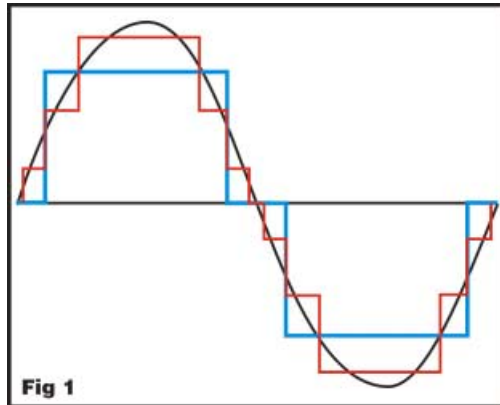


••• Inverter Generators and RVs

The “Hows” and “Whys” of Inverters and Inverter Generators.

Inverter and inverter generators are becoming more and more popular with campers of all kinds. The engines typically vary the speed to track the load so that at low load there is very



little noise. For the same reason, these generators are very fuel efficient. But sometimes people find that these generators will not satisfactorily drive common loads such as battery chargers, converters, microwave ovens and so on. This article will explain the different types of inverter generators, how they differ and why some types are not suitable for some loads. Since the inverter inside the inverter generator is quite similar to the stand-alone 12 volt to 120 volt inverters, this article also applies to those.

- Modified Square Wave
 - Pseudo Sine Wave
 - True Sine Wave
- Of these, only the last three are commonly seen, as the square wave is considered obsolete.

One might wonder why there are so many types of inverters. The primary reason is cost. Some types of devices won't work on the cheaper modified square wave of cheaper inverters and generators. Audio/video equipment, some computers and some microwave ovens require a nearly pure (low distortion) sine wave input. In audio/video equipment, the higher frequency harmonics present in distorted sine waves can come through as buzzing

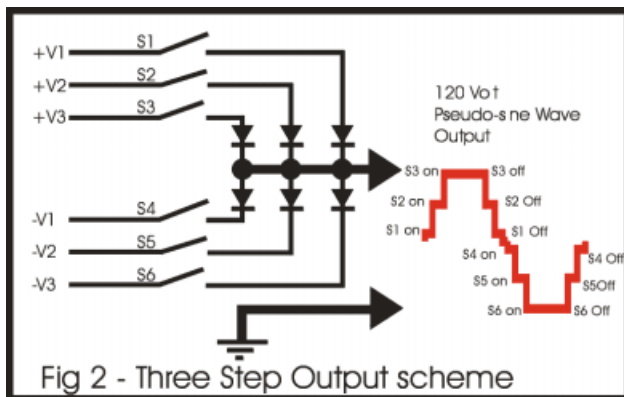
in the speakers. And some microwave ovens depend on the peak value of 120 volt sine wave input to make their power. If these devices are to be run from a generator or inverter, then the generator or inverter must supply a sine wave or something pretty close to it. A regular AC generator, one that runs at either 1800 RPM or 3600 RPM, makes a pretty decent sine wave. But to make a nice sine wave from an inverter is expensive. Therefore this type of inverter is reserved for the most expensive products.

As is intuitive, the three step wave produces a closer approximation of a sine wave and thus will satisfactorily operate more devices than the single step one. The tradeoff is cost and complexity. Each of the voltage steps requires its own voltage supply, its own transistor switch plus the necessary control circuitry.

Figure 2 is a line drawing of a typical three step output stage. The voltages V1 through V3 are increasingly higher DC voltages generated by either the generator or a DC-DC inverter in the case of a stand-alone inverter. A micro-processor generates the pseudo sine wave by sequentially switching S1



The Honda EX350 Inverter Generator



Inverters - What's the difference?

There are four major types of inverters. These are

- Square Wave

For many other loads, a less than perfect sine wave is adequate. The issue then becomes a trade-off between cost and waveform purity. An approximation of a sine wave may be created by outputting one or more stepped square wave with the amplitudes chosen to approximate the sine. The more steps, the more like a sine wave the output is. The more steps, the higher the cost. The two go hand in hand.

Take a look at Fig 1 above. The black trace is, of course our ideal sine wave. The blue wave is a single step approximation. The red wave is a three step

through S3 on, S3 through S1 off, S4 through S6 on, S6 through S4 off. It repeats this 60 times a second. As one can see, the most steps in the pseudo-sine wave, the more complicated and thus more expensive the inverter is.

A three step inverter is high end. Many inverters I've examined employ only two steps. Many others employ only one, as in the blue trace in Fig 1. This special case is also known as “modified square wave”. This scheme works surprisingly well for many loads. Audio and microwave ovens being the two notable exceptions.

An example of this modified square wave is the Honda EX350 generator. This cute little generator uses a small

weed-whacker-type 2-stroke engine that drives a motorcycle-type permanent magnet three phase alternator. This alternator varies in both frequency and voltage as the engine speed changes. The raw output of the alternator is fed to an integral inverter that produces a modified square wave similar to the blue trace in Fig 1.

Photo 1 is a oscilloscope shot of the actual output of my EX350 generator. Notice the RMS voltage indication on the right side - 120 volts even though the peak voltage is only 142 volts. For a sine wave, the peak voltage would be $120 * 1.414 = 169$ volts. This difference in peak voltage is what makes or breaks the operation of

microwave ovens, some battery chargers and some RV converters. Switching converters are particularly sensitive to the value of the peak voltage of the input power.

Photo 2 shows a scope shot of both the voltage and the current output of this generator driving a 300 watt resistive load, in this case a quartz-halogen flood light.

This scheme works well for a resistive load like an incandescent light. But things get a bit more complicated with inductive loads such as the ferroresonant converter in my motorhome. Photo 3 shows my EX350 driving the ferroresonant converter in my motorhome. The current waveform is

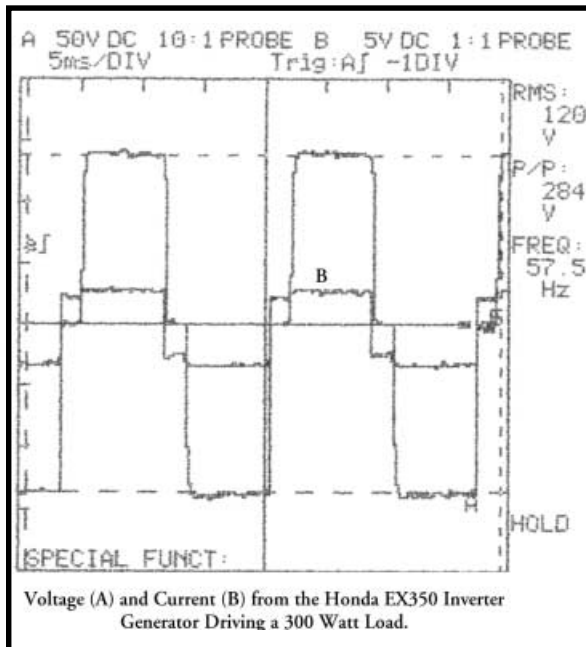


Photo 2

particularly interesting. Immediately when the voltage wave rises, the current starts flowing. This current is charging the magnetic circuit in the ferroresonant transformer core. When the inverter output voltage becomes high enough to drive current into the house battery, the current suddenly dips as the stored energy in the core feeds the output. As this energy runs out, the input current again starts flowing.

All this fast on and off activity can generate interference with radios and TVs and can even be unhealthy to the generator inverter. In this particular case, the generator seems happy and it doesn't bother my radio. And because of the ferroresonant transformer, the converter charges the house battery just fine. But this might not always be the case. If the characteristics of either the generator or converter change just a little bit, the two may not work together. This is a situation that must be tested on a case by case basis.

Things get a whole lot more interesting when one connects a compact fluorescent

(CF) lamp to the generator. This particular CF lamp uses a solid state ballast. Look at all that current oscillation on Photo 4! This activity can be heard on my AM radio and puts a line across the screen of a nearby TV. The light seems to operate OK, certainly much better than the scope photo would indicate.

A common situation encountered with modified sine wave generators like the EX350 is trying to charge a battery using a conventional battery charger. The battery charger consists of a transformer, a rectifier and perhaps some support electronics like an ammeter or charge control circuitry. To understand the problem with modified square wave generators, let's first examine how the battery charger works when plugged into a conventional outlet.

Let's suppose we have this battery charger plugged into a convenience outlet and connected to a battery. On each half-cycle of the 60 hz line voltage, the voltage first increases and then decreases in the shape of a sine. The transformer secondary follows this voltage. Connected to the secondary is the rectifier that converts the AC to DC for battery charging. Only when the instantaneous voltage AC voltage exceeds the battery voltage plus the 0.7 voltage drop of the rectifier does charging current flow. Photo 5 illustrates this effect. The two lines at "1" and "2" mark on the voltage sine wave where the rectifier

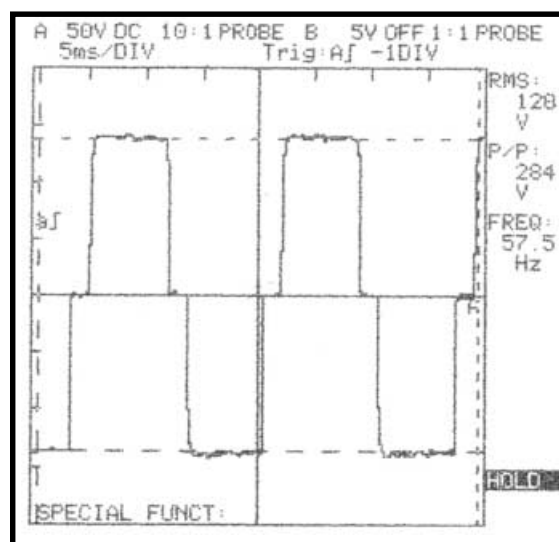


Photo 1 - Scope picture of the generator's output

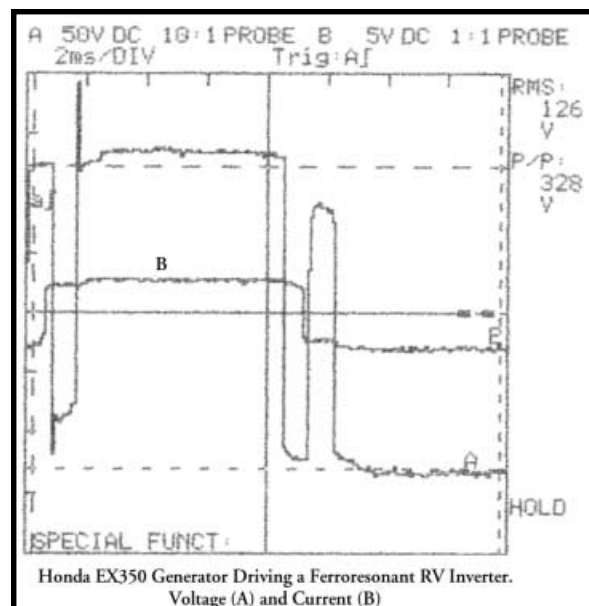


Photo 3

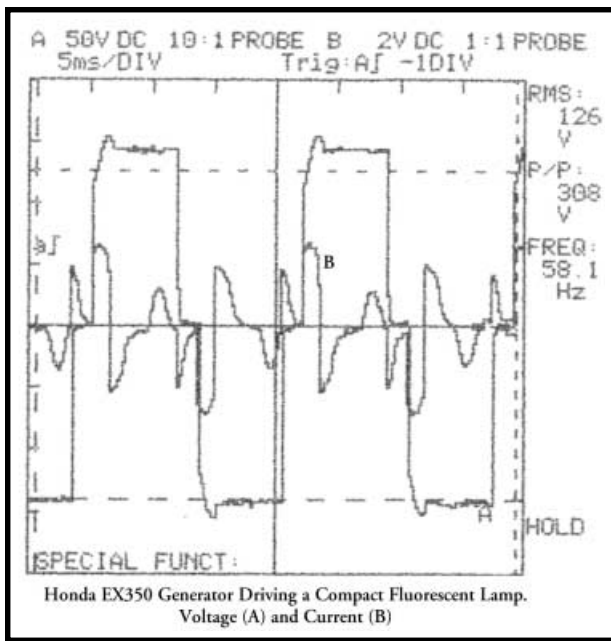


Photo 4

starts conducting and causing current to flow.

The problem arises when a charger of this type is connected to the modified square wave inverter. Recall from Photo 1 and our discussion on page 1 that the peak voltage does not rise as high as the sine wave does. The horizontal line on Photo 5 shows about where the square wave would reach. In this particular case, the square wave would never reach a voltage sufficient to make the rectifier conduct and so the battery would never charge even though power is connected and a true RMS voltmeter would indicate about 120 volts. This is the fundamental problem with modified square wave inverters. This particular charger connected to my particular EX350 produces some charging current but not nearly as much as when plugged into a wall outlet.

The same problem can arise with switching converters because the input of the converter is a rectifier that charges a capacitor instead of a battery. If the square wave peak voltage is not enough to make the input rectifier conduct, the converter will not function.

And the same problem can arise with a microwave oven because there is a transformer driving a rectifier which

supplies the high voltage necessary to operate the magnetron microwave source. It's very frustrating to connect a microwave to one of these generators. The clock will light up and the oven will turn on but it will produce no heat. Now we know that no microwave oven is going to operate from the EX350's meager 300 watt output. But Honda makes larger inverter generators that theoretically could run a microwave depending on how sensitive the microwave is to the input voltage waveform.

Is there a surefire way to figure out if a particular generator and converter or battery charger or microwave is going to work together? Not really. The only real way is to test. The purpose of this article is to help you interpret what you see when you test.

One might ask, "Why fool with such a generator if it is likely not to work?" The answer is simple. Inverter-generators permit the engine speed to be

erators from Honda and Onan control the throttle automatically. I recently saw a larger 650 watt Honda inverter generator that required my walking over to see if it was actually running! That's quiet.

Since it is necessary to test the generator with the actual loads it is to drive, it is important to buy from a dealer who will either loan or rent you a demo model or who will refund your money if the generator doesn't work. Some dealers will not refund your money if you've gassed or oiled the engine. It becomes somewhat difficult to test a generator that can't be gassed up and run. Stay away from these types of dealers.

John

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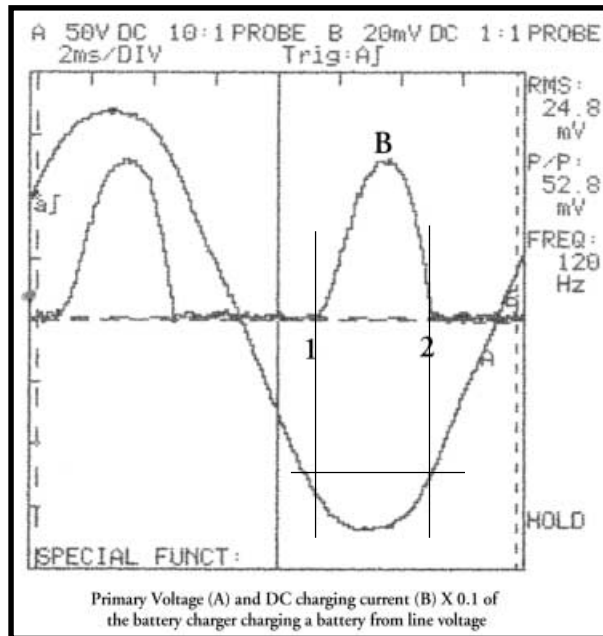


Photo 5

varied with load since the output frequency is no longer dependent on RPM. At less than full load the engine can be slowed down which tremendously reduces the noise and the fuel consumption. The EX350 contains a manual speed control. The larger inverter gen-