CARPENTER'S MATE

THOSE LITTLE magnetic gadgets that carpenters use to locate studs work fine if you're looking for ferrous nails. They won't do the job, though, for a boat owner trying to avoid sanding and sawing the brass hardware used on his craft.

If you have this problem, you can save some of the time you're spending developing a sailor's vocabulary and some of the money you use replacing chewed up saw blades by building the "Carpenter's Mate." It locates ferrous or non-ferrous metals quickly and easily.

The Carpenter's Mate, not much bigger than a pack of cigarettes, works just the same as larger types of metal locators except that it has a very restricted range and better resolution (pin-point accuracy). By using a small search coil (mounted inside the plastic case) maximum range has been reduced to about 2 inches while resolution is increased so that even a small wire brad—detected head on—can be spotted. The Carpenter's Mate slips easily into your shirt pocket and can be put into operation as fast as you can turn it on.

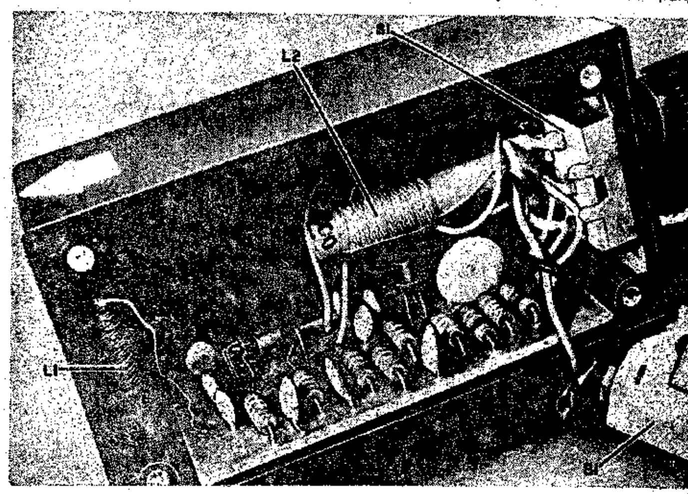
Construction. The circuit of the Carpenter's Mate is shown in Fig. 1. Layout is critical and since radio frequencies are involved, good w[illegible]ing practice should be followed and a[illegible]ads should be as short as possible. A circuit board simplifies the construction. You can make your own using Fig. 2 as a guide or you can buy one.

Parts placement [illegible]he board is shown in Fig. 3. The leads of *Q1* and *Q2* are bent so that the flat sides of their bodies can be placed adjacent to one another and glued together. This helps to maintain the two transistors at the same temperature to stabilize the relative frequencies of the two oscillators.

The sensing coil, *L1*, is made by modifying a standard J.W. Miller #6300 or equivalent High-Q variable inductor. Make the modification by removing the tuning slug and carefully cutting the threaded brass tuning screw off flush with the ferrite core material. Then carefully unsolder the lead wires from the terminals on the side of the coil and use a sharp knife to cut the form so that the coil winding is centered between the ends of the form. Slide the ferrite slug back into the coil and center it before securing it in place with a dab of cement.

The completed unit is housed in a 1⅝" × 4" × 2⅛" plastic utility box (see Fig. 4). To prevent tone changes associated with touching exposed metal hardware, all internal components, including *L1*, *S1*, and the PC board are glued in place with epoxy cement. Clean all mating surfaces thoroughly with steel wool before gluing. Blow away all steel-wool debris to avoid shorts. Drill a hole for *S1* at one end of the box and glue it in place. Then drill a hole on the same end for the mounting clip of *L2* and snap it into place. Drill a small hole near these two to pass the earphone cord. Make a knot at the inside end of the cord to prevent it from being pulled through.

Fig. 4. The entire instrument is easily mounted in a small plastic b[illegible] arrowheads to indicate the center of the search coil. All parts mount with epoxy.



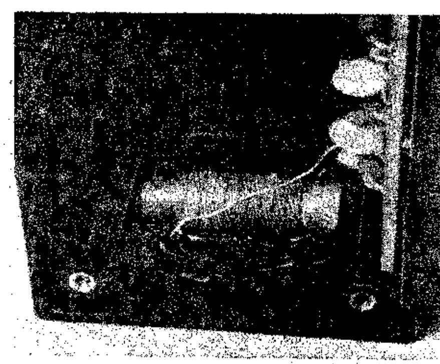
Mount *L1* at the center of the undrilled end of the box, using epoxy cement. Before mounting, make sure that the leads are long enough to reach the terminals on the PC board. If they are not, either unwind a little wire from the coil or solder on short extensions. Before mounting the PC b[illegible]d, connect up the circuit and put a sm[illegible] knob on the protruding shaft of *L2*. Turn on the power and adjust *L2* until a whistle is heard in the earphone. Once you hear this whistle, you know that the circuit is operating. Turn off the power [illegible] cement the board in place using a d[illegible]of cement at each corner.

When attaching the battery clip to the cover, place it slightly off center to keep it from interfering with the circuit board components when the cover is in place.

Operation. Hold the unit clear of any metal, turn it on, and insert the earphone in your ear. Withdraw the core from *L2* by turning its adjusting screw knob counterclockwise. As the slug passes through the coil, you will hear a rising and falling tone. While any position of the slug which produces a tone may be used as an operating point, the most desirable setting can be found in the following manner. Start with the slug screwed out about an inch. At approximately this point, a tone considerably louder than the others will be heard. Continue to withdraw the core until a null is reached. Slightly before this null point is the best position for locating non-ferrous metals. In this case, the presence of a non-ferrous metal causes a slight increase in the oscillator frequency, causing the signal to go toward the null point. For detection of ferrous materials, withdraw the slug so that the tone is slightly beyond the null point. The presence of a ferrous object then decreases the oscillator frequency, again bringing the tone down to the null. By positioning the slug on either side of the null, it is possible to identify either ferrous or non-ferrous materials. If you leave the slug so that a relatively low audio frequency is head, the frequency will go up or down depending on the metal detected.

To get some practice using the Carpenter's Mate, use a test surface which you know contains a piece of brass hardware. With the case held so that the side adjacent to the sensing coil is pressed lightly against th[illegible]st surface, move the device over the area. The tone will decrease noticeably when the sensing coil is directly over the brass. With the proper adjustment [illegible] *L2*, the null point will be reached w[illegible] the metal is detected.

Four clearly visible arrows can be drawn or pasted on the sides of the box at the *L1* end so that scribe marks can be made on the test surface to locate the detected metal under the center of the coil. If the coil is exactly centered in the end of the box, the arrows should be centered on the sides. It is possible to orient *L1* so that it butts against the end of the box. In this case, the sensitive area is greatly reduced permitting more accuracy in location. However, with this arrangement there is always the chance that the coil will be dislodged when the instrument is moved about. —30—



Coil L1 should be mounted with epoxy cement on the blank end of the box in exact orientation shown.

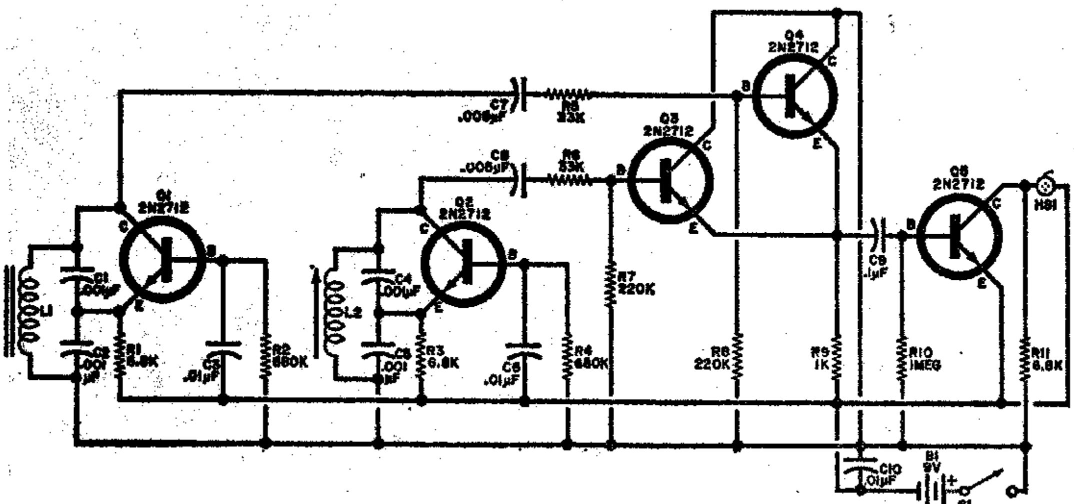
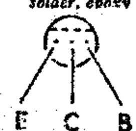


Fig. 1. The two r.f. oscillators (Q1 and Q2) mix in the two emitter followers (Q3 and Q4) and produce an audible sound that is a function of their frequency difference. This difference occurs when L1 is brought close to a piece of metal.

PARTS LIST

B1—9-volt transistor battery
C1,C2,C4,C5—0.001-μF ceramic disc capacitor
C3,C6,C10—0.01-μF capacitor
C7,C8—0.005-μF capacitor
C9—0.1-μF capacitor
HS1—High-impedance earphone
L1, L2—High-Q Ferrite Antenna (J.W. Miller #6300 or similar)
Q1-Q5—2N2712 transistor
R1,R3,R11—6800-ohm
R2,R4—680,000-ohm
R5,R6—33,000-ohm
R7,R8—220,000-ohm
R9—1000-ohm
R10—1-megohm
(All resistors ½-watt)
Misc.—Plastic case 1⅝" x 4" x 2⅛" with metal cover, battery connector, battery clip, wire, solder, epoxy cement.



BOTTOM VIEW
2N2712

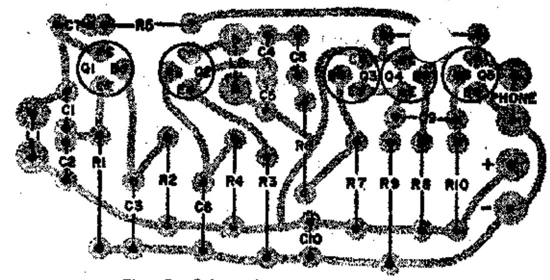


Fig. 3. Other than transistors, component polarities are not critical.

CONSTRUCTION NOTES

Please use extreme caution when soldering transistors in place. Heat sink all leads with needle nose pliers and use a low wattage soldering iron (35 watts max) The circuit board must be thoroughly cleaned with steel wool prior to soldering any component in place.

Resistor color coding is as follows:

R1, R3, R11	6800 ohm	blue-grey-red
R2, R4	680 K	blue-grey-yellow
R5, R6	33K	Orange-orange-orange
R7, R8	220K	Red- red-yellow
R9	1 K	brown-black-red
R10	1 meg	brown-black-green

HOW IT WORKS

Transistors *Q1* and *Q2* and their associated components form two independent Colpitts oscillators. The outputs of these oscillators are combined in the mixer composed of *Q3* and *Q4* and the resulting signal appears across the common load resistor *R9*. Since the mixer is nonlinear, the output signal contains the two original frequencies and also the sum and difference of the two. However, only the difference signal is within the range of human hearing. This signal is amplified by *Q5* and used to drive the high-impedance crystal earphone.

When a metallic object (either ferrous or nonferrous) comes close enough to *L1* to intercept and distort the magnetic field surrounding the coil, there is a change in the effective inductance of the coil. This causes a change in the frequency of the "sense" oscillator *(Q1)*. This relatively small change in the frequency of the oscillator can be heard as a significant change in the tone in the earphone.

To minimize "pulling" of the oscillators and the tendency of the two to lock on to the same frequency, the "local" oscillator *(Q2)* is adjusted to run at about twice the frequency of the "sense" oscillator.