Inexpensive Digital Multimeters – A Short Survey and Review

Mike Rivers

Prologue

The genesis for this article is another article that I wrote as part of my series "Trust but Verify" in Recording Magazine. That article involves making voltage measurements of audio signal, and for that you need a real voltmeter, at least long enough to calibrate an A/D converter and make your measurements by converting digital level to voltage. However, given that most of the Recording readers are musicians who have a home recording setup. They're not technologists or maintenance techs and, in these days of nearly unrepairable studio gear, aren't likely to own a multimeter. I couldn't, in good conscience, suggest that they need to buy a $400 test instrument that they might only use once, so I sought out some less expensive alternatives. I contacted Circuit Specialists, a distributor of electronics tools and test equipment, to see what they could recommend in a digital multimeter (DMM) in the $25 - $50 range. They sent me three meters for evaluation so I could be sure they were capable of making reasonable accurate measurements of millivolt-level audio frequency sine waves. I figured that as long as I had the meters here, I might was well do a little write-up on them and provide some background information for those of you who don't presently have a multimeter. I think everyone should have one, but that's just me.

What's A Multimeter?

The "multi" in multimeter means that it measures AC and DC voltage, current, resistance, and sometimes other things. There are both analog and digital multimeters, but in general, today digital multimeters are less expensive due to lower component cost. Any DMM can make "workshop grade" measurements with reasonable accuracy, however, some are better than others for working with audio equipment. Some DMMs include frequency measurement covering the full audio band, but when it comes to measuring AC voltage, most are inaccurate at frequencies above about 500 Hz. Unlike the D/A converters in your audio interface, when it comes to AC measurements, general purpose DMMs don't expect to see AC voltages other than from a power line or power transformer. But even with the limited frequency response, you can make useful measurements on audio equipment, sometimes with the help of a computer based recording system that you already have.

Pertinent Specifications

Accuracy and resolution are important if you want to be able to measure voltages close to mic level, 10 mV or less. There are three parts of the specification that come into play here:

- Tolerance - expressed as a percentage of the reading
- Digital accuracy – expressed as ± a few numbers of the lowest order digit
- Counts – expressed as the highest value of the most significant digit that the meter displays. Sometimes it's expressed as fractional digits, for example, 3½ digits.

Tolerance is straightforward. It's the uncertainty of the measurement due to just about anything involved in the manufacture of the meter such as component tolerance, D/A conversion accuracy, and drift with temperature and age.

Digital accuracy is a function of the resolution of the analog to digital conversion within the meter. Better meters use more bits and better clocking, but the sub-$100 meters usually have an ambiguity of ± 2 or 3 digits, some of which, when making low voltage measurements, is a function of noise pickup through the test leads. A true 2.05 volts might be displayed as a value somewhere between 2.02 and 2.08 volts. To further confuse and confound, sometimes (though rarely the case in a 4-digit display) the resolution of the A/D converter is less than that of the display, so the least significant digit or digits may not be significant at all. Also, some meters leave out a digit or two, or even every other digit, because of how the binary count translates to decimal numbers.

Before explaining counts and half-digits, it's important to understand range. All multimeters, digital or analog, internally scale the incoming voltage or current to fit within a readable meter scale. Think about an analog meter capable of measuring up to 1000 volts. 10 millivolts represents 1/100,000th of the total scale length, so you could only guess the actual value from the meter pointer position barely off zero. But it if the range was scaled to 0-100 millivolts, you could easily read the value with good accuracy. An analog multimeter always has a range switch to select the maximum value at the end of the scale. DMMs also switch ranges to fit the measured value to the number of digits the meter can display while offering the maximum resolution for the measured value.

Some DMMs have a manual range switch while others are auto-ranging and automatically find the best range for the measurement being performed. Unlike an analog meter that will slam its pointer into the full-scale stop and perhaps spew a little smoke if you apply 120 volts when switched to the 3V range, a DMM can (with exception of high current measurements) accept up to its maximum rated voltage at the input terminals, and a manual-range DMM will just give you an over-range indication so you can switch it to a range that fits.

But, you ask, "This is digital. Can't we just add more digits to display larger values?" Initially, DMMs were strictly lab instruments, indeed having enough digits in the display to show the measured value to two or three decimal places without scaling or range switching. However, when there was a demand for less expensive instrument, they came up with a clever way to use only four digits in the display, and then, not even a full four digits. This brings in the concept of the "half digit."

So, what's a "half digit" anyway? It's the high order digit of the display, but unlike a full digit that can have any value between 0 and 9, a half-digit doesn't go that high. When this concept was first introduced, the high order digit was either 0 (which is usually not displayed) or 1. When the display reaches 1999 (wherever the decimal point might be), next higher incremental value isn't displayed as 2000, but rather as [0]200, with the decimal point moving one digit to the left. A fresh 1.5V battery might read 1.593 volts, but put another in series with it and, rather than reading 3.186 V, a 3½ digit meter will display 3.19 volts. In newer meters, that "half" digit could be 2 or 3 (sometimes called 3/4 digit), maybe as large as 5. So a meter with 5 as its most significant digit can count from 0 to 5999 before dropping back to 0600. This is referred to as "6000 counts."

The article that drove this look at DMMs was for measuring analog signals in audio equipment, which means that they need to measure AC voltages as small as a couple of millivolts and up to about 30 volts, more if you also use it to check the AC line voltage before plugging in a piece of gear. Generally, the most sensitive (lowest) range of a DMM is higher for AC than for DC, so this is something to look out for when you need to measure small AC voltages. And while I'm on the subject, I'll add that manufacturers never really intended their general purpose DMMs to be used as audio level meters – they assume that AC measurements will be at the power line frequency – 60 Hz, 50 Hz, maybe 400 Hz on an old airplane. While some DMMs offer frequency measurement up to hundreds of kHz, they won't measure AC voltage accurately at a frequency above about 400 Hz.

Here's Where The Review Part Starts

The three meters here for evaluation are:

Owon B35 ≈ $50
Mastech MS8264 ≈$25
Circuit Specialists CSI2010 ≈ $25 (this is Circuit Specialists' house brand)

The Owon is auto-ranging, the other two switch range along with the function. They're all about the same size and weight and are comfortable when hand held. All have a rubberized "bumper" surrounding their plastic case, and all have a folding stand hinged at the rear so they will stand up on the workbench at a convenient viewing angle. While not part of this review, I used two of my own DMMs for comparison, a Fluke 77, and a generic cheapie with a Craftsman badge, for comparison. The Fluke is an electronic maintenance shop grade auto-ranging DMM which I've had for 30 years and it's good and accurate as new, but today costs close to $400. The Craftsman is currently $10 at Sears (sometimes as little as free at Harbor Freight with any purchase) - I carry it in my tool case when I go out on a remote recording or live sound gig so I won't cry if it gets lost or damaged.

For this photo, all of the meters are connected to the same power supply and, as they should, all read the same to the extent of their resolution. Note that the Owon has one more digit after the decimal point than the others. This is because it has a larger "half digit" than the rest.

Normally when I review a piece of audio gear (which is, normally, what I do), I'll start going through its spec sheet, seeing how close in actual use the device comes to its published specification, and filling in the gaps where something should have been listed but wasn't, and clarifying incompletely stated specifications. I can't do much of that here because I don't have laboratory standards against which I can check absolute accuracy.

I can say, however, that all three of the meters that I have here for evaluation fell within their specified tolerance when compared with my trusty Fluke 77. So when it comes to voltage, current, and resistance, all of them are good enough for troubleshooting, verification, and learning about your gear, though I wouldn't certify a device based on the accuracy of their measurements. Most of what I'll be talking about is ease of use, what they can measure beyond the basic voltage, current, and resistance, and general look and feel. Here's a comparative rundown on the three meters:

Function (full scale range)	CSI1210	Mastech MS8264	Owon B35
Display Counts	2000 (0-1999)	2000 (0-1999)	6000 (0-5999)
DC Voltage	200 mV, 2 V, 20 V, 200 V, 1000 V	200 mV, 2 V, 20 V, 200 V, 1000 V	Individual mV and V functions: 60 mV, 600 mV 60 mV-750 V Auto-ranging
AC Voltage	200 mV, 2 V, 20 V, 200 V, 700 V	2 V, 20 V, 200 V, 750 V	Same as DC. Select button selects AC or DC
DC Current	2 mA, 20 mA, 200 mA, 20 A	20 mA, 200 mA, 10 A	Individual µA, mA, and A functions: 600 µA, 600 µA-6A, 20 A Auto-ranging
AC Current	Same as DC	2 mA, 200 mA, 10 A	Same as DC. Select button selects AC or DC
Resistance	200Ω, 2kΩ, 20kΩ, 200kΩ, 20MΩ, 200 MΩ	200Ω, 2kΩ, 20kΩ, 200kΩ, 2 MΩ 20MΩ, 200 MΩ	600Ω – 10MΩ
Continuity/Diode	Beep, Light, Displays diode forward voltage drop	Beep <30Ω on 200Ω range, separate range for diode voltage drop	Beep, diode voltage drop
Capacitance	2 nF, 20 nF, 200 nF, 2 µF, 200 µF	20 nF, 200 nF, 2 µF, 20 µF	40 nF – 4000 µF Auto-ranging Note: Resistance, capacitance, continuity, and diode measurements are on a single function, selected with the Select button
Temperature	No	-20°C - 1000°C! my sample displays in °C only	-50°C – 400°C -58°F – 752°F
hFE	Yes	Yes	Yes
Frequency	No	Up to 20 kHz	0.5 Hz–9.999 MHz Also measures duty cycle

Special Features

All of these meters do more than the basic three measurements of voltage, current, and resistance. You can get a summary from the table above. Both the Owon and Mastech measure temperature and include a thermocouple. All of these meters measure capacitance and hFE. The CSI has a transistor lead socket on its front panel while the other meters include a plug-in adapter with the transistor socket. The Mastech adapter is also used to connect the temperature probe and both the Mastech and Owon adapters can be used to connect capacitor leads directly to avoid adding the stray capacitance of the test leads to the measurement for small value capacitors.

All of the meters have a Hold button to freeze the display, handy when you want to write down a measurement, and the Owon and Mastech have a button to switch on a display backlight. The Owon offers a couple of relative measurement features that may be of some use. One captures the maximum and minimum value of a changing measurement, another sets a measured value as a reference and displays the difference between it and another measurement. I used this to match a pair of resistors.

The Owon has the unique feature of a Bluetooth remote display and remote control. This deserves a review of its own so I'll be brief here. Pairing the meter with a dedicated Android or iOS app allows you to read and operate the meter remotely. In addition to providing a remote display, it can use your mobile device's text-to-speech to read the displayed value to you, log readings at selectable time intervals, and plot readings with respect to time. And if you have two meters, you can display both together, for example to measure voltage with one and current with the other.

In Use

This is where I put a device under review through its paces, measure parameters that I think are important to know but aren't in the published specifications, check accuracy, and generally comment on ease of use, look and feel. I don't have the means to measure voltage and resistance to significantly greater accuracy than any of these meters, so there's no point in quibbling about a difference of one or two counts in the least significant digit. These are bench instruments, not lab instruments, though they can be pressed into lab-like measurement service with some care.

The two greatest differences between the DMMs under review here are with their controls and the maximum number of counts displayed. The CSI and Mastech meters both have a rotary switch that selects both the measurement function (ohms, DCV, ACV, etc.) and the full scale value. Both are true 3½ digit displays (2000 counts) and both display just the single digit 1 indicating that the input is over range and that you need to switch to the next highest range. I didn't try to test them to destruction by putting in 400 volts when set to the 2 volt range, but none of the meters blew up when fed a reasonable amount over range.

Both indicate the selected range by a number placed just below the decimal point. In addition, the Mastech and Owon conveniently show what function you're measuring, for example that you have it switched to DC when you're trying to measure an AC voltage. Here's the Mastech display showing that it's measuring AC voltage on the 20 volt range.

All of these meters arrive at their final reading within a second or two for voltage, resistance, and current measurements, though with a 2000 µF capacitor, it took about 15 seconds for the measurement to display. The manual says it may take more than 30 seconds to measure 4000 µF.

Once you get the hang of the symbols for measurement function, the range/function switch on all of the meters is fairly easy to read and use. I have a couple of niggles though, which are probably more indicative of the manufacturing quality expected from a $25 meter. On my CSI, the knob pointer was slightly misaligned, not so far that it made setting ambiguous, but far enough off to notice.

If you're unfamiliar with the graphic symbols, the sine wave and bar represent, respectively, AC and DC measurements.

The text on the CSI front panel alternates between orange and white to differentiate between adjacent functions, while the Mastech has little orange separators between adjacent functions. On my unit, there was no separator between 10A AC and 10A DC, so I doctored this photo with a red line to show what was missing. Incidentally, while A, V, and Ω are obvious for Amps, Volts, and Ohms, capacitance is designated with F, for Farads.

I found the sequence of numbers surrounding the function/range knob on the two manual-ranging meters to be somewhat confusing. The DC Amps ranges on the Mastech (shown above) increase from 20 mA (at the lower right of the photo) to 10 A when the knob is turned clockwise, which seems logical. However, the ranges of its neighboring function, AC Amps, *decrease* from 10 A to 2 mA with clockwise rotation. On the CSI, both DC and AC voltage ranges increase with clockwise rotation of the knob, though on the Mastech, AC voltage ranges decrease and DC voltage ranges increase with clockwise rotation. To me, this is just goofy, but I suppose after using the meter for a while you won't notice it.

The two manual-ranging meters have a pretty straightforward user interface, but the auto-ranging Owon is rather different. With manual range switching, you switch to what you want to measure, then, other than perhaps moving a test lead to a different jack for measuring a capacitor or high current, you're good to go. The Owon (pictured at left) puts me slightly in mind of a digital mixing console or DAW software program - making just about any setting requires using two controls.

The rotary knob selects the basic function, but you don't simply select voltage, current, or resistance - volts and millivolts each have their own switch position, as do microamps, milliamps, and amps. When you've selected a voltage or current function with the knob, the Select button toggles between DC (the default) and AC measurement. Continuity (beeper), diode forward voltage drop, capacitance, and resistance (the default) all share a single position on the rotary knob, with the Select button used to page through the four functions. The Hz% switch position is for measuring frequency and duty cycle, with the Hz/Duty button toggling between the two measurements. For temperature measurements, the Select button toggles between Fahrenheit and Celsius.

The Range button defeats the auto-ranging function and locks in a range, moving and fixing the decimal place. This is a convenient feature for troubleshooting when, for example, you're tracing the +15 V "power rail" voltage throughout a chassis or circuit board. With auto-ranging, whenever you move the test probe from one point to the next, it momentarily sees 0 volts, then has to find the range again before the display stabilizes. If you're measuring the same voltage at several points in the circuit, you can save a little time, eye strain, and patience by locking the range.

The Owon Specs indicate that it measures frequency up to 9.999 MHz, but I couldn't confirm that since I don't have a generator that goes above 1 MHz.

Interestingly, for frequency measurements, the high order digit goes to 9 rather than 5 for voltage, current, and resistance measurements.

Dribs and Drabs

All of these meters come with test leads of fair-to-middlin' quality, with banana plugs on the meter end and pointed probe tips on the measuring end. All have

removable insulating sleeves to reduce the amount of "hot" probe tip exposed. The Owon leads are provided alligator clips that screw on to the end of the test probes. They're kind of large and gross, more appropriate for working on your car or in a circuit breaker box than an electronics chassis. Being at the end of a long lever arm, the clip has a tendency to fall off. If you'll be using a meter often, it's worth buying a better quality "universal" test lead set that allows you to replace the probe directly with a clip when needed. The test lead sockets on the Mastech feel a bit less secure than those on the other meters, though none had a problem with connections.

The CSI and Mastech meters are powered by a standard 9 V battery, and the battery cover on both is a bit of a fuss to open. The CSI requires peeling back the rubber bumper in order to slide the cover off. The Mastech battery cover is secured with two Phillips head screws. The Owon is powered by two AA cells, and its battery cover secured with a Torx 9x40 tamper-proof screw. It would be nice if Owon supplied the proper driver since it's not a common household tool, and you'll need to install batteries before using the meter.

The Mastech is the heaviest of the batch, the CSI the lightest. The Owon comes with a cloth zipper case that has room for the meter, test leads, temperature probe, and hFE adapter. The Mastech has clips molded into the back of its rubber bumper that provide a handy way for storing the test leads and keeping them from getting tangled in your toolbox or tool drawer.

Documentation is pretty minimal. The CSI "manual" is nothing but a listing of the measurements it makes and their accuracy. The Mastech and Owon manuals are a little more informative, and Owon has an on-line manual that's more detailed than the one packed along with the meter. Meters are supposed to be simple so you shouldn't need much of a manual, but these are more complex than your grandfather's (or my) Triplett 630.

The Wrap

Any of these meters will serve you well on the bench as long as you don't expect lab accuracy and precision. For that you'll need to spend several hundred dollars more. The Owon was my overall top pick of this lot for a couple of reasons. First, because of its 6000 count display, more measurements can be made with greater resolution than on the 2000 count meters. It can measure AC in the millivolt range with reasonably good accuracy, and the Bluetooth remote control and data logging is a nice bonus. Also, it's the only one of the group that offers a bar graph below the numerical display, handy when you're trying to adjust something for a peak or null. It's easier to watch that moving bar than trying to keep track of changing digits.

At the lower cost end, it's kind of a tossup between the CSI and Mastech with my preference leaning slightly toward the CSI because its function switch is a little easier to read and, although it doesn't measure temperature, requires no adapters to lose. In full disclosure, I'll tell you that the CSI-2010 that arrived in the carton with the other meters had a problem on some ranges. Circuit Specialists sent me another one promptly and that one worked just fine, though both had the same slight switch pointer misalignment. The Mastech has a display backlight that's really valuable when working in the back of a rack or under a stage, and that test lead storage system works well and keeps things neat.

Measure stuff, and learn things.