

Construction project:

Low cost Stud Finder

Here's a very low cost and easy to build little unit that will indicate the position of wooden studs and noggins inside walls clad in the usual gypsum board or fibro. Build it up to take the guesswork out of hanging pictures, or mounting shelves...

How many times have you wanted to hang a picture and found that the hook you hammered into the wall missed the stud behind? Gypsum board and fresh air don't provide a very secure mounting, unfortunately.

The same thing can happen with shelf brackets. You need a solid base for these, even more than with picture hooks. Finding the stud (upright framing members) or noggin (horizontal bracing members) is almost essential, and the old trick of tapping along the board with your cranked finger often isn't accurate enough.

It can also be important to find the positions of the studs and noggins when you want to run electrical wiring - so you can avoid them, or at least arrange your run to minimise the number that will need to be drilled.

Here is the answer. A simple but effective build it yourself tool. It's easy to assemble and can be constructed in a couple of hours.

It provides two forms of indication. A light emitting diode (LED) in the centre position of the sensor changes brightness with variations in the dielectric material beneath. At the same time a piezoelectric transducer produces an audible output that varies from a ticking sound to a constant tone, depending on the density of the material under the sensor head.

In use, the sensitivity control is adjusted with the Stud Finder placed on the wall or other medium to be scanned. Take the following example: We have a plaster or gypsum board wall on which to hang a large picture frame. Two uprights are required to support the hooks. Simply place the Finder on the wall and adjust the control until the transducer just starts to tick. Sweep the finder across the surface and bingo! - there will be a distinct change in sound and LED brightness, reaching a peak over the hidden stud or noggin.

The unit is easy to use, very sensitive and fully adjustable to suit varying materials.

Incidentally this project has been designed by the R&D Department of Dick Smith Electronics, and copyright to the PC board pattern and front panel artwork is held by that company. This means that they cannot be reproduced

commercially. However complete kits for the project will be available from all Dick Smith Electronics stores, and many dealers. The kit is designated with the catalog number K-2723.

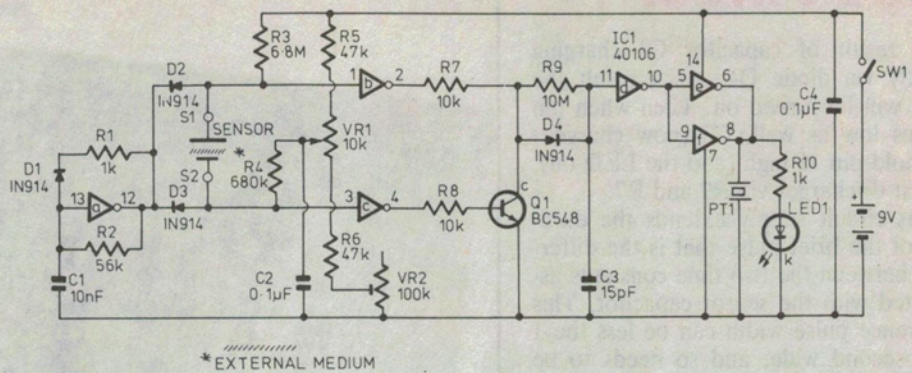
How it works

The sensing system of the Stud Finder is designed to detect changes in the dielectric constant of materials under the sensing head. A sensitivity control allows setting of the detection threshold point for varying materials.

The circuit uses CMOS Schmitt trigger inverters as the active components.



The circuit for our Stud Finder is deceptively simple. Explaining exactly how it works isn't nearly so easy...



Six inverters are used in all, provided by a single 40106 hex inverter device. This makes for low cost and a simple layout.

The principle of operation is based around the detection of changes in the effective dielectric constant of the medium being scanned (the wall board), caused by the presence of a stud or noggin behind it.

The sensor is actually a two-plate capacitor, with the external wall material as its dielectric or coupling material. The two plates S1 and S2 are actually copper areas of a small PCB, mounted hard up against the bottom of the Stud Finder's case. They are deliberately made of different sizes, with S1 a fairly large solid rectangle and S2 a smaller-area open rectangle around it.

One of the 40106 Schmitt inverter elements IC1(a) is connected as an astable oscillator. This oscillates at about 3kHz, with a very short duty cycle caused by the ratio of R1 and R2. Resistor R1 essentially determines the "pin 12 low" part of the oscillator cycle, while R2 determines the "pin 12 high" part - both in conjunction with capacitor C1. The ratio of high to low times at pin 13 is therefore quite high, with the low time typically only around 6.5 microseconds.

The effect of diodes D2 and D3 is to discharge the S1/S2 sensor capacitor by connecting both plates to the circuit's negative rail, during the brief time that the output of IC1(a) goes low. Then when the output of the oscillator goes high again, D2 and D3 cease conducting. This allows the sensor capacitor to begin charging, via R3 on the S1 side (connected directly to the positive rail) and R4 on the other (connected to an adjustable voltage from VR1, the sensitivity control).

Large plate S1 is connected to pin 1 of inverter IC1(b), while small plate S2 connects to pin 3 of inverter IC1(c). So

when D2 and D3 turn off, the voltages at pins 1 and 3 begin rising up towards the switching thresholds of the two inverters, as the S1/S2 capacitor charges up via R3 and R4.

Operation of this part of the circuit is quite subtle. Because of the difference in size between the two plates S1 and S2, and the different resistor values connected to each, the effect of even quite small changes in their mutual capacitance is to vary the time taken for the

A look inside the case. Apart from the sensor itself, on the lower PCB, there's only a single IC with one transistor and a handful of parts.

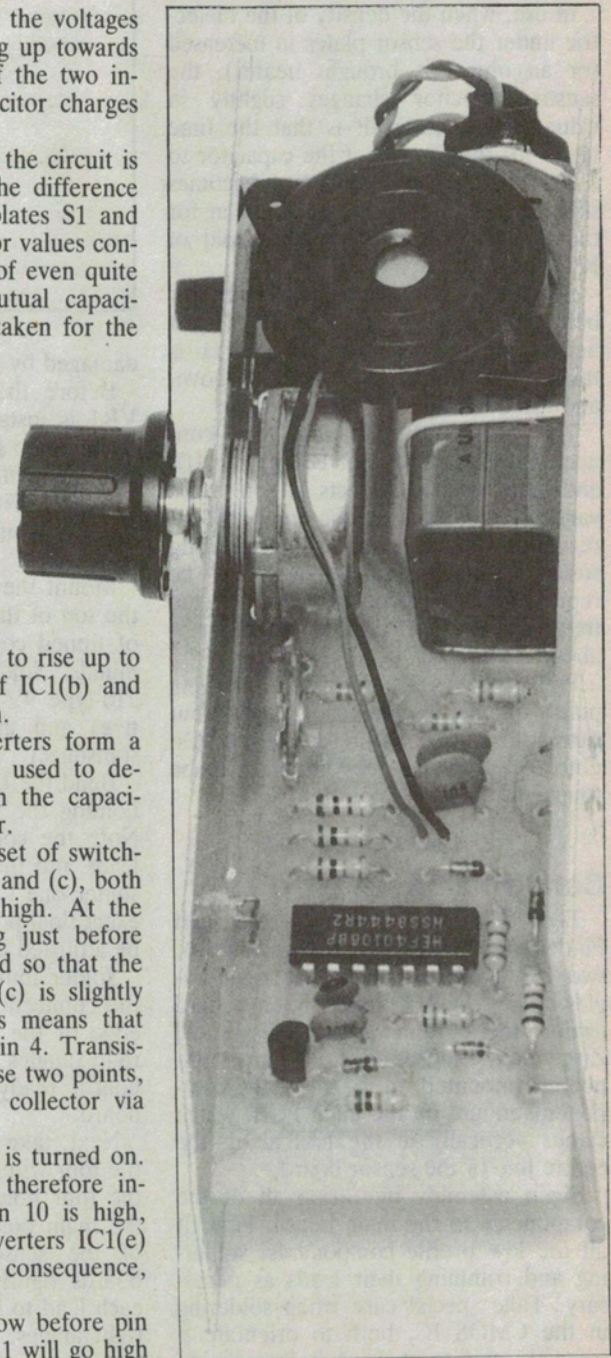
voltages at pin 1 and pin 3 to rise up to the switching thresholds of IC1(b) and (c), in a differential fashion.

In effect these two inverters form a very sensitive comparator, used to detect very slight changes in the capacitance of the S1/S2 capacitor.

Normally, before the onset of switching or triggering of IC1(b) and (c), both pin 2 and pin 4 will be high. At the point of sensitivity setting just before maximum, VR1 is adjusted so that the triggering of inverter IC1(c) is slightly after that of IC1(b). This means that pin 2 will go low before pin 4. Transistor Q1 is connected to these two points, the base via R8 and the collector via R7.

When pin 4 is high, Q1 is turned on. Its collector is near 0V, therefore inverter IC1(d)'s output pin 10 is high, forcing the outputs of inverters IC1(e) and (f) to go low. As a consequence, the LED will be off.

Now, should pin 4 go low before pin 2, Q1 will be off, so pin 11 will go high



Stud Finder

as a result of capacitor C3 charging quickly via diode D4. As a result the LED will be turned on. Then when pin 2 goes low as well, C3 (now charged) will hold pin 11 high (and the LED on), until it discharges via R9 and R7.

This circuit simply extends the duration of the brief pulse that is the difference between the two time constants associated with the sensor capacitor. This difference pulse width can be less the 1 microsecond wide, and so needs to be extended in order to be registered as sound or light by the output system.

In use, when the density of the dielectric under the sensor plates is increased (or an object is brought nearer), the sensor capacitor changes slightly in value. The nett result is that the time taken for the S2 side of the capacitor to reach the threshold of IC1(c) becomes slightly shorter than the time taken for the S1 side to reach the threshold of IC1(b).

Because of this pin 4 goes low before pin 2, and Q1 is turned off just before pin 2 goes low. So pin 11 is taken high briefly, as described above, and the LED turns on.

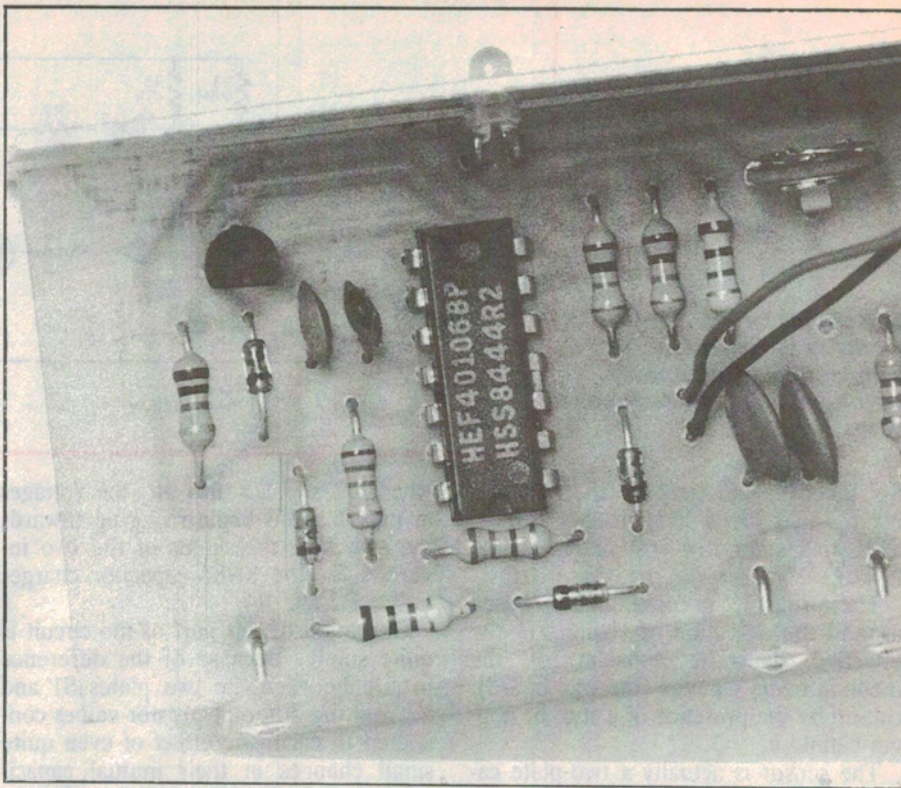
The piezo transducer is also connected to the outputs of IC1(e) and (f), and as a result it reflects in sound the varying conditions of the input. Slight reactions will be heard as short ticking sounds, while larger changes will be represented by a constant tone at the frequency of the astable oscillator - about 3kHz.

Preset pot VR2 adjusts the operating point of the circuit for the different threshold levels of different 40106 ICs. Once set, this pot does not have to be touched in normal operation.

Construction

The components used in the Stud Finder are mounted on an assembly of two PC boards, mounted at right angles. The sensor board mounts hard against the bottom of the unit's small Zippy box, and does not have any components mounted on it. All of the components mount on the main PCB, which stands vertically in the box along the centre line of the sensor board.

Begin assembly by fitting all of the components to the main board. First fit all the low profile components, soldering and trimming their leads as necessary. Take special care when soldering in the CMOS IC, both to orientate it correctly and to prevent it from being



damaged by static electricity.

Before the PC board mounting pot VR1 is installed, it is advisable to cut the shaft to length to fit the knob being used. We cut the prototype 18mm from the body. Fit the pot to the board with the pin shoulders right up to the board surface.

Mount the on-off slider switch flat on the top of the board using three lengths of tinned copper wire through the terminals. Solder in the leads from the 216-type 9V battery snap (red to positive) and also those from the piezo transducer.

Bend the LED pins close to the body, holding the legs with long nose pliers. Note the correct orientation. Push the leads into the PCB holes, but only tack solder one leg at this stage because the exact final position of the LED needs to be adjusted later.

Solder four lengths of copper wire to the connection points along the bottom edge of the main PCB. Bend these at right angles to point away from the board, ready to mate with the sensor board.

Next, take the sensor board and align the four wires from the main board with the four holes down the middle - with the main board on the non-copper side of the sensor board. Push the two boards tightly together and bend over each lead to hold the two in position, at right angles. Then cut off each lead at the edge of the pad and flatten the wire

against the board. Solder each lead, making sure each joint is as low in profile as possible on the copper side. This is to avoid problems when the assembly is mounted in the box (the sensor board needs to be able to mount hard against the bottom of the Zippy box, for maximum sensitivity).

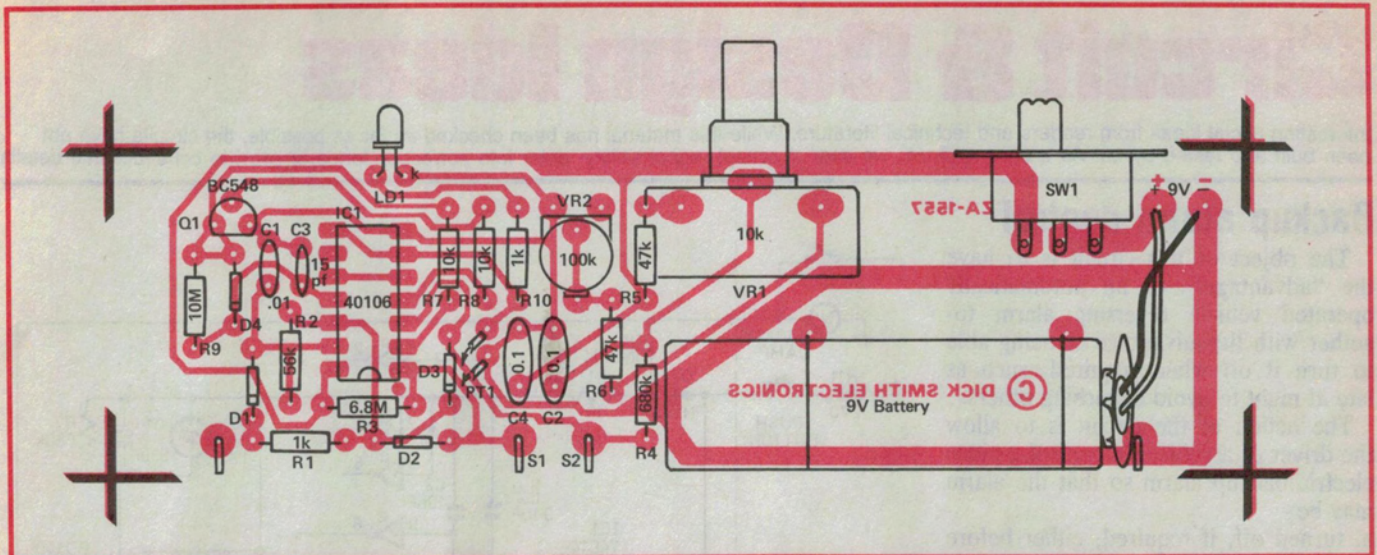
To hold the battery in a stable position, mount it as shown and support with wire straps between the main and sensor board.

The completed assembly should slip into the Zippy box with ease. The edge of the main board should be just below the surface of the box edges, to allow you room to fit the aluminium panel. If it is too high, you may have to reduce the profile of the solder joints on the bottom of the sensor board.

The aluminium front panel has to be drilled to suit the components penetrating its surface. The diagram shows the detail of these cutouts. You can use the label as a template to mark these positions. The pot and LED holes can be carefully drilled, but the switch hole has to be pilot drilled and then filed to the required rectangular shape with a needle file (or cut with a piercing saw).

No holes have been indicated for the switch mount screws. We found they were not necessary in the prototype, but you can add these if you like.

Try the panel for fit before the next step. If necessary, adjust the position of the LED for the best fit with the hole in



Construction should be easy using this overlay diagram and the picture opposite as a guide.

the front panel. When this is right, solder and trim the leads.

After each hole in the front panel has been dressed and freed from burrs, the self-adhesive label can be applied. Make sure it is correctly aligned before pressing it down on the surface. Then punch or cut out the holes carefully. Use a small scalpel blade or similar to cut to the edge of the switch opening. The drills used for the pot and LED holes can be used to punch through the label from front to rear.

The piezo transducer fits neatly between the battery and the box wall, adjacent to the pot. The front panel holds it in place.

Setting up

Power up the unit. The LED and transducer may or may not operate at this stage, depending on the position of presets VR1 and VR2.

To set the correct operating point, set sensitivity control VR1 to the mid position and put the PCB assembly in the Zippy box. Make sure the sensor PCB is hard against the bottom of the box. Place the box flat on some wooden surface, and adjust VR2 with a screwdriver until the LED just starts to light. Now fit the box front panel (without screws), along with the knob.

Try the unit on different materials: wood, plaster, plastic, glass etc. The sensitivity control should adjust for varying materials within a third of its full travel, centred around the mid position. Note that these adjustments are made with your fingers around the sides of the box, near the bottom (on-off switch) end. You will notice a slight variation in sensitivity setting as you touch the knob.

After adjustment is complete, the lid can be screwed in position. If you wish to put a nut on the pot, two to three washers may be needed to pack the pot body from the panel. Fit the knob and your Stud Finder is ready to use.

Using it

Place the Stud Finder flat on the surface to be scanned, holding it with one hand at the bottom end of the box. Adjust the sensitivity control until the transducer just starts to tick, then take your hand from the knob. The ticking should stop. You may need to re-adjust to get the most sensitive setting.

Now run the finder over the wall to get an idea of its operation. The LED at the cross centres indicate the centre of the sensor. Try the unit with known conditions, thickness of panels, types of materials etc.

The Stud Finder is capable of working with a great variety of materials and is sensitive enough to penetrate thick panels.

Remember, it basically detects changes in dielectric. Don't expect it to detect metal through metal - although it is perfectly happy to detect metal studs, pipes or conduits through insulating panels.

With a little operating experience, you can also use it to detect electrical wiring close to the surface. The field around the wires modulates the sound from the transducer.

The Stud Finder will even indicate the direction of grain in a piece of wood when the sensitivity control is set carefully. Even a knot or dense part in the grain structure can be found.

You may well be able to think of other applications for the Stud Finder,

taking advantage of its principle of operation. It could conceivably be used to sense the presence of fluid in a plastic pipe, as a proximity detector, to check for the presence of moisture, or perhaps even as a pH meter. E

PARTS LIST

- 1 Main PCB, 124 x 36mm, code ZA-1557
- 1 Sensor PCB, 105 x 59mm, code ZA-1558
- 1 Zippy box, 132 x 69 x 42mm
- 1 216-type 9V battery with snap lead
- 1 Piezo transducer
- 1 Mini DPDT slider switch

Semiconductors

- 1 40106 CMOS hex Schmitt inverter
- 1 BC548 or similar NPN transistor
- 4 1N914, 1N4148 or similar diode
- 1 3mm red LED

Resistors

- 1/4W carbon: 2 x 1k, 2 x 10k, 2 x 47k, 1 x 56k, 1 x 680k, 1 x 6.8M, 1 x 10M
- 1 10k linear PCB mount pot
- 1 100k linear vertical or horizontal PCB mount trimpot

Capacitors

- 1 15pF ceramic
- 1 10nF ceramic
- 2 0.1uF ceramic

Miscellaneous

Tinned copper wire, knob for pot, insulated hookup wire for mounting battery, etc.