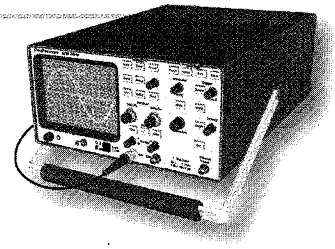
Pocket dBm RF Power Meter



This little but accurate RF power meter may be just what your workbench needs.

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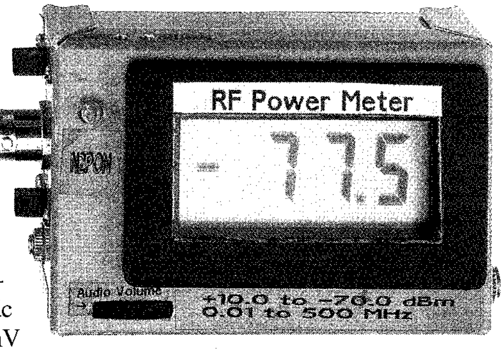


This is one of the most useful projects I have built. It is a simple, RF power meter that accurately measures in 0.1 dBm increments. This meter measures from +10.0 dBm to –70.0 dBm over the frequency range of 0.01 to 500 MHz. The heart of this meter is the Analog Devices AD8307AN Logarithmic Amplifier.[1] This 8-pin IC converts RF into a 25 mV dc/dB output over the frequency range of dc to 500 MHz. This chip is combined with a 200.0 mV digital panel meter module to accurately display digital dBm. Gain and offset have been thermally stabilized in this circuit from 40 to 80° F.

Where it Came From

I built the first meter in June 2001 after studying the *QST* article "Simple RF-Power Measurement" by Hayward and Larkin.[2] Then I decided to build a second meter in January 2006. An inside view of both meters is shown in Figure 1. The second meter has a volume control on the audio output.

All of the references have some good information. I especially like K3NHI's 20 dB input attenuator, and G8KBB goes through a thorough accuracy analysis.[3,4] The AD8307 circuit is taken from Hayward and Larkin article except that I added a switch to provide a 50 or a 1000 Ω input. The 1000 Ω setting enables in-circuit parallel (line-tap) measurements with less VSWR change. Also in this small package, I got flatter frequency response by using two turns for L1. Probably some of the inductance is cancelled by the shielding. With calibration at 120 MHz, my overall frequency response varied from –2.2 dB at 10 kHz, –1.0 dB at 15 kHz, +0.6 dB around 30 MHz to –1 dB at 500 MHz.

How it's Made

The Digital Panel Meter used is a 3½ digit LCD meter model PM-128 or PM-200. They operate from 9 to 12 V dc and measure 200.0 mV dc. The decimal point is selectable by wire jumper. The input impedance is greater than 100 MΩ and the digits are 13 mm high. A black plastic bezel is supplied with the PM-128 meter, but I chose to simply cover the box cutout with a piece of 0.040 inch clear plastic from the local hobby shop. The second meter uses the PM-200 and I also decided to add a clear plastic cover to it. RTV or superglue was used to attach the clear plastic. The Digital Panel Meter modules are about $12 from All Electronics (800-826-5432). Notice that you could just bring out two terminals and use any 200.0 mV DVM as the display.

The schematic and parts list are provided in Figure 2. The AD8307 pin 4 output is scaled to 1 mV/dB by the 10 kΩ pot and associated 100 kΩ resistors. The 1 kΩ NTC thermistor paralleled with R10, a 698 Ω resistor, provides about +0.7 dB gain correction at 40°F for the chosen 50 dBm calibration span (–10.0 and –60.0). Install the thermistor with sleeving to prevent air currents from causing drift in the output.

The negative input to the panel meter is adjusted to about 88 mV by the 1 kΩ pot. This causes the meter to read about –77 dBm with no RF input. This offset is thermally stabilized by selecting R4 and R6. If the 1 kΩ pot were connected directly to the LED, the offset goes about 1.3 dB negative at 40° F. If the 1 kΩ pot were connected directly to the voltage regulator then there is a positive 1.1dB shift with a temperature change from 80°F to 40°F.

My first circuit used a 5 V regulator and it gave similar thermal performance. I changed to the 4 V regulator to achieve maximum battery life from four alkaline cells.

These thermal corrections are for the complete circuit. If you are very particular,

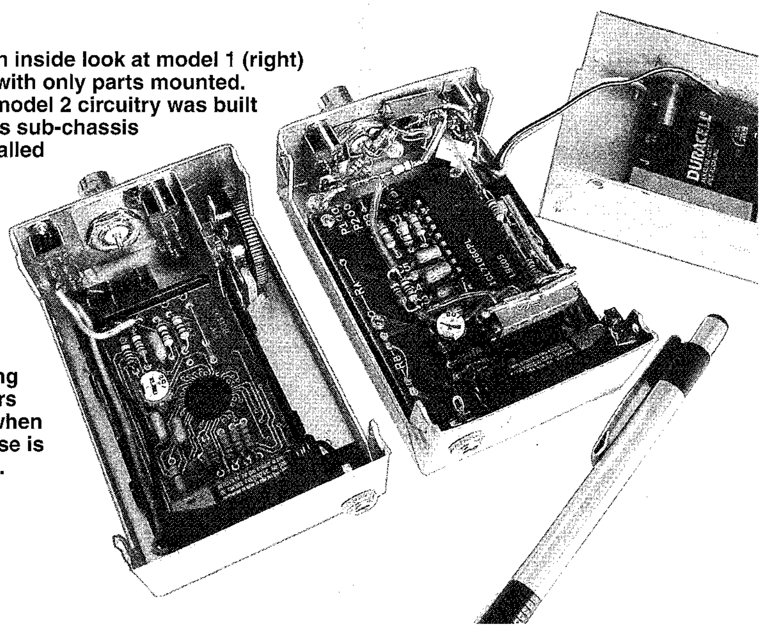


Figure 1 — An inside look at model 1 (right) and model 2 with only parts mounted. Some of the model 2 circuitry was built onto the brass sub-chassis and then installed into the case. Note two turns on L1 to the right of the BNC connector. On Model 2 access holes for gain and offset trimming potentiometers are covered when the rear of case is fully installed.

[1]Notes appear on page 67.

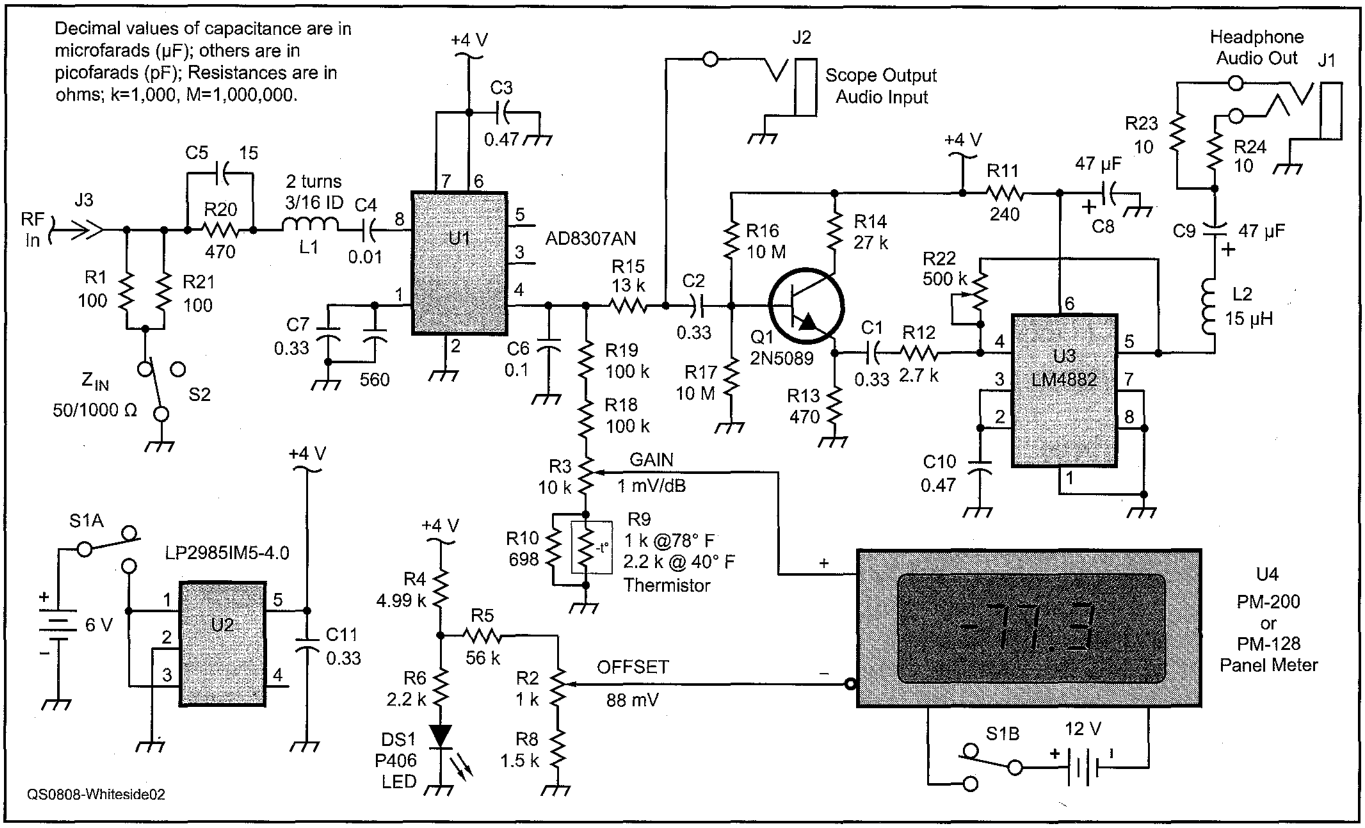


Figure 2 — Schematic of the pocket dBm RF power meter. All resistors are ¼, 1% metal film, most from RadioShack assortment 271-309. The audio amplifier section uses 5% resistors. All Electronics is found at www.allelectronics.com, Chaney Electronics at www.chaneyelectronics.com and Digi-Key at www.digikey.com.

C1-C2, C11 — 0.33 µF, 25 V capacitor.
C3, C4 — 0.01 µF, 25 V capacitor.
C5 — 15 pF, 25 V capacitor.
C6 — 0.1 µF, 25 V capacitor.
C7 — 0.33 µF, 25 V capacitor in parallel with 560 pF, 25 V capacitor.
C8, C9 — 47 µF, 25 V electrolytic capacitor.
C10 — 0.47 µF, 25 V capacitor.
DS1 — P406-ND high brightness LED. Available from Digi-Key.
J1 — ⅛ inch stereo headphone jack.
J2 — 3/32 inch mono jack.
J3 — BNC panel connector.
L1 — 2 turns, 3/16 ID wound on C4 lead.
L2 — 10 to 15 µH inductor.
R1, R21 — 100 Ω, ¼ W resistor.
R2 — 1 kΩ, 15 turn, trimming potentiometer.
R3 — 10 kΩ, 15 turn, trimming potentiometer.
R4 — 4.99 kΩ, ¼ W resistor.
R5 — 56 kΩ, ¼ W resistor.
R6 — 2.2 kΩ, ¼ W resistor.
R8 — 1.5 kΩ, ¼ W resistor.
R9 — Thermistor, 1 kΩ at 78°F, G14610. Available from Chaney Electronics.
R10 — 698 Ω, ¼ W resistor.
R11 — 240 Ω, ¼ W resistor
R12 — 2.7 kΩ, ¼ W resistor.
R13, R20 — 470 Ω, ¼ W resistor.
R14 — 27 kΩ, ¼ W resistor.
R15 — 13 kΩ, ¼ W resistor.
R16, R17 — 10 MΩ, ¼ W resistor.
R18, R19 — 100 kΩ, ¼ W resistor.
R20 — 470 Ω, ¼ W resistor.
R22 — 500 kΩ trimming potentiometer.
R23, R24 — 10 Ω, ¼ W resistor.
S1,S2 — DPDT slide switch, RadioShack 275-407.
U1 — AD8307AN (Digi-Key).
U2 — LP2985IM5-4.0 low dropout 4 V regulator. Available from Digi-Key.
U3 — LM4882 audio amplifier (Digi-Key).
U4 — Digital Panel Meter, PM-128 or PM-200. Available from All Electronics.
Box — Bud-CU-2101-B.

you may choose to tweak the values of R4 and R10 for your complete assembly. This circuit was calibrated at 80°F, 120 MHz, –10.0 and –60.0 dBm (HP8640B). Then after 15 minutes in the refrigerator at 40°F, the meter read –9.9 and –60.0 dBm. I was delighted with that. The dBm meter tracks the HP8640B attenuator output to within about ±0.2 dB. For best accuracy, calibrate at the frequency you use most. I have not determined whether the difference is in the attenuator output or in the dBm meter.

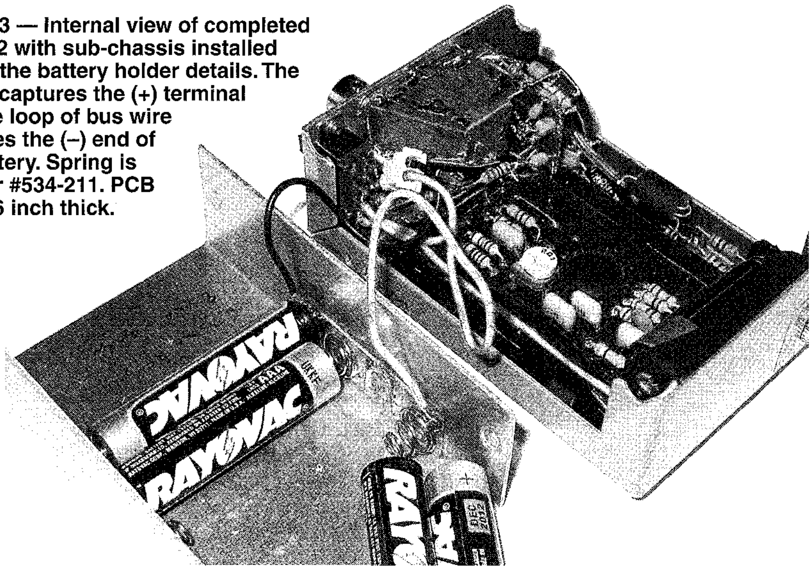
The AD8307 demodulates AM signals so the audio amplifier allows you to verify what signal you are measuring. A signal of 1 kHz, 30% AM modulation gives a nearly constant 5 mV_{rms} of 1 kHz ac at pin 4 independent of signal power. The 2N5089 audio preamp provides low noise at low current. So we get a 350 kΩ input impedance and 17 dB gain without a lot of noise. The LM4882 adds more gain while only drawing about 2 mA. The overall audio gain is about 93 dB. The audio section allows listening to 900 MHz data bursts from my cordless phone and with a ¼ inch loop picks up the 2.4 GHz microwave oven leakage (modulated by an internal stirring fan) at 8 feet. The digital section does not respond to those high frequencies.

A short whip allows listening to the local FM stations with whip orientation selecting the station. (Their signal is not purely FM.) Notice that the AD8307 is a voltage responding log amp and will not give accurate level readings with AM signals. A –30 dBm carrier that is 100% modulated with 1 kHz gives a reading of –34.9 dBm rather than the correct –28.2 dBm (+1.76 dB). 50% modulation read –30.7 when the correct value is –29.5 dBm (+0.5 dB). FM modulated signals read correctly.

Building the Box

Using tin snips, I cut the 2.125 × 3.25 × 1.625 inch aluminum box down from 1.625 to 1.1 inches in depth. This makes the box pocket size. Some of the circuit was built on a brass sub-chassis and then installed in the box. The batteries are an MN21 12 V and a 7K67 6 V in the first model and I built a custom battery holder using 0.026 inch thick PCB to fit 4 AAA cells in model 2. Battery springs (Mouser #534-211) just fit the positive terminal of AAA cells. Then a loop of bus wire soldered to the opposite PCB helps capture the negative end of

Figure 3 — Internal view of completed model 2 with sub-chassis installed shows the battery holder details. The spring captures the (+) terminal and the loop of bus wire captures the (–) end of the battery. Spring is Mouser #534-211. PCB is 0.026 inch thick.



the cells and a tiny piece of smaller buss wire was soldered in the center of the loop for a contact. The box was just the right length to install all this crosswise by gluing the PCB to the sides. The AAA batteries are installed "backwards" to normal battery holders. See Figure 3. The 12 V supplies about 1 mA to the panel meter and the 6 V supplies about 8 mA to the RF and audio circuits. Originally, I used rechargeables, but I find the alkaline cells work better for my occasional usage. Batteries last about 2 years.

Keeping Out Strays

External RF can be a problem with such a sensitive meter. On model 1 I added a small brass tab to connect across the box slot at the RF end. With that the meter changed less than 0.5 dB while the 2 meter handheld transceiver transmits 100 mW from 9 inches away. On model 2 I built a shield box from copper foil tape to partially surround the AD8307 input circuitry. This shield box reduced 120 MHz pickup by 24 dB. I used a 1 inch loop driven by the signal generator to find the most sensitive spot, which is at the box seam near the BNC fitting. The DPM with shorted inputs did not react to RF there at the 100 mW level. So the DPM is well filtered. If your local field levels are a lot higher than this you may have to use extra care to avoid unwanted pickup. Even coax shielding begins to leak at about 70 dB. The RF ON/OFF switch of my HP8640B leaks at about 60 dB. That is, with the signal generator set to 0 dBm output, switching off the RF still leaves me with about a –60 dBm reading on the pocket dBm meter. Try wrapping two turns of aluminum foil around your box if you suspect RF pickup. Rubber bands are useful to hold the foil tightly in place.

More than Just a Meter

Since this meter circuit also serves as a broadband AM demodulator, you can use it at your local airport without having to tune to find the correct frequency. Of course, you will probably hear more than one conversation at a time. Sitting on the ground at Oshkosh, Wisconsin with a flexible rubber antenna, I could faintly hear the air traffic departure information (ATIS) and at the same time I very clearly heard an aircraft on instruments talking to Chicago Center as he climbed through 3000 feet. The local airport weather transmission is clearly audible at a distance of about ½ mile. An aircraft band receiver is much better, of course, but the RF power meter works well enough for casual local reception without tuning. Signals at 120 MHz AM modulated 30% with 1 kHz are just audible in the headphones at about the –95 dBm level.

Notes

[1]**www.analog.com/en/**.

[2]W. Hayward, W7ZOI, and R. Larkin, W7PUA, "Simple RF-Power Measurement," *QST*, Jun 2001, pp 38-43.

[3]D. Roberts, G8KBB, "A Simple Digital Power Meter," *RSGB Technical Compendium* (RadCom 1999), pp 97-104.

[4]R. Kopski, K3NHI, "An Advanced VHF Wattmeter," *QEX*, May/Jun 2002, pp 3-8.

[5]R. Kopski, K3NHI, "A Simple RF Power Calibrator," *QEX*, Jan/Feb 2004, pp 51-54.

[6]R. Hayward, KA7EXM, "A PIC-based HF/VHF Power Meter," *QEX*, May/Jun 2005, pp 3-10.

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