TITLE: The All-New 2002 Year Model Volts Wagon

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As we saw in the November Kitplanes®, the Radio Shack (nee Trumeter) little digital modules are just the ticket for mounting in a regular old 2¼ instrument hole. There are several varieties of this little module, and we used the clock module in November to make a pretty snazzy (and inexpensive) digital clock with timer. This month we'll take the digital voltmeter ($25) and a handful of passive components to make a very accurate voltmeter/ammeter combination gauge.

How accurate? Well, the voltmeter has a guaranteed internal accuracy of 0.1% (with a typical accuracy of 0.05%), so if we use precision resistors in the voltmeter circuit, we can achieve this same internal accuracy. Unfortunately, every time you move the accuracy to the left by a decimal place, you move the price to the right by a decimal place. 5% resistors are about a penny apiece, 1% resistors are a dime apiece, and 0.1% resistors are a dollar apiece. Me? I go for the 5% resistor with a 20 cent variable resistor at R8 to set the accuracy, but it is certainly possible to use 0.1% resistors for R6 and R8 if you want to spend the money.

The ammeter is a different story. Here we are *forced* to use a variable resistor to set our zero point, so the use of precision multipliers doesn't make a lot of sense. And, the home-made shunt isn't going to be much closer than 10% anyway, so absolute accuracy isn't really necessary. I mean, are you *really* concerned about the difference in charge rate between 9 amps and 10 amps?

But we're getting a bit ahead of ourselves. Let's examine the basic meter and see what we really have to achieve. The plain old meter without any multiplying resistors in front of it has a full-scale sensitivity of ± 199 millivolts. By a judicious application of multiplying resistors and placing the digital decimal points to give us a sensible reading, we can have a voltmeter that reads to two decimal places (i.e. 13.82 volts) and an ammeter that reads to one decimal place (22.3 amps). In either case, we are converting the quantity we want to read to something in the range of 0 to ±199 millivolts. In the case of volts, we will convert by a factor of 100:1 and in the amps case we will convert by a factor of about 4:1 (plus, with amps, a little finagle factoring to keep the shunt loss and heating to a minimum).

The voltmeter multipliers are easy – R6 and R8 make a 100:1 divider (*) and then this divided down voltage to the "HI" input of the module. The "LO" input of the module is grounded, so the voltmeter reads (for example) 13.24 millivolts when the battery bus is at 13.24 volts. If we then light pin 13's decimal point, it will position the decimal point properly. If we also light the "V" pad on the module (see the data sheet that comes with the module to identify these pads) then the entire display will read "13.24 V", which is what we originally set out to do.

((*) Yes, I know this is a 101:1 divider, but you can't buy 99K resistors, so let me fudge for a 1% error, okay?)

The ammeter is going to be a bit trickier. Since the basic module reads in millivolts, somehow we are going to have to convert amps to millivolts. Ohm taught us how to do that a couple of hundred years ago…a known resistance with a known current gives us a known voltage. How do we get a known resistance into the act? To paraphrase a large investment company, "We *wind* it." Huh? Sure, if we have a known wire gauge (say, #18), we know that each foot of that wire has a resistance. In this case of #18, it has a resistance of 6.4 milliohms per foot. If we know how many millivolts we want to drop, it is a fairly simple matter to calculate the number of feet of wire to use to act as a "shunt" (see, for example, the Excel spreadsheet at www.rstengineering.com at "Jim's Page" for an easy way to do this).

Let's say that we want to drop a maximum of 50 millivolts for our maximum rated current of 50 amps. Ohm tells us that a 1 milliohm resistor will do the job for us, and now the problem resolves itself into finding a 1 milliohm resistor. I guarantee you that you will not find one at your friendly local Shack, nor your friendly local industrial electronics distributor, or anywhere else, for that matter. If you want to spend money, you can buy a standard 50 millivolt shunt from any of the popular aircraft instrument manufacturers (Westberg, etc.) but it is just as easy (and a lot cheaper) to just wind your own. Lessee now, if #18 is 6.4 milliohms per foot and I want one milliohm…seems to me that just a tad less than 2" of wire (1.875" to be exact) will do the job. Given that a millivolt is an amp, we ought to be able to just connect the voltmeter across the shunt and we are done.

Oh, not so. You see, that little meter has its own internal negative voltage source so that we can sense positive amps as well as negative amps, and the internal resistance of the device is such that if we make a 4:1 divider on both the HI and LO inputs, the various impedances are massaged to give us a direct reading in amps and tenths of amps (100 mA) on the meter movement. R7/R9 make one of these dividers for the HI side, and the combination of R11/R12/R13 make the divider for the LO side. Note that the LO side divider is a bit more than 4:1 and is purposely done this way to take the offset out of the equation so that zero on the meter is truly zero amps through the shunt.

Normally I like to say that everything on the board can be had at "The Shack", but I'd like to bend your ear a bit about this design. Remember that the full scale on this meter is measured in *millivolts* and that the last digit to the right is therefore dealing in *microvolts*. When we are measuring volts and amps and expecting the microvolt digit to stay put over temperature, we're outside the range of carbon film resistors and two-bit trimpots. The temperature coefficients of these devices are just too far outside anything that I'd call stable to be a true precision instrument. Therefore, if you don't mind a little drift over temperature in the right digit, use the carbon film resistors listed in the parts list. If you want stability, use metal film fixed resistors (The Shack has them, but they are not stock items. See the Mouser 270 series at a dime apiece for a good quality low tempco resistor.) In addition, it is certainly possible to mess around with fixed resistors and a cheap trimpot for R11-13, but using a 10K ten-turn potentiometer for the R12/R13 combination is certainly a lot more professional. See The Shack 271-343 or even better and cheaper, the Mouser 72-TX93 series.

Similarly, if you want a lab quality voltmeter, use an 82K metal film resistor for R6 and a 1K ten-turn pot for R8.

As to building the faceplate, if you have the drawing from last month's clock in Kitplanes®, the dimensions are absolutely identical. Just don't drill the hole above the meter because all you need to do is switch from volts to amps with a single switch. All the rest of the dimensions are the same for the rectangular cutout and the switch location.

Questions from the floor --

"Can it be used on a 24 volt airplane?" Yes it can. However, you are going to sacrifice one digit of resolution because now the meter has to go above the 19.99 volt limit that this circuit provides. Drop R8 to 100 ohms and force the decimal point to be at the 199.9 position. The instructions that come with the meter tell you how to do this.

"Can it be designed for autoswitching from volts to amps?" Yes, but not easily, nor within the scope of the average home electronics enthusiast.

"Does my Shack have these meters in stock?" No, they have to come by mail to your home out of Fort Worth.

"Does anybody sell these meters for less than The Shack?" Not that I've been able to find. Even factory direct, you can't beat The Shack's price until you buy them in quantities of 1000 or more.

"Are the pictures you show with this article actual aircraft quality hardware?" Of course not. This is a proof of concept breadboard. Anything I fly with is going to be a bit better constructed than this. The terminal strip, for example, is a 20 amp terminal strip. If this were going in my airplane, the shunt would be mounted on something like a block of Teflon that will take the temperatures generated. The resistors aren't going to be hung by the ends of their leads. A lot of cleanup will have to happen before I fly this project.

"Can the meter be converted to read oil pressure and temperature, EGT and CHT, fuel quantity…?" Well, bless my soul. Come by next month and I'll show you how to do just that.

Author's Note: Jim Weir is the chief avioniker at RST Engineering. He will be glad to answer avionics questions for this article or on any avionics subject in the Internet newsgroup rec.aviation.homebuilt. If you are having trouble with newsgroups, go to www.rst-engr.com and click on the "How To Use The Net" link.