BY RICHARD CADENA

UPS delivers protection

A diverse range of events can cause surges, spikes, and other fluctuations to the electrical grid—any of which could damage or destroy a show's sound system or lighting console . . .

THE PERFECT FRONT OF HOUSE? It has plenty of real estate, enough for my Starbucks, my laptop, at least two video monitors, preferably four...Let's see...Am I forgetting anything? Oh yeah, the console. That's all I need. I don't need anything else. Except an ergonomic chair. Just my Starbucks, my laptop, four *big* monitors, the console, and a nice, comfy chair, and that's all I need. And my headset. And that's all I need.

Actually, there *is* at least one more thing, and it's not a paddleball. It's something no front of house should be without and it's something every self-respecting tech knows all about. It's relatively inexpensive, easy to operate and set up, and it can save your gear and your reputation as a tech who knows how to insure the show goes on. Have you guessed it yet? Of course you have, yo**U** smart **P**er**S**on, you. It's an uninterruptible power supply, better known as a UPS.

Oh, *that*, you say. That's just an extra piece of gear to lug around and waste more money on, so says you.

Not so, says the voice of experience. A UPS is as necessary as that Starbucks in your hand, maybe even more so. Blasphemy you say? Well then, consider this...

That electrical grid you plug into every day seems like a placid, serene, quiet place. In reality, it's more like a stormy ocean in high wind. It might appear as if the voltage is stable because when you measure it, it seems to be calm and motionless, but in fact it is fluctuating all the time. There are all sorts of events that cause surges, spikes, and other fluctuations, any of which could damage or destroy that $250,000 sound system or that $100,000 console you're using to prop up your laptop.

Power disturbances occur any time there is a fault, meaning that a live conductor has come in accidental contact with another live conductor or with the earth (or "ground" in North America), or when transmission lines are switched, which happens very often, or when lightning strikes directly on the electrical grid or even in close proximity to it. Sometimes it's not a voltage surge, but a sagging voltage that can cause damage. Too many people turning on their air conditioners at the same time, a lightning strike bringing down a transmission line, or any number of scenarios can cause a brownout or a blackout.

Here's a pop quiz for all you audio whizzes out there. What would happen if there was a brownout, and your processing gear shut itself down while your amplifiers stayed on? Oh snap, there goes your speakers! And where does data go that isn't backed up when power is lost? Poof! It vanishes.

One of the best ways of protecting yourself from electrical disturbances is to make sure all of your sensitive electronic gear is powered through an uninterruptible power supply (UPS) with surge protection. A UPS can be classified according to function, whether they operate in standby, are line-interactive, or online, and also according to how they convert from battery-supplied DC to household AC. The type that you use will depend on what you're protecting and how you're using the gear. The most common type, which is often found in homes and offices, is a standby UPS.

Those of you who know me won't be surprised to learn that I took apart a UPS of my own to see what is inside. You might be surprised to learn, however, that not a single hammer was involved in its deconstruction. This particular one is a CyberPower CPS325SL with a 120 V, 10 A, 60 Hz input. It has four outlets, two on battery backup and two of which are surge-protected but not backed up by a battery. The label on the back of the unit says the outlets are 120 V, about 0.325 VA, 2.7 A, 60 Hz, 185 W. What follows is a description of how a desktop UPS, suitable for powering a lighting console or sound mixer, is constructed, and works, based on my vivisection of the CyberPower CPS325SL.

The voltage rating is straightforward, but the VA might need some explanation. VA is a measure of something called "apparent power." It's simply the voltage multiplied by the number of amperes that it can output. The reason we use VA instead of watts is because some loads have a low power factor and draw more current than you would calculate using the AC power formula.

For example, I have an LED fixture that says it is 185 W but the power factor is about 0.5. If you disregard the power factor and calculate the current draw using the AC power formula, you would get:

P = V x I x PF (where PF = power factor)
(disregarding power factor): 185W = 120V x I
I = 1.54A

In reality, the thing draws about 3 A, because the power factor is actually 0.5.
185W = 120V x I x 0.5
I = 185 ÷ (120 x 0.5) = 3A

The limiting factor is not the number of watts that can be connected to a supply, but the number of amperes that can be drawn from it before the combination of current and resistance creates enough heat to damage the insulation, either by melting it right away or by making it brittle enough that it will crack sooner or later. Therefore, if they list the wattage instead of the VA, then an assumption has to be made about the power factor; otherwise, you could connect the rated number of watts with a low power factor and overload the supply.

As an aside, the unit is actually labeled incorrectly. It says 120 V, ~0.325 VA, 2.7 A, but it should say 0.324 kVA or 324 VA (120V x 2.7A = 324VA). It's a small error— three orders of magnitude!

The ratings aside, a standby UPS serves to suppress voltage surges and electrical noise, and to back up the supply with stored energy usually using a sealed lead acid battery. The noise filtering and voltage suppression are the first stages of the standby UPS.

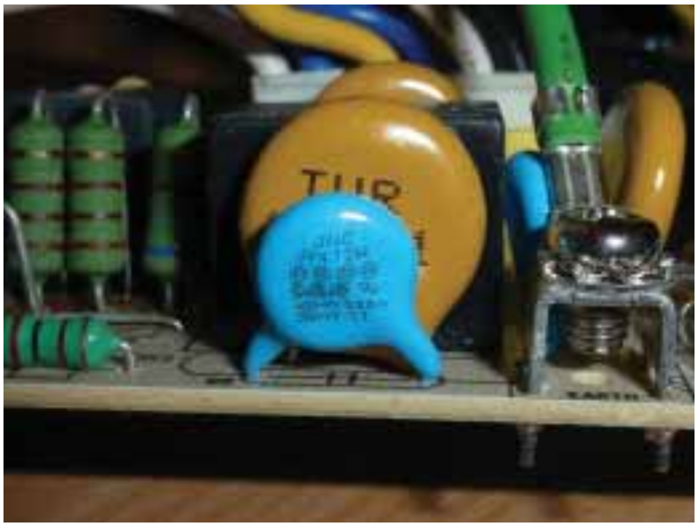


Figure 1 – The blue capacitor filters high frequency noise and the amber varistor absorbs energy surges.

Noise filtering is done with capacitors. If you follow the power cable into the unit, the first thing you encounter, after the 10-amp, manually resettable circuit breaker and the outlets, is a capacitor in parallel with varistor. The capacitor's job is to filter out any high-frequency noise that gets on the line. That can happen through inductance with machinery or any high frequency switching that takes place in the proximity of the power circuit. For example, if someone plugged in a vacuum cleaner into this UPS, it would generate high-frequency electromagnetic interference (EMI) that could be picked up by the electrical circuit and fed to everything that is plugged into the UPS.

A capacitor filters high frequency noise by conducting in proportion to the frequency: the higher the frequency, the lower the impedance. They follow this formula:

$X_C(\Omega) = 1 \div (2 \text{ x } \varpi \text{ x } \quad \text{ x } C)$

where X is the reactance as measured in ohms (Oh, c'mon; it's not that hard! Just think of reactance as the same thing as resistance, except here it's caused by capacitance instead of a resistor.), π is 3.14, ω (lower case omega) is frequency (it's 60 Hz in North America or 50 Hz in Europe and Australia), and C is the value of the capacitor in farads or microfarads.

This particular capacitor is a JNC JY472M, which has a value of 0.0047 µF (0.0000000047 µF). If we plug in the right numbers, we can see that the reactance is about 663,145 Ω at 60 Hz. That's a lot of impedance. Since this thing is connected from line to ground or earth, when 120 V at 60 Hz is applied to it, 0.18 mA will flow from line to ground or earth. But if the frequency is higher, say 100 kHz, then the impedance drops to 39,789 Ω and the drain current is 300 mA, which should be enough to filter out the noise.

The varistor serves to protect everything that's plugged into the UPS by effectively absorbing surges and not allowing the voltage to rise above a certain level. It's connected between the line and the ground or earth, and, when the voltage surges, it clamps down on the voltage from line to ground. Varistors can be sacrificial devices; if the line surges high enough it can pop the varistor like a firecracker. Hopefully, the grid gods will take pity on our varistors so they can safely absorb all the energy that's thrown at them without causing them to fry.

Next, there is a charger fed by the line voltage, and its job is to convert alternating-current to direct-current in order to charge the onboard battery, and an inverter that, when power is lost, converts the battery's DC back to AC.

Going from AC to DC is a relatively easy matter. First of all, there is a transformer that steps down the voltage from 120 V to around 12 VAC. The output of the transformer is fed to four diodes connected in a configuration called a full-wave bridge rectifier. It converts the AC wave form to a fully-rectified wave form. The positive half cycle of the incoming current sine-wave takes one path through the bridge rectifier, through the load, and back to the source. The negative half cycle takes a different path through the bridge rectifier, through the load, and back to the source. But the two half cycles pass current in the same direction, so the bridge rectifier essentially inverts the negative half cycle and makes it positive, and that converts the alternating current wave form to pulsing DC.

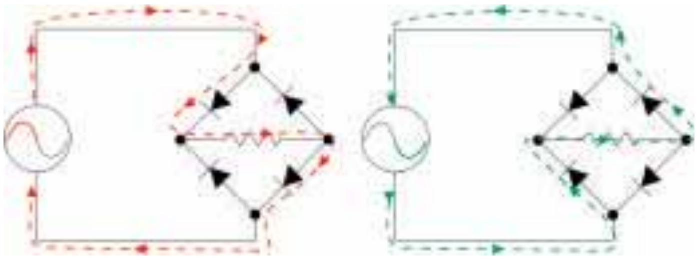
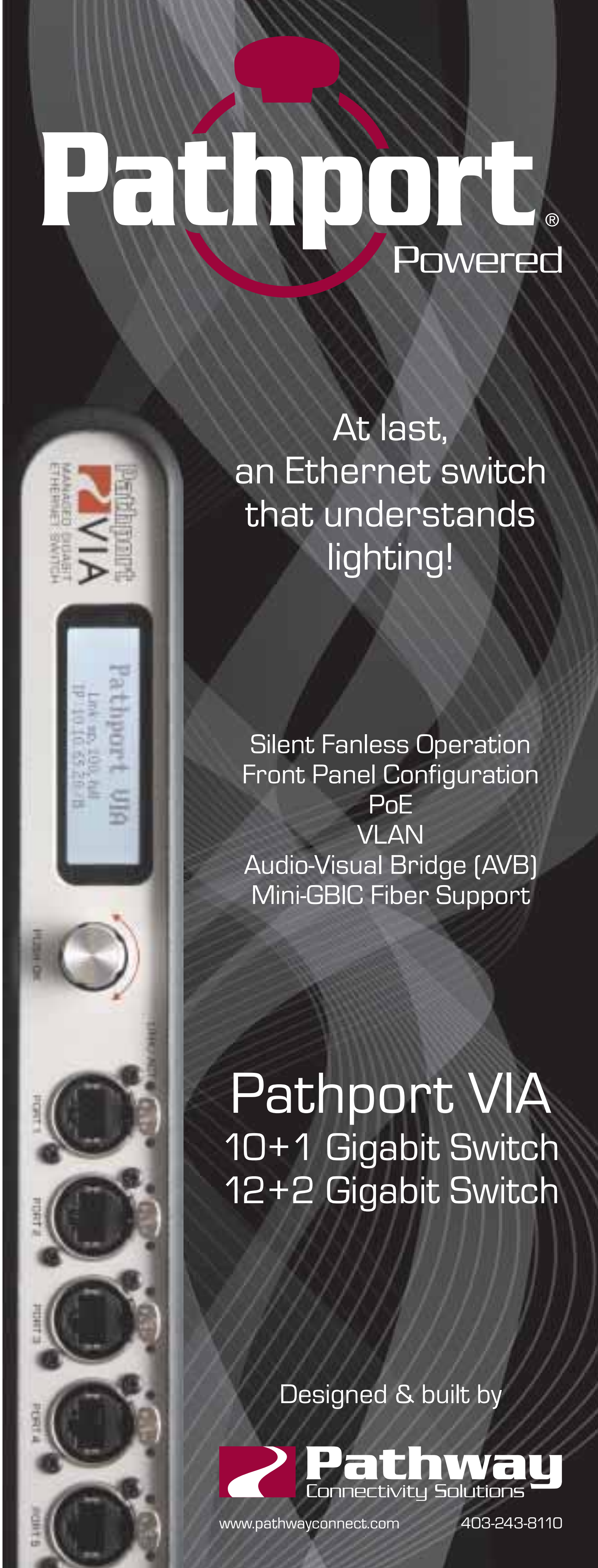


Figure 2 – (L): During the positive half cycle, the current flows along the red path; (R) During the negative half cycle, the current flows along the green path.

Figure 3 – The output of the bridge rectifier above is a pulsing DC current.

Once the current is converted to pulsing DC, then it is smoothed by a capacitor, which charges when the applied voltage rises and holds its charge when the voltage falls. The result is that the pulsing DC wave form changes to a rippled DC, with very little variation



between pulses. Lastly, there is a LM317T voltage regulator whose job it is to hold the voltage constant.

The DC is applied directly to the battery, and that keeps it charged so that, in the event of a power loss, the inverter can convert the DC from the battery to some form of AC. That's where the term "inverter" comes from: It's an AC-to-DC converter working in reverse. The key to going from "verting" to "inverting" is the pair of miniature baby sugar cube single-pole/double-throw (SPDT) relays. They are dry contact closure relays that switch between wall power and battery power when the loss of power is detected.

In battery-power mode, the inverter circuit takes over and supplies AC to the connected loads. But it's much trickier to convert DC to an AC sine-wave than it is to go the other way. There are many ways to do this, some of which are very simple but don't produce a sine-wave, and others that do produce a sine-wave but are much more complex and cost more.

It turns out that the UPS I'm working with falls into the first category. It actually produces a form of square-wave that UPS manufacturers like to call a "modified sine-wave" but in fact, it isn't a sine-wave at all. It switches from 0 V to about +175 V, back to 0 V and then to -175 V at a frequency of 60 Hz. It's a modified sine-wave in the same way that a box is a modified sphere. I think "modified square-wave" is more a more accurate description, but a less appealing marketing term.

Figure 4 – Voltage and current wave form on battery supply. The load was a 500 W incandescent lamp.

Nevertheless, this wave form works just fine with certain loads, but not so fine with others. There are other UPSs that produce a sine-wave with little distortion. They typically have integrated circuits and timing chips to produce the waveform, and MOSFETs (metal-oxide semiconductor field-effect transistors), which can handle high current and interrupt a circuit under load, which can switch at a high frequency. A sine-wave inverter is similar to a switch-mode power supply with some additional circuitry.

There are a number of UPSs with sine-wave inverters on the market, and some of them come with a warranty that covers connected equipment. Tripp Lite's HTR10-2U, for example, covers up to $250,000 worth of connected equipment, the CyberPower CP1000PFCLCD covers connected equipment up to $350,000, and the Juice Goose NXRT-Pro Series offers $50,000 in protection for connected loads.

Some lighting consoles, like the MA Lighting grandMA, have built-in battery backup. When power is lost, the backup battery takes over and runs the console just long enough for you to save your work, back up to an external device, and shut down. A brand-new, fully charged battery will run a grandMA 1 for about 10 minutes and a grandMA 2 for about seven minutes. But there is no power conditioning, so you should still use surge protection.

Choosing the right size UPS is a matter of the amount of load you want to connect, the length of time you want to be able to run it on battery power, and the features you want, like the number of outlets, online monitoring, et cetera. The battery in a UPS is rated in amp-hours. To calculate the required capacity, simply multiply the number of amperes by the amount of time in hours. For example, if your front of house pulls a total of three amperes and you want it to run for up to 30 minutes, then you would need a UPS with a capacity of 1.5 amp-hours (3 A x 0.5 hours = 1.5 amp-hours).

Choosing between a UPS with a square wave or a sine-wave inverter is a matter of what it is that you're trying to protect. If the connected load is inductive, that is, if it has a transformer, ballast, choke, or coil of wire like a motor, then you should consider spending extra money for a UPS with a sine-wave inverter. If you are using a UPS without a sine-wave inverter, just make sure your devices are not running hot, which is an indication that they are not happy and are likely to fail prematurely. Choose wisely, because thousands of dollars could be riding on your decision. ■

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