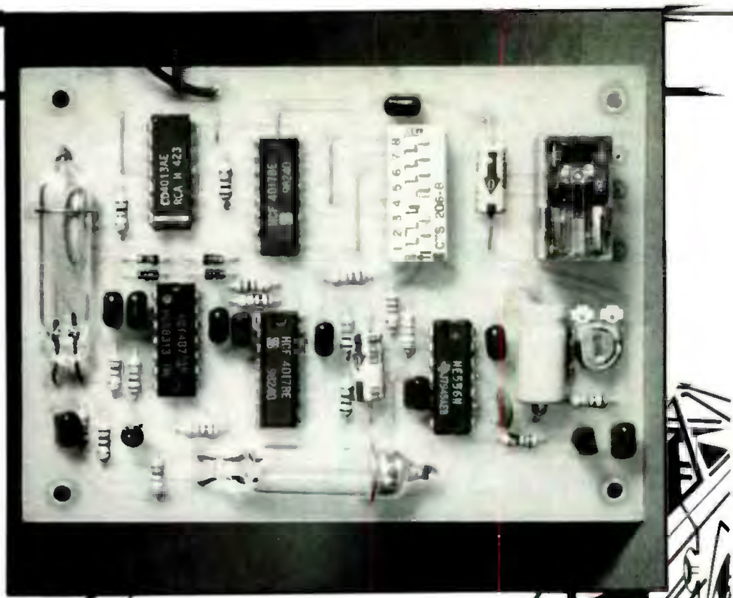
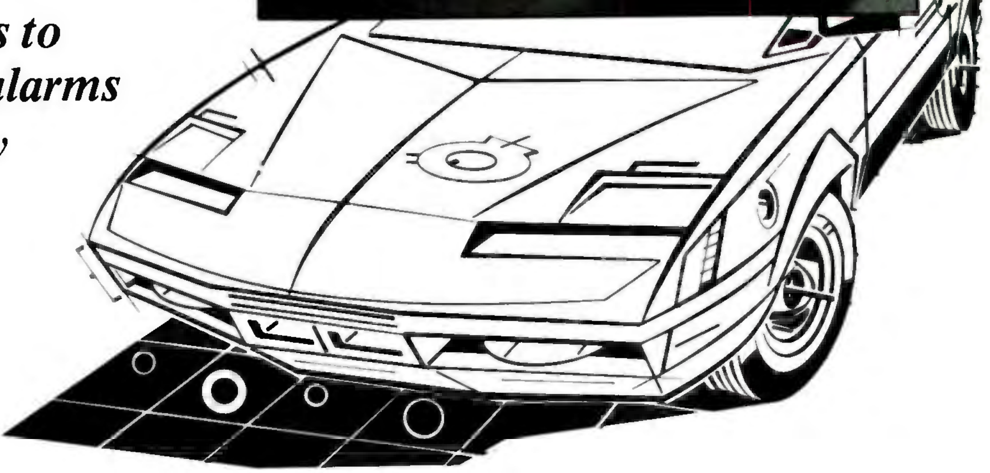
Super-Sensitive Tilt Switch For Automotive Alarms





Uses mercury switches to protect against false alarms generated by ordinary vibrations

By Walter W. Schopp

Automotive alarm tilt/motion switches usually consist of a spring-steel blade attached to a fixed block and a weight on opposite ends. Any motion other than unauthorized entry or an attempt to tow the vehicle is likely to trigger the alarm. Such a sensor installed in a truck that has heavy-duty springs requires a thief to weigh at least 300 to cause enough motion to trip the alarm. Such a sensor installed in a small car that has weak springs can trigger the alarm if a gust of wind buffets the car. Also, the exposed contacts under the hood are vulnerable to oxidation or coating with oil and/or grime, either of which can prevent contact and cause the alarm to fail to sound.

Sensitive mercury switches can make excellent sensors for motion detection, assuming some inherent problems can be overcome. Because mercury switches had to always be open before the alarm could be triggered, if you parked on a grade, one or both switches were likely to close, negating the utility of the alarm. This is not the case with our Super-Sensitive Tilt Switch.

It makes no difference if the mercury switches around which this project is built are open or closed when the alarm is armed. The project establishes the status of the switches and then senses only a *change* in status after arming. So, regardless of whether a switch is open or closed, closing or opening it generates a trigger pulse. Mounting two mercury switches 90° with respect to each other, permits motion to be detected in two different directions. This is a considerable improvement over the single-direction sensing of blade-type switches.

Our Super-Sensitive Tilt Switch has a clocked control circuit that triggers to permit a number of false alarms to occur within a predetermined time without setting off the alarm. When the alarm is armed, a relay energizes for a time that is adjustable from 10 seconds to 2 minutes 30 seconds and then resets. A relay provides contacts that permit the Tilt Switch to be used with alarms that are normally open and close to trigger an alarm or normally closed and open to trigger an alarm condition. You simply wire your present alarm system to the project via the appropriate relay contacts.

About the Circuit

The complete schematic diagram of the Super-Sensitive Tilt Switch circuitry is shown in Fig. 1. This circuit operates on a internal clock that produces a pulse signal that releases the stored input disturbance signal. The same signal divided by 10 provides a reset signal for the time window that permits a certain number of disturbances to be recognized in a timed period before the alarm actually responds. The same integrated circuit is also used to provide the timed output for the alarm.

Each time mercury switch *S1* or *S2* opens or closes, one of the gates to which it connects produces a positive-going output. This positive-going output couples through the corresponding capacitor (*C2*, *C3*, *C13* or *C14*) to its respective diode (*D1*, *D2*, *D3* or *D4*). The diodes prevent the positive spike from being attenuated by a negative charge on one of the capacitors from the other gates. When the unit is turned on, the status of the switches is established in the "as-is" condition.

When the status of one mercury switch changes, the positive pulse from one of the *IC1* gates is fed to "one and only one" flip-flop configuration *IC3*. The input of *IC3* is pulled down by *R18* so that it will respond only to positive pulses. The input pulse sets the first flip-flop in *IC3*, which remains set until a clock signal is received, at which time an output pulse is transferred to the next stage and the one and only one is reset. This prevents the circuit from responding to a large number of pulses produced when the vehicle is rocked once and produces only a single disturbance signal during the 1-second clock period.

The output from *IC3* is one clock pulse long and is applied to the input of decade counter *IC4*. Each time *IC4* is clocked by a disturbance of the mercury switches, its output is advanced one step. The 0 to 7 outputs of *IC4* are brought out to DIP switch *S3*. Setting of this switch permits the first to the eighth output to be recognized. The 1-second clock pulses used to trigger *IC3* are divided by 10

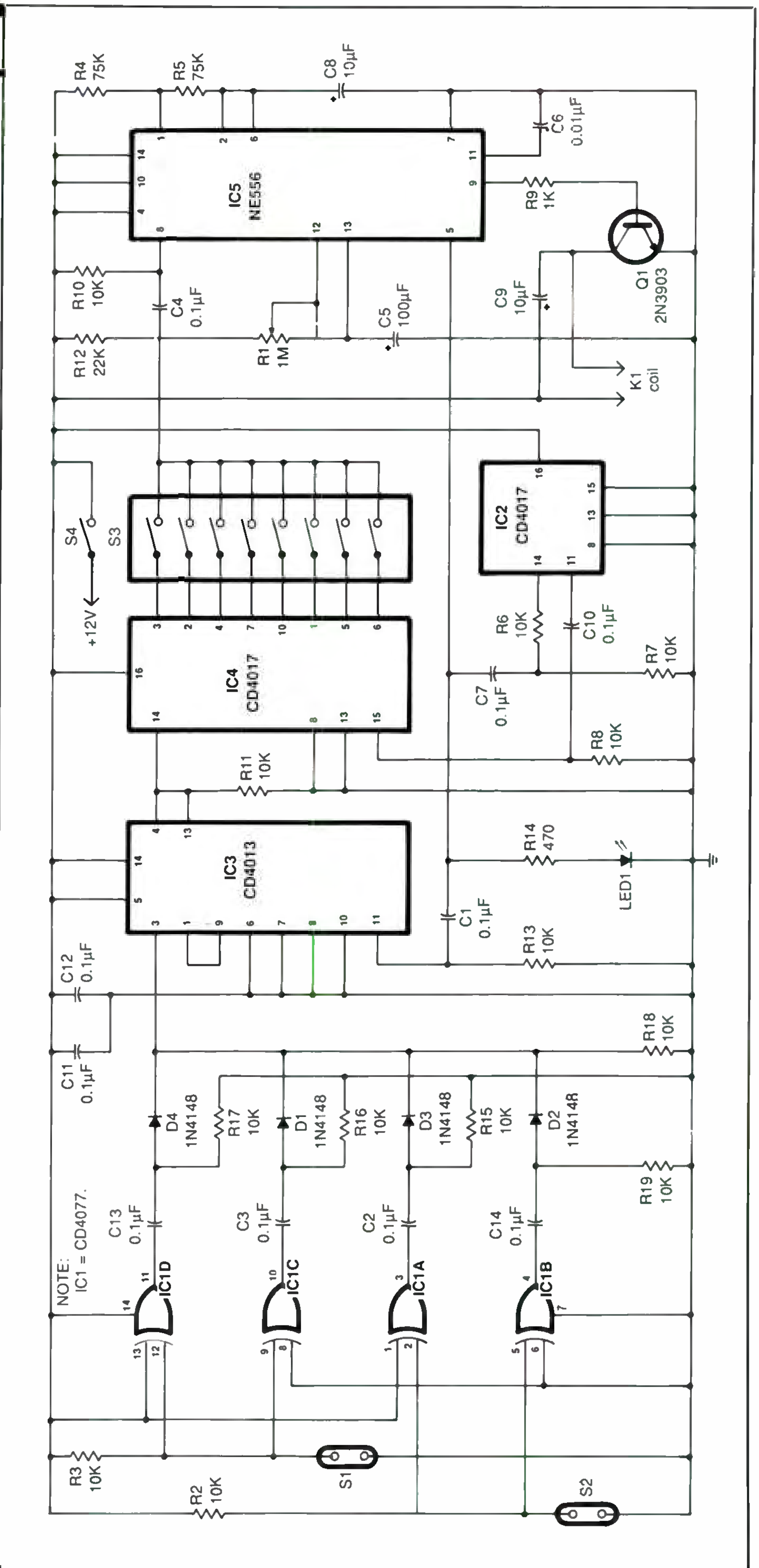


Fig. 1. Schematic diagram of circuitry used in Super-Sensitive Tilt Switch.

PARTS LIST

Semiconductors
D1 thru D4—1N4148 or 1N914 signal diode
IC1—CD4077 quad XOR gate
IC2,IC4—CD4017 decade counter
IC3—CD4013 dual-D flip-flop
IC5—NE556 dual timer
LED1—Any light-emitting diode
Q1—2N3903 or similar general-purpose npn silicon transistor

Capacitors
C1 thru C4,C7,C10 thru C14-0.1-µF, 50-volt ceramic disc
C5—100-µF, 16-volt electrolytic
C6—0.01-µF, 50-volt ceramic disc
C8,C9—10-µF, 25-volt electrolytic

Resistors (¼-watt, 10% tolerance)
R2,R3,R6,R7,R8,R10,R11,R13,R15 thru R19—10,000 ohms
R4,R5—75,000 ohms
R9—1,000 ohms
R12—22,000 ohms
R14—470 ohms
R1—1-megohm, pc-mount trimmer potentiometer (Digi-Key Cat. No. K4A16 or similar)

Miscellaneous
K1—12-volt dpdt relay (Aromat No. HB212—Jameco Cat. No. HB212)
S1,S2—Mercury switch (available from Electronic Enterprises for $10 per pair ppd.)
S3—Eight-position DIP switch
S4—Key switch (see text)
Printed-circuit board or perforated board with holes on 0.1" centers and suitable Wire Wrap or soldering hardware (see text); suitable enclosure (optional); sockets for all ICs; automotive crimp-on splice connector (optional—see text); foam plastic tape or silicone adhesive (see text); rubber grommets; spacers; ring or spade lugs and outside-tooth lockwashers (see text); machine hardware; stranded and solid hookup wire; solder; etc.

Component Sources

Digi-Key Corp.
701 Brooks Ave., P.O. Box 677
Thief River Falls, MN 56701-067
Tel.: 1-800-344-4539

Electronic Enterprises
3305 Pestana Way
Livermore, CA

Jameco Electronics
1355 Shoreway Rd.
Belmont, CA 94002
Tel.: 415-592-8097

by *IC2*, with the resulting signal used to reset *IC4* every 10 seconds.

The output from the counter is pulse coupled through *C4* to one half of dual timer chip *IC5*. The timer input is pulled up by *R10* and responds to only negative pulses. This prevents the timer from responding to the counter when it is reset and a positive output is applied to the 0 output of the counter. When the disturbance signal causes the output of the counter to move from its 0 to the 1 output, a negative-going signal is produced that triggers the timer.

When the timer is tripped, a positive output is applied to the base of *Q1* through *R9*. This sends *Q1* into conduction and energizes relay *K1*. The relay remains energized for a period determined by the time constant of *R1*, *R12* and *C5*. Resistor *R12* sets the minimum timer period.

The other half of dual timer *IC5* generates the 1-second clock pulse. Timing of this pulse is determined by the values used for *R4*, *R5* and *C8*. Light-emitting diode *LED1* provides visual indication that the 1-second clock is operating. Thus, it can be used to adjust this timing. Adjustment is done by changing the resistance values of *R4* and *R5* or by changing the capacitance value of *C8*. The frequency of the generator is determined using the formula $F = 1.44/[(R4 + 2R5) \times C8]$.

When position 1 of *S3* is closed, the alarm triggers on the first mercury-switch disturbance. With *S3* in this condition, ultimate sensitivity is achieved. This mode can be used in situations where there is no possibility of movement unless it is authorized. This mode could trigger many false alarms caused by wind gusts when used on a automobile or trailer. If position 8 of *S3* is closed, the circuit permits seven disturbances of the mercury switches within a window time of 10 seconds without the alarm going off. On the eighth disturbance, the alarm triggers. Any closing of positions 2 through 7 of *S3* provides a reliable system free of false alarms.

Construction

There is nothing critical with regard to building the Super-Sensitive Tilt Switch. Therefore, you can use any wiring technique with which you feel comfortable, though printed-circuit assembly is recommended in the rigorous automotive environment.

If you wish to assemble your circuit on a pc board, use the actual-size etching-and-drilling guide shown in Fig. 2 to fabricate the board. Alternatively, if you prefer point-to-point wiring, use perforated board that has holes on 0.1-inch centers and suitable Wire Wrap or soldering hardware. Whichever wiring technique you use, it is a good idea to socket all DIP ICs. Use premium sockets that provide sure-grip seating for the chips.

From here on, we will assume you are assembling your circuit on a pc board. With this in mind, refer to Fig. 3 for details on where to install the various components and how they are to be oriented. (If you go the point-to-point wiring route, use Fig. 3 as a rough guide to component layout and refer back to Fig. 1 for wiring details.)

Begin wiring the board by installing and soldering into place the wire jumpers at the locations indicated in Fig. 3. Seven jumpers in all must be installed. You can use solid bare or insulated hookup wire for the jumpers. Note that the sockets for *IC3* and *IC4* fully or partially cover two of the jumper wires previously installed.

Say You Saw It In Modern Electronics

Do *not* plug the ICs into the sockets until after you have conducted voltage checks and are certain that the board is properly wired.

Once the jumpers are in place, install and solder into place the five IC sockets. Make sure when soldering the pins of these sockets to the copper pads on the bottom of the board that you do not create any solder bridges. Clear any solder bridges as you go along with a vacuum-type desoldering tool or desoldering braid.

Next, install and solder into place the resistors. This done, install and solder into place the capacitors and diodes, making sure that the electrolytic capacitors and diodes are properly polarized before soldering their leads into place. Making sure you properly orient the LED, plug its leads into the holes provided for them in the board and position the LED so that the bottom of its case is approximately ⅛ inch above the surface of the board. Solder both leads to the copper pads on the bottom of the board.

Install and solder into place trimmer resistor *R1* and set it for about middle of rotation. Then install and solder into place the relay, and follow up with the transistor. Make sure the latter is properly based before soldering its leads into place.

Strip ¼ inch of insulation from one end and ½ inch of insulation from the other end of separate 6-foot lengths of red- and black-insulated stranded hookup wires. Do the same for three more 6-foot lengths of any other color insulation stranded hookup wires. Tightly twist together the exposed fine conductors at both ends of all wires and sparingly tin with solder.

Plug the free end from which the ¼ inch of insulation was removed from the black-insulated wire into the hole labeled GROUND and solder into place. Repeat the procedure with the red-insulated wire and the hole labeled +12V. Then plug the ends from which the ¼ inch of insulation was removed from the remaining wires into the holes labeled COM, N.C. and N.O. and solder these into place.

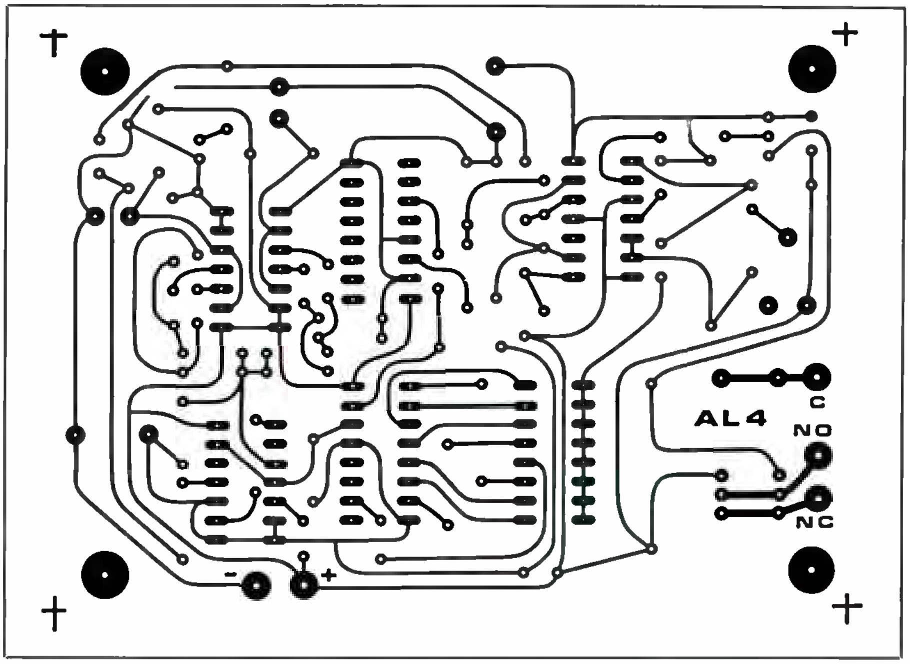


Fig. 2. Actual-size etching-and-drilling guide to use for fabricating printed-circuit board.

The last items to be installed on the circuit-board assembly are the mercury switches. When handling these, use care to prevent shattering them and releasing the toxic liquid mercury. Any mercury switch can be used in this project, as long as it fits into the limited space provided on the circuit-board assembly.

Cut two strips of foam plastic tape to dimensions of 1¼ long by ⅜ wide. Peel away the protective strip and use the adhesive backing to secure the two pieces of tape to the board in the areas where the mercury switches are to mount.

Next, gently bend the leads on both switches to form a 90° angle to the glass envelopes. Plug the leads of the switches into the appropriate holes on the board but do not solder into place yet. Plug the ends of a 4-inch length of bare solid hookup wire into the holes provided for *S1* so that the wire crosses the glass envelope. While holding the wire against the envelope, loosely twist together the free ends of the wire on the other side of the board. Do *not* make the wire cinch tight enough to cause the switch to press hard into the foam tape. It should gently hold the switch in place. Solder the wires to the pads on the bottom of the board and clip away the excess. Then solder the leads of the switch to their pads. Repeat the procedure for *S2*.

It is important that you do not omit the cinch wires. Not only do these wires mechanically secure the switches into place, they also provide electrical paths that complete the wiring on the solder side of the board. The foam-tape strips provide shock mounting for the switches. If you wish, you can substitute beads of silicone adhesive for the foam tape.

If you wish, you can mount the circuit-board assembly inside an enclosure that comfortably accommodates it. You can use an all-plastic or all-metal enclosure or an enclosure that is basically plastic and has a metal panel. Machine the enclosure to provide mounting holes for the circuit-board assembly and entry/exit holes for the wiring. If you use a metal enclosure, deburr the holes drilled for the cables to remove sharp edges and line them with small rubber grommets.

Checkout & Installation

Make sure no ICs are plugged into the sockets. Clip the common lead of a dc voltmeter or multimeter set to the dc-volts function to circuit ground. Connect the power leads of the project to a source of 12-volt dc power. This can be either a bench power supply or the electrical system of your motor vehicle.

Touch the "hot" probe of the meter to pin 8 of the *IC1* socket, pin 16 of the *IC2* and *IC4* sockets, pins 5 and 14 of the *IC3* socket, and pins 4, 10 and 14 of the *IC5* socket. In all cases, you should obtain a meter reading of approximately + 12 volts. If you fail to obtain this reading at any point mentioned, disconnect power from the project and rectify the problem before proceeding.

When you are certain that the board has been properly wired, disconnect power from it. Plug the ICs into their respective sockets, handling them with the same care you would exercise for any other MOS device. Make sure each IC is properly oriented and that no pins overhang the socket or fold under between IC and socket.

Mount the circuit-board assembly inside the enclosure, using ¼-inch spacers and 4-40 × ¾-inch machine screws, lockwashers and nuts. Tie strain-relieving knots about 6 inches from the circuit-board assembly in the power and signal cables and feed the free ends of the cables through their holes in the enclosure.

Power up the project once again and check *LED1* to determine if the 1-second clock is working. Check pin 15 of *IC4* for a positive pulse every 10 seconds or 10 clock pulses. If this clock signal is present, the Tilt Switch is functioning properly. Closing position 1 of *S3* should cause the relay to energize on the first clock pulse after the disturbance. When using this Tilt Switch, make sure only one position of *S3* is set to "on" and all other positions are set to "off." Otherwise, the Tilt Switch will respond to the lowest setting of the DIP switch.

Once you have ascertained proper operation of the Tilt Switch, select a mounting location for the project. This can be in a convenient location inside the engine well or in the passenger compartment behind the dashboard or other concealed location. Just make sure that you have access to the electrical system of the vehicle where power to it cannot be cut without triggering an alarm and the existing alarm inputs.

Mount the project in the selected location so that it is level, with the top of the circuit-board assembly facing up. Make sure the vehicle is level to obtain best operating conditions.

Connect and solder spade or ring lugs to the ground, N.O. and N.C. leads from the project. Do not at this time terminate the + 12V lead. Use an existing screw in your vehicle or trailer to secure the ground leads to chassis ground, using an existing screw in your vehicle or trailer. After removing the screw, sand the area around the hole with fine emery cloth to obtain shiny bare metal. When securing the two spade or ring lugs into place with the screw, sandwich an outer-tooth lockwasher between the chassis and lower lug to assure a solid electrical connection.

Determine the requirements of the input to your alarm. If the alarm requires a switch closure to trigger, use the normally-open (N.O.) lead from the project to make the connection. If it requires a switch to open to trigger an alarm, use the normally-closed (N.C.) lead.

Switch *S4* shown in Fig. 1 is used for arming the Tilt Switch by supplying 12-volt power from the electrical system of your vehicle. This can be an externally mounted key switch that you turn on after the vehicle or trailer has settled down. The best location for the switch is the rear of the hood on the driver's side or on the panel between the door and the hood. On a trailer, mount this switch in any location where it can be accessed without disturbing the trailer.

Once the arming switch has been mounted, crimp and solder the free

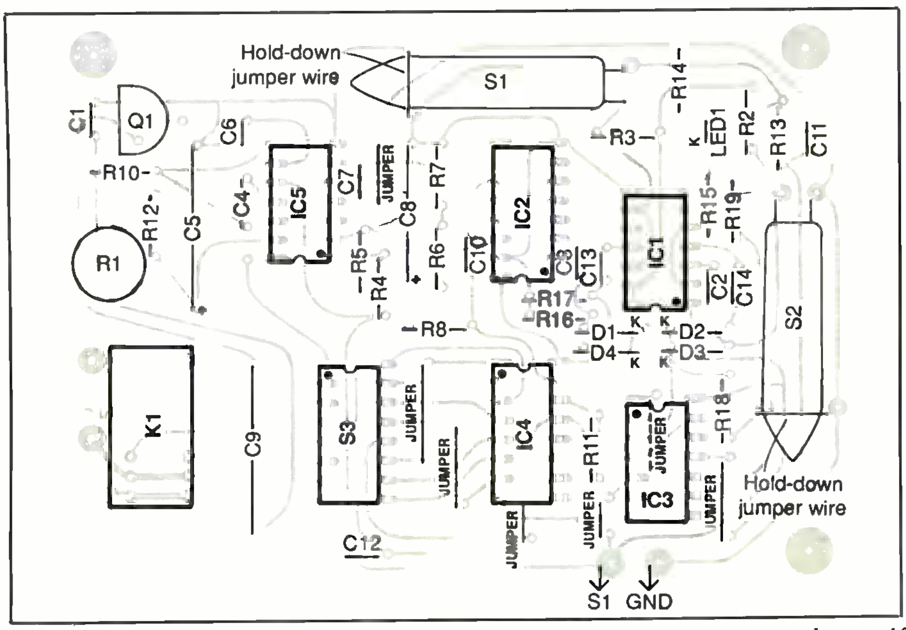


Fig. 3. Wiring guide for pc board. Use this as a rough guide component layout if you point-to-point wire the circuit.

end of the + 12V wire from the project to one of its lugs. Then use another length of stranded hookup wire, prepared as described above, to bridge between the other lug of the switch and an electrical line that is live with + 12 volts at all times, regardless if the ignition is switched on or off. Make the connection to this line using an automotive splice connector or directly by soldering it to the + 12-volt wire. If you go the latter route, cut the + 12-volt line of the vehicle's electrical system and strip ⅜ inch of insulation from both cut ends. Tightly twist together the cut ends and the free end of the wire coming from *S4*. Solder the connection and completely insulate it with electrical tape.

With the Super-Sensitive Tilt Switch installed in your vehicle or trailer and connected to its alarm system, you can be sure of solid protection against unauthorized intrusion and towing—without the annoyance of false alarms. **ME**