The RF Porta-Test

A portable tester for the radio experimenter

The pocket multimeter is the most used piece of test equipment for people in electronics. It's small, cheap and measures many things, sometimes including frequency. Unfortunately multimeters miss other common RF tests such as output power, field strength and transmission monitoring that normally requires a benchful of specialised gear.

Different test equipment does different things, but inside there are similar shared stages, such as oscillators, amplifiers, detectors and meter movements. Build several in the one box and you have a multi-purpose instrument with some creative switching. And because the dearest parts are switches, cases and meter movements, you get an instrument with eight or more functions for little more than the cost for one alone.

Designing this 'Swiss army knife' of RF instruments is sure to involve compromise, especially with a hand-held unit like this. However nothing like the RF Porta-Test is commercially available for the price and its numerous functions provide unbeatable convenience.

Construction is a snap for those who've made a few projects. Only common parts are used and substitutions are easy. Beginners daunted by the switching should start function by function, connecting the switches in later.

Functions and circuit description

The RF Porta-Test has the following functions:

- RF power meter. RF is applied across a 50 ohm dummy load formed by parallel resistors. The AC voltage produced is rectified and fed to the meter movement via a dropping resistor. This resistor is set for 100% meter deflection at the desired maximum power range.
- Amplified field strength meter. RF power is sensed by the telescopic whip and rectified in a two-diode voltage doubler circuit. The resultant DC is amplified by an LM386 before being fed to the meter. This unit is broad band, responding to signals of all frequencies.
- Amplified absorption wavemeter. Works much like the field strength meter but has a tuned circuit (adjustable over 0.7 – 1.9 & 3.4 – 17 MHz) so that it only responds to signals of a set frequency.
- Audio signal tracer. Again uses the LM386 but as an audio amplifier circuit. Also handy as an accessory amplifier for projects.
- AM transmission monitor. Connecting the absorption wavemeter to the audio signal tracer forms a receiver suitable for testing AM transmitters on 160, 80, 40, 30 and 20 metres. It will also pick up AM broadcast stations within about 20km.
- SSB/CW transmission monitor. Similar to the AM transmission monitor but with a local oscillator to test amateur transmitters operating on 3.58, 7.16, 14.32 or 28.64 MHz.
- WWV receiver. When connected to a full-sized antenna the SSB/CW transmission monitor is sensitive enough to receive WWV on 5 MHz at night. Amateurs on 3.580 MHz can also be heard.
- Fixed frequency RF signal generator/band marker. Switchable 3.58 and 5 MHz crystal oscillator with harmonics allows testing of receivers on 3.58, 5, 7.16, 10, 10.74, 14.32, 15, 17.9 , 20, 21.48, 25 or 28.64 MHz.

Only a handful of parts are needed to perform all these functions. The most important are (i) an analogue meter movement, (ii) LM386 audio or DC amplifier, (iii) tuning capacitor and coils for the wavemeter, (iv) NPN transistor for the crystal oscillator, and (v) resistors for the dummy load. In addition rotary and toggle switches allow these stages to be switched in or out as required.

Obtaining components

Only fairly common parts are used. Salvaging switches, the speaker, meter movement, telescopic aerial, knobs and case can halve the cost. The germanium diode can also be salvaged – they are common in discarded radios and are identifiable by their clear glass cases with two bands near one end.

Though they look like rotary switches in the circuit diagram, the switches in the HF oscillator and field strength meter/wavemeter stages are actually toggle switches with a centre off position. The 'neutral' position reduces wiring and saves panel space. A pair of standard double throw switches can be substituted for each switch if desired.

Any enclosure with a panel large enough for the speaker, meter movement, switches and sockets will suffice. Don't go too thin, otherwise there won't be clearance for the telescopic whip, battery and circuitry. If in doubt use a bigger box to allow room for a proper tuning dial, larger meter or switches for more functions.

My meter movement is 250uA but other values can be used with different series resistors for the power meter function. The series resistor values are calculated by determining the peak RF voltage needed for each range and using a value that provides full-scale deflection. More detail is provided in the panel.

Meter movements and power meter resistor values

The values of the two resistors in the RF power measuring section of the Porta-Test depend on the meter movement used.

Recall that power equals voltage squared divided by resistance. Power in this case is how much we want to measure up to. I went for 5 watts for the high range and 0.2 watts for the low range. Resistance is the 50 ohms of the dummy load. Using the above formula we see that voltage squared is 250 for 5 watts and 25 for 0.2 watts. Taking the square root of this gives 15.8 and 3.16 volts respectively. Both are multiplied by 1.414 to provide peak values (22.3 and 4.47 volts) that we will base our meter calculations on.

Our task then is to select series resistor values that allow the meter to read full scale when 22.3 or 4.47 volts DC is applied. Applying Ohms Law based on a 250uA meter, we arrive at resistor values of 89.3k and 17.9k respectively. Two 180k resistors in parallel give 90k, while 18k is a standard value. Given the small meter movement, accuracy is unlikely to be better than 10 or 20 percent and these values are near enough.

If you don't know how much current your meter needs to read full scale, try this simple test. Take a fresh 9 volt battery and 39k resistor. Hold these in series across the meter. If it shows almost full scale you know it's a 250 uA meter (10 volts with 40k is easier if doing the sums). Just under half scale would be a 500mA meter while a 1mA meter would read under quarter scale. If you pin the meter you have a more sensitive movement (perhaps 50 or 100uA) and should repeat the test with a higher series resistor - eg 180k will give 50uA with 9 volts.

Construction

The larger components are screwed or glued to the front panel. Some smaller parts are mounted point to point behind the front panel. This looks messy but provides for short leads – important for RF equipment. The LM386 stage (which operates at DC and audio frequencies only) is on its own small board mounted behind the speaker. Unclad perforated board is used here.

A good plan is to build and test one or two stages at a time as successful completion provides motivation to carry on. The RF power meter uses the fewest parts and can be built first. The RF-carrying parts, ie the six dummy load resistors, diode and capacitor, should be mounted on the rear of the antenna socket to minimise lead length. You may wish to test this before wiring up the switch – temporarily connect the meter negative terminal to earth and the positive terminal to the power meter's two resistors.

Applying RF should make the meter move. Calibrate by applying various DC voltage across the dummy load, calculating what power each voltage represents, and noting the scale reading. Tape a calibration chart to the case if desired.

The field strength meter's front-end can be tackled next. Leave out both RF chokes, the variable capacitor and all circuitry to the right of the gain control. Temporarily connect the meter's positive terminal to the wiper of the gain control and set to maximum. Applying a few watts of RF near the meter should cause a deflection. The RF choke actually resonates at 1.8 MHz when the tuning capacitor is near minimum so the circuit functions as a wavemeter on 160 metres.

Construct the wavemeter portion by adding the variable capacitor. Set the trimmers on the back to minimum and bridge the oscillator and aerial tabs to place both sections in parallel and maximise capacitance. Add the switch and inductors (which are actually RF chokes available for about $2 each).

With 7 MHz of RF applied near the antenna adjust the variable capacitor for peak meter reading. This should appear somewhere near the clockwise end on the low frequency range (10uH coil switched in) and the anti-clockwise end for the high frequency range (3.3uH coil switched in). Repeat for 3.5 MHz (low range) and 14 MHz (high range).

Several compromises were made to simplify switching between the wavemeter and field strength meter. For example the tuning capacitor is permanently wired across the 1mH RF choke used for the field strength meter. This should be set clockwise (minimum capacitance) to minimise its effect. However even when this is done meter sensitivity will be low at upper HF and VHF frequencies. Add an extra toggle switch to isolate the unwanted wavemeter components if this is a problem.

Once happy with the non-powered parts of the meter, start building the LM386 stage. While this chip is most familiar in its use as an audio amplifier, its main use here is as a DC amplifier for the field strength and wavemeter functions. The LM386 and related parts are mounted on unclad perforated circuit board about 3 x 4 centimetres.

Connect this stage to the field strength meter/wavemeter circuitry and the meter movement (for testing there is no need to wire in the rotary switch yet but your connections should be based on it being in centre position). Connect a 9 volt battery and watch the meter needle. If the circuit is operating correctly you will see it move when you adjust the 5k trimmer potentiometer. Set this potentiometer so that the meter is reading zero.

Repeat the field strength and wavemeter tests, with the gain potentiometer set to maximum initially. If all is well there will be an indication on the meter when RF is applied, with greater sensitivity now with the amplifier connected. Connecting the speaker (via its coupling capacitor) instead of the meter should allow 'duck talk' to be heard if testing on SSB. Also note the click or faint hum if you insert some wire into the AF input socket – this proves the signal tracer is working.

The final active part of the circuit is the switchable crystal oscillator. Its main use is for the SSB/CW transmitter monitor since it provides the beat frequency oscillator for what is effectively a direct conversion receiver. It also provides a useful signal source for testing receivers and calibrating the wavemeter. The switch, again a centre off unit, switches between 3.58 MHz, no signal, and 5 MHz.

Varying the capacitors in series with each crystal allow a slight frequency shift. The lower the value the higher the frequency. Aligning to an exact frequency is useful for it to be a crude frequency standard or to allow effective reception of the WWV time signal on 5 MHz. Similarly the 3.579 MHz crystal could be tweaked to 3.580 MHz as this is popular frequency at night. Values between about 22 and 100pF are suggested, with a trimmer suggested for more precise adjustment.

The output from the crystal oscillator is fed to the wavemeter's diode detector. There is no direct electrical connection – instead it is coupled loosely through a few turns of insulated enamelled copper wire wrapped around the junction of the diodes.

A few millivolts of RF available from the same socket used for the signal tracer's audio input is available to test or calibrate a receiver. An RF choke here blocks stray RF from entering the LM386 amplifier stage. HF outputs include 3.58, 5, 7.16, 10, 10.74, 14.32, 15, 17.9, 20, 21.48, 25, 25.06, 28.64 and 30 MHz. An unplanned benefit is that the RF oscillator helps calibrate the wavemeter as the meter needle swings when the wavemeter is adjusted near an oscillator frequency or harmonic. This helps identify the main amateur bands covered without need for a dial scale.

The wiring around the 3 position 4 pole rotary switch is the hardest part of the project. If done wrongly no function will work and there may be odd readings or sounds. Initially wire the power meter only section of the switch (using the contacts that connect when the switch is in its clockwisemost position) and check this still works. Repeat for the field strength/wavemeter and monitor sections.

Ensure that the battery and LM386 circuit board are anchored out of harm's way and close the case. A small plastic bag over the battery can prevent shorting.

Use

The Porta-Test has many switches and controls for a small instrument. It takes a bit of getting used to as several interact for various functions.

The RF power meter is the easiest – there are no controls apart from the rotary function switch.

For the field strength meter set the function switch to middle position, the FSM/WM switch to middle or neutral position and the tuning capacitor to minimum capacitance (clockwise). Switching the function switch to the monitor mode allows what's picked up to be heard on the speaker rather than displayed on the meter. The crystal oscillator should be off for this test.

The wavemeter is similar to the field strength meter except one of the coils is selected and the variable capacitor adjusted for a peak reading. Again the monitor function allows reception of the AM signal. You can monitor SSB or CW signals on 3.580 MHz or harmonics by switching the oscillator to 3.58 MHz so it beats with the incoming signal. Connect a large outside antenna and you may be able to hear WWV through the monitor at night when the frequency is switched to 5 MHz and the wavemeter peaked accordingly.

The internal oscillator has other uses as well. It can be used to calibrate the wavemeter on 3.58 MHz, 5 MHz and harmonics. With both the wavemeter and oscillator on look for meter deflection when tuning the wavemeter.

For the fixed frequency RF signal generator switch the function to RF power output to remove power from the un-needed LM386 stage. Selecting either 3.58 or 5 MHz activates the oscillator. For calibrating and testing receivers a small amount of oscillator output is available from the RF out/AF in socket.

Finally the AF signal tracer can be used with the function switch in monitor and all other functions off.

A separate on-off switch is not needed. Instead when not in use switch to the RF power meter function and set the crystal oscillator switch to centre (off) position.

Conclusion

It's hard to know when to stop when developing projects like this. A dropping resistor and two sockets provides a DC voltmeter function while a diode probe allows RF voltage measurements. Switching in the battery permits resistance and continuity tests. Check crystals by adding a crystal socket on the front panel. More wavemeter coils broaden its range. And a larger dial and meter movement increases versatility but at the expense of size.

However even as it stands this instrument is incredibly versatile. Build it and you'll never know how you coped without it!

Peter Parker VK3YE

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