Power Supply Requirements
There is very little written about the "real" power needs for a DCC system. And the DCC manufacturers themselves are most remiss by simply giving a range of voltages that will work with their system, and adding that your existing model train control power pack will work. While any voltage within the given range will work, it's not likely to be the best for your system. And using your existing train control power pack may well be a greater detriment than just using the wrong voltage for your scale.

Using the wrong voltage and/or low current can cause a variety of problems:

1. High voltage can cause booster overheating
2. Low voltage can cause poor loco performance
3. Low current can cause operations performance
4. Low current can cause short-circuit protection to be unreliable

So it is important that you use the correct power supply for your system.

The goal here is to define what the "correct" voltage is for your scale, the "minimum" current for your system, and explain what the detriment is for not using the "proper" power supply.

Current

The amount of current available for the rails is determined by the booster. Not all boosters are the same. The MRC Command 2000 puts out about three amps. Many Lenz boosters put out 3.5 amps. Digitrax offers five-amp boosters for small to medium scales, and eight-amp boosters for large scales. Most other companies offer five-amp boosters for small to medium scales and ten-amp boosters for large scales.

Think of the booster as an amplifier. However, unlike a stereo amplifier, more is not always better. On one hand, it's easy to understand that O and G scales need more current than N and HO scales. But it's not as easy to see that more current for N and HO is not necessarily good. N and HO scale locos are more delicate than O and G scale. The parts in large scale locos are larger and heavier simply due to the size requirements. These larger parts can handle a short circuit of higher current better than the fine parts in HO and N scales.

With traditional DC analog control, your throttle control is probably only capable of putting somewhere between one and two amps on the rails at any one time enough to run one multi-header train. But, with DCC, the booster can put enough power on the rails to run several locos at one time. For example, Digitrax's five-amp boosters are capable of running about ten to 12 HO scale locos at once, plus light a few passenger cars to boot. If you have a short circuit with that, you'll have up to five amps of current coursing through your loco plenty to melt down an N or HO scale loco. Fortunately, all DCC boosters have short-circuit protection built in so your locos won't melt. However, there is still a chance the short-circuit protection won't work properly when needed. And if this happens, it can melt a loco's trucks right out from under it.

Now, let me say right here that short-circuit meltdown rarely happens. In dealing with thousands of users since 1994, I know of only three or four situations where this has happened. But, if it happens to you with one of your favorite locos, it could be devastating. So it's incumbent upon you to install the proper equipment correctly, and test it to make sure it's working properly. In all the situations I know of where meltdown happened, each one was preventable had the user made a few simple checks and taken a few simple precautions.

One thing that's needed is the proper track power bus wiring - heavy enough to carry a short circuit of the magnitude the booster is capable of producing. This means wire heavy enough for five amps if using a five-amp booster, or heavy enough for eight amps if using an eight amp booster, etc. While the short-circuit protection can work for the most part with wire a little too small, it won't be as reliable, and absolutely won't work with wire that is much too small. My rule of thumb is to use wire one size larger than you think it should take for the distance and current. Doing this not only assures proper operation of short-circuit protection, but provides the absolute smoothest running trains possible (no speedups/slowdowns caused by wire resistance). In other words, you should use wire of adequate or larger size even if it weren't for short-circuit protection reliability.

There is a way to test your track wiring for short-circuit protection once you have your system hooked up. The places least likely to work are points on the rail that are half way between track feeders. So, test each one of those points by putting something metal across the rails to cause a short circuit. If the booster shuts down, good. If you have to push the metal object down hard on the rails to get this to shut the booster down, that's not good add another feeder at that point. Remember, when your loco derails, you won't be there to push it hard on the rails - it will just sit there passing all that current.

If you're going to use an eight or ten amp booster, you'll need heavier wire than if you're using a five amp booster. Further, even with heavier wire, an N or HO scale loco is more likely to create a "resistive" short than an O or G scale simply because O and G scale locos are heavier and will short out harder (like pressing down on the metal piece to make a short circuit). And since the eight and ten amp boosters need to accommodate heavier draws for O and G scales, these smaller "resistive" shorts will be harder for the larger boosters to see.

The long and short of it is this: stay with five amps or less for fine S-Scale and smaller. Eight amps and higher is for hi-rail S and larger scales. But the larger boosters are so attractive more current for the money. Well, there is a way to safely use an eight- or ten-amp booster with smaller scales - by using track power circuit breakers such as Digitrax's PM42 (Quad Power Management Unit). With Digitrax's PM42, you can use an eight-amp booster and divide that power between four different districts with short-circuit protection set to 3.5 amps (or more depending on needs) for any one district. In fact, using the PM42 even with the five-amp booster is not a bad idea. The 3.5-amp circuit breaker in the PM42 can provide another level of protection.

This doesn't mean that since you have four districts set for 3.5 amps that you will have up to 14 amps of current you won't. What it means is that no one district will be allowed to use more than 3.5 of the eight or ten amps that are available. Since the PM42, set at 3.5 amps, can see a resistive short easier than an eight- or ten-amp booster, it's far less likely to cause a meltdown.

When wiring this, use wire sized appropriately for the higher current between the booster and the PM42, and wire sized appropriately for five amps from the PM42 out to the track feeders. Even though the PM42 will be set for 3.5 amps, we use five amps for the calculation to insure proper power distribution for less-than-optimal situations.

Some WWW sites recommend using automotive bulbs as a way to limit the current of higher-powered boosters. Do *NOT* do this! All this will achieve is to further thwart the circuit breaker protection built into the booster. And believe me, the three amps these bulbs can pass is enough to melt HO and N scale locos.

Some WWW sites recommend using automotive bulbs as a way to keep even smaller boosters from cutting power off during a short circuit. In other words, they are purposely thwarting the boosters short-circuit protection so the rest of their layout won't stop due to a derailment. Again, do *NOT* do this! If you want to protect the rest of the layout, use Digitrax's PM42s that's what they're made for.

Again, loco melt down due to a derailment is rare, and may never happen to you even if you don't pay attention to the information above. But, if you do pay attention to it, the likelihood you'll have a melt-down is greatly reduced.

How do you run more trains than one booster can power? Add more boosters. Not to add more current to the rails, but to divide the layout into various power districts each with its own booster. With Digitrax's LocoNet and Digitrax's boosters, you can add as many boosters as you'll ever need. If you think you'll need a lot of boosters for your "massive" layout, be sure your system allows as many as you'll need. But remember, one five amp booster can handle up to ten to 12 HO scale locos. Since most layouts won't allow for running more than about 20 locos at one time, it's rare that anyone will need more than two boosters. On the other hand, if you're in hi-rail O or G scale, you could need many eight amp boosters.

Another thing that can cause short-circuit protection to not be as reliable as it can be is using a power supply inadequate for the booster. It's really simple to understand to make a five-amp booster's short-circuit protection work as reliably as possible, it needs a power supply that can produce a five amp short circuit not that a short needs five amps to make the protection work, but for maximum reliability it needs to have that potential. Here's why:

Boosters monitor the speed with which power needs ramp up. That is, it allows the normal current increase that it takes to start a train moving. But when the current increases faster than it should ever need for normal operation, it knows there is a short circuit. This happens so fast that it doesn't need to reach the five-amp limit for the booster to shut down. However, let's say that you're using an inadequate power supply one that only provides three amps, for example. If you're running several locos, using a fair amount of the available current, when one of them derails to cause a resistive short circuit, the current can't increase quickly enough for the booster to see it as a short circuit because the booster is already passing along most of the current the power supply is capable of putting out. Since it can't sense a fast increase in current, and it can never reach five amps, the booster won't shut down. Remember, three amps. is enough to melt N scale and some HO scale trucks.

So, regardless of the current capability of the booster you're using, it needs a power supply that is capable of putting out about 0.5 amps more than the booster is rated for. For example, a 3.5 amp booster needs four amps or more, a five amp booster needs 5.5 amps or more, etc. It's OK to have a power supply capable of more current than the booster is rated for you can simply install a circuit breaker or fuse between the power supply and booster. But in no case do you want to use a power supply that provides less than the needed amount of current.

There is no way to test for a worst-case scenario when using a power supply of too little current. Since all short circuit derailments happen at different times, with varying degrees of resistance in the short circuit itself (depending on how the loco is making contact with both rails), and with different numbers of trains running, it just all depends on how the current ramps up for the booster to see it. The best thing is to just get an adequate power supply to start with and you won't have any of these things to think about.

So, it's a good idea to use the shorting method to test your track. If it won't shut down that way, it's unlikely it will shut down for a derailment.

Voltage

Voltage is another story. Where all you need to do with current is have more than the specifications of the booster, voltage is a double edged sword: too little voltage and train performance suffers, too much voltage and the booster runs hotter than necessary.

We know of one person who purchased an AC power supply from one of our competitors because it was cheap. Problem is, it put out 21 volts. Since 21 volts is within the voltage range specified in the booster manufacturers manual, he used it. Problem was that when running as few as five Kato locos, the booster would overheat and shut down. He put a fan on the heat sink in the back to keep this from happening. While the fan masked the problem to allow him to continue running trains, the problem was that the heat was still being made and with all things electronic, heat is the enemy.

So, why do manufacturers give such a wide voltage range to operate in? I can think of two things they are thinking about: the various needs of various scales, and the absolute voltage range that the booster can tolerate. Why they don't explain what would be best for each scale is beyond me. So, I'll do it here for you.

Most boosters are usable with all scales, Z through G. For this, they provide three different settings: N, HO, O/G. The N scale setting is used for Z scale, and the HO setting is generally used for S scale. In any case, the only difference between these scale settings is the voltage put on the rails. N scale is about

12.5 VAC, HO is about 15 VAC, and O/G is about 21 VAC. Different boosters vary in voltage, even within a manufacturer. Some boosters have voltage adjustments, others don't.

The guy who used the 21 volt power supply for HO scale errantly thought that the voltage range given by the manufacturer was good for all scales. However, it's easy to show that isn't the case. If the voltage range was meant to be good for all scales, you'd think that you could use a 21 volt power supply to operate in the O/G scale setting. But you know, even if you aren't an EE, that you can't put 21 volts on the track if you're only putting 12 volts in. This proves that the manufacturer's supplied voltage range is NOT for all scales. So, a 21 volt input is no more suitable for HO scale than 12 volts is for O/G scale. If he had thought about it a bit about this, he would have realized that this is the case. But this doesn't relieve the manufacturer of his responsibility to point this out.

So, what is the ideal voltage for each scale? Think of voltage as food the substance that provides fuel for the work to be done.

If we don't eat enough food, we will starve, and slow down. Likewise with trains. If there's not enough voltage, the booster can't put enough voltage on the tracks, and the trains will run slower than they should.

On the other hand, if we eat too much food, we either have to do more work or exercise to burn it off, or we get fat something has to be done with the excess. Likewise, if you provide too much voltage to a booster, the excess has to be burned off as heat - something has to be done with the excess, and there's no way to store it as fat.

<u>Voltage vs. Scale Recommendations</u>

At no load, a typical open frame unregulated power supply will put out more volts than it is rated for. For example, a 14-volt power supply will put out 15 to 16 volts. But, when it's loaded with the rated current, it will sag to its rated voltage.

Boosters have voltage regulation built in. That is, they try to maintain a certain amount of voltage on the track at all times. When power-supply voltage fluctuates due to sag or house voltage variations, track voltage will remain about the same.

For regulation to work, there must be more input voltage than the regulator is set for. That is, if you're trying to regulate at 15 volts, you must have more than 15 volts going into the regulator for it to maintain 15 volts. How much more? Just more. But if the house voltage fluctuates, more today may be less tomorrow. So you need enough more to accommodate power-supply variations, and house voltage fluctuations say, two volts more.

When you put AC voltage into a booster, the first thing it goes through is a bridge rectifier to convert it to DC voltage. When it goes through this rectifier, it gains about 40% in voltage, then looses a few volts when going through various electronic components of the booster.

Let's say we're using a 14 VAC power supply for HO scale. This converts to about 16.6 volts when factoring in electronic component drop only about 1.6 volts more than is needed for the track. But remember, an unloaded power supply puts out more than its rating. So if we figure that the power supply will really be putting out about 15 VAC most of the time, we'll have about 18 volts to regulate down to 15 volts enough for good regulation.

While this excess voltage has to be burned of as heat, it is necessary for good regulation. More voltage than that will gain you nothing, and will have to be burned of as even more heat.

So the key is this: put in the voltage that is ideal for the device. Any less voltage makes performance suffer. Any more makes excess heat that has to be dissipated.

The ideal input voltage depends on which scale setting your booster is set for, not what scale you're actually running. The booster puts more voltage on the track when set for HO scale than when set for N scale, so it needs more voltage in when set for HO scale than when set for N scale.

Note: Digitrax recommends using the N scale setting for HO scale. I don't agree with that, and Digitrax has never provided a clear answer as to why they recommend it.

- For the N scale setting, 12 VAC is about ideal
- For the HO scale setting, 14 VAC is about ideal.
- For the O/G scale setting, 18 VAC is about ideal.
- The ideal voltage is different if using a DC power supply. When going through the bridge rectifier in the booster, DC voltage does not increase like AC voltage does. However, it still looses voltage as it passes though various electronic components. So, if using a DC power supply:

- For the N-scale setting, 16 VDC is about ideal
- For the HO-scale setting, 19 VDC is about ideal.

- For the O/G scale setting, 25 VDC is about ideal

Heat

With all things electronic, heat is the enemy. Now, I can't say that if a booster runs cooler it's guaranteed to last a certain length of time, no more than anyone can say if you don't smoke you'll live to be 100. All boosters are different, used differently, and will have different life spans. But, like not smoking, we can say that if a booster runs cooler, its life expectancy will probably be longer than if it runs hotter.

Right here, I want to make something very clear. If your booster, without a fan, is heating up to a point of shutting down without continuously drawing at least 75% of its rated power, something is wrong. Either the booster is defective, or the power supply is putting in too much voltage. And while you should use a fan on your booster whether or not it is over heating, putting a fan on an overheating booster will only mask the real problem the problem of making too much heat is still there. If your power supply is putting in too much voltage, causing this problem, get rid of that power supply, and get one that puts out the correct voltage for the scale setting you are using.

There are two components to heat: making heat, and retaining heat.

Putting a fan on the heat sink will dissipate heat that is made, and prevent heat buildup. But it won't stop the components from making excessive heat to start with and making excessive heat can be almost as bad as heat buildup.

The best tactic for the longest-possible booster life and best performance is two steps: first use the correct voltage for the scale you're running - to lessen the amount of heat made. Then put a fan on the heat sink to dissipate what heat is made.

Final Notes

While 14 VAC is ideal for HO scale, a 16 VAC power supply is not "way" too high. It will only make a little extra heat. If you have a 16 VAC power supply, it probably wouldn't be worth it to throw it out and get a new 14 volt power supply. But if you're buying one, get the 14 VAC instead of a 16 VAC power supply. And, I wouldn't use 16 VAC on N scale any more than I'd use 18 VAC on HO scale. For N scale, if you have anything more than a 14 VAC power supply, do your booster a favor and get a 12 VAC power supply.

Many people try to compensate for a low current power supply by getting a power supply that has more voltage. And some slick salesmen will convince them that there is no difference by showing them the VA rating.

VA rating? What's that? Well, if you take the volts and multiply by the current, you have a Volt/Amp rating. For example, since 5.5 amps is ideal for Digitrax's five amp systems, and 14 volts AC is ideal for HO scale, the ideal VA rating is 77. But that doesn't mean that an 18-volt power supply at 4.3 amps is also ideal. As we've learned, the extra volts will have to be burned off as heat, the lack of one amp will reduce the number of trains the system can run at one time, and short-circuit protection won't be as reliable.

Also, experience shows that many digitally regulated (switching) power supplies can play havoc with the booster's ability to work properly. You're better off buying a low cost non-regulated power supply

Conclusion

Most manufacturers suggest you can use your existing power pack to get started. While that is true, you shouldn't even consider using it for any longer than necessary.

If your power supply cannot produce the amount of current your booster is rated for, you will not be able to run as many locos without seeing them slow down and speed up as other trains are started and stopped. But worse, it can keep short circuit protection from being reliable.

Another important need is voltage. Again, most manufacturers do not provide ample information for you to choose a proper power supply. They will say something like, 12 to 24 volts AC, or 12 to 26 volts DC leaving you with the false belief that any power supply within that range is just fine for any scale you run. While the booster will work with any of those voltages, it will not work most efficiently at all of those voltages, or worse will run too hot, thereby decreasing the boosters' life expectancy. Therefore, it's important to use a power supply with the ideal voltage for whichever scale setting you use.

Lastly, when putting AC voltage in, the voltage increases by about 40% when it goes through the booster's bridge rectifier. So putting 21 VAC in really provides about 29 volts. All that isn't used for the track, except for some for electronic part drop and regulation, must be burned off as heat. So, don't let a dealer sell you a power supply that is not right for the system, just because he doesn't have one that is right. You paid a lot of money for your system, so do it a favor and provide it with the nutrition it needs to do the job it was designed to do.

For Digitrax's DB150 and DCS100 boosters, and other manufacturers' boosters up to five amps, we offer the MTF-V-5 power supply. Five-amp boosters have nothing to gain by getting a larger or more expensive power supply. And since the MTF-V-5 has optimum voltages for all three scale settings, you need not worry about overheating the booster.

If you're running HO scale with a five amp (or less) booster, you can also use the Digitrax PS515 power supply. Since it only has the HO scale voltage, and is a five-amp power supply, it is limited to being used with five-amp boosters running on the HO scale setting. If running on any scale setting other than HO, we recommend you use our MTF-V-5.

For Digitrax's DB200+ and DCS200 boosters, and other manufacturers' boosters up to ten amps, we offer the MTF-V-10 power supply. It also has optimum voltages for all three scale settings.