. 8B) is for the lightning sensor that momentarily disarms the system and prevents false alarms.

Mount all resistors first, then the semiconductors. The capacitors should be mounted last. Take care to apply the minimum amounts of heat and solder consistent with the formation of good solder joints. Each module should be housed in a suitable enclosure. The lightning and motion detectors should be mounted in an enclosure measuring approximately $2\frac{3}{4}'' \times 2\frac{1}{8}'' \times 1\frac{5}{8}''$ (7cm × 5.4cm × 4.1cm). Each printed circuit is mounted using $\frac{1}{4}''$ (6.4-mm) spacers. A $\frac{5}{16}''$ (8-mm) hole should be drilled in the front of each sensor enclosure directly in line with the center of the ULN-2232A integrated circuit to allow light to reach the IC.

The circuits and circuit boards of the motion and lightning sensors are identical except for part number designations and component (capacitor) values. These are given in both the component placement guides of Fig. 8 and the wiring diagrams of Fig. 11.

A master wiring diagram for the Opdec system appears in Fig. 12. Interconnecting the modules will be greatly simplified if barrier block terminal strips are installed on the module enclosures and connected to the appropriate circuit board foil pads. The strips should be letter-coded to agree with the scheme used in Fig. 12 and the component-placement guides, and the wires used to interconnect modules should be color-coded. Because the cost of the ULN-2322A IC sensor is comparable to that

Continued from page 96

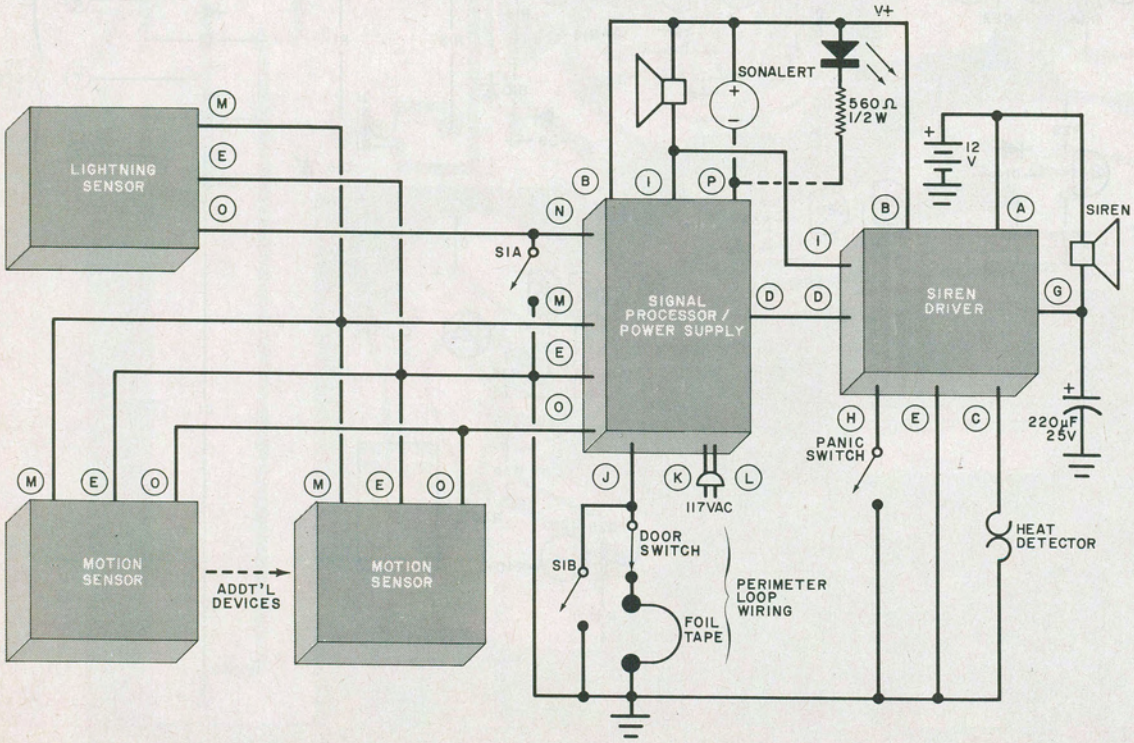


Fig. 12. Master wiring guide for complete Opdec system with optional closed loop and heat detector.

Alarm

(Continued from page 64)

of a quality magnetic reed switch, it can be used liberally throughout the premises to be protected. Each sensor module should be connected to the Signal Processor module using three lengths of flexible, stranded hookup wire (No. 22 or larger). Heavier gauge hookup wire (No. 18 or larger) should be used for the rest of the connections.

Installation and Use. The siren and the Siren Driver module should be installed in the attic or some other area where the intruder will not be able to locate it readily. The Signal Processor module can be mounted in any convenient area such as an entrance closet. As was mentioned earlier, any attempt to tamper with the Signal Processor module will set off the siren. The ARM/DISARM switch, *S1*, should be located in a convenient spot but not easily detectable by an intruder.

DESIGN SPECIFICATIONS
ULN-2232A
SPRAGUE INTEGRATED
MOTION DETECTOR

Supply voltage: +3.0 to +4.5 volts dc
Ambient temperature: +10°C to +40°C
Current demand: 20 mA maximum when V_{CC} equals +4.5 volts
Minimum sensing range: 8' (2.4 m)
Sensitivity: $\Delta L = \pm 5\%$ at 1 Hz
Ambient light: 0.1 fc to 100 fc (1.08 lux to 1076.4 lux or 1.08 lumens/m² to 1076.4 lumens/m²)
Alarm sweep: 200 to 1000 Hz
Alarm sweep rate: 5 Hz
Audio output: 100 mW continuous
Device fabrication: Monolithic IC containing linear amplifiers employing pnp and npn bipolar junction transistors; I²L gates, counters, and D/A converter; low-leakage photodiode; and bipolar junction power transistors.

The ideal number and location of Motion Sensor modules in your Opdec system depends on the size of your home or office and the number of areas that need protection. Sensor modules can be placed on kitchen counters, on TV receivers, or even mounted within a suspended ceiling into which a (5/16" or 8-mm) hole has been drilled. In deciding where modules are to be placed, keep in mind that they sense motion by detecting *changes* in light level. Therefore, do not aim a Motion Sensor module toward a window or any flashing lights. During the daytime, there should be suf-

ficient natural illumination to permit operation of the sensors. At night, however, some source of artificial light will have to be used. Readily available photoelectric or electromechanically timed devices can be employed to automatically turn on such lights at dusk. Make sure that the artificial light sources are *simultaneously* activated and that one of them is placed near the lightning detector. This module will momentarily disarm the system, thus preventing the Motion Sensor modules from triggering the Signal Processor when power is applied to the lamps.

Options. Depending on factors peculiar to each site at which an Opdec system is to be installed, there are several optional changes that can be made. For example, if you think that lightning or some similar phenomenon is not a problem in the area to be protected, simply eliminate the lightning detector. Also, you can mount a key-operated dpst switch outside the premises to be protected for use as *S1*. If this is done, the exit and entry delays will no longer be needed. Accordingly, the following Signal Processor components can be eliminated: transistors *Q8*, *Q10*, and *Q11*; diodes *D8*, *D9* and *D10*; resistors *R14*, *R15*, and *R16*; and capacitors *C17* and *C20*. If this is done, connect the position lug of both portions of the dpst switch to point E. Connect one switch pole to the base of *Q13* and the other pole to that of *Q15*.

If you prefer to have the alarm remain on indefinitely after the system has been triggered, eliminate the automatic timeout feature. This is done by omitting the following Signal Processor components: transistors *Q17* through *Q20*; diode *D14*; resistors *R28* through *R31*, and *R33*; and capacitors *C21* and *C22*. Finally, if a back-up battery power source is not needed, the Siren Driver module, the siren, and the battery can be eliminated. If this is done, the collector of *Q26* (point I) can be used to sink current from the positive supply through a dynamic loudspeaker to ground.

In Conclusion. Opdec is an inexpensive but sophisticated alarm system that can enhance the security of business or residential premises. Its optical sensors can detect not only intruders but also smoke of fire. The system is thoughtfully designed and is readily expanded to include heat detectors, closed-loop sense wiring, and a large number of optical Motion Sensor modules. ◇