FREQUENCY MULTIPLIER FOR YOUR COUNTER

Here's an easy way to add low-frequency accuracy—and speed—to your counter. No modifications are required.

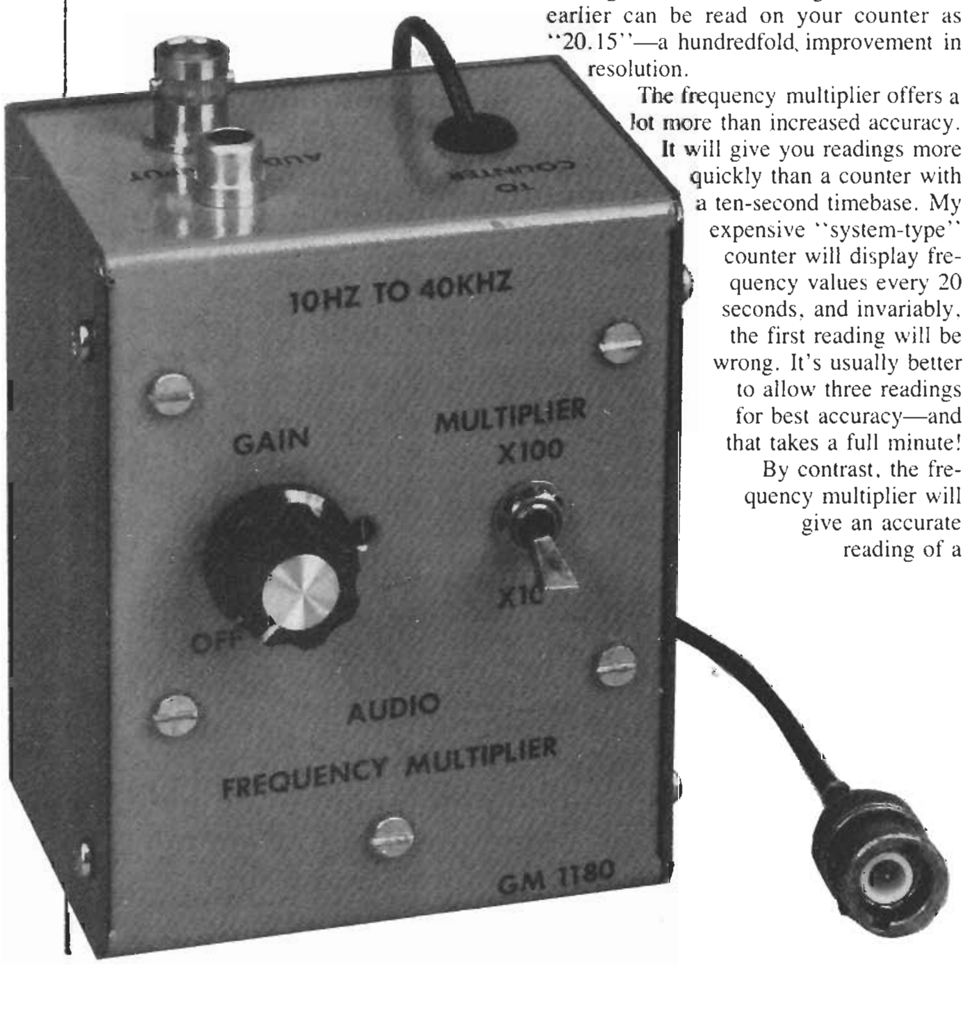
GARY McCLELLAN

FOR YEARS THERE HAVE BEEN PLENTY OF devices like prescalers available to extend the high-frequency range of the average counter. But for those of us who work with audio frequencies, the selection of add-on's hasn't been so great and that can cause a problem when you try to measure something like a 20-Hz signal accurately.

Most of the time the counter reads "20," but it frequently jumps to "19" or "21." That's a total of 10% error (5% above, and 5% below), and not very good if you're trying to get a precise reading. The usual solution is either to use a counter that has a ten-second timebase, or that has period-measurement capability. Such counters are usually fairly expensive, though. But wait—there's a far-lower-cost solution to the problem, and it requires no modifications to your counter!

The audio-frequency multiplier described here allows you to measure signals from 10 Hz to 40 kHz accurately and quickly using your existing counter. The multiplier is a little box that goes between your test cable and counter. With it you can multiply the frequency of the incoming signal by a factor of ten or a hundred for easier reading. Now, the 20-Hz signal mentioned earlier can be read on your counter as "20.15"—a hundredfold improvement in resolution.

The frequency multiplier offers a lot more than increased accuracy. It will give you readings more quickly than a counter with a ten-second timebase. My expensive "system-type" counter will display frequency values every 20 seconds, and invariably, the first reading will be wrong. It's usually better to allow three readings for best accuracy—and that takes a full minute! By contrast, the frequency multiplier will give an accurate reading of a 20-Hz signal within just six seconds—and that includes the two-second update time of the typical inexpensive counter. Furthermore, the circuit responds to small changes faster than my expensive counter, and the speed increases as the frequency being measured does. If you hate to stand around and wait for the display on an expensive counter to be updated, you're bound to like this device.



Many expensive counters have period-measurement capabilities, which means fast, accurate, display of *time*, but some calculation is needed to convert that figure to frequency. The frequency multiplier gives a direct readout of frequency without time-consuming calculations. (To be fair, though, if the signal frequency is not stable—if it jitters a bit—the figure derived from the period measurement will be more accurate.)

It's tough to estimate project costs these days, but you should be able to build the frequency multiplier for under $15; quite possibly for under $10 if you have a well-stocked junk box. Costs are kept down by using common, low-cost IC's and parts. There's one board to "stuff," with four IC's on it, and little else. The board is installed in a cabinet along with a few more parts, and that is about all there is to it. The prototype was built in one afternoon, and there is no reason why you can't build the frequency multiplier about as quickly.

How it works

The frequency multiplier is basically a PLL (*P*hase *L*ocked *L*oop) circuit, and is similar to the Programma 1 synthesized pulse-generator featured in the October 1980 issue of **Radio-Electronics** . Many of the same IC's are used, and the circuit design is similar, but the thumbwheel switches are replaced by a single switch for × 10 or × 100 output. Also, the input signal replaces the 100-Hz reference used in the Programma 1. Refer to Fig. 1 as we look at how the frequency multiplier works.

Low-frequency signals appearing at the input pass through the GAIN potentiometer, R101, which permits the frequency multiplier to handle a very wide range of signal levels. Then, the attenuated signal drives IC1, which shapes it into a square wave. That signal drives phase detector IC2.

Another part of the same IC also serves as a VCO (*V*oltage *C*ontrolled *O*scillator). It accepts a DC voltage from the phase detector and generates a square-wave signal. The VCO can generate signals ranging from under 100 Hz to over 400 kHz without any switching. From the VCO, the signal-path branches out.

One branch takes the signal to IC3, a NAND gate. That gate acts as a switch, and allows signals to pass to the frequency counter *only* when the PLL is locked onto a good signal. That suppresses the stray readings you would normally get without an input signal, or with signals the device can't handle. The output from the VCO also drives two divide-by-ten counters, both of which are contained in IC4. The outputs from the dividers are selected by S101, the MULTIPLIER switch. The output selected drives the phase detector, which generates the DC control-voltage for the VCO. Thus, a simple PLL circuit, that can generate frequencies ten times or a hundred times the input frequency, is formed.

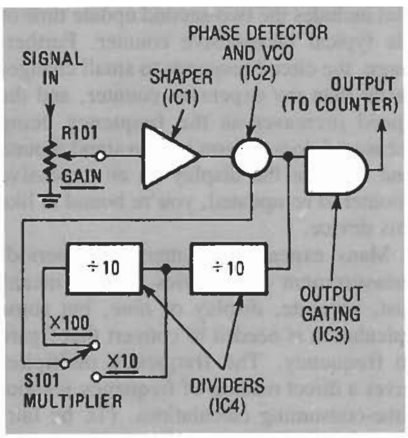


FIG. 1—MULTIPLICATION FACTOR is determined by number of divide-by-ten counters used.

Let's look at some of the finer points of the circuitry. Refer to the schematic diagram in Fig. 2 for details. The shaper amp consists of a fast CMOS CA3130 op-amp, IC1. Its high-frequency response is reduced by C3 so the circuit won't oscillate, yet will have flat gain over its 10-Hz to 40-kHz input range. The inputs of the op-amp are biased to half the supply voltage by R1 and R3, eliminating the need for a split (positive and negative voltages) power supply.

Resistors R4 and R5 set the hysteresis or "trip" point for the circuit, which is about 350 mV. The output signal is a nine-volt square wave that drives the phase-detector portion of IC2. The phase detector compares the signal with that from the MULTIPLIER switch, and outputs a DC voltage at pin 13 of the IC. That drives a network known as a *loop filter*, which smooths out the pulses from the phase detector, giving a clean DC-signal.

The VCO input is at pin 9 of IC2, and the timing capacitor that sets the frequency range is C5. The VCO output appears at pin 4, and drives both IC3 and IC4. Resistor R9 and capacitor C7 form another filter to "debounce" the signal from pin 1 of IC2 (which indicates that the PLL is locked onto the signal) so that it can enable IC3-a's NAND gate whenever a good signal is present at pin 4 of IC2. Resistor R10 is included so that the charge on C7 won't blow IC3 when the power is turned off. The output of IC3 is reduced by R11/R12 to about 900 mV peak-to-peak, which is a comfortable level for most counters. The remaining circuitry consists of a standard CMOS dual divide-by-ten counter, IC4.

Components

Because most people will want to raid their junk boxes for parts for the multiplier, let's discuss substitutions. Since most of the component values aren't critical, some substitutions can be made. The exceptions to that are resistors R1 and R3, which bias the op-amp. If you have to substitute for them, you must make sure that the values of both substitutes are identical. Another area you should watch is the loop filter. Try to use the values indicated for C6, R7, and R8 if you can. (If you have trouble finding a 1.8K resistor for R8, you can either combine two resistors in series or parallel to get the correct value, or use a 1.5K or 2K one.)

Also, be sure to use a tantalum-type capacitor for C6. If you use an electrolytic, with its higher leakage, the performance of the multiplier will suffer. Finally, C5 must be 220 pF—it sets the VCO range, which is critical.

Aside from observing those precautions, you are free to make reasonable substitutions from your junk box. Remember to test the parts before installing them; that can save troubleshooting later.

Construction

A PC board will make construction a lot easier and will help to insure that the device will work the first time it is tried. You can also use perforated construction-board, but be careful with the parts layout—you are

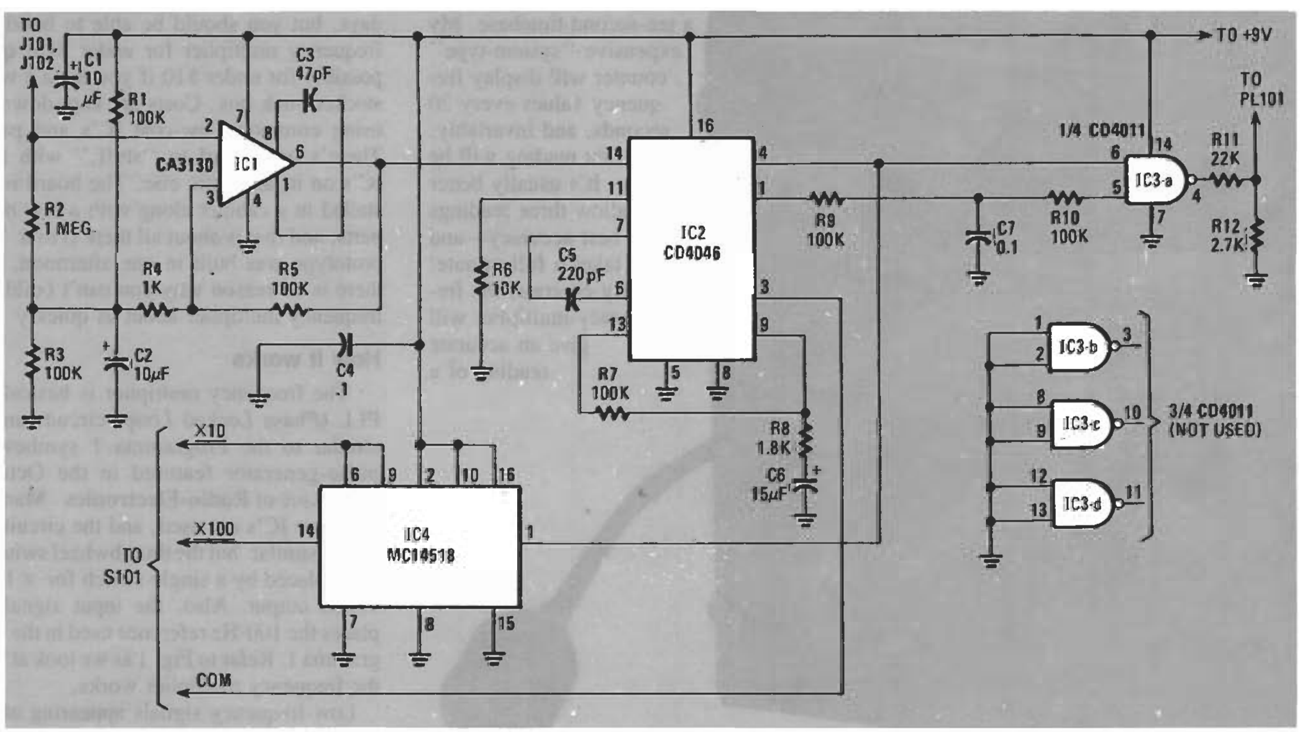


FIG. 2—A LOGIC-HIGH OUTPUT from pin 1 of IC2 indicates that the PLL is locked and allows IC3, a NAND gate to pass the pulse string from IC2's pin 4.

working with high-gain analog circuitry and noisy digital-circuitry. The PC-board layout shown in Fig. 3 is ideal for the circuit, and you may want to copy it even if you use point-to-point wiring.

Start construction by installing the board-mounted components. Refer to Figs. 4 and 5 as you proceed. Position the board as shown in Fig. 4 and leave the board in that position until you are finished with it.

Install an 8-pin IC socket at the IC1 location. Be sure to orient any pin-1 identification (notch or dot) on that socket so that it points up. Then install a 16-pin socket with its pin-1 identification pointing down at IC2, and another, pointing right, at IC4. Finally, install a 14-pin socket at IC3 so it faces to the right.

With the four IC sockets in place, next come the resistors. Start at the IC1 socket. Install a 1-megohm resistor at R2, and then a 1K resistor next to it at R4. Move down and install a 100K resistor at R3. After that, install two 100K resistors at R1 and R5, at the "tail" end of IC1.

The second batch of resistors is located around IC2. Install a 10K unit at R6 first,

PARTS LIST

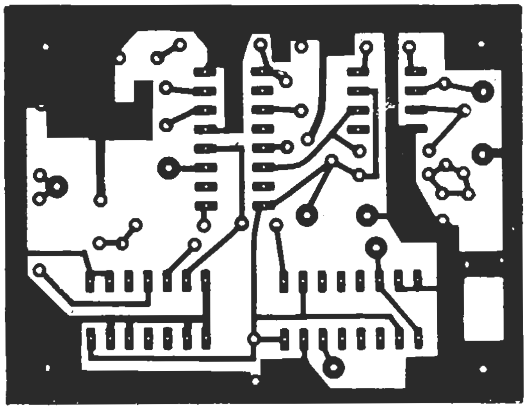
All resistors ¼-watt, 5%
R1, R3, R5, R7, R9, R10—100,000 ohms
R2—1 megohm
R4—1000 ohms
R6—10,000 ohms
R8—1800 ohms
R11—22,000 ohms
R12—2700 ohms
R101—1 megohm, potentiometer, linear taper with SPST switch (S102)

Capacitors
C1, C2—10 µF, 16 volts, electrolytic or tantalum
C3—47 pF, ceramic disc
C4, C7—0.1 µF, 16 volts, ceramic disc
C5—220 pF, ceramic disc
C6—15 µF, 16 volts, tantalum
C101—0.1 µF, 100 volts, Mylar

Semiconductors
IC1—CA3130AE CMOS op-amp
IC2—CD4046 CMOS PLL
IC3—CD4011 CMOS quad 2-input NAND gate
IC4—MC14518 or CD4518 CMOS dual synchronous ÷10 counter
J101—female BNC connector, chassis-mount
J102—RCA phono jack, chassis mount
PL101—male BNC connector
S101—SPDT toggle switch
S102—SPST switch (part of R101)
B1—9-volt transistor battery

Miscellaneous: PC board, cabinet (LMB type CR-332 or similar), 1½-inch spacers, 9-volt battery snap, battery clip, IC sockets, wire, solder, etc.

The following is available from Technico Services, PO Box 20HC, Orangehurst, Fullerton, CA 92633: Etched and drilled PC board (MULT), $6.00. Kit of all parts *excluding PC board* (MULT-P) is available for $35.00 from: ABC Electronics, 2033 La Habra Blvd., La Habra, CA 90631. CA residents please add 6% sales tax; foreign orders please add $1.00 for shipping.



3 INCHES

FIG. 3—FULL-SIZE foil pattern for frequency multiplier can be used for making your own PC board.

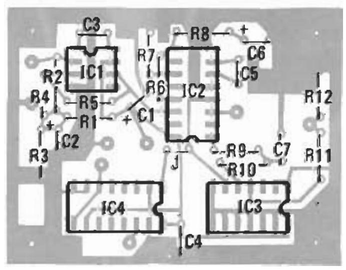


FIG. 4—MAKE CERTAIN that IC's and polarized capacitors are oriented properly. Failure to do so can cause sensitive parts to be destroyed.

then a 100K resistor between it and IC2 at R7. Move up and install a 1.8K resistor at R8. Then, on the other side of IC2, install two 100K units at R9 and R10. At the right edge of the board install a 2.7K resistor at R12, and a 22K one at R11. Stop at that point and check your work. Correct any mistakes you may find before going farther.

Next come the capacitors. Start near IC1 as you did with the resistors and install a 10-µF electrolytic or tantalum capacitor at C2. Note that the positive side faces R2. Install a 47-pF ceramic disc at C3. Install a 10-µF electrolytic or tantalum at C1, making sure that the positive side points toward IC4. On the other side of IC2 install a 15-µF tantalum capacitor at C6 with its "plus" sign pointing toward the 1.8K resistor, R8. Then below it install a 220-pF disc at C5. Finish up by installing 0.1-µF ceramic discs at C7 and C4. Be sure to check your work after all the capacitors are installed.

Install a wire jumper near pin 1 of IC2 and then cut five pieces of hookup wire, each about three inches long. Strip both ends of the wires, and solder one to each of the five pads marked with asterisks in Fig. 6. The remaining connections to the board will be made when it is installed in the box.

Connect S101 as shown in Fig. 6 and then finish up the board by installing the IC's. Install the CA3130 at IC1, a CD4046 at IC2, a CD4011 at IC3, and a MC14518 (or CD4518) at IC4. Double check to be sure the IC's are installed correctly: if they're in backwards, they'll probably be damaged when power is applied to the board. Set the board aside temporarily.

The enclosure comes next. Figure 5 shows how the case-mounted components can be laid out. One thing we did that needs comment concerns the input jacks. In our laboratory, all the connectors are of the BNC type, so that's what was used for J101. For some applications, though, an RCA-type jack is preferable, so J102, connected in parallel with J101, is of that sort. Use whatever best suits your needs.

You can install the PC board in the box using long (about 1½ inches) threaded spacers behind S101 and R101. If you can't locate the spacers, use "L" brackets to fasten the board to the top of the box. Don't mount the board in place, yet, though; there's still a bit of wiring left to be done. Refer again to Fig. 5 for details.

Start by mounting and wiring the GAIN pot (R101). Attach one end of a 0.1 µF Mylar capacitor (C101) to the wiper of the potentiometer. As indicated in Fig. 6, the ground lug of the pot should be connected both to the ground wire coming from the board *and* to the case. The "hot" end of the control should be connected to the center connectors of J101 and J102. The other end of C101 should be connected to the board as shown in Fig. 6.

Connect the left-hand (as seen in Fig. 6) battery wire (−) to the switch mounted on the pot (S102), and wire a transistor-battery snap between that switch and the other battery-pad on the board. Mount S101 on the case and install the board. Finish up by attaching PL101 to one end of a three-foot length of thin coaxial cable (like RG-174/AU) and the other end of the cable to the points indicated in the parts-placement diagram *on the foil side of the board*. Tack-solder the shield of the cable to the ground plane of the board. Position C101 so it doesn't short against anything.

Check over your work for shorts and other potential problem-causers, and correct anything that's amiss. Install a 9-volt battery and you're ready to go.

Applications

Using the frequency multiplier is easy.

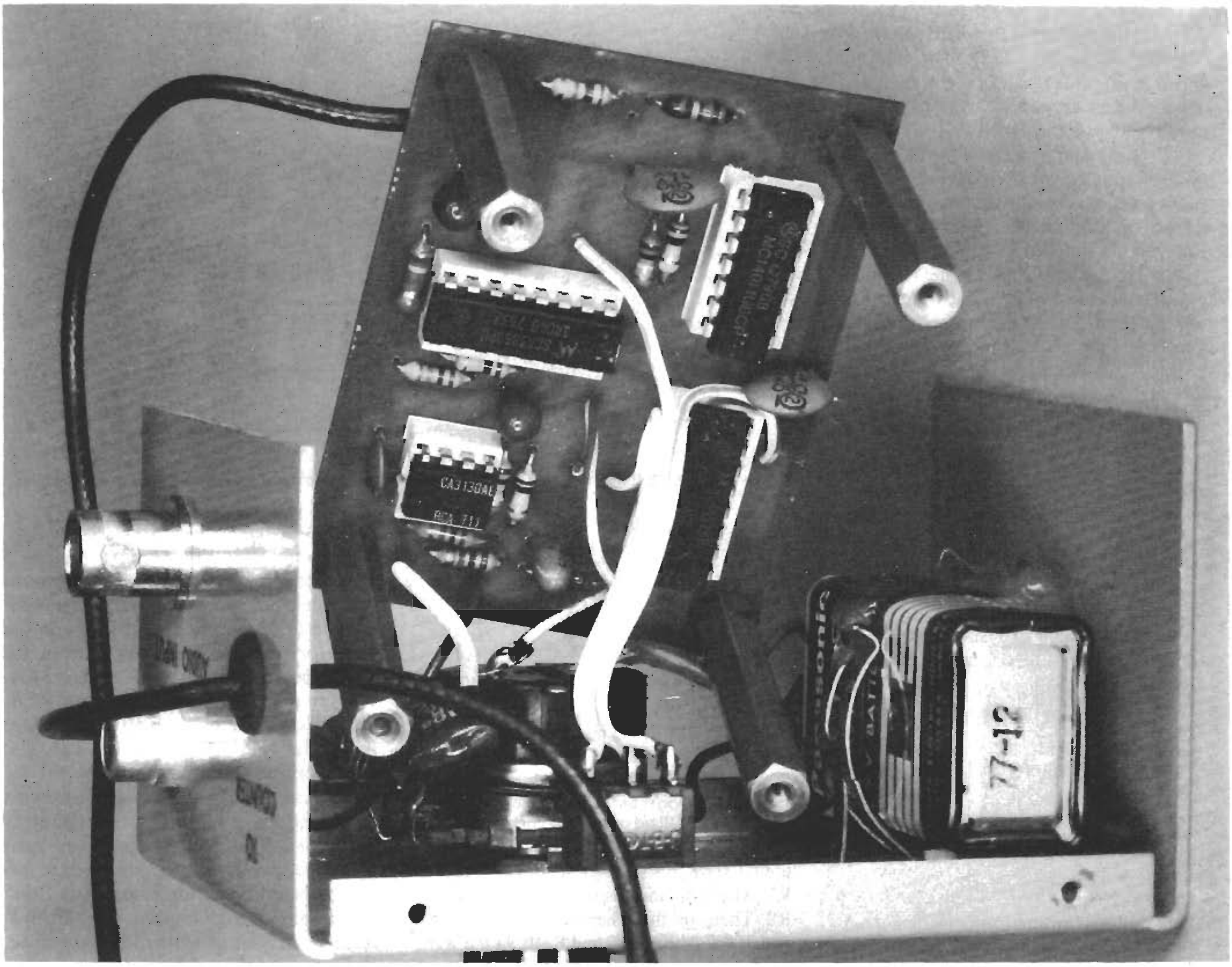


FIG. 5—1½-INCH threaded spacers are used to attach PC board to top of case.

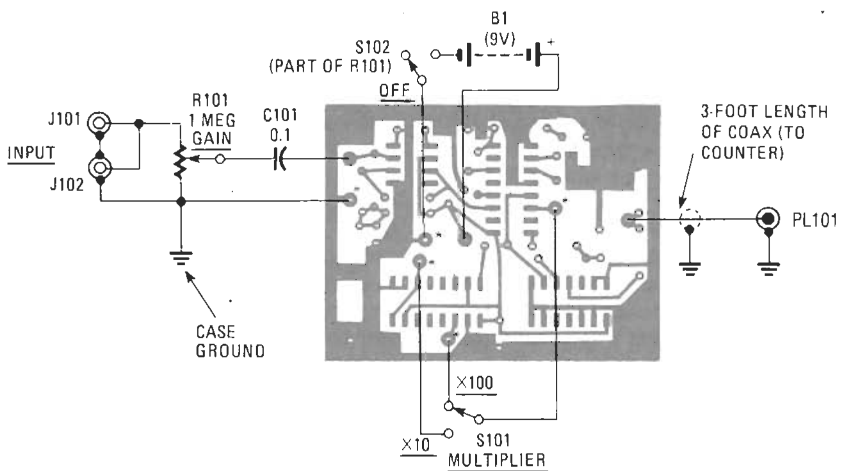


FIG. 6—CONNECTIONS TO CASE-MOUNTED parts. Shield of coax used for output is tack-soldered to ground foil on bottom of board.

Simply connect the audio signal to be measured to J101 or J102 and connect PL101 to your counter. Set the MULTIPLIER switch to ×10 and advance the GAIN control until the counter gives a stable reading. Note that advancing the control beyond that point will have little or no effect. If you need better resolution, and the frequency you're measuring is 4-kHz or lower, switch the MULTIPLIER to ×100.

Here are a few tips that you may find helpful. When you look at the display on your counter, remember to mentally shift the decimal point one place to the left when you're using the ×10 range, and two places to the left when you're using the ×100 range. A reading of "200" on the ×10 range will represent "20.0" and a reading of "2000" on the ×100 range will represent "20.00." That will soon become automatic.

The frequency multiplier does have some limitations. For example, the VCO range of the unit is 100 Hz to 400 kHz. That means that with the MULTIPLIER switch set to the ×10 position, the input frequency must be between 10 Hz and 40 kHz, since 40 kHz × 10 is 400 kHz—the upper limit of the VCO. Similarly, on the ×100 range you are restricted to a range of 10 Hz to 4 kHz. If you are not within those limits, there will be no reading on the counter.

Because the current drain (500-750 μA) on the battery is so light, you may wonder how you'll know when to change it. Replace it when the upper frequency-limit starts to drop, and you can no longer get outputs in the 300-kHz to 400-kHz range. The maximum range will drop with the battery voltage. Another clue that it's time for battery replacement is the multiplier's suddenly refusing to multiply. That's a sure sign that it's time to change the battery.

Finally, for those of you who would like (or need) more gain, it can be increased simply by making the value of R4 (1K) smaller. Nothing else need be changed. **R-E**