

Simple RF Power Reference

For RF power meter calibration

Paul Wade W1GHZ ©2006
w1ghz@arrl.net

You've just finished building a new RF power meter, like the ABPM from Down East Microwave (www.downeastmicrowave.com) – how do you calibrate it? Or perhaps you've acquired a surplus unit – how do you check the calibration? You need some known reference point or a friend with a calibrated meter.

Some recent commercial power meters, like the HP 435, include a reference output to check and set the calibration of the meter. These fine meters are occasionally found as surplus at very reasonable prices, probably because the RF sensor heads command such exorbitant prices that the meter alone is unattractive. However, the meter is worth a modest amount for the reference output alone, to be used to check other power meters, either homebrew or older surplus.

With inexpensive RF power detector chips made for wireless networking, it is easy to homebrew a good microwave power meter like ABPM – so I started thinking about ways to make a reproducible reference source for RF power. The obvious starting point was the HP 435; I looked at the schematic, but it didn't feel right.

One readily available, reproducible, component is a diode. If we use a pair of anti-parallel (back-to-back) diodes as a clipper, we get a pretty predictable voltage. Of course, the clipping action generates lots of harmonics – this is a good way to make a frequency multiplier or harmonic mixer – so a low-pass filter is needed to get a sine wave output. Many power detectors are sensitive to harmonics and give erroneous readings unless the signal is pretty clean. Finally, filters are only predictable with matched resistive loads, so an attenuator helps keep things matched.

For an oscillator with a reasonably predictable output, I chose a standard computer oscillator. Since the HP 435 output is at 50 MHz, high enough for microwave instruments but low enough for VHF and down, it seemed like a good idea. For diodes, the 1N914 or 1N4148 is available almost anywhere for pennies. The low-pass filter uses RF chokes for inductors and ordinary disk capacitors, and the attenuator is just three resistors. A small 3-terminal regulator provides constant voltage to keep things stable. The complete schematic is shown in Figure 1.

The real question is whether it is reproducible. Figure 1 was drawn in free Linear Technology LTSpice/SwitcherCAD III software (www.linear.com) to simulate the circuit. I fiddled with the values of R1 and R2 at different temperatures and oscillator outputs to find a combination where the final output was pretty constant as the temperature and oscillator output varied. The simulation file is power_ref50.asc.

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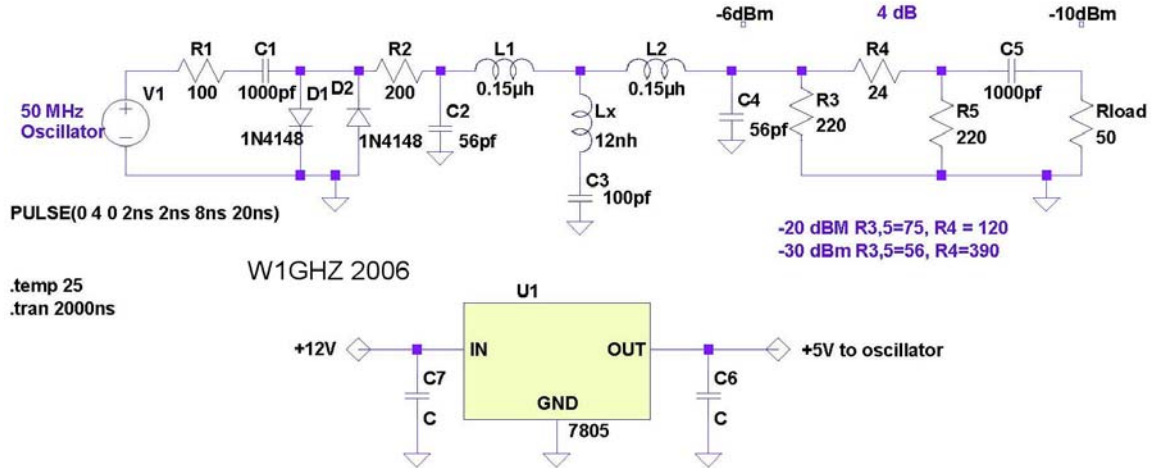


Figure 1

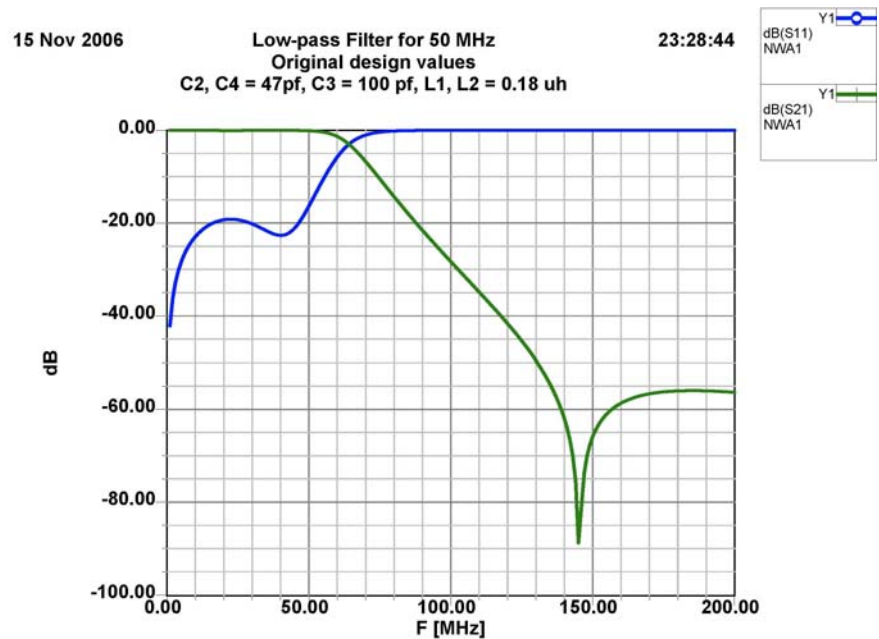
The low-pass filter was designed with free Ansoft Designer SV software (www.ansoft.com), using the filter design wizard. I chose a “Chebyshev type-3” filter – the extra inductor in series with the middle capacitor, C3, forms a series-resonant circuit at the third harmonic which greatly increases rejection. Calculated filter performance is shown in Figure 2, and the filter design file is LPF50.asdn.

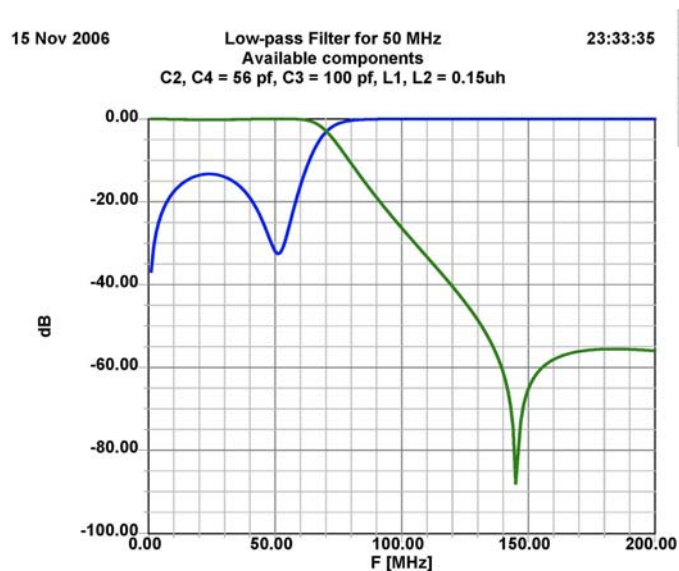
Time to build a couple. I was ordering some Miniboards (3 for \$59) from ExpressPCB (www.expresspcb.com) for another project, so I added this layout to a corner of the PCB using the free software, pushed the button, added my credit card number, and got the boards four days later.

Available parts

Since I had only used common parts with standard values, I didn't order any parts. A quick tour of the junk box found everything except inductors of the right value, 0.18nh.

The closest available were 0.15nh and 0.22nh. Back to the Designer software – I couldn't get the filter to work well above 40 MHz with the 0.22nh inductors, but I had a bag of 40 MHz oscillators so I made a unit at 40 MHz. With the 0.15nh inductors, juggling capacitor values gave better results at 50 MHz than the original design, as shown in Figure 3.





The measured outputs, from one unit at 40 MHz and one at 50 MHz, were just a hair (within 0.25 dB) higher than the design value of -10 dBm, 0.1 milliwatts. I was pleasantly surprised. The filter seems to work pretty well, with the second harmonic down 45 dB and the third harmonic down 68 dB, so the output is a clean sine wave.

A photo of the complete unit is shown in Figure 4. The only problem I found is that one of the oscillators apparently draws a bit too much current for some 78L05 voltage regulators, so the board layout now includes larger holes for the larger 7805 version in a TO-220 package.

To calibrate a power meter, this unit and a step attenuator (or a few fixed attenuators) are needed. No attenuation = -10 dBm, add a 10 dB step for -20 dBm, etc. For higher powers, a small amplifier, like a simple MMIC is also needed. Insert attenuation after the amplifier to get back to a -10 dBm indication to find the amplified power level, then work up and down from there.

Having a known power level is useful for calibrating other instruments, like a spectrum analyzer or an RF voltmeter, and could be used to calibrate a receiver S-meter for meaningful readings.

Summary

I believe copies of this unit should be within 1 dB of the nominal -10 dBm output, close enough for amateur use. How accurate is a surplus meter that hasn't been calibrated in ten or twenty years, anyway? The circuit should work fine at any lower frequency for which an oscillator is available, but the filter must be recalculated. Parts cost from Digikey or Mouser should be about \$5 for components, plus box and connector — the expensive parts, but this will fit fine in the traditional Altoids tin. The circuit is certainly simple enough for dead-bug construction, but I am willing to have some more PC boards made if there is enough interest. The board layout and design files, all for free software, are available at my www.w1ghz.org webpage.

