500MHz 7-digit frequency meter

2nd article details calibration & troubleshooting

In this second article on the 500MHz frequency meter, we detail a useful troubleshooting procedure and describe several methods of calibration. Also included are some hints on using the new frequency meter.

by GREG SWAIN

Normally, we would expect the 500MHz frequency meter to work "straight off", provided that the constructor has made no wiring errors. But, if you are unlucky enough to strike trouble, the following troubleshooting procedure should solve your problems. It assumes that the constructor has access to little more than a multimeter.

The initial reaction of most constructors to a malfunctioning project is to use language that would make a bullock driver blush. While this doesn't really solve anything, it can help put the constructor in a more rational frame of mind to solve the problem at hand. So let's assume that your new 500MHz DFM is not functioning correctly and that the profanities have now ceased.

Before doing anything else, use your eyes. Go over the completed project carefully, checking component orientation, component values, and external wiring. You should also check the copper side of the PCB for missed solder joints, solder bridges between tracks, and faults in the copper pattern.

But while a careful visual check can save you a lot of hassles later on, the fault may not always be obvious. That being the case, it's simply a matter of checking the circuit stage by stage until the problem is "licked".

THE POWER SUPPLY

As indicated last month, the +5V and +12V supply rails should be checked before plugging in the 7216A counter chip. If either supply rail is incorrect, check the corresponding regulator input. You should get readings of about 20V and 10V for the LM340T12 and LM340T5 regulators respectively.

Assuming that the inputs are correct, check to see that the regulators are correctly oriented or have not been inadvertently swapped. If no wiring errors have been made, you may have a faulty regulator.

If the regulator input voltages do not check out, go over the remaining power supply components very carefully. You may have a faulty diode, or you may have installed a diode or capacitor back to front.

Once the power supply is functioning correctly, you should also check that the +5V and +12V rails are actually connected to the appropriate supply pins of the ICs. The 7216A may now be inserted into its socket.

COUNTER AND DISPLAY

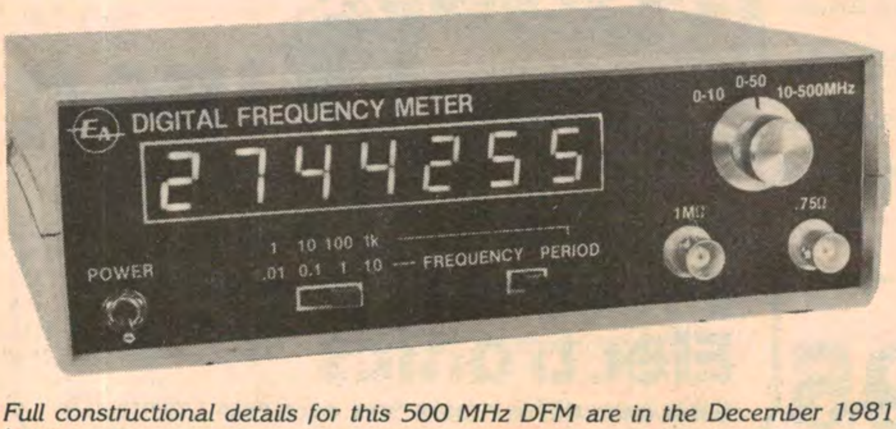
Troubleshooting the main section of the circuit begins with checking out the 7216A counter IC and display. This part of the circuit is actually quite easy to test by using the in-built "Display Test" function in the 7216A.

The procedure is as follows: Disconnect pin 1 of the 7216A from circuit and connect it to pin 15 (the D7 output) via a 10kΩ resistor. This is best done by withdrawing the 7216A from its socket and bending pin 1 out so that it is at right angles to the remaining pins. The IC is then reinserted in its socket and a couple of clip leads used to make the connections.

Note: pin 15 is left in circuit during this test procedure.

At switch-on, all digits in the display should be lit with each digit displaying an "8" — ie the "Display Test" function should enable all segments of the display. If any displays fail to light, check for continuity between the digit driver outputs (D0-D6) of the 7216A and pin 3 of the displays. These and other continuity checks can be made without removing the PCB from the case.

If there is continuity, disconnect pin 3 of the display from circuit and momentarily short it to pin 3 of the adjacent display. If the display still

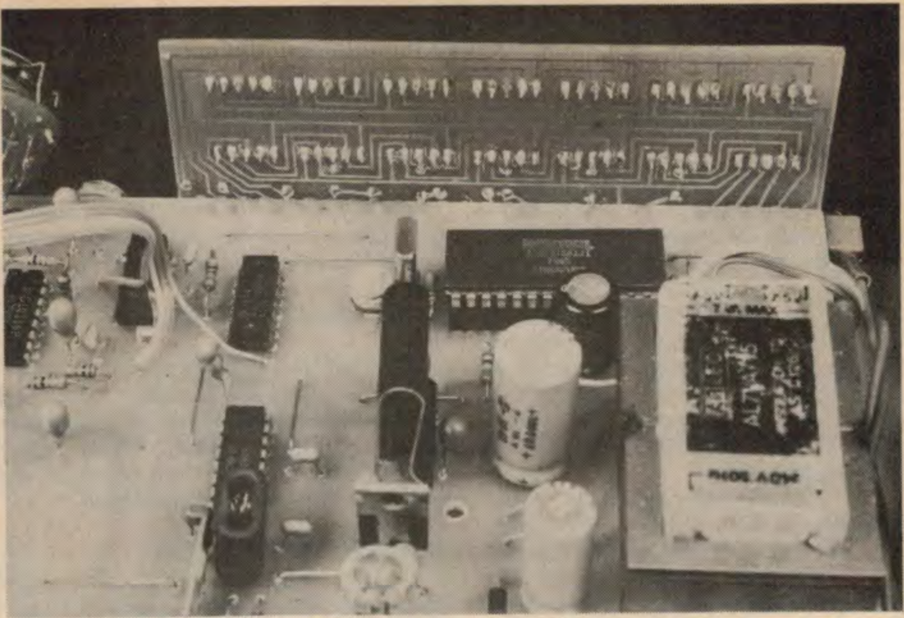


Full constructional details for this 500 MHz DFM are in the December 1981 issue.

refuses to light it is defunct. If, on the other hand, the display does light, you may have a faulty 7216A counter IC (nasty!).

Similarly, if any segments fail to light, check for breaks in the segment drives lines between the 7216A and the displays, and between the displays themselves. For example, if the "g" segments on all seven digits fail to light, check for continuity between pin 6 of the 7216A and pin 10 of the first display digit. If there is continuity, momentarily short pins 9 and 10 of the displays; if the "g" segments now light, the 7216A is probably faulty.

Remember that the segment lines are common to each display. So if the "g" segments of only the last three digits fail to light, check the "g" segment line for continuity between digits four and five.



Held over from December, this photograph shows the wiring in the vicinity of the 7216A counter chip. Note how the display panel is mounted.

BLANK DISPLAY

One problem that could puzzle some constructors is a completely blank display at switch-on. Assuming that the power supply checks out, the most likely reasons for this situation are: (1) a fault in the wiring to switch S3; or (2) the 10MHz oscillator is not working.

To track the fault down, connect the unit in the "Display Test" mode. If all digits now light, the fault lies in the wiring to switch S3. You could have an open circuit between the wiper of S3 and pin 14 of the 7216A or an open circuit between the switch and one of the digit outputs D0, D1, D2 or D3.

If the display remains blank, the oscillator circuit is the likely culprit (either that, or that 7216A is a dud). Assuming that you don't have a CRO, go over the circuit carefully looking for wrong components and open-circuit or bridged PCB tracks. Check also that there is +5V to the 39pF capacitor and the 39pF trimmer.

If these checks lead you nowhere, don't assume that the 7216A is faulty. Before parting with around $40, it would wise to check the situation out thoroughly. The best way to do this is to substitute an external oscillator (or clock) for the on-board oscillator to discover just where the fault lies.

Fig. 1 shows a simple CMOS oscillator based on a low-cost 4011 quad 2-input NAND gate. This circuit can be quickly wired up on stripboard and powered from the +5V rail in the DFM. The fourth gate in the package is unused but should have its inputs, pins 12 and 13, pulled high.

Note: virtually any inverter-type CMOS IC can be substituted for the 4011, eg 4001, 4009, 4049. Check the pin numbering though.

Having wired up the oscillator, feed the output directly into pin 25 of the 7216A (there is no need to disconnect pin 25 from circuit). If the display now lights, the 7216A is cleared and the fault lies in the oscillator. You could have a dud crystal, for example.

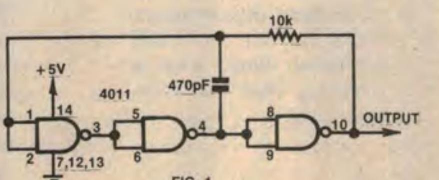


FIG. 1

Fig. 1: this simple CMOS oscillator can be used to check out the 7216A.

It is here that we come to an interesting side effect of our test procedure. With the resistance and capacitance values shown, the circuit of Fig. 1 oscillates at approximately 90kHz — roughly 100 times lower than the normal 10MHz timebase. This means that the digit multiplexing rate will be reduced to about 5Hz when using the external oscillator, since multiplex signals are derived from the timebase.

At this low frequency, you can actually see the digits flashing on and off in sequence.

Now withdraw the capacitor from circuit. The oscillator frequency will increase to about 1MHz and all digits will appear to be continuously lit. Even if your counter runs perfectly, why not make up the circuit of Fig. 1 for a practical demonstration of how multiplexing works. You can slow down or speed up the oscillator by increasing or decreasing the capacitor and resistor values.

If the display refuses to light with the external oscillator, the 7216A is about to give you a severe pain in the wallet area. Either that, or your external oscillator is not working correctly — check on a CRO or another DFM if possible. One point to keep in mind is that failure of the 7216A will be relatively rare, unless you do something silly like inserting the IC back to front.

Assuming that the LED displays are now functioning, restore the pin 1 connection to the 7216A and operate the gating time switch S3. As stated last month, the display should show four zeros in the 10s position, three in the 1s position, two in the 0.1s position and one in the .01s position. Check the wiring to switch S3 if difficulties are encountered here.

If, at any stage, the displays give readings other than numbers, check for shorted segment lines and upside down displays. The tops of the displays are identified by small corrugations and, if you look closely, the decimal point should be just visible in the lower right hand corner.

0-50MHz PREAMPLIFIER

The 0-50MHz preamplifier circuit can be divided into three stages: a FET-input stage, a 10116 triple differential amplifier, and a transistor level translator (Q2 and Q3). Let's assume that there is a fault somewhere betweeen the input socket and pin 9 of IC6c.

Set the range switch to 10MHz, the gating switch to 1s, and touch the input to the 10116 (pin 9) with a short length of tinned copper wire. If the display now shows a large random count (but not when you touch the wire on centre conductor of the input socket), the trouble lies in the preceding FET stage. If no count appears, you will have to take some voltage readings around the 10116 and the following Q2/Q3 transistor stage.

As noted previously, the 10116 has differential inputs and outputs, all operating at ECL (emitter-coupled logic) levels of betwen 3.2V and 4.2V (at room temperature). Pin 11 of the 10116 should be around 3.7V while pins 2 and 3 will be at 3.2V and 4.2V (or 4.2V and 3.2V). All the other output pins will tend to sit around 3.7V with no signal applied.

If any of these voltages are not within reasonable limits (±0.3V), the most likely cause is a wiring error or open circuit or bridged PCB track. Replace the 10116 only as a last resort.

Voltages around Q2 and Q3 may now be checked. The emitters of Q2 and Q3 should be around 4V while Q2's collector will be at 0V or 3V, depending on the output of IC2a. Now put your finger on the input to the 10116. Assuming the use of a multimeter, Q2's collector should read approximately 1.5V, while pins 2 and 3 of IC2a should read 3.7V (note: these are average voltages, not peak voltages as displayed on a CRO).

This last test indicates whether or not the 10116 and level translator stages are working correctly. If the 10116 checks out but Q2's collector remains at 0V or 3V with an input signal applied, one of the transistors is probably either faulty or incorrectly oriented. Note that Q2 and Q3 should face in opposite directions on the PCB.

MULTIPLEXER & DIVIDER

Any problems here will most likely be due to incorrect wiring to switch S1. Check that pins 2, 12 and 13 of IC6 are low for the 10MHz and 50MHz ranges, and that pins 3, 4, 10 and 11 are high. On the 500MHz range, pins 2, 5, 8, 12 and 13 should all be high while pin 11 should be low.

Pin 6 should be at either 0V or 4V with no input signal, and about 2V (average) with an input signal.

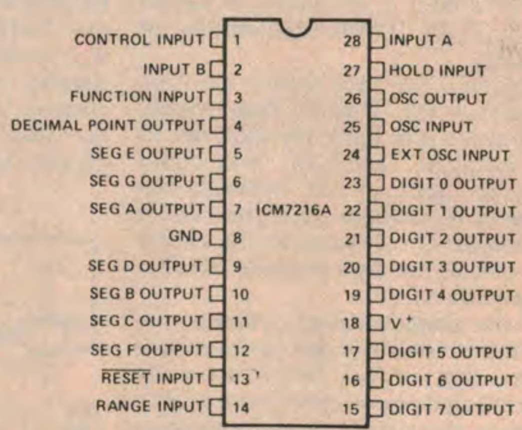
A rough and ready check can be made of the 74196 in the following way. Set the range switch to 10MHz and the gating switch to 0.1s, and couple yourself to the 10116 input (pin 9) again. At the same time, switch between 10MHz and 50MHz ranges. The resulting random counts should show a ratio of approximately 10.

Pin 2 of the 74196 should read 0V or 5V with no input signal applied, and approximately 2V-2.5V (average) with an input signal. Check the circuit around the 74196 carefully if problems are encountered here.

500MHz PRESCALER

There's not much to go wrong here, since the circuit consists of just two ICs (IC4 and IC5) and a few minor components, Unfortunately, the circuit is difficult to troubleshoot without the aid of high-level signal source of 10MHz or more and (preferably) a CRO.

This diagram shows the pin-out configuration for the 7216A counter chip. Chip features include eight digit outputs (D0-D7), an external oscillator input, and a "Display Test" function (see text).



Carry out the usual wiring checks before replacing either of the ICs (which are expensive). In particular, check voltages at the various IC pins and look for possible shorts between the signal line and ground. You could have a short at the input socket, a solder bridge, or D3 or D4 could be short circuit.

If these checks reveal nothing, remove the RF choke and the OM350 (IC4) from circuit and connect a wire link between the vacant pin 1 and pin 5 holes of IC4. Now feed a high-level (600mV) RF signal greater than 10MHz into the 75Ω input. If the circuit now functions replace the OM350; if not, the 11C90 is suspect.

Don't replace either IC4 or IC5 until you've verified that the 74LS00 (IC6) is working correctly, however. If you have any doubts, remove IC6 and test the circuit with a wire link between pin 11 of IC5 and pin 8 of IC3 (don't forget to re-insert the OM350 and the RF choke).

CALIBRATION

Calibration consists of setting the timebase accurately by adjusting the small trimmer capacitor in the crystal oscillator circuit. Before making this adjustment, however, the frequency meter should be run for 15 minutes or more with the lid on to allow internal operating temperatures to stabilise.

By far the easiest way to perform calibration is to use the horizontal output stage of a colour TV receiver as the reference source. In most cases, there is no need to make a direct connection to the TV receiver. All you have to do is dangle the input lead to the frequency meter in the vicinity of the horizontal output stage and adjust the trimmer until the display reads 15,625Hz.

The frequency meter should be switched to the 10MHz range and to 1s gating during this calibration procedure.

Do not try to pick up the 15,625Hz line frequency in the vicinity of the yoke — it generates too many spurious harmonics to give a reliable reading.

If you have a 10:1 divider probe (and are feeling adventurous), you can also calibrate against the 4.433619MHz PAL subcarrier frequency. To do this, locate the crystal oscillator in the chroma circuit and hook the probe onto one side of the crystal. Adjustments to the frequency meter may now be made, but make sure that the TV is displaying a colour program.

Note that loading effects can cause the TV oscillator circuit to shift frequency, so that programs that would normally be in colour are shown in black and white. If you do experience this problem, try hooking onto another part of the oscillator circuit. By the same token, a 10:1 divider probe is mandatory if loading problems are to be avoided.

Other methods of calibration include making comparison measurements with a frequency meter of known accuracy, and using a CB or amateur transceiver as the reference source. Again, there is no need to make a direct connection to the transceiver. Just connect a short length of wire to the centre-pin of the 1MΩ input socket and dangle it close to the antenna or dummy load for the transceiver.

With no signal from the transceiver, the input wire will pick up ambient noise to produce a random count. This will be swamped when the transmitter is keyed. The transmitter should be set to AM, not SSB, and there should be no modulation.

This means of calibration assumes that the transmitter frequencies are accurate. If there is any doubt on this score, then the validity of the method is dubious.

Some constructors may find during calibration that their frequency meter reads low and that the trimmer capacitor has insufficient range to correct this situation. If this proves to be the case, connect a 15pF ceramic capacitor to the underside of the PCB in parallel with the trimmer and try again. If the frequency meter still reads way too low, it's possible that you have been supplied with a series resonant crystal instead of a parallel resonant type.

Note: a series resonant crystal in a parallel resonant circuit will oscillate at a frequency higher than its nominal frequency. The difference will usually be so much that the crystal cannot be trimmed to the wanted frequency. If the timebase is too high, the frequency meter will read low; if the timebase is too low the frequency meter will read high.

GATING SWITCH	FREQUENCY (Hz) (10MHz RANGE)	GATING SWITCH	PERIOD (μs) (10MHz RANGE)
.01	Multiply by 100	1	Divide by 10
0.1	Multiply by 10	10	Divide by 100
1	Multiply by 1	100	Divide by 1000
10	Divide by 10	1000	Divide by 10,000

NOTE 1: multiply frequency readings by 10 for the 50MHz range and by 100 for the 10-500MHz range.

NOTE 2: divide period readings by 10 for the 50MHz range and by 100 for the 10-500MHZ range

USING THE DFM

Finally, a few comments on using the new frequency meter. First, always use shielded cable for input connections — 75Ω TV coax is fine. Using unshielded leads, even short lengths, will lead to errors due to induced noise.

You should also remember that measurements may be affected by the degree of loading on the circuit under test, so a 10:1 divider probe may be a worthwhile investment in many applications. Input impedance on the 10MHz and 50MHz ranges is 1MΩ for signals less than 0.6V peak, and 100kΩ for low frequency signals greater than 0.6V peak. Input impedance for signals greater than 0.6V peak decreases rapidly as frequencies increase.

The 500MHz range has a nominal input impedance of 75Ω.

The maximum input voltages which may be fed to the two "front-ends" of the DFM are limited by the ratings of the protection diodes and associated limiting resistors and blocking capacitors. We recommend that the maximum input voltage to the low frequency ranges (0-50MHz) be no more than 30V RMS, while the voltage to the prescaler should be no more than about 500mV RMS.

Because our circuit does not employ decimal point indication, some readers may have difficulty in interpreting readings. The accompanying table is intended to overcome this problem. We suggest that you make a photostat copy of this table and mount it under a sheet of perspex on the lid of the case for permanent reference.

A couple of examples will suffice to illustrate how the table is used: (1) measurements on the 50MHz range with the gating switch set to 0.1s are multiplied by 100 to get a reading in Hz; (2) period measurements on the 10MHz range with the gating switch set to 10 cycles are divided by 100 to get a reading in microseconds (μs).

Finally, the circuit diagram (p45, Dec) should show a 0.1μF capacitor between pin 14 and ground. The wiring diagram on p47 is correct.