

Ample Power Company



Microwave Ovens and Quasi-Sine Wave AC

Editor's Note: This article was first published in November, 1990. The gel batteries mentioned are now available as Gel One batteries.

Modified Dollars

If one day your boss informed you that henceforth you would be paid in *modified dollars*, you'd probably be a little concerned, particularly if others said that modified dollars were small, round and made out of copper. We'll discuss modified sinewaves later.

Apples and Oranges

How often do we hear the expression, *you can't compare apples and oranges*? Often? The fact is that apples and oranges can be compared in many ways. Consider the attributes of the trees that they grow on. Are the trees similar? Apples and oranges both grow out of a stem, have an outer skin that is different than the inside, contain seeds, and belong to a genus of plants we call fruits. You can even compare apples and oranges with regard to relative volumes. What about calories per volume? Apples are not oranges and vice versa, but, as demonstrated, they can be compared in many meaningful ways. Is it possible to compare sinewaves and modified sinewaves?

Modified Sinewaves

The inverter salesperson that dreamed up the term *modified sinewave* practiced the philosophy *promulgate obfuscation*. Presumably, a sinewave and a modified sinewave have something quite elementary in common. A modified apple, for instance, would possess enough recognizable features to be obviously an apple. If one calls an apple stem a modified apple, we're going to object. Likewise if one calls an orange a modified apple, we'll object. According to Webster, to modify means to change slightly.

Sinewaves alternate between positive and negative. A so-called modified sinewave does the same. Similarities beyond this point are scarce. Certainly, no inverter that claims to produce modified sinewaves ever started with a sinewave and modified it slightly. Some appliances operate well with either a sinewave or an inverter, but others suffer performance penalties. The microwave oven, in particular, doesn't like modified sinewaves.

Microwave Ovens and Inverters

In a prior article we measured output from a microwave oven with different AC voltage inputs. We discovered that the cooking power generated by the microwave pretty much followed the amount of AC voltage . . . the higher the AC input, the greater the cooking power.

In this issue we explore cooking power with an inverter. An inverter is a device that takes DC battery power and converts it to alternating current, AC. As you may be aware, the typical inverter doesn't produce the sinewave that is generated by public utilities

and auxiliary generators. Inverter output is a series of rectangular pulses that have little correlation to a sinewave. The logical question arises, how does a microwave oven operate when the source of AC input is an inverter? Does a microwave oven really prefer a sinewave?

To answer these questions we performed a few tests along the same lines as those done with utility power in the last issue. The experiment itself was pretty simple. Put a known weight of water in a paper cup. Measure its temperature. Put the covered cup into the microwave oven for a fixed time, at a given AC input voltage. Measure the water temperature again to determine how much heat the water has absorbed. For more details regarding the correlation of heat and power, refer to the article.

This AC experiment had to be modified to test inverters. Inverters, after all, regulate the RMS output voltage by varying the width of the rectangular pulses that they deliver to the load. As mentioned, inverters take DC power and convert it to AC, and in doing so, maintain a relatively constant RMS output. The question we wish to resolve with the inverter is this . . . is there a difference in cooking power related to the DC voltage that is applied to the inverter?

This question is not obvious. An inverter regulates its AC output to a constant RMS voltage. RMS, which stands for *root mean squared* is a measurement method that allows the heating power of AC and DC waveshapes to be compared. Given 120 Volts RMS, a resistive element heater will produce the same heat on an AC or DC waveshape. But a microwave isn't a heater. Is it possible that for the same RMS input voltage, say 120 Volts, that the microwave acts differently? Let's find out.

An inverter is called to operate over a wide voltage range. When an alternator is running, the applied DC voltage may be 14.5 Volts. When the battery is not being charged, the DC voltage may vary from 12.8 Volts down to 10.2 Volts. The inverter attempts, and quite successfully, to maintain a constant RMS AC output over these extremes of DC input. Our experiment, then, is to apply different DC voltages to the inverter and measure the cooking power of the microwave. With a constant RMS voltage output, will the microwave operate the same for any DC voltage input? The graph shows the results. Cooking power, measured in Btu, is plotted against DC voltage applied to the inverter.

What the graph shows is the fact that cooking power is directly related to the DC voltage applied to the inverter. In other words, the inverter cooks better at high DC voltages than at lower voltages, despite the fact that the AC output is a relatively constant RMS value. Is this curious?

Also shown on the graph is an efficiency percentage. Since the inverter maintained a relatively constant 120 VAC RMS output, independent of the input DC voltage, we took the Btu that the mi-

crowave produced on a 120 VAC sinewave and called that value 100%. The 120 VAC heating power was 62 Btu. To compute efficiency, we reduced the heating power provided by the inverter/microwave combination by 10%. The reason we did this is the fact that the inverter is electrically about 90% efficient. Its true efficiency, however, must take into account the inefficiencies that arise from the difference in waveshapes.

Notice that to produce 62 Btu of heating in 3 minutes requires that the inverter input be greater than 14 Volts! That is, to get the same amount of heating power as 120 VAC sinewave, the inverter must be run when charging, since batteries alone will not provide 14 Volts. Notice how inefficient the microwave is when the inverter is driven by 11.5–12 Volts, a rather typical range with heavy draw.

Without knowing why the microwave oven performs better on a higher DC input, immediate and useful conclusions follows. If you have an inverter, use it when the batteries are fully charged. It also helps to have batteries that hold up their voltage under heavy loads. We touched on this subject in *Living on 12 Volts with Ample Power* without getting into the whys and wherefores. Liquid electrolyte deep cycle batteries with thick plates sag quite severely with heavy loads. In the case of our experiment, the inverter drew about 100 Amps. A fully charged liquid 8D battery fell almost immediately below 11.5 Volts. In the graph, the measurements below 11.59 Volts were taken with a liquid 8D.

Measurements above 11.59 Volts up to about 12.7 Volts were taken using a Prevailier 8D. As shown, there's quite a difference in efficiency between the voltages. We can conclude that less Ah will be used to make a cup of coffee in the microwave using Prevailier batteries instead of more conventional liquid electrolyte batteries.

While we used a single 8D in our experiment, in practice it would help to have a larger battery bank so that the current draw is not such a high percentage of capacity. It follows, of course, that fewer

Prevailier batteries will equal the performance of more liquid batteries. While an 8D Prevailier costs more than a liquid 8D, for the same performance, total bank cost may be less with Prevailiers.

To achieve DC voltages greater than 12.7 Volts, we used an Ample Power charger that produces 160 Amps. As shown by the measurement points, we adjusted it to various voltages and ran the heating test. The charger produces pure DC, so we could have run the inverter directly from the charger, but since we had the battery hooked up, we left it in the circuit.

Another consideration when applying inverters is the cable length between the batteries and the inverter. Long cables will drop more voltage and reduce inverter efficiency accordingly. In our experiment, we connected the inverter to the battery using only the cable length supplied with the inverter. We did have a shunt in the negative lead. It drops only 50 millivolts at 200 Amps, so we lost about 25 mV at 100 Amps.

Not all appliances operated from an inverter are as sensitive to the AC wave shape as the microwave oven. Toasters and hair dryers are resistive elements so that 120 Volts RMS is the same from a sinewave as from an inverter. Even so, inverters are less electrically efficient from lower battery voltages, so it pays to have a large bank of batteries or Prevailiers even when driving resistive loads such as toasters or hair dryers.

Why is it that the microwave oven operates at such low efficiency when operated from an inverter? After all, the inverter output is quite well regulated at a constant 120 Volts RMS. The answer can be simply stated; a microwave oven is sensitive to the peak AC voltage that is applied, and an inverter doesn't maintain a constant peak voltage. In fact, the peak voltage that the inverter delivers is directly related to the battery voltage that powers the inverter. As we saw from the experiment, cooking power was less with low battery voltage, and less with low AC voltage input.

