An Advanced VHF Wattmeter

A few modifications greatly increase the utility of a popular QST *project*

By Bob Kopski, K3NHI

This homebrew instrument is based on the RF power meter project by Wes Hayward, W7ZOI and Bob Larkin, K7PUA that appears in *QST*, June 2001. The reference article presented a simple instrument for the homebrewer to measure RF power well through VHF. I decided to build it but with some personalization and enhancements to better suit my needs and interests. When I sent a thank-you note to the designers for the original article along with some information about mine, Wes encouraged me to do this write-up. "Go for it!" were his words.

If you compare this version with the original, the first thing you'll see is that this box has a lot more stuff on the front panel (see Fig 1). There are now two meters and more controls. Almost all these additions are associated with the instrument's low-frequency signal processing or "support" circuitry. Except for the inclusion of a convenient 20-dB slide-switch attenuator, the original RF section is unchanged.

The reference instrument incorporated a built-in analog meter and provision to connect an external DVM. It also utilized a conversion chart to relate meter readings to RF power. I wanted both digital and analog displays built in for both an accurate, high-resolution numeric power readout and a trend indicator at the same time. I also wanted to avoid using a calibration chart if possible.

All that's needed to accomplish these goals is a custom face for the analog meter plus some circuitry for the scaling and level-shifting of internal signals. This signal processing results in direct dBm readings on both meters—no conversion chart is needed. The DVM also displays the correct polarity sign. There's neither rocket science nor smoke and mirrors here folks: It's all done simply with op amps and resistors! The schematic tells all (See Fig 2).

In the process of designing these basic circuit functions, it occurred to me that other simple additions would add a lot to the utility of the instrument. Thus, the project grew "on the fly." One of these extras is a gain-change option that includes an external OFFSET control for the analog display.

This enhancement switches the ana-

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log meter reading from 10 dB to 1 dB per major division. The panel mounted OFFSET control allows any readable input power level to be brought into the analog meter's range. It's really a "slide-back" function. Thus, this meter can change from a display calibrated in dBm to a relative-dB reading. At the same time, the DVM continues to read the absolute power level in dBm. It's the best of both worlds, I think. Since the analog panel meter responds reasonably quickly, it's like a "souped-up" trend meter, good for tuning filters and such.

Another addition is the incorporation of a separate signal output scaled to 10 mV/dB. This permits easy, calibrated swept displays. Thus, one could sweep filters, for example, and have a very usable scope display with a known, convenient log-scale response.

In conjunction with this last feature, I included a switched output-bandwidth filter as shown. This was done with the speculation that such a feature might be useful with varying sweep speeds. I've yet to fully exercise this feature; but while I was drilling panel holes, I drilled for this too!

In hindsight, I realize now I might also have included a battery-check switch to monitor the two internal 9-V batteries via the analog meter, since it's there anyway. (The DVM can't measure it's own 9-V battery supply.) Oh well—I'm sure some of you can think of other things that you might like to add for your own interests, as well.

Construction

I do not have high ambient RF levels and so I do not need a cast metal enclosure. I used a standard 3×4×5-inch Minibox instead. This has enough room for the panel, internal circuits and two 9-V batteries (see Fig 3).

My RF subassembly is shown in Fig 4. I used the original "dead-bug" technique on PC-board material. You can incorporate the 20-dB attenuator, some other operational feature or just simply follow the reference article. In any case, I suggest you stick with the original design details immediately surrounding the AD8307 IC. I did and all works well.

The signal-processing circuitry can be built in almost any way you prefer, including the original dead-bug or "ugly" way. I like to use PC "hole-board" for this sort of thing (see Fig 5). I've included the layout of this assembly for those who'd like to try it (see Figs 6 and 7). Here are a few tips to go with it.

The board is cut from RadioShack (#276-168). This hole-board has a pre-etched IC pattern and buses on it. The addition of some wire jumpers makes it a complete custom circuit board ready for the components. Please note that two wire jumpers pass *under* the IC socket. Be sure to install these *before* the 14-pin socket goes in. Probably the most important assembly guidance I can offer is to carefully study the layout for parts placement and *count holes*!

When your board assembly is done, carefully remove the flux, and inspect it thoroughly with a magnifying lens for short circuits. This step helps keep smoke levels under control for me. I prefer to dress the lead wires through some strain-relieving insulated wire loops through unused holes in the board, as shown in Fig 5. I also prefer to twist together multiple wires that go to a particular panel part such as switches.

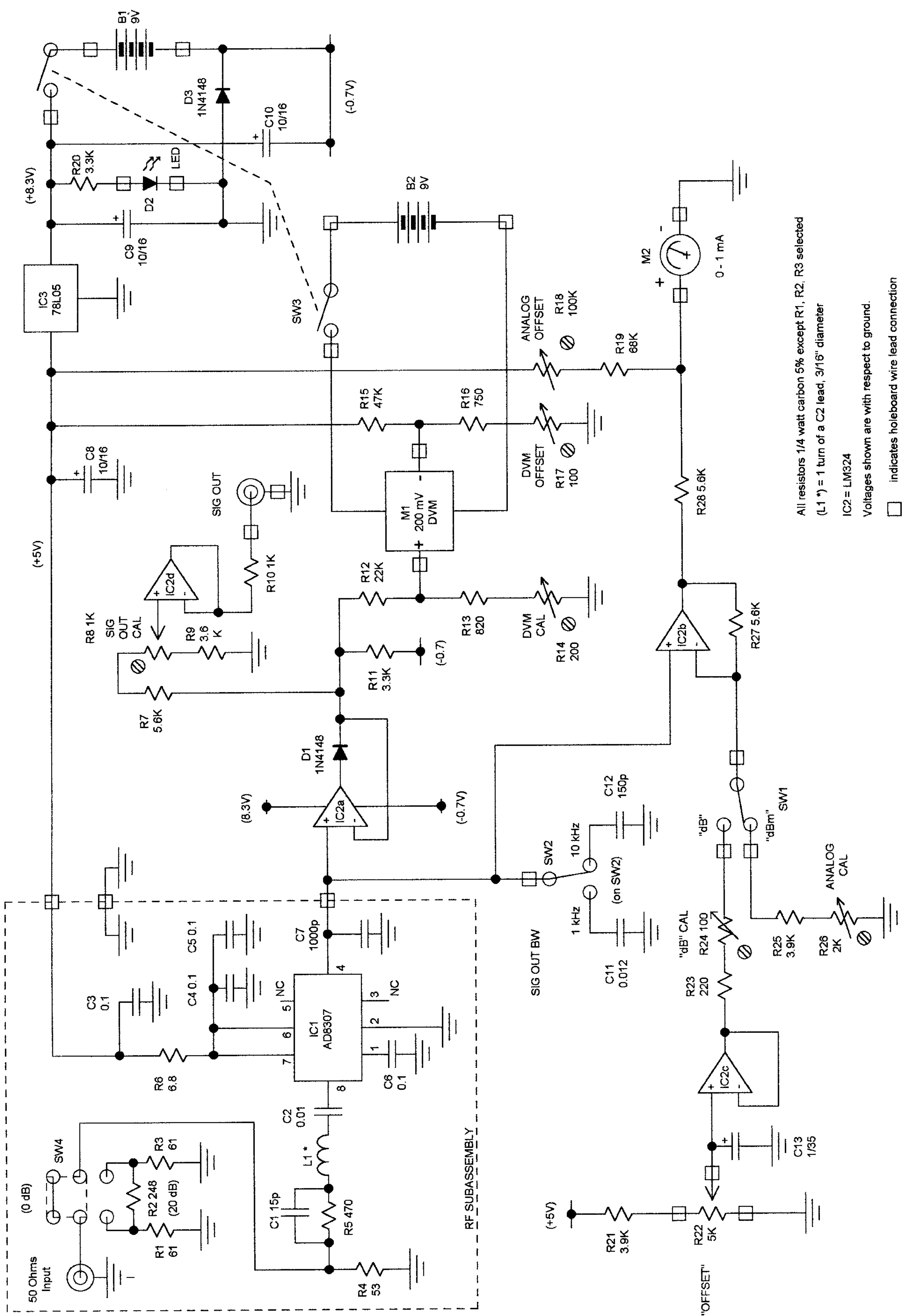
I suggest you do some simple open and short checks on the completed subassembly with an ohmmeter before powering it up and connecting the reasonably expensive AD8307 on the RF subassembly.

I generally lay out instrument panels with a drawing program and print them using an inkjet printer on good-quality paper. I stick the paper to the metal box with rub-on glue stick. Not

Fig 1—The advanced VHF power meter includes a digital panel meter for accurate, high-resolution power readings plus an analog meter for trend information. The instrument bottoms out around –76 dBm but calibration very good above –70 dBm.

Fig 2 (right)—A schematic of the VHF power meter. All resistors are 1/4 W, 5% carbon components unless otherwise indicated. All capacitors are ceramic unless otherwise indicated.

C1—15 pF
C2—0.01 µF
C3-C6—0.1 µF
C7—1000 pF
C8-C10—10 µF, 16 V, tantalum
C11—0.012 µF
C12—150 pF
C13—1 µF, 35 V, tantalum
D1, D3—1N4148 diode
D2—LED, as preferred
IC1—AD8307 log amplifier, (Kanga, 3521 Spring Lake Dr, Findlay OH 45840)
IC2—LM324 quad op amp
IC3—78L05 5-V regulator
M1—200 mV DVM (PM-128 panel meter from Circuit Specialists, Hosfelt or as preferred)
M2—0-1 mA meter (JAMECO 171897 or as preferred)
R1, R3—61 Ω, selected
R2—248 Ω, selected
R4—53 Ω, selected
R5—470 Ω
R6—6.8 Ω
R7, R27, R28—5.6 kΩ
R8—1 kΩ trimmer (Digi-Key 36G13-ND or equivalent)
R9—3.6 kΩ
R10—1 kΩ
R11, R20—3.3 kΩ
R12—22 kΩ
R13—820 Ω
R14—200 Ω trimmer (Digi-Key 36G22-ND or equivalent)
R15—47 kΩ
R16—750 Ω
R17, R24—100 Ω trimmer (Digi-Key 36G12-ND or equivalent)
R18—100 k Ω trimmer (Digi-Key 36G15-ND or equivalent)
R19—68 kΩ
R21, R25—3.9 kΩ
R22—5 kΩ 10-turn potentiometer (Mouser 594-53411502 or equivalent)
R23—220 Ω
R26—2 kΩ trimmer (Digi-Key 36G23-ND or equivalent)
SW1, SW3—DPDT mini-toggle
SW2—SPDT mini-toggle switch
SW4—DPDT slide switch (Digi-Key SW333-ND or equivalent)
BNC connector
Phono jack
Box—3×4×5-inch Minibox
9 V—Eveready 522 or equivalent
9 V—6 AA cells and holder
Battery connectors (2)
PC Board-double sided
Holeboard RadioShack #276-168
14-pin IC socket



All resistors 1/4 watt carbon 5% except R1, R2, R3 selected
(L1 *) = 1 turn of a C2 lead, 3/16" diameter
IC2 = LM324
Voltages shown are with respect to ground.
indicates holeboard wire lead connection
B1 9V
B2 9V
D3 1N4148
C10 10/16
(-0.7V)
(+8.3V)
R20 3.3K
D2
LED
C9 10/16
IC3 78L05
SW3
M2
0 - 1 mA
ANALOG OFFSET
R18 100K
R19 68K
R15 47K
R16 750
DVM OFFSET
R17 100
C8 10/16
SIG OUT
M1 200 mV DVM
(+5V)
IC2d
R10 1K
R12 22K
R13 820
DVM CAL
R14 200
R28 5.6K
R8 1K
SIG OUT CAL
R9 3.6 K
R11 3.3K
(-0.7)
IC2b
R27 5.6K
R7 5.6K
D1 1N4148
(8.3V)
IC2a
(-0.7V)
C12 150p
SW2
10 kHz
1 kHz
(on SW2)
C11 0.012
SIG OUT BW
"dB"
"dBm"
SW1
ANALOG CAL
"dB" CAL
R24 100
R25 3.9K
R26 2K
R23 220
C5 0.1
C7 1000p
C4 0.1
C3 0.1
NC
IC1 AD8307
C6 0.1
R6 6.8
C2 0.01
L1 *
IC2c
C13 1/35
(0 dB)
SW4
R3 61
R2 248 (20 dB)
R1 61
C1 15p
R5 470
RF SUBASSEMBLY
50 Ohms Input
R4 53
R21 3.9K
R22 5K
"OFFSET"

all glue sticks work well for this. I do this process twice.

The first printout—an expendable template—includes the drill centers and other mechanical details. I use it as a drill and cutout guide. When all this heavy-duty work is done, I remove the paper by soaking in water. Some drying, deburring and solvent-cleaning of the Minibox readies it for the second and final panel paper.

The second paper is printed with the nice-looking panel details but without the construction markings. Once this paper is glued in place, I overlay it with Contact-brand clear film for durability. The final task is to cut away the overlay papers where the metalwork holes are; that is easily done with an X-acto knife and a #11 blade. The result is as you see it. It looks good, don't you think? By the way, the analog meter scale is drawn and printed the same way (see Fig 8).

I use *TurboCad* in both my electronic and R/C aeromodeling hobbies; but I think other drawing programs should be usable as well. You can also download a useable demo version of *TurboCad* from **www.turbocad.com**.

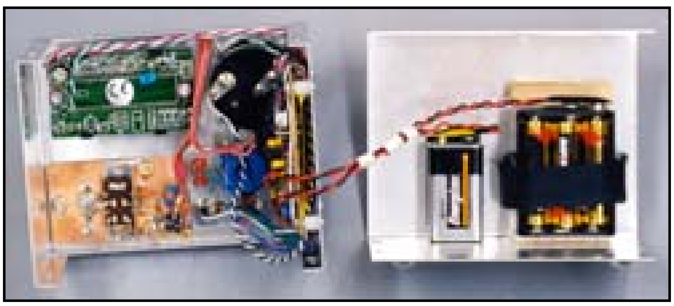
Calibration and Operation

I suggest you review the discussion in the reference article concerning RF sources for calibration of your power meter. Once you have a suitable known source, start by calibrating the DVM. Trimmer R14 sets the gain so that an *x*-dB change in input power results in an *x*-mV change in DVM reading; that is, so that 1 mV = 1 dB. Trimmer R14 locates this result in the right place. In other words, R17 makes the DVM read the power level correctly while R14 makes changes in power level read correctly.

This same idea holds for the analog panel meter, as well. With switch SW1 in dBm mode, R26 sets the rate of change of the display while R18 makes a given power level read correctly. When all is done properly, both digital and analog meters display both the same power level and the same changes in power level.

Incidentally, these adjustments are usually iterative in nature. Expect to go back and forth a few times between each cal and offset trimmer pair until convergence occurs and the respective meter reads correctly across its full range.

As above, trimmer R24 sets the gain for the analog meter in the decibel mode. In this case, though, there is no associated offset trimmer. Rather, the panel mounted OFFSET pot is used as needed in the application of the instrument. In use, it is adjusted to establish a reference reading on the analog face (usually "0") for *any* useable in-



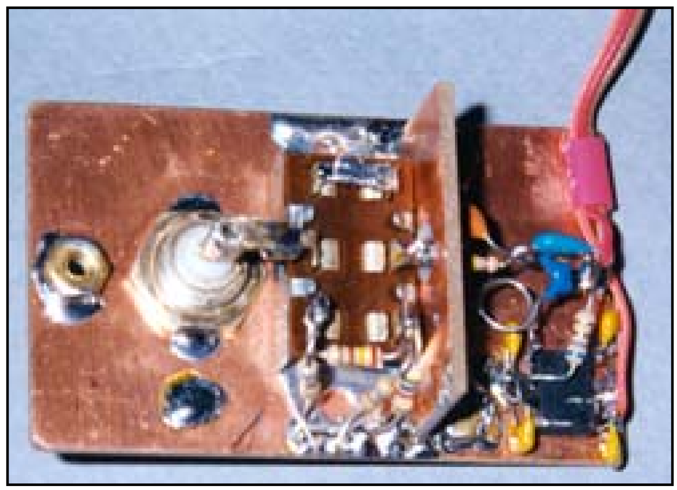


Fig 3 (above)—What's inside the 3×4×5-inch Minibox: A 9-V battery for the DVM, six AA cells power everything else. The batteries are held in place with hook and loop tape.
Fig 4(right)—The RF subassembly uses dead-bug construction and includes a 20-dB step attenuator. It is held against case front inside by three screws. A three-wire cable connects it to the signal-processing board.

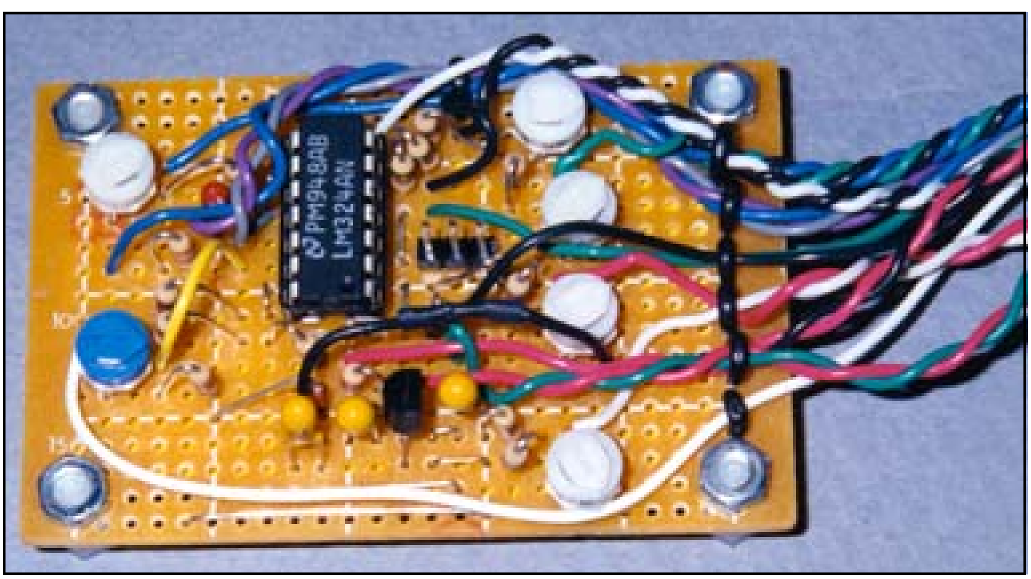


Fig 5—The signal-processing board is based on a RadioShack printed hole board. Notice the centrally located three-pin connector used to interface with the RF subassembly.

put power. Thus in this mode, the decibel readings of the analog meter are no longer referenced to a milliwatt (dBm), but it can accurately display power changes in decibels OFFSET control. In effect, it becomes an expanded-scale meter. Because this pot must accommodate a very wide signal range, a multiturn pot is highly recommended. Mine is a three-turn component, but 10 turns would be better, and such components are more readily available.

Trimmer R7 calibrates the output signal to the design value of 10 mV/dB—it's another gain trim. Notice that this signal output rests on a non-offsetable dc value. That is usually of no consequence in application. If you'd prefer to ac-couple this output (0.1 µF should do the trick), or add an offset-control circuit, feel free to do so.

Conclusion

Notice how it's possible to expand upon one basic project and customize it for your own needs and interests. It's funny how some would call that bashing! Now it's your turn to duplicate or customize your own rendition of this VHF wattmeter. Maybe there's a published homebrew item you'd like to embellish or simplify. As the man said, "Go for it!"

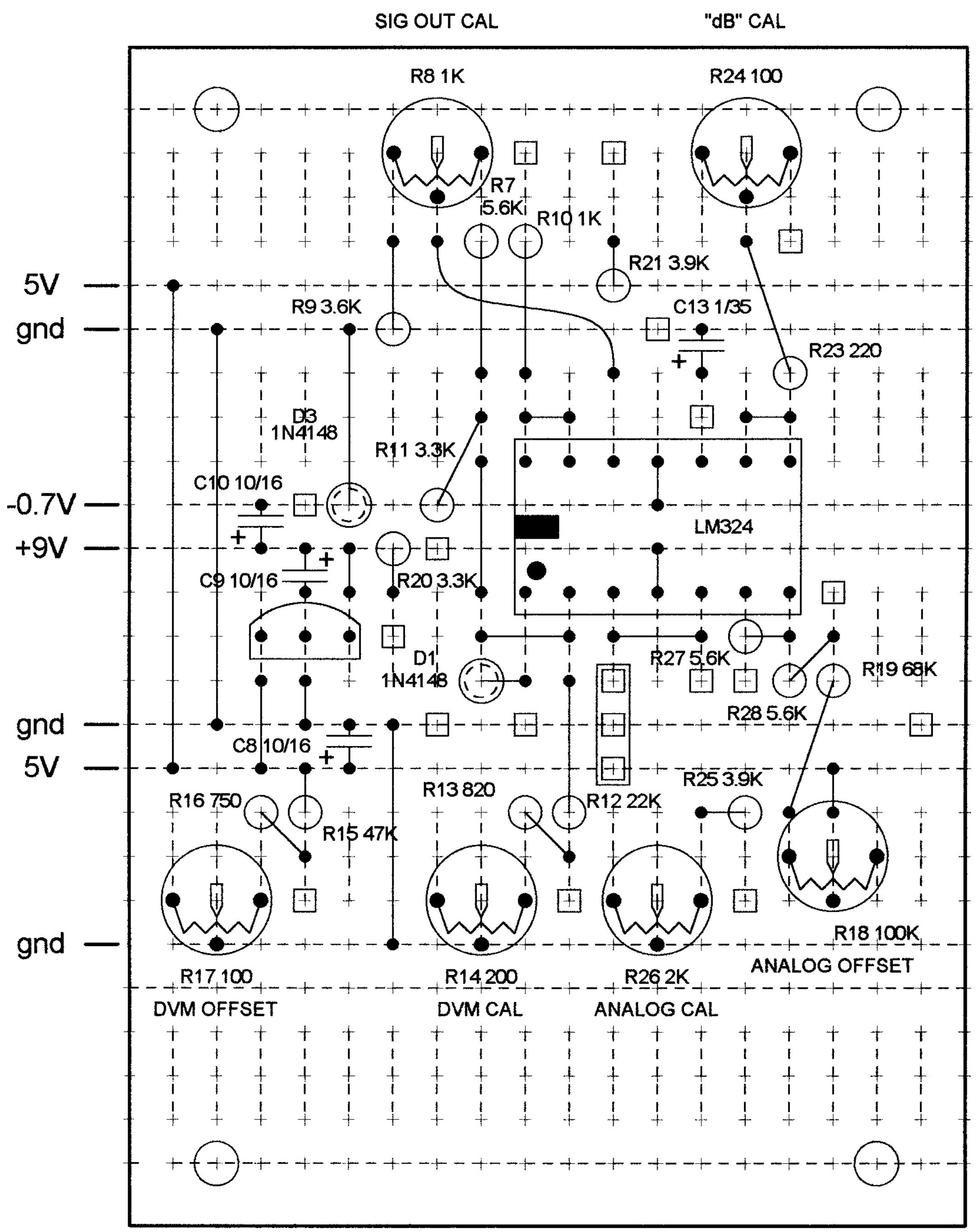


Fig 6—Component placement diagram for the signal processing board. This view is from the component side with the printed-circuit traces and lands from the other side shown dotted.

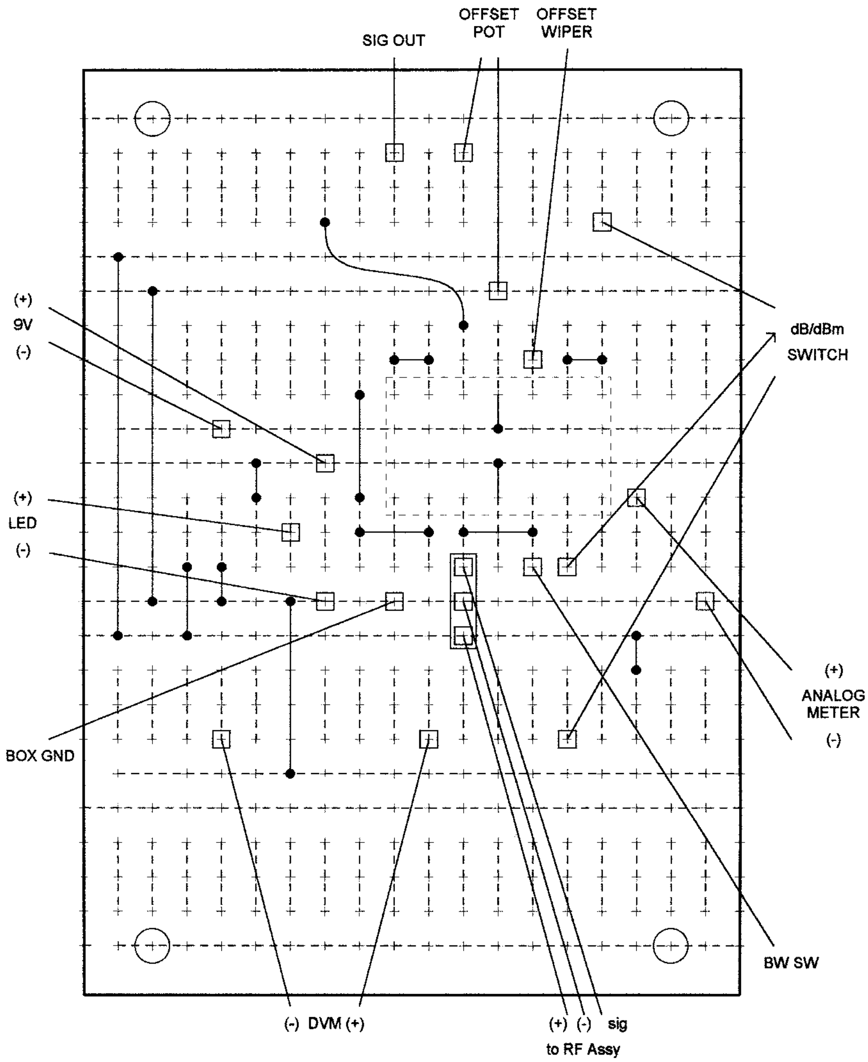


Fig 7—Wiring and jumper diagram for the signal-processing board. This view is from the component side with the printed-circuit traces and lands from the other side shown dotted.

Fig 8—The original 0-1 mA meter scale has been replaced with an eye-catching and functional power-meter scale. The replacement scale was made using a drawing program and an inkjet printer.

I'd be happy to correspond with *QEX* readers. Please include a SASE with any correspondence for which you'd like a reply.

Bob is a recently retired Senior Design Engineer with a major defense contractor. He holds BSEE and BSEP degrees from Lehigh University.

As a life-long electronics, ham and aeromodeling hobbyist, he routinely combines all three pursuits for the fun of it. His Technician ticket dates to about 1959, at which time he wanted to homebrew 6-meter radio-control equipment for R/C aeromodels. He still routinely flies on six and has operated fixed and mobile stations on six. He has published an original six-meter H-T. His broadly based aeromodeling interest dates to the early 1950s, but he has specialized in electrically powered R/C models for over 25 years. He has been a Contributing Editor to Model Aviation magazine for over 19 years with a monthly column devoted to the electric flying specialty Additionally, he has published many construction articles covering both model aircraft design and aeromodeling related electronics. He enjoys it all! □□