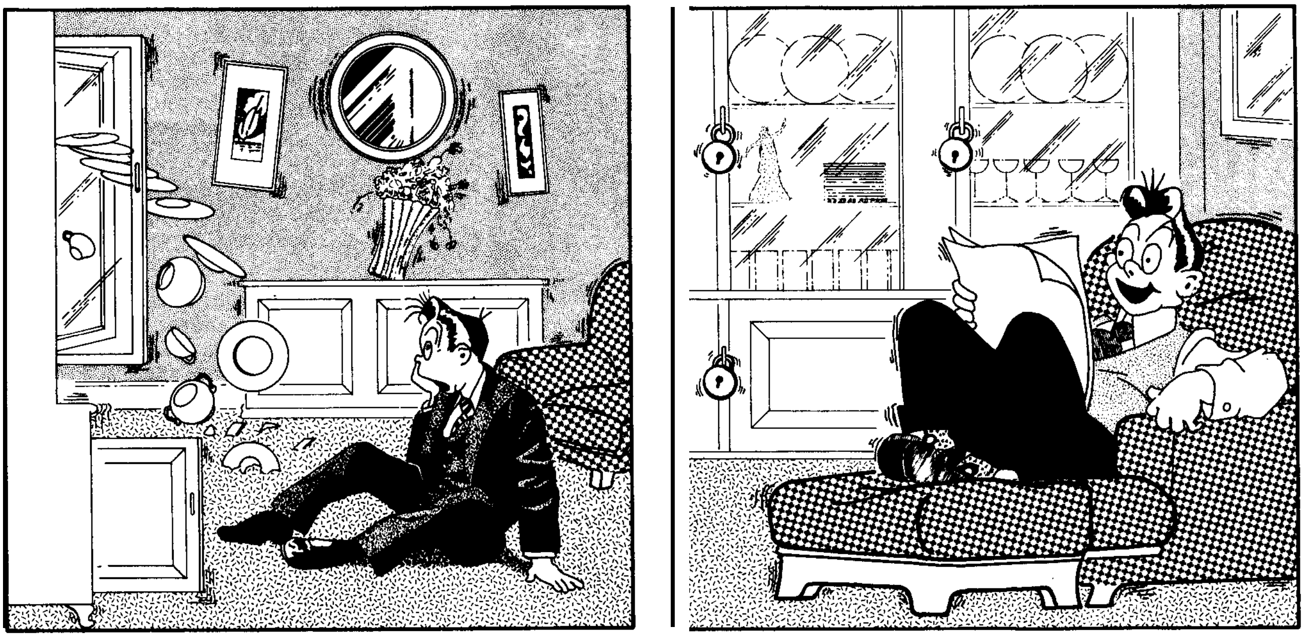
BUILD AN EARTHQUAKE DETECTOR



If you live in an earthquake zone, this vibration sensor can save your property or your life. If not, it can be used as a burglar alarm, intrusion detector, or a game of skill.

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For many of us that live in a seismically active region, an earthquake is a very real and constant threat. Even moderate earthquakes that are not strong enough to hurt anyone can cause a significant amount of damage to the contents of your house if you are not prepared. Although earthquake prediction has made great strides over the years, it is still very much an art form rather than a science. Earthquakes can strike without warning, and when they do, you do not have time to lock the kitchen cabinets or turn on any emergency lighting, much less find suitable shelter. If those steps can be done automatically at the first sign of an earthquake, property destruction and personal injury can be avoided or minimized.

The Earthquake Detector described here is the heart of such an automatic system. The author uses this device to automatically latch all of the kitchen cabinets when an earthquake strikes. The circuit can also be used as a burglar or impact alarm when mounted in a car. When mounted to a garbage can, It can sound a loud alarm if an animal tries to get into the container, A self-contained alarm unit can also be used as a simple game to see how far and how fast someone can carry the device before it triggers.

How It Works. A seismograph, which most people are aware of, is a device that measures and records the amount of seismic activity on a strip or drum of paper using vibrating pens, The sensors for that device usually consist of some type of suspended weight with a way to measure how much it moves when the sensor is shaken. The same method is used for the Earthquake Detector. A weight, in the form of a screw, is suspended on the end of a spring. The head of the screw passes through the center of a metal ring. When the sensor starts to shake, the spring and screw start to swing back and forth like a pendulum. As long as the shaking continues, the swing of the screw will keep increasing as the spring keeps absorbing mechanical energy. At some point the screw head will touch the metal ring, completing a circuit between the spring and the ring.

Since the actual contact time of the vibration sensor is very short, a retriggerable timer circuit is used to create a usable control signal. As long as the vibration sensor keeps opening and closing its contact, the timer will keep resetting itself to the beginning of its timing cycle, and the output of the timer will remain active. Once the vibrations stop and the energy in the spring is dissipated, the timer will remain active until the end of its timing cycle; only then will it turn the output off. If the sensor is damaged and is closed continuously, the timer circuit simply times out, turning the output off.

The output of the timer circuit controls a relay, That lets the unit be very versatile when controlling other devices. The switched load is limited only by the rating of the contacts in the relay itself.

When the circuit is activated, a flip-flop turns on an LED, which will remain on after the circuit times out. Only pressing a reset switch will turn the LED off. That will show if the circuit was set off at any time since the reset button was last pressed.

The earthquake sensor uses all CMOS ICs, giving the unit a very low current draw when the detector is not triggered, To be more specific, the standby current load Is less than one microamp, rising to 40 mA while the relay is energized and dropping to 5 mA when just the LED is on

Circuit Description. The schematlc diagram for the Earthquake Detector is shown in Fig. 1. When power is first applled through J1, Cl is charged through R1. During constant shaking, S3 (the vibration sensor) closes, letting Cl dump its charge to the timer circuit. As S3 opens, Cl is quickly recharged. In case S3 is damaged during a severe shaking and remains permanently closed, Cl will not be able to charge.

The timer circuit itself is built around IC1, a CD4536 programmable timer. That particular device was chosen because of its versatility, It is especially useful for providing long time delays (up to 23 hours) with good repeatability. It uses an internal 24-stage binary ripple counter to achieve those long delays without the need for a large capacitor value, which is typically used when trying to achieve a long timing period with an RC-based circuit such as an LM555.

The timing period of IC1 is set with R4-R6 and C2. The values used let the output period be adjustable from about 30 seconds to 10 minutes. If a trigger pulse occurs during the timing cycle, the 24-stage ripple counter resets, reinitializing the timing cycle. That way, the output remains on during the entire event and extends past the last trigger by the set time. For example, if the timing period is set to 1 minute, a 3-minute earthquake will activate the output for a total of 4 minutes.

The output of IC1 is buffered by IC3-a, an inverter gate, The signal then splits between IC2-a and Q1. The transistor operates RY1, whose contacts are brought out to J2. Having both a normally-open and a normally-closed contact gives the circuit flexibility in controlling other devices. The flip-flop (IC2-a) is the trigger-memory circuit that latches on when IC1 activates. The output of IC2-a drives LED1 through IC3-b.

Test button S2 is in parallel with vibration detector S3 and provides a means to test the operation of the circuit. Reset button S1 will reset IC1 if it is active, and also resets IC2, so that LED1 will go out as well.

The circuit is designed to run at 12 volts, but can be used at any voltage between 3 and 18 volts. If the circuit will be used at a voltage level other than 12 volts, the unit specified for RY1 must be replaced with a unit with the proper voltage rating for its coil. A different value for R7 also must be calculated so that the current flowing through LED1 is limited to 5 milliamps.

Building the Earthquake Detector. Circuit construction is not critical; any suitable construction technique can be used. The only important point to keep in mind is the type of environment that the detector will be used in-it should be able to work while being shaken. Because of that, sockets for the ICs are not a good idea.

The circuit will fit nicely on a single-sided PC board. If you wish to make your own, a foil pattern has been supplied. Alternatively, an etched and drilled PC board can be purchased from the source given in the Parts List. If you use either of those sources for the PC board, use the parts-placement diagram in Fig. 2 for locating the various components.

In general, the easiest way to build the board is to start with the

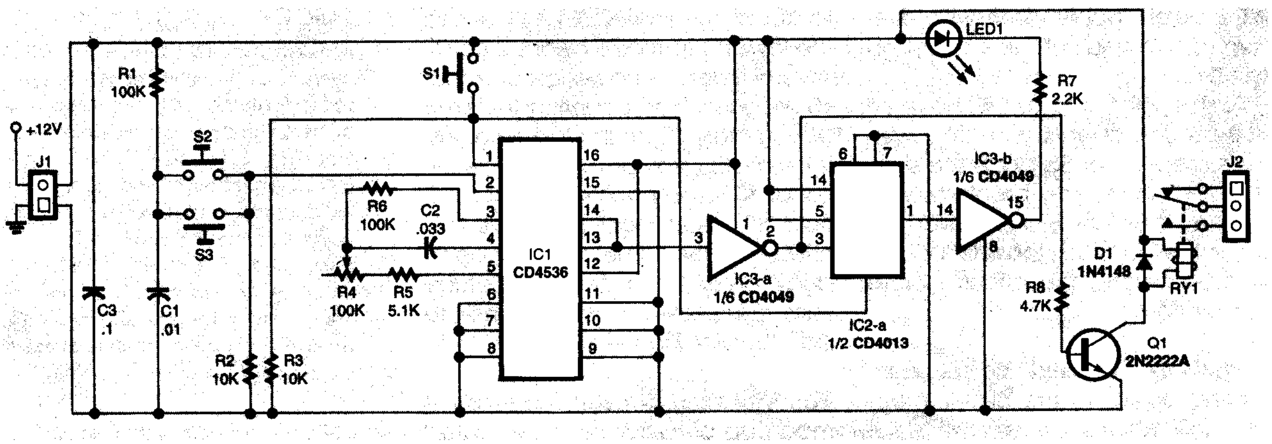


*Fig. 1. The Earthquake Detector is built around a programmable timer chip that can be reset while timing out to extend the overall timing period. A **flip-fop** latches an LED to indicate if the circuit has been activated. Using CMOS technology keeps the current drain incredibly low.*

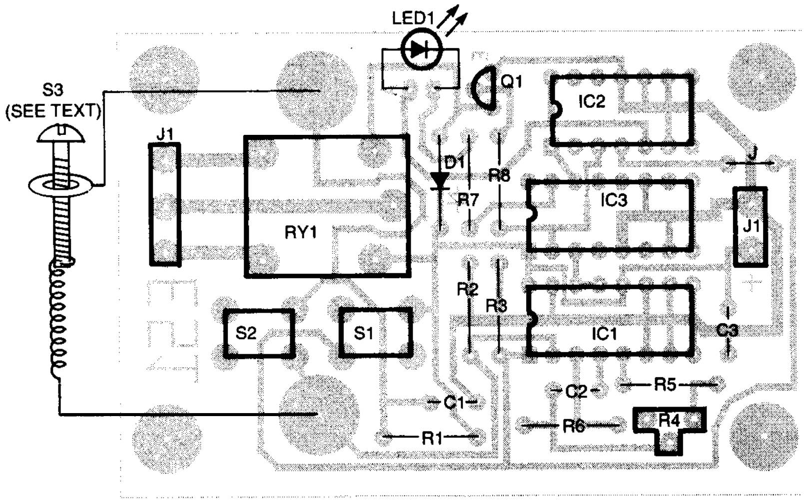


Fig. 2. Use this parts-placement diagram when assembling the Earthquake Detector. Don't forget the small jumper next to J1.

shortest parts first, and then work your way up to the taller ones. Note: do not install S3, which is located on the solder side of the board, until you are instructed to do so. When using that method, the diodes and resistors would be installed first, followed by the capacitors, ICs, transistors, etc. The installation of the relay and connectors would complete the job. One of the scrap resistor leads can be used for the single jumper next to J1. While you are building the board, keep in mind that CMOS ICs are very sensitive to static electricity-take the proper handling precautions.

Although screw-type connectors are indicated for J1 and J2, you might want to solder those connections for greater reliability. If you do decide to go that route, use heavy-gauge stranded wires for the power supply and whatever mechanism you will be controlling with RY1.

At this point, you should have all of the components mounted with the exception of S3. Since it is easier to test and fix any problems with the circuit before S3 is installed on the solder side of the PC board, we'll be testing the circuit before completion.

Preliminary Testing. Before connecting power to the circuit, measure the resistance across J1; it should measure about 3 megohms in one direction and 17 megohms in the other. If the high reading is closer to 30 megohms, Q1 might be reversed. If the readings are not significantly lower than those values, connect the power and turn the unit on. Pressing S2 should activate RY1 and light LED1. Pressing S1 should release RY1 and clear LED1. Set potentiometer R4 to its lowest resistance. Press S2 again; RY1 should stay on for about 30 seconds. With R4 set to its maximum resistance, the on time should increase to about 10 minutes. Set R4 back to the lowest resistance again. Press S2 several times over a period of about 10 seconds. Start counting the time as you press S2 for the last time. The relay should stay active for an additional 30 seconds. Finally press and hold S2. Keep holding it until RY1 releases; the time should once again be 30 seconds. With all of the tests completed, it is now time to add the vibration sensor.

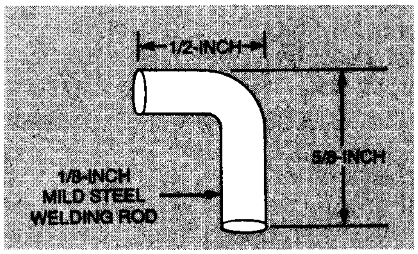


Fig. 3. The vibration sensor is formed from pieces of welding rod. This piece supports the spring.

The Vibration Sensor. The sensor is made up of two parts: a weighted spring and a contact loop. Two pieces need to be made from short lengths of mild-steel gas-welding rod. Mild-steel gas-welding rod normally has a very thin coat of copper to prevent oxidization and hence will appear copper in color.

PARTS LIST FOR THE EARTHQUAKE DETECTOR

SEMICONDUCTORS

IC1—CD4536 or MC14536 programmable timer
IC2—CD4013 or MC14013 dual D Flip-Flop
IC3—CD4049 or MC14049 hex inverter
Q1—2N2222A NPN silicon transistor
D1—1N4148 silicon diode
LED1—Light-emitting diode, yellow

RESISTORS

(All resistors are ¼-watt, 5% units unless otherwise noted.)
R1, R6—100,000-ohm
R2, R3—10,000-ohm
R4—100,000-ohm potentiometer (BOURNS 3316W or similar)
R5—5100-ohm
R7—2200-ohm
R8—4700-ohm

CAPACITORS

C1—0.01-µF, ceramic disc
C2—0.033-µF, ceramic disc
C3—0.1-µF, ceramic disc

ADDITIONAL PARTS AND MATERIALS

S1, S2—Momentary pushbutton switch (Digi-Key P8009S-ND or similar)
S3—Vibration sensor (see text)
RY1—12-volt single-pole, double-throw relay (OMRON G5L-114P-PS or similar)
J1—2-terminal PC-mount terminal block (optional, see text)
J2—3-terminal PC-mount terminal block (optional, see text)
8-32 ¾-inch brass screw, pen spring (see text), hardware, etc.

Note: The following items are available from Kool Kits, 2567 Byron Road, North Vancouver, BC, Canada V7H 1L9, E-mail: bobb@prostyle.com, Web: http://www.prostyle.com/koolkits: Complete kit of parts for the Earthquake Detector, including etched and drilled circuit board, relay, buttons, connectors, ICs and enough welding rod to form the sensor loop and spring bracket (spring is not included, see text) (ES1-KIT), $24.95; etched and drilled circuit board and enough welding rod to form the sensor loop and spring bracket (ES1-PCB), $9.95. Please add $5.00 shipping and handling. BC residents must add appropriate sales tax. All prices in US funds. International orders outside Canada and US please add $5.00.

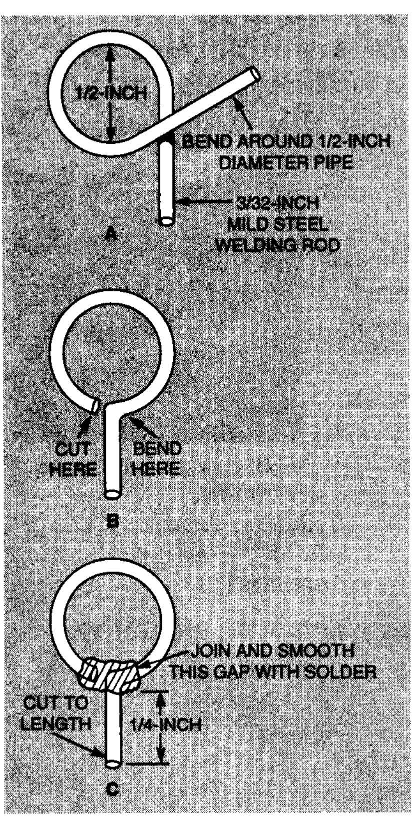
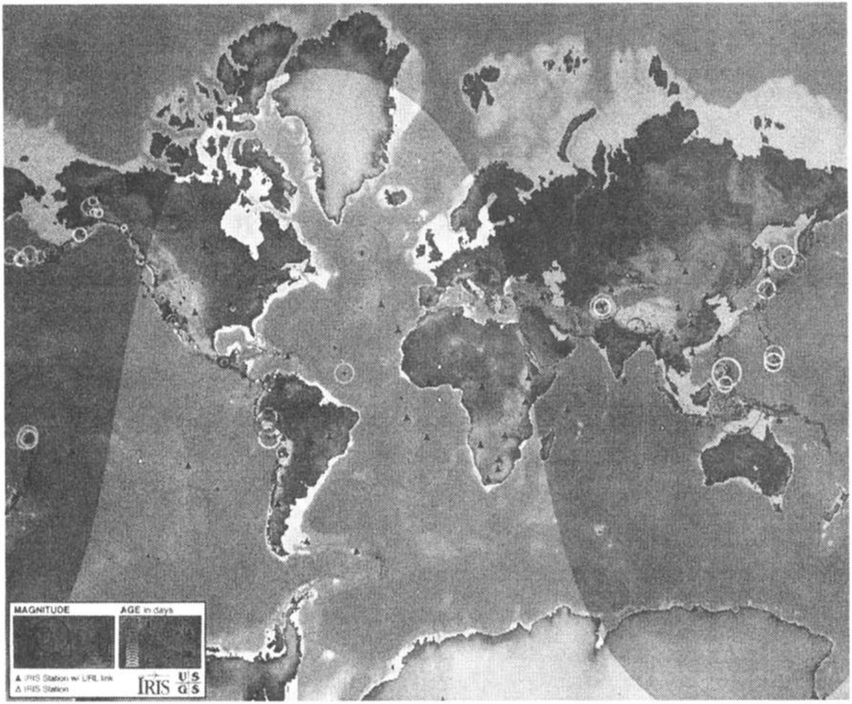


Fig. 4. The contact loop for the vibration sensor is made from some welding rod. The rod is bent into a circle (A). One end is bent at a 45-degree angle and the other end cut off at the bend (B). The loop is closed with some solder (C).



The Incorporated Research Institutions for Seismology (IRIS) has an interesting Web site that features a real-time map of worldwide seismic activity. The map is updated every 30 minutes. Not only are the quakes shown with their intensity and how recently they occurred, the locations of the various seismograph stations are also shown. Seismic activity for the last five years shows the definite outline of the Earth's tectonic plates. Where those plates rub against each other, earthquakes are most likely.

That copper coating will make it easy to solder the parts of the sensor together.

Start with the spring support. It is simply a length of l/8-inch welding rod that is bent to an L shape with the dimensions shown in Fig. 3. The easiest way to form the 90-degree bend is to insert one end of the rod into a vise to the desired length and gently tap on the side of the rod with a hammer. Once the rod has been bent, cut the piece to the proper length using a hacksaw and file off any burrs from of the ends of the bent rod.

The contact loop is formed using a short length of 3/32-inch welding rod. Creating the loop is a bit more complicated, but it is easily done by following the steps shown in Fig. 4. First, form the loop by bending the rod around a M-inch pipe. The loop of rod should look like Fig. 4A. Cut one end of the rod where it crosses the other end. Insert the formed loop into a vise and bend the uncut end 45 degrees so that the loop is centered over the tail. The piece should now look like Fig 4B. Finally, solder the end of the loop to the bend to form a closed loop as shown in Fig. 4C. That will prevent the sensor spring from getting snagged on the edge of the rod at the bottom of the loop. You will have to use a soldering gun, torch, or high-capacity soldering iron-an iron used for PC boards will not have enough heat capacity to make a good joint.

insert the contact loop into the pad for S2 from the solder side of the board as shown in Fig. 2. That hole should be drilled to fit the rod. Align the loop so that it is parallel to the bottom of the board and facing the other pad. The photo in Fig. 5 will give you an idea of what the completed sensor will look like. Use a high-powered soldering gun or iron to solder the loop in place. Use enough solder to form a good crown, as that joint has to provide sufficient mechanical strength to hold the loop in place.

The long side of the L-shaped bracket rod is soldered to the other pad in a similar fashion. Orient the bend so that the end of the rod is pointing at the center of the contact loop.

Most people have a collection of inexpensive plastic pens, usually with some type of advertising printed on them, sitting in a drawer waiting for a refill. The spring from one of those pens is perfect for the vibration sensor. Thread one end of the spring onto a 4-40 brass screw about 1/8 inch and slide the other end onto the L-shaped bracket piece so that the bolt is positioned inside the contact loop. Slide the spring up the shaft of the rod so that the bolt end of the spring is just above the contact loop. Solder the spring onto the rod. When the spring oscillates and makes contact with the detector loop, the bolt should be making contact, not the spring. Do not solder the bolt onto the spring at this time.

Final Setup and Calibration. The Earthquake Detector must be mounted in a vertical position so that the bolt hangs down through the approximate center of the contact loop. it should also be mounted solidly to the structure of the house, such as to a wail joist. You can mount ail of the components of the detector and power supply to a

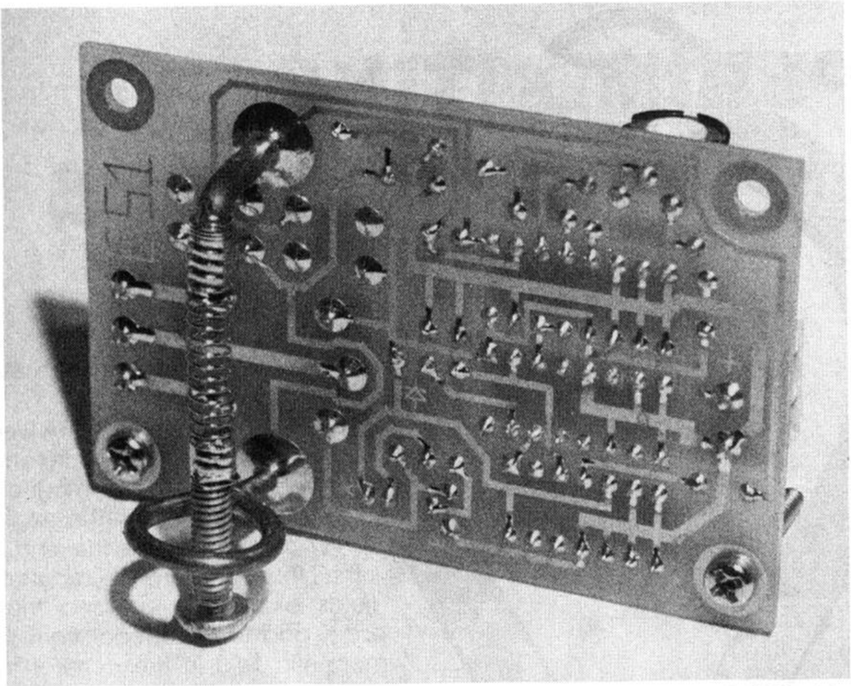
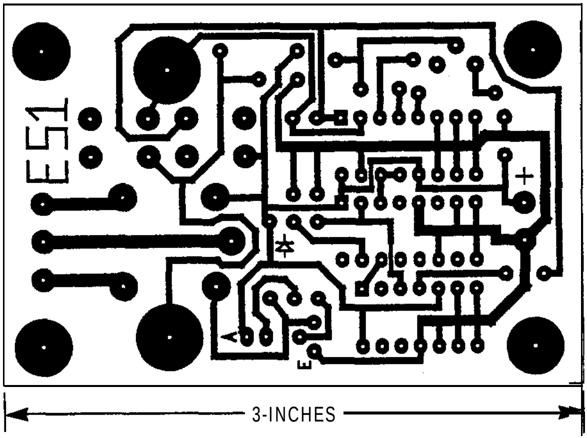


Fig. 5. Here is how the vibration sensor looks when it is completed. Soldered to the foil side of the PC board, the screw hangs down through the center of the loop. When the spring absorbs enough energy from vibration, the screw hits the contact loop, completing the circuit.



Here's the foil pattern for the Earthquake Detector. The circuit is simple enough to use a single-sided board.

plywood base and then, using long wood screws, mount the plywood base to a wall, centering the screw holes on the joists behind the wall.

With the detector in operation, inspect it from time to time to check for false triggers, indicated by LED1, If you do get any false alarms, check to see that the sensor screw is properly adjusted in the center of the contact loop. If it is, you will have to desensitize the detector. That can be done by screwing the bolt farther into the spring, If you still have a problem with false alarms, try a shorter bolt; that will lessen the weight on the end of the spring. Once the sensor is properly adjusted, solder the bolt to the spring, being careful not to get any solder on the sensor loop.

There are many possible applications for the Earthquake Detector, For example, in the author's kitchen the detector operates solenoids that engage hooks on the cabinet doors when a tremor activates the unit. A 12-volt sealed lead-acid battery provides power so that the system does not have to rely on the 11 O-volt AC house current during an earthquake. The battery is constantly kept charged by using a trickle-charge circuit that was purchased with the battery. In the first two years that the circuit has been in use, it has been activated by two minor tremors, performing flawlessly each time.

There are a lot of good sites on the Internet worth checking out regarding earthquakes. One example is the Incorporated Research institutions for Seismology, located at http://www.iris.edu. That site has an interesting seismic-monitor page that shows a world map that is updated every 30 minutes with the latest seismic activity. For practical information on preparing for an earthquake and links to other sites, try http://quake.wr.usgs.gov. Ω