Making It Count

Using a frequency counter requires some basic understanding of the instrument's capabilities and how it can be applied

(Photo credits: Tracey Trumbull)

By Bill Owen

Last month, we presented plans to build a compact, portable frequency counter that spans audio through microwave frequencies. Making it count, as with any other frequency counter, is simply a matter of understanding how to use it properly.

To use such an instrument effectively, and without damaging it, requires the operator to know something about the signal it will receive. This shouldn't be surprising; the same is true when working with a multimeter, where you should know if the signal is ac or dc and what is the anticipated voltage range to be set. And as with any test instrument, different models often have different features and operating nuances. It's important, therefore, to study the manufacturer's operating manual and familiarize yourself with the counter's switches and controls.

You should never exceed any instrument's input limitation, of course. In the case of a frequency counter, neophytes may overlook such a precaution for one reason or another. For example, one might have an inordinate desire to check out his electric utility company's ability to maintain ac current at precisely 60 Hertz by connecting a counter's input probe directly to a 117-volt ac outlet. Do *not* do this, naturally . . . unless you want to see your counter go up in a puff of smoke and possibly suffer an electric shock yourself!

Use caution, too, when measuring a transmitter's antenna output. Do not directly connect the counter's input to the transmitter's output because the instrument's input circuitry will likely be damaged when the transmitter is keyed. Other, safe ways to check a transmitter's output will be explored later.

To give you a clearer idea about the seriousness of keeping in mind the strength of any input signal applied to a frequency counter, let's look at the compact counter for which construction plans were presented. Each of its two frequency-range modes has a different maximum input signal it can accept without damage.

Range A, which has a frequency range of 10 Hz to 12 MHz and a 1-megohm input impedance, has a maximum input specification or damage level of 100 volts ac plus dc. Range B, which covers 10 MHz to 2.2 GHz and has a 50-ohm impedance input, has an input limit of only 2 volts. Imagine what a disaster it would be if the range switch was accidentally changed from "A" to "B" while inputting, say, a 50-volt signal!

There are other unfamiliar elements of concern when operating a frequency counter. For example, its input sensitivity might change with frequency. Consequently, one should have some idea of the approximate frequency to be counted. Furthermore, signals have to be properly coupled between the counter and the device being checked. Ignoring the foregoing, the counter might display no reading, an unstable reading or even a wrong count.

None of the foregoing operating considerations can be considered to be outrageous. However, they may indeed be somewhat disconcerting to anyone not used to working with high frequencies, the major area in which frequency counters are used, whether it's for checking a ham radio transmitter's frequency or a computer's clock frequency.

There are two basic ways to make a counter read frequencies. One is the traditional way of directly coupling the counter's input connector through a cable or a probe to a device's output (always observing the precautions previously cited). Alternately, a pick-up antenna can be employed to receive the signal to be counted through the air.

Direct-Connection Method

As an example of the direct-connection method, you can verify frequencies of various signal generators by directly connecting a cable between the generator's output and the counter's input. This might sound easy enough, and it is—with an exception. Using the right connectors for the job can be a frustrating chore at times. Consequently, plan on having an assortment of adapters on hand.

The counter in this project uses a female "BNC" (military designation, UG1094U) for its input connector, which is pretty much standard on many types of generators and other test equipment. Type "N" is also commonly used, so a Type N-to-BNC adapter would certainly be useful to have. I recommend, too, having a 6-foot-long coaxial cable with a male BNC on each end on hand for connection adapting purposes.

Many oscilloscopes also have a vertical signal output connector on the rear panel. You can directly connect the counter's input to it to give you a frequency readout of the waveform being displayed on the scope. Only high-priced scopes have accurate frequency readouts, which you can match for a modest investment.

I cited some frequency counter connection caveats earlier, warning about the dangers of direct connection in some instances. There are ways around this, though. For example, what if you really had to know the frequency of the current coming out of a wall tap? One way to circumvent destroying the instrument by taking a frontal connection attack (and possibly exposing yourself to an electrical shock because the portable counter will be grounded through your hand) is to use a low-voltage transformer to step down voltage to a tolerable level and to isolate the power line. Note that the subject portable counter must be set to its "A" range even here to avoid damage.

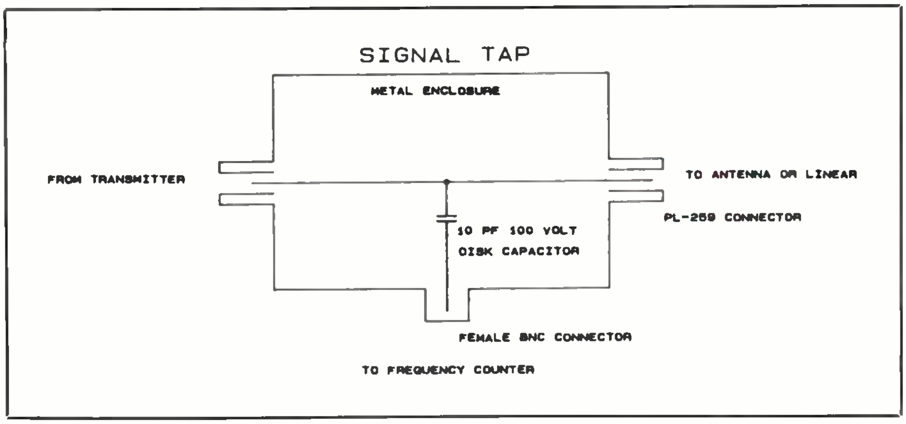


Fig. 1. Details of a tap arrangement for safely counting the frequency at the output of a radio transmitter.

You can measure a transmitter's output frequency by using some keen coupling techniques that avoid a straight connection line between it and the counter. For example, you might use the signal tap illustrated in Fig. 1. The design has to be approximated because the transmission frequency and power level will affect operation. As a result, some insertion loss might be incurred.

There are more ways to skin the cat, of course. You can use adequate attenuators to reduce the power level to a safe level for the counter's input, for instance. Some much costlier frequency counters even have built-in switchable attenuators.

Keep in mind that testing a transmitter without using a non-radiating dummy load can interfere with the radio communications of others who are active on the same frequency. Also remember that counters measure steady radio-frequency energy, such as a continuous carrier wave. The instrument is not designed to work with an audio modulated carrier, much as Morse Code isn't. This might seem to indicate that you cannot count the output of a single-sideband transmitter since audio has to be used to generate it.

You can get around this, however, because some SSB transmitters have carrier-insertion provisions. What if yours doesn't? Well, old timers say you can simply send a single tone whose frequency is known through the microphone. According to them, then count the output, taking care that you do not do so with a direct connection, and subtract or add the single tone's frequency (depending on whether you're switched to upper or lower sideband) from your frequency counter's reading.

Specialized probes can enhance the utility of a frequency counter. This can be the case with the counter project at hand, which could try to count a low-frequency source such as an audio signal while having an inherent gigahertz (GHz) bandwidth. The counter has to be able to distinguish between a low-frequency signal and high-frequency noise and harmonics that could be present.

To do this with our low-cost compact counter requires the use of an attenuation probe, such as a 10× oscilloscope probe. For instance, you might have a 5-volt signal with a signal-to-noise ratio of 40 dB that could have a 50-millivolt noise level. The signal is clearly sufficiently high to be counted. The hat trick is simply to reduce the 5-volt level to the point where it's still high enough to be measured, while at the same time the noise component has been reduced to

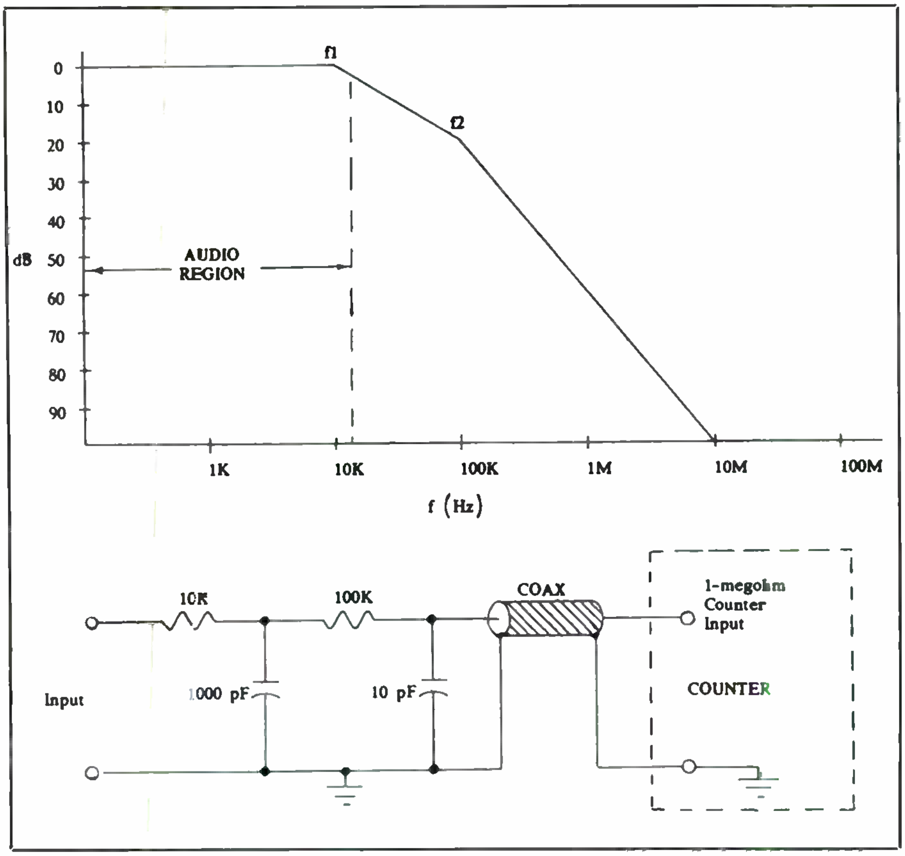


Fig. 2. Frequency-response plot of a low-pass filter and schematic diagram of a low-pass probe.

the point where it cannot be counted.

In using this technique, be sure that the counter is in the higher input impedance range ("A" is 1 megohm in the project counter). If you switch to the low 50-ohm impedance range ("B" in the project counter), the scope probe's 10-megohm series impedance will eat up most of the signal. This would leave too low a signal value to trigger the counter. Only 1 × probes or direct cables can work on the very-high-frequency range ("B") due to its very low input impedance.

Low-frequency measurements are made easier by using a low-pass-filter probe. It reduces false counting from higher-frequency components. A schematic for such a two-stage filter is illustrated in Fig. 2, along with its response curve. Component values are not critical and the device is easy to build. (The probe can only be used for low-frequency counting, as in the project's "A" range.)

There will be times when you may want to take your count inside a circuit. Perhaps this is in the oscillator circuit. Don't be surprised to discover that you can't get a satisfactory reading in such instances. The signal level will likely be too low. You'll either require a preamplifier or probe with a built-in wideband amplifier to boost the gain or use a high-priced counter with a built-in wideband amplifier to obtain a usable signal.

Measuring crystal oscillators can be a problem because a probe might load the circuit, causing the frequency to shift or, worse, cause the oscillator to cease oscillating. Many oscillator circuits provide a calibration test point to avoid this. The best way to proceed in a crystal oscillator is to use either a 10× scope probe or a large-value series resistor.

The largest possible resistor value should be used that will still allow a measurement to be made. Typical values range from from 100K to 100 megohms. You might also use a multi-turn loop of wire (sometimes called a "sniffer") as a pickup that's placed close to the crystal if the device radiates sufficient energy. This method should have minimal influence on the oscillator's frequency since the circuit isn't loaded.

Note that only the relatively low-frequency range ("A") should be used for direct measurements. Signals of higher-frequency oscillators have to be indirectly counted using the sniffer device to avoid having the counter's 50-ohm input impedance stop the circuit's oscillation.

Indirect-Connection Methods

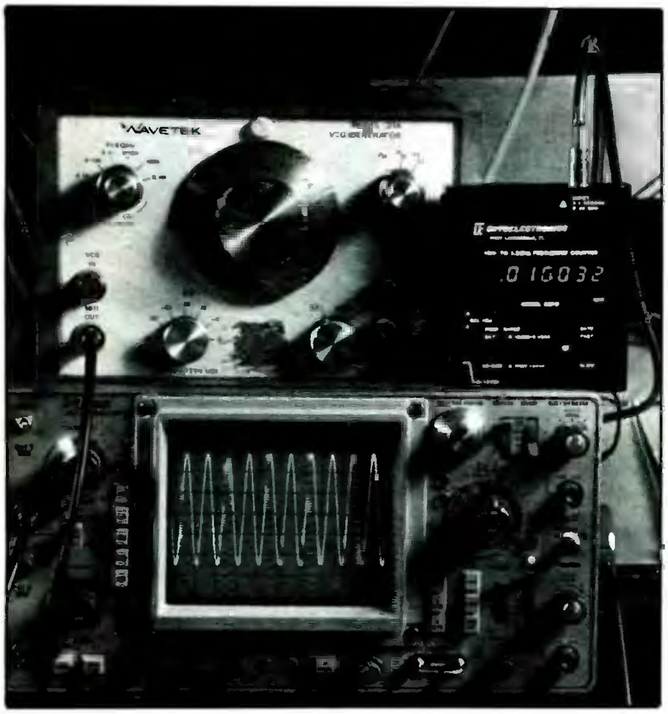
The "sniffer" device mentioned earlier is an example of an indirect-connection method of "coupling" a counter to whatever you're counting. You can also use a short whip antenna connected to the counter's input to pick up a radiated signal from, say, a transmitter—if you're close enough and the output signal is strong enough. This is a popular way to use a frequency counter, greatly expanding its applications.

A frequency counter isn't like a radio, of course. Whereas a radio is designed to be tuned to selected frequencies, a counter is a broad-band device that responds to the dominant (strongest) frequency of the moment.

In practical terms, there may be a 100-kW transmitter a few blocks away and a 1-watt transmitter 10 feet away. The counter will see the 1-watt unit first because there's an inverse-square relationship between signal strength and distance.

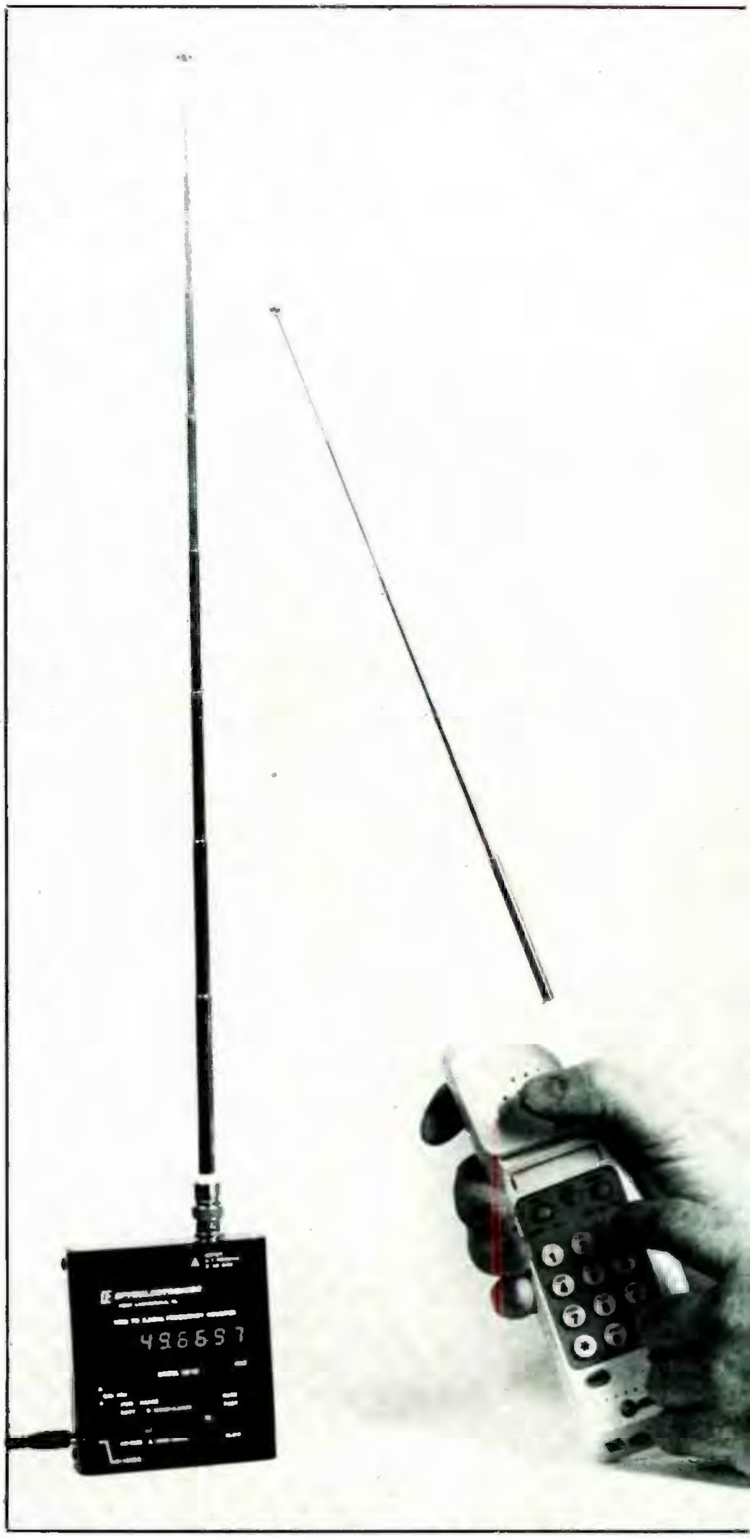
As a result of the foregoing, the counter can be used to measure an unknown signal near it without the operator having to tune in the frequency. This opens new vistas for the

Counter Connection Methods

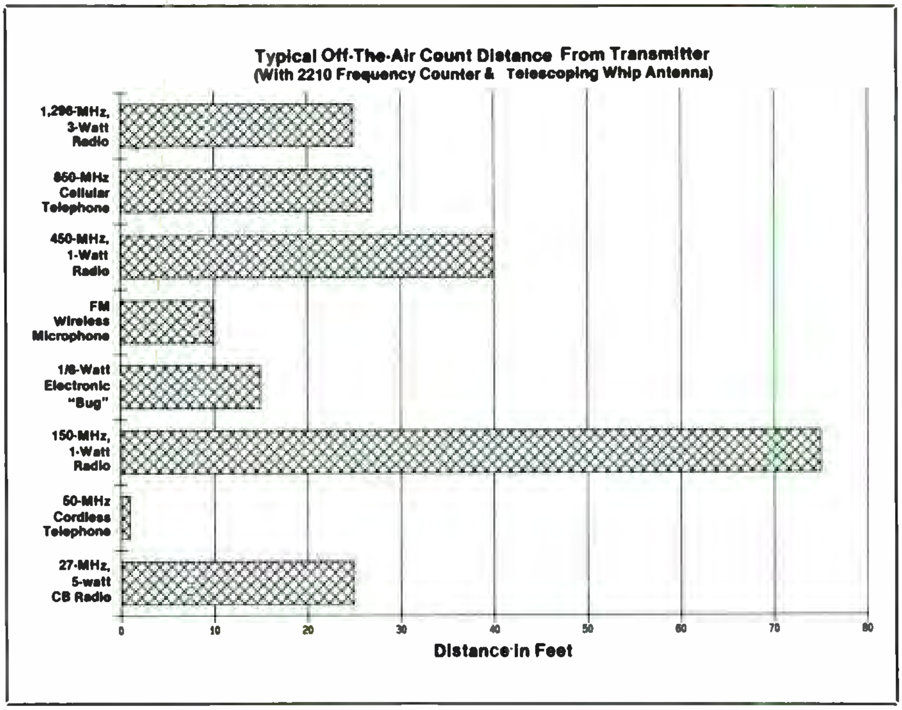


Direct Cable. Directly connecting a frequency counter to an oscilloscope's vertical channel output jack at the rear verifies a 1-kHz signal.

Direct Probe. A 1×, general-purpose direct probe is used to connect the counter to a crystal oscillator circuit.



Off-The-Air. A counter with a telescoping whip antenna measures the frequency generated by a cordless telephone.



owner of a frequency counter, especially if it's a battery-powered portable one like the project is.

An accompanying frequency chart illustrates typical distance-to-transmitter plots for counting the frequency of a host of common r-f sources. Measurements were made with our assembled project counter using an 18-inch telescoping whip antenna connected to the device's input. Obviously, distances in which accurate counting could be accomplished would be greater if an antenna made expressly for the radio frequency to be picked up were used. Other variables here would include transmitter output power, transmitter height, and the counter's sensitivity to the frequency being captured.

With a 1-watt 2-meter radio transmitting at nearly 150 MHz being counted from 75 feet away, it's shown that a telescoping whip antenna can be readily used when the source isn't far away. The whip was fully extended in this case; it would be collapsed as frequency increased. A "rubber duck" antenna, though conveniently small, causes the effective counting range to decrease as much as 50 percent in some cases.

For scanner frequency counting, broad-band antennas designed for these frequencies will provide greater range than the whip used here. There are a number of sources that sell such scanner antennas.

The public service frequencies transmitted locally are favorites for frequency catching. It's legal to sniff out any frequency, you know, punch it up on a scanner if it's in its range, and listen in on the transmission. (*Of course, the listener is still prohibited from using the information heard for personal gain or disclosing its contents to other parties not involved unless by the express permission of the originating party—Ed.*) This enables one to catch the frequency that, say, a patrol car officer is transmitting on, and listen in through your scanner. The same holds true for fire-department transmissions, commercial two-way mobile radio communications, and other transmissions.

When frequency-catching from a car, an external antenna is recommended, such as Antenna Specialties' Model MON-52. When properly configured, a drive through a military base or airline terminal area can be interesting projects.

Since the frequency-counter project combines high sensitivity with portability, it lends itself to the cloak-and-dagger world, too. Simply walking around a room with the hand-held counter's telescoping antenna fully extended will likely lock in on a "bug" if it's there. Professional r-f listening devices are almost exclusively in the 100-MHz through 450-MHz range and, typically, have at least 100 milliwatts of power.

Once you know a bug is present, you'll likely find it with some careful searching. Amateur spies with no access (or money) to commercial listening devices will use cheap FM wireless microphones, which have very low power outputs. The counter project won't pick up its frequency as readily as the professional listening devices, of course. Our chart shows that 10 feet is about maximum distance for the mike. However, the associated threat from this type of snooping is generally a lot less perilous than that of the pro.

Bear in mind that if you're walking around a room with a powered-up counter with antenna attached, and there is no strong r-f signal in the area, a constantly changing counter display will likely be generated. Don't try to interpret such readings, which are meaningless. Such self-oscillation from internal r-f amplifier/antenna interaction is due to a counter having good sensitivity. It's merely responding to background radio frequencies. With a little experimenting, you'll quickly learn how to distinguish between this and a frequency-locked readout.

Conclusion

Frequency counters are finding wider areas of application than ever before

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because they are getting better and cheaper. Nevertheless, there are still some counting chores that they cannot normally handle without elaborate circuit support.

So don't expect to check out the crystal oscillator in your wrist watch with any moderately priced counter. Its micro-power operating level is too low. Nor would you normally be able to count a radio-control signal that's pulse modulated. Some garage door remote-control openers use this system; so do model radio-control cars, boats and planes. And infrared signals such as used by remote-control circuits for TV, VCR and compact disc applications cannot be counted.

You cannot expect to be able to count signals that aren't continuous for at least as long as a counter's shortest gate period, either. Naturally. There are more costly bench-type counters that feature more and shorter gate-time selections than the compact, portable counter, Optoelectronics' Model 2210, whose construction plans were described in detail last month. You can compare its fastest 0.1-second time with Optoelectronics' Model 8024-S's 0.01-second gate period. But then you're talking about a larger, heavier instrument that costs almost four times as much as the project.

Ten years ago, a counter meeting the basic specifications of the compact counter would have cost thousands of dollars and likely would be mounted in a 19-inch rack. Use of such counters was generally limited to engineers or technicians.

Today, however, digital frequency counters are even utilized by non-technical operators, from law-enforcement officers to scanner buffs. The operating hints described here will serve them as well as you technically oriented people in getting the most out of any modern counter.

Counter Kit Information

The following items are available from Optoelectronics Inc., 5821 N.E. 14 Ave., Ft. Lauderdale, FL 33334 (800-327-5812; in Florida, 305-771-2050): A kit of all components but not including enclosure, $99. Available separately are: double-sided pc board with plated-through holes, Part No. PCB-2210, $25; 9-volt dc, 300-mA plug-in power supply, Part No. AC-22, $9.99; Ni-Cd battery, Part No. NiCad-22, $20; enclosure and hardware, Part No. CAB-22, $20.00. Also offered is an assembled and calibrated unit, Model 2210, for $189. Add 5% for postage and handling. Florida residents, please add 6% state sales tax.