# Build The Frisker

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*Sniff out metallic contraband with this hand-held device.*

As you probably know, recent events have made us all more security conscious. It is now common to require those entering public and governmental buildings, boarding airplanes or cruise ships, and even attending high-profile sporting and entertainment events, to submit to some kind of security check. People have to pass through a metal detector on entry; and briefcases, baggage, and packages are generally inspected, and often X-rayed.

Frequently, frisking occurs if any metal is detected, and any one may be subject to random frisking. To eliminate actual hand contact, a device that looks like a wand or small baton is commonly used. This device is a small metal-detector system for locating hidden forbidden items, such as knives, guns, or anything that could be used as a weapon.

This article describes the theory, operation, and construction of the Frisker, a small metal detector similar to those described above — used by security personnel to find concealed metallic objects while avoiding physical contact with the subject. The Frisker will find such concealed weapons or any improvised weapons made of metal without requiring the subject to remove them from his or her pocket.

### How It Works.

Unlike X-ray systems, there is no hazardous radiation that could cause personal injury or could damage incidental items, such as photographic materials and some medicines. The device consists of a probe about nine inches long and one inch in diameter, with a small enclosure at one end for battery and speaker. This enclosure also serves as the handle. The metal detector's electronics and sensing coil are contained within the probe.

In actual use, the unit is turned on and a tone emanates from the built-in speaker. (See Fig. 1.) The end of the probe is run across suspected areas that may contain metal. A change in speaker volume or tone frequency indicates the presence of metal in that area. A common 9-volt transistor-radio battery powers the Frisker.

### Theory Of Operation.

When a metallic object is brought near a coil of wire, the inductance of that coil will change. A non-ferrous metallic object will act as a shorted turn and cause the coil inductance to decrease. Ferrous metals will also cause an inductance change, which may be an increase in inductance due to permeability effects, combined with the same shorted turn effect.

Ordinary steel or iron objects larger than the sensing coil will produce more of a shorted turn effect, while ferrites or smaller iron objects may cause an inductance increase. If this coil is part of a frequency-determining circuit such as the inductance in an L-C oscillator, this increase will cause a small frequency shift. Translating this shift into an audio tone makes it audible to a human ear, if the tone is used to drive a small speaker.

The detector-oscillator frequency is mixed with a fixed-reference frequency derived from a crystal oscillator. A mixer circuit produces an audio signal equal in frequency to the difference in frequency of the detector oscillator and the reference. Since small differences in audio frequency tones are noticeable, a frequency shift of 50 Hz or less in the detector oscillator can be readily heard.

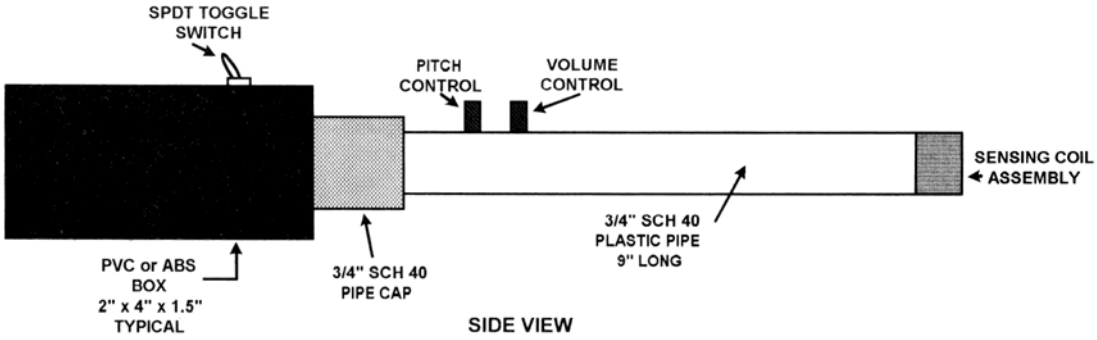
### Construction.

Refer to the block diagram (Fig. 2) and the schematic of the Frisker (Fig. 3) for the following discussion. A foil pattern for the Frisker is provided in Fig. 7. An oscillator circuit — consisting of the JFET, Q1, and associated components — contains a sensing coil, L1, which is mounted at the end of the probe assembly shown in Fig. 1. Capacitors C3, C4, and C5 — along with varactor diode D2, bypass capacitor C2, and L1 — make up a resonant circuit tuned to approximately 125 kHz. The frequency can be adjusted to this value via trimmer C5 and the bias voltage on D2, and set with pot R19 and isolation resistor R2. The coil, L1, is tapped, and the tap is connected to the source of Q1.

The junction of L1 and tuning capacitors C3, C4, and C5 is connected to the gate of the JFET via C1 and bias network R1 and D1. Capacitor C6 bypasses the drain of Q1 to ground. and DC is fed through R4 from the Vcc supply, which may be +5 to +9 volts. Any metallic object near L1 will affect the frequency of oscillation. The reference frequency is generated by IC1 and associated components.

Much of the circuitry needed is contained within this chip. Crystal X1 is a 4-MHz crystal and operates in fundamental mode. Components R13, C9, C10, and bias resistor R11 make up the crystal circuit. The oscillator active components are inside the chip. The signal at 4 MHz is divided by 32 internally in the chip, and a 125-kHz square wave appears at pin 5 of this chip. Resistors R10 and R5 feed some of this reference signal to the emitter of mixer transistor Q2. The decoupling components, R14 and C13, provide DC power to C1.

Mixer transistor Q2 is biased by R5, R6, R7, R8, and R9. Capacitor C7 prevents degenerative feedback and keeps the gain of Q2 high. The detector oscillator signal is coupled via isolation resistor R3 and capacitor C8 to the base



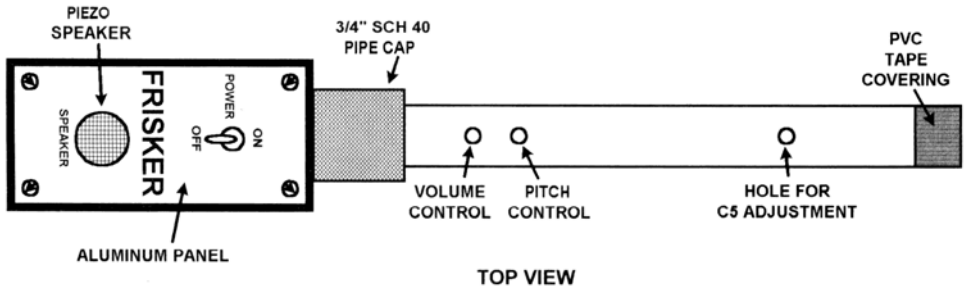




FIG. 1. PACKAGING

## PARTS LIST FOR THE FRISKER

### SEMICONDUCTORS

IC1—CD4060BE, 14-stage ripple-carry binary counter/divider and oscillator
IC2—LM386N
Q1—MPF102, JFET, N-Channel
Q2—2N3904, NPN-Si, AF/RF amp, driver
D1—1N914, silicon switching diode
D2—MV209, rectifier

### RESISTORS

(All resistors are ¼-watt, 5% units.)
R1—220,000-ohm
R2, R12, R15—10,000-ohm
R3, R6, R7—33,000-ohm
R4—470-ohm
R5, R14—100-ohm
R8—100,000-ohm
R9, R10—4700-ohm
R11—2200-megohm
R13—2200-ohm
R16 —1000-ohm
R17—10-ohm
R18, R19—100,000-ohm potentiometer

### CAPACITORS

C1—22-pF, NPO, ±5%
C2, C13, C15, C16—.01-µF, ceramic-disc, GMV
C3—100-pF, NPO, ±5%
C4—47-, 82- or 120-pF, NPO, ±5%
C5—3–40-pF, trimmer
C6, C17—0.22-µF, 35-volt, tantalum
C7, C11—0.47-µF, 35-volt, tantalum
C8—470-pF, ceramic-disc, ±20%
C9—47-pF, NPO, ±5%
C10—33-pF, NPO, ±5%
C12—.001-µF, Mylar
C14, C18—100-µF, 16-volt, electrolytic

### COILS AND CHOKES

L1—Sensing coil, 375 T, center-tapped
X1—Crystal, 4-MHz, ± .01%, 20-pF, parallel-cut

### ADDITIONAL PARTS AND MATERIALS

SPDT toggle switch, two shafts for pots, piezo speaker (Z > 16-ohm), 9-volt battery, battery connector, PVC or ABS box, ¾-inch × 9-inch tubing (PVC, Sch 40), ¾-inch PVC pipe cap, PVC cement, PC board, hardware as required

A kit of parts is available from North Country Radio, PO Box 53, Wykagyl Station, New Rochelle, NY, 10804-0053, and can be ordered on their Web *site:www.northcountryradio.com*. E-mail sales and order information: rgraf30832@aol.com. E-mail tech support: support@northcountryradio.com. Kit price is $49.75 plus $5.50 for p/h. NY residents please add $4.10 NY sales tax The kit includes a drilled, etched, and screened PC board; all the parts that mount on it; switch; a suitable plastic case; speaker; plastic pipe; pipe cap; and complete, detailed documentation. Cement, tape, miscellaneous hardware, and 9-volt battery are not included and are easily obtained at your local hardware supplier or home center.

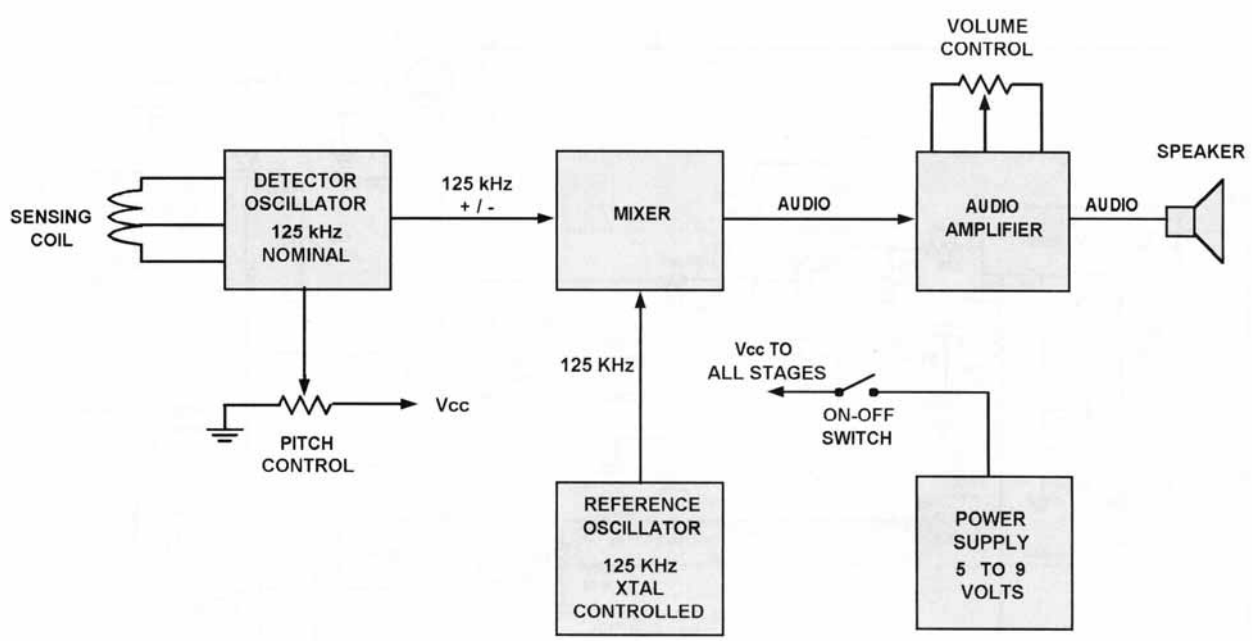



**FIG. 2. BLOCK DIAGRAM**



of Q2. Mixing of the detector and reference oscillator signals takes place in the emitter-base junction of Q2. The mixing products (mainly the detector and reference oscillators, and their sum and difference frequencies) are amplified by Q2 and appear at the collector. Components R12, C11, and C12 form a DC-blocking and low-pass filter network and suppress the higher frequency components. All we want is the frequency difference product, which lies in the audio range. Resistor R18 is the volume control, and R15 and C15 further attenuate unwanted high-frequency components. Semiconductor IC2 together with peripheral components C17, R17, and C18 make up an audio amplifier stage that delivers up to a few hundred milliwatts of audio to a small speaker mounted off the PC board.

The Frisker is designed to only sense objects within an inch or so of the probe tip. Sensitivity is proportional to coil size; and a larger coil would detect objects at greater distance, but with somewhat decreased resolution. Also, proximity effects would be somewhat more evident (capacitive detuning of the oscillator). With a larger coil (4-8 inches diameter or 10-20 cm), the Frisker could be used as a conventional metal detector. The 2-cm coil used here is a reasonable compromise between sensitivity and size.

The electronics are mounted in the probe assembly on a single-sided PC board, 0.7 x 5.5 inches. (See Fig. 4 for the PC board parts layout and component and lead locations.) This board is designed to fit inside a standard 3/4-inch (19-mm ID) schedule 40 PVC plastic pipe. A length of 9 inches (23 cm) was used, but this is not critical. This material is very inexpensive and readily available at home improvement centers and in the plumbing sections of hardware stores. Often, small lengths are available at these stores, as an alternative to the standard ten-foot lengths that are sold by plumbing suppliers.

A PVC-pipe cap secures the probe to a small plastic box (2 x 4 x 1.5 inches, or 5 x 10 x 4 cm) that houses the 9-volt battery, on-off switch, and a small piezo speaker. The PVC cap is cemented to the plastic box (made of ABS or PVC plastic) using standard plastic pipe cement, and a hole is drilled for passing the four leads from the PC board into the box. CAUTION: PVC cement is toxic, volatile, and very flammable. Do the cementing outdoors far away from any flame or lit cigarettes. Be very quick and use only enough cement to coat the surfaces — no more, as it sets very rapidly. Although this cement will appear dry in a few minutes, set the parts aside for at least two hours to ensure that the bond is strong enough to withstand handling.

The sensing (detector) coil is mounted to the other end of the plastic pipe using PVC electrician's tape. It consists of 375 turns of #36 wire, center-tapped, on a 3/4-inch plastic bobbin. It is scramble wound. A ready-made coil is included in the Parts Kit available from the source listed in the Parts List. The coil fits on the end of 3/4-inch pipe, and the tape may be coated with PVC cement to form a permanent bond. This is unnecessary as it prevents easy access to the PC board inside the pipe. The board is held in place by the two shafts for the frequency adjust and volume pots and cannot move once the shafts are installed. Three holes of 0.187 inches (about 7 mm) are drilled into the probe housing for the two pot shafts to protrude and for access to trimmer capacitor C5. See Figs. 5 and 6 for details of construction. Packaging is not critical and you may wish to make some modifications to fit the parts you have available.

### A Simple Tune-Up.

After checking the assembly of the PC board for errors, connect a speaker of 16-ohm impedance, or higher, to the speaker leads. Connect the sensor coil to the PC board leaving the coil leads loosely twisted together and about 3 inches long. Connect a 5- to 9-volt supply to the power leads. Be careful to observe polarity, as reversed battery polarity could damage C14 and IC2, and possibly IC1.

You should hear an audio tone of some sort from the speaker. Set C5 with the plates half meshed (mid-way between full and minimum capacity.)

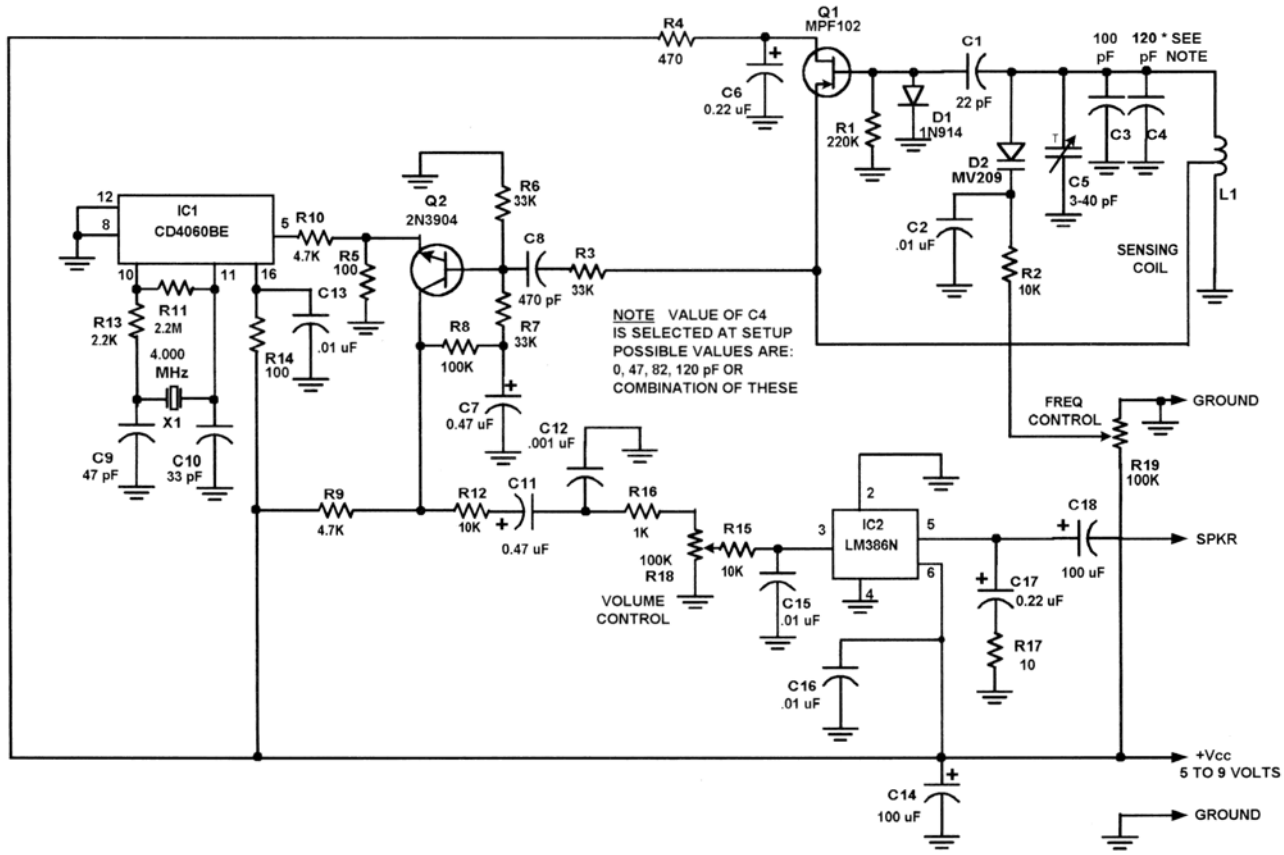



**FIG. 3. SCHEMATIC**

Adjust the volume control, R18, for comfortable volume and R19 for a tone frequency around 1-2 kHz (a whistle, not critical). Now adjust C5 so the pitch gets lower, ideally to zero. At this point, the tone will disappear as a low growl. Continuing to rotate C5 in the same direction will cause the pitch to rise again. The point at which the pitch is lowest and disappears is called "zero beat." You may have to select different values for C4 if you cannot get this whistle.

If rotating R19 fully clockwise decreases the pitch, the oscillator is too low in frequency. In this case, use an 82-pF capacitor in place of the 120-pF capacitor, C4. If the pitch is now better but not quite enough, try the 47-pF capacitor. Similarly, if turning R19 to the left decreases the pitch but not enough to get very low-pitched tones, add a 47-pF capacitor across the existing C4, or even 82-pF in some cases. The tuning range of C5 is small (about 2-3 kHz); therefore, it is normal to have to change C4 if C5 cannot compensate for tolerances. The optimum value of C4 is that which results in zero beat with both R19 and C5 set near the center of their adjustment range.

Alternatively. if you have a frequency counter you can connect it to the source of Q1 through a 15- to 33-K resistor and then adjust C5 for 125 kHz with R19 centered. The sensing coil should be away from any metal when this adjustment is made. Bringing metal (coin, keys, a knife, etc.) near the sensing coil should cause a noticeable change in pitch. If no audible whistle is obtained at all with any value of Q5, there is something wrong.

Check your assembly and the circuit board for shorts and open joints. Look for misplaced/misoriented components. There is little to go wrong if the assembly is correctly done. After you are sure all is operating correctly, disconnect the power supply. Solder four 6- to 8- inch leads to the PC board for power and speaker connections. Slide the board into the PVC pipe (see Fig. 5) and position it inside the plastic pipe so that the centers of the pots R18 and R19 are visible through the two closely spaced holes at one end.

The third hole should be directly over C5 to allow future access to the trim-

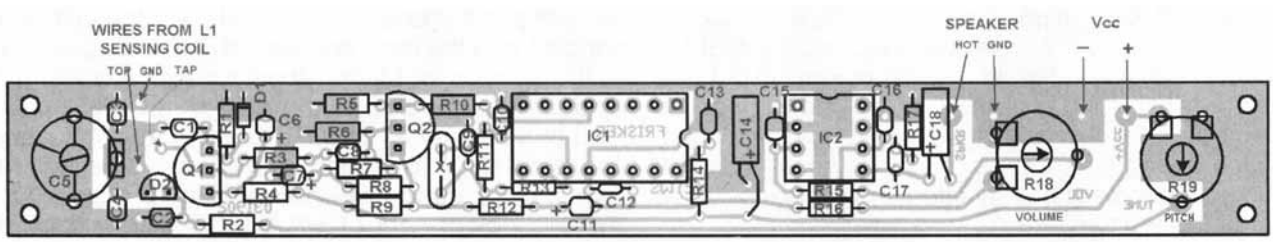



**FIG. 4. PARTS PLACEMENT AND LAYOUT**
**COMPONENT SIDE VIEW**

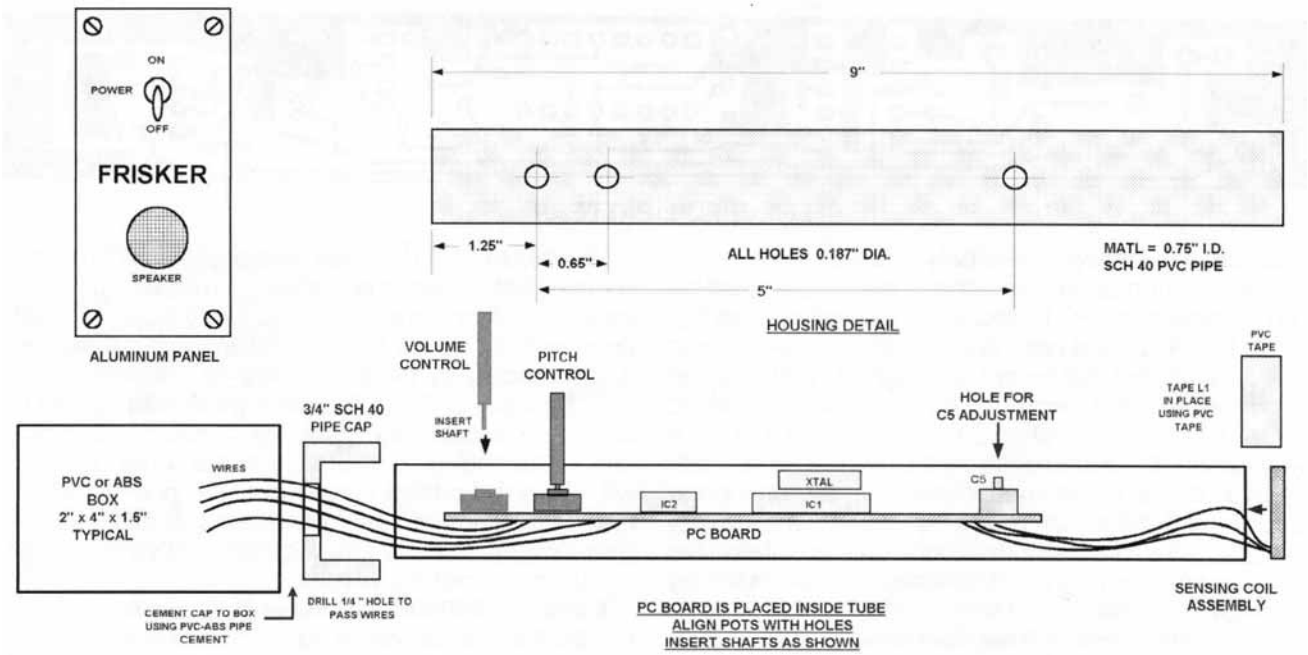



**FIG. 5. CONSTRUCTION**

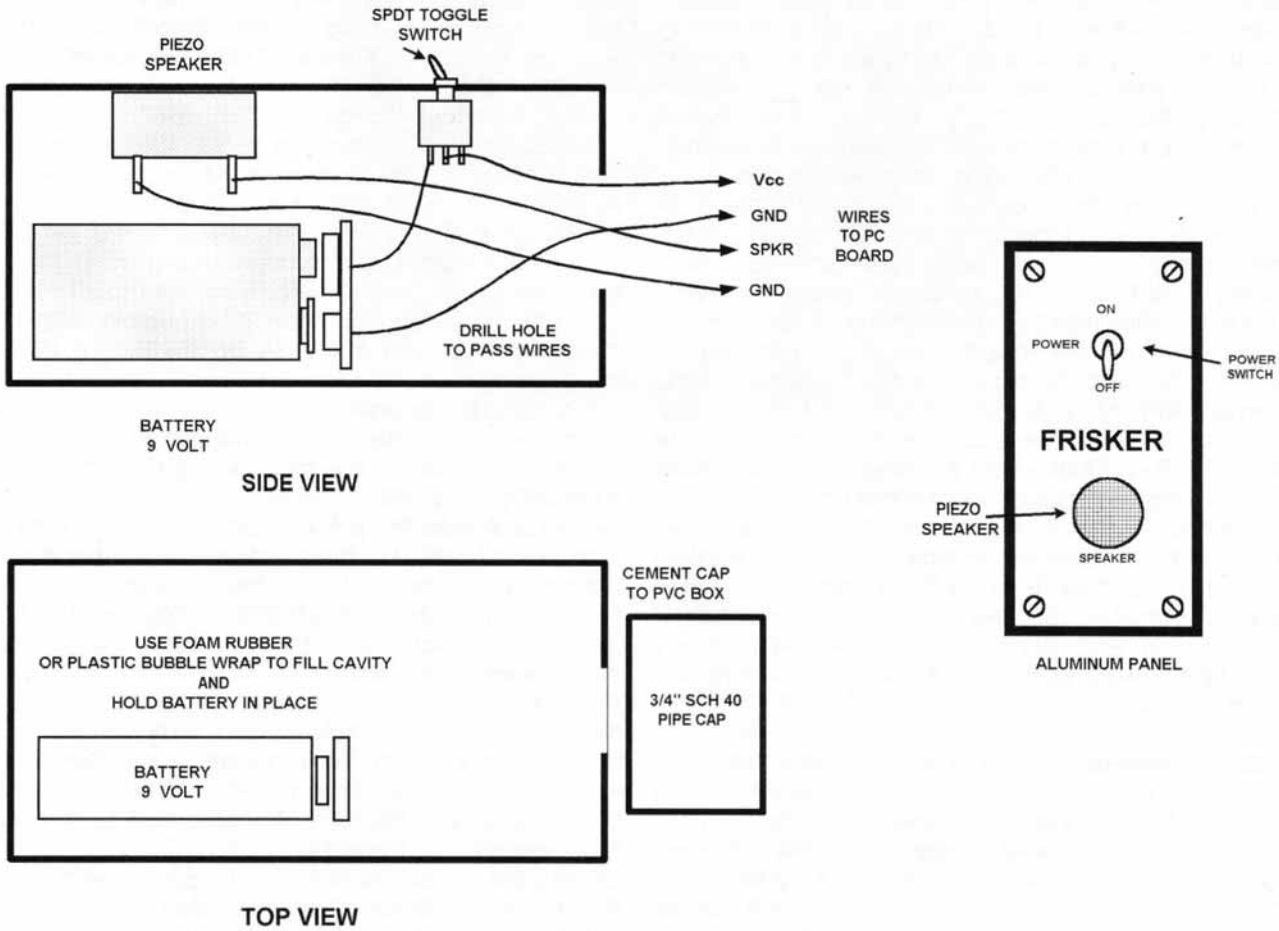



**FIG. 6. BATTERY BOX & WIRING**

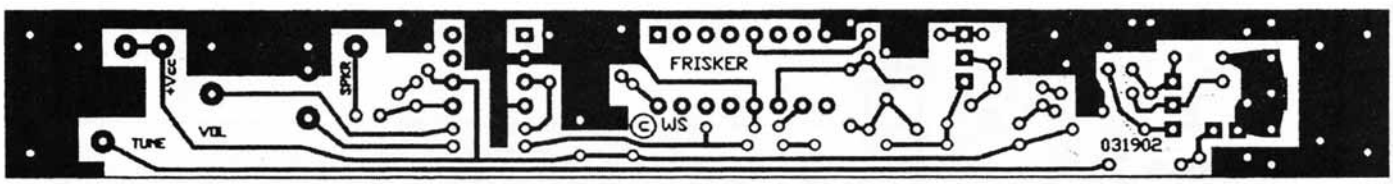



FIG. 7. FOIL PATTERN

mer capacitor for any final adjustments. Insert the two pot shafts into R18 and R19; this will lock the board in place. Fasten the sensing coil, L1, to the end of the tube. The wires can be twisted together. Be sure they do not block the hole for C5 access. The leads connected to the control end of the PC board are brought out the other end. A small notch cut or filed into the coil end of the tube provides clearance for the leads of L1, as well as for flush mounting of L1 to the tube end.

The small plastic box has a battery and speaker mounted inside it, with an on-off switch (see Fig. 6). A PVC 3/4-inch pipe cap was cemented to the top of the box as described earlier. The tube assembly is then inserted into the pipe cap. DO NOT CEMENT THIS TOGETHER. You will permanently seal the assembly, making access to the PC board difficult or impossible without cutting the plastic. Friction fit is sufficient, or you can drill a small hole and use a small (#4 x º-inch) self-tapping or sheet metal screw if you prefer.

### Using The Frisker.

The Frisker works by placing the sensing coil against the subject and moving it around, while listening for a change in audio pitch. A slight steady change in tone caused by body capacitance may occur, but metal will cause a much larger change. Coins, keys, and other metallic objects can be readily detected. Surgical implants will not usually cause an indication if deep inside the subject. The Frisker can also be used around the house to locate nails and screws in trim, moldings, and walls. This feature will also prove handy when doing certain household chores, such as mounting pictures, shelves, and other objects on the walls.