

**4 WAYS TO BUILD YOUR**  
**Power Supply**  
**Skill Set**



# Introduction

Today's designs place higher demands on the systems that power them, and you may find that more of your design problems are being caused by these power systems. In this eBook, our experts help you better understand **power supply** issues and provide 4 ways to build your power supply skill set.



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Learn More About Power Supplies

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TIP 1

# Understanding CV and CC

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# TIP 1 Understanding CV and CC

## How to Set Constant Voltage and Constant Current

One of the most important concepts for anyone using power supplies is understanding constant voltage (CV) and constant current (CC). Here are some basic rules to help you get started.

The output of a power supply can operate in either CV or CC mode depending on the voltage setting, current limit setting, and load resistance.

- If the load current is low and the current drawn is LESS than the current setting, the power supply will operate in CV mode. The voltage is regulated, keeping the value constant, with the current being determined by the load.
- If the load current is high and the load is trying to draw MORE current than the current setting, the power supply will limit the current at the current setting value and operate in CC mode. The current is regulated with the voltage being determined by the load.

Most power supplies are designed in such a way that it is optimized for CV operation. This means that the power supply will look at the voltage setting first and adjust all other secondary variables to achieve the programmed voltage setting. Look for a power supply that maintains a constant voltage—even in a dynamic environment—but can also provide a constant current when needed.

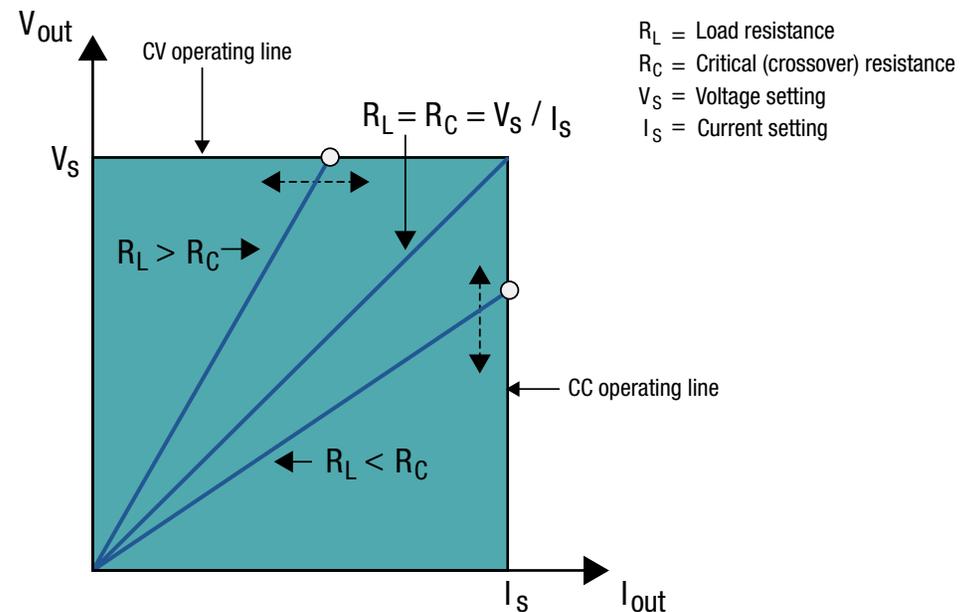


Figure 1: Operating locus of a CC/CV power supply.

## LEARN MORE



Blog: *The difference between constant current and current limit in DC power supplies*



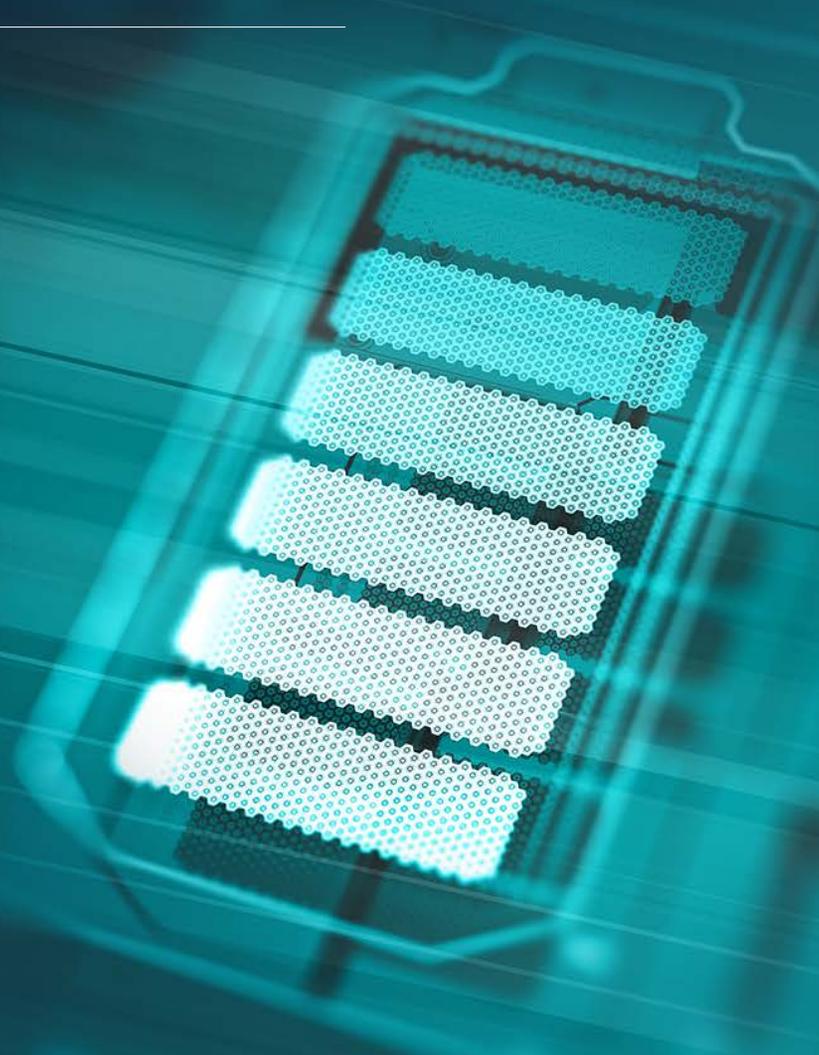
CV AND CC



TIP 2

# Get a Voltage or Current Boost

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## TIP 2

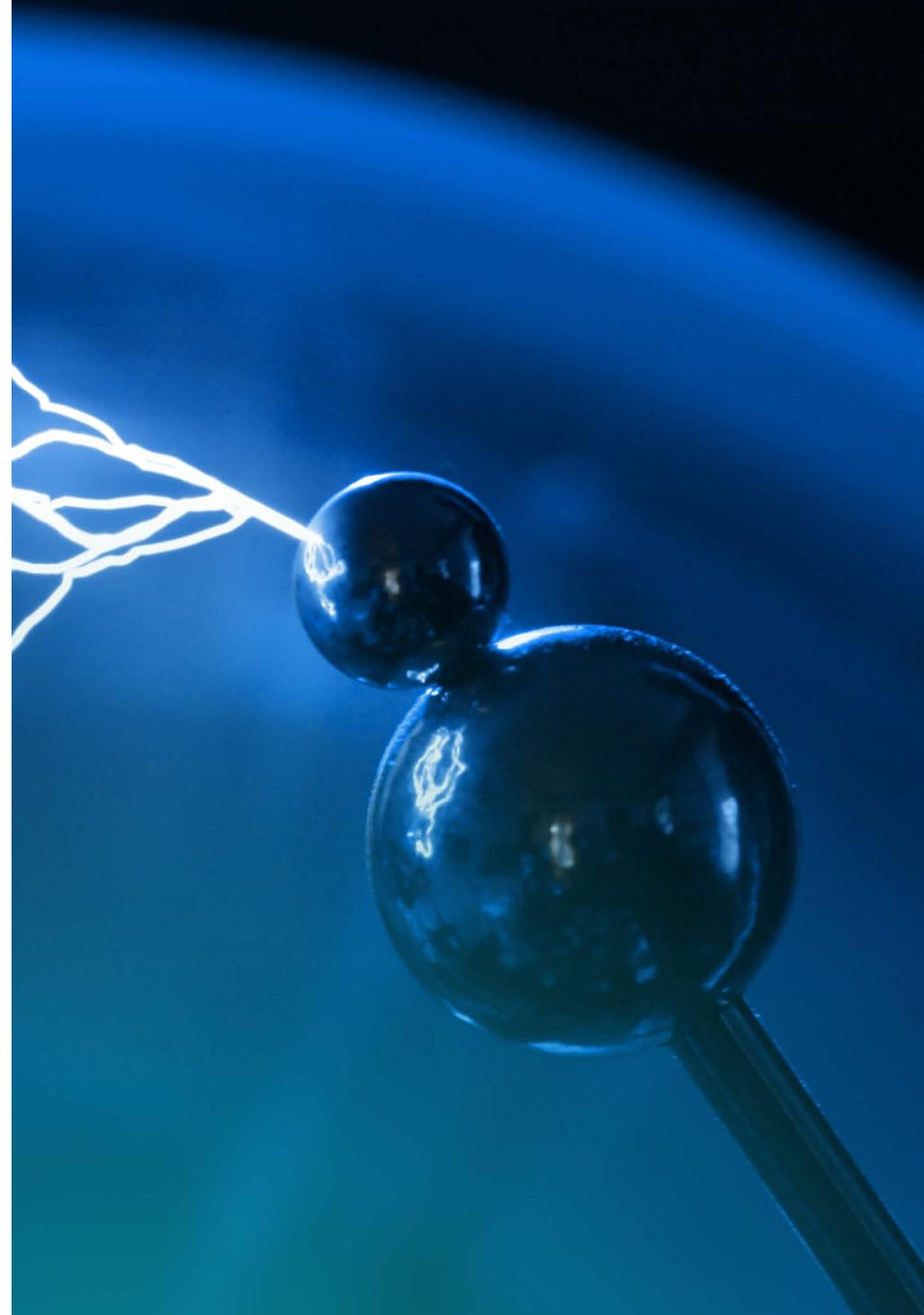
# Get a Voltage or Current Boost

### Connect Multiple Power Supplies for Higher Voltage or Current

There may be situations when you need more voltage or current than your power supply can provide. Here are some simple steps to connect two or more power supplies to meet those needs. For higher voltage, connect power supply outputs in series, and for higher current, connect outputs in parallel. Set each power supply output independently so that the voltages or current sum to the total desired value.

For **higher voltage**, first set each output to the maximum desired current limit the load can safely handle. Then, equally distribute the total desired voltage to each power supply output. For example, if you are using three outputs, set each to one third the total desired voltage.

- Never exceed the floating voltage rating (output terminal isolation) of any of the outputs
- Never subject any of the power supply outputs to a reverse voltage
- Only connect outputs that have identical voltage and current ratings in series



For **higher current** equally distribute the total desired current limit to each power supply.

- One output must operate in constant voltage (CV) mode and the other(s) in constant current (CC) mode
- The output load must draw enough current to keep the CC output(s) in CC mode
- Only connect outputs that have identical voltage and current ratings in parallel

Set the voltage of the CC outputs to a value slightly higher than the voltage value of the CV outputs. The actual voltage across CC outputs is determined by the load (see Tip 1). In the parallel setup, the CV output determines the voltage at the load and across the CC outputs (Figure 3). The CV unit will only supply enough current to fulfill the total load demand.

## LEARN MORE



*Video: Bench Power Supply Auto Series/Parallel connections, Keysight E36300 Series*

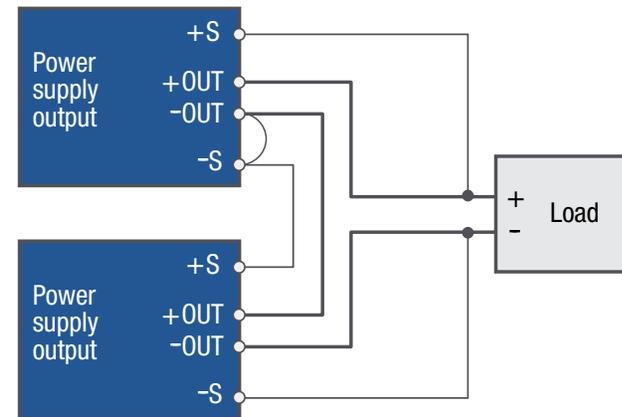


Figure 2: Series connection with remote sense.

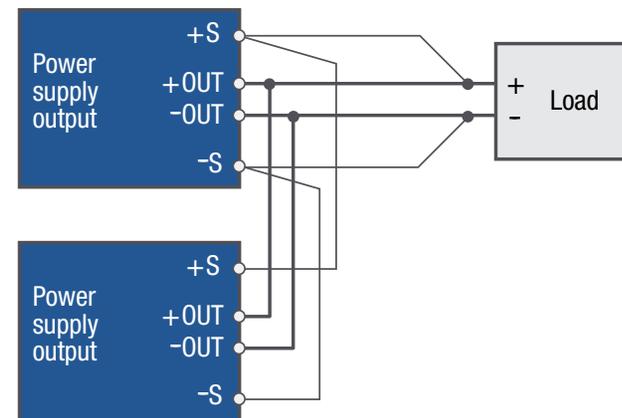


Figure 3: Parallel connection with remote sense.

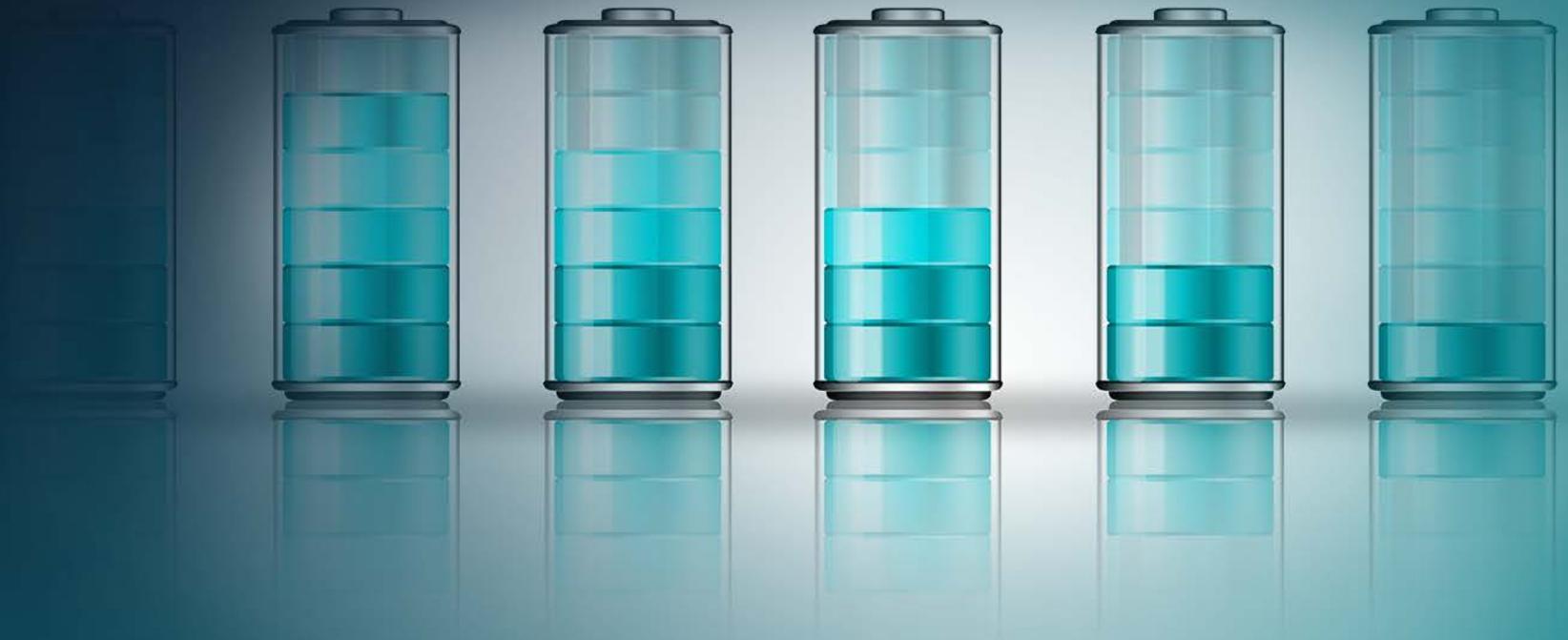




TIP 3

# Dealing with Unexpected Temperature Effects

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## TIP 3

# Dealing with Unexpected Temperature Effects

### Calculate and Apply Temperature Coefficients

Not only do the devices under test vary with temperature, but so do the instruments you use to make measurements. On a cold, winter day we tested Lithium Ion batteries at room temperature and found that the voltage of the cells drifted **up** as time progressed, not **down** as we expected.

The nighttime decrease in room temperature increased cell voltage—an effect stronger than the expected decrease in voltage as a result of cell self-discharge during the day. Since the power supplies that are used to apply power to cells also vary with temperature, you may need to apply the temperature coefficients to properly characterize the output voltage down to microvolts.

The following is an example using the Keysight N6761A Precision Module that features a low-voltage range. The [N6761A's specification table](#) documents the valid temperature range at  $23^{\circ}\text{C} \pm 5^{\circ}\text{C}$  after a 30-minute warm-up.



To apply a temperature coefficient, you must treat it like an error term. Let's assume that the operating temperature is 33°C, or 10°C above the calibration temperature of 23°C and a voltage output of 5.0000 V.

**Voltage programming temperature coefficient = ±(40 ppm + 70 µV) per °C.**

1. To correct for the 10°C temperature difference from calibration temperature, you will need to account for the difference in the operating temperature and voltage range specification. The low voltage range spec is valid at 23°C ±5°C or up to 28 °C. You will need to apply the temperature coefficient for the (5 °C) difference in the operating temperature (33 °C) and low voltage range spec (28 °C):

$$\pm(40 \text{ ppm}(5 \text{ V}) + 70 \text{ µV}) (5 \text{ °C.}) = 40\text{ppm}(5 \text{ V})( 5 \text{ °C.}) + 70 \text{ uV } (5 \text{ °C.}) = 1.35 \text{ mV}$$

2. The temperature-induced error must be added to the programming error for the low-voltage range provided in the N6761A specification table:

$$\pm(0.016\%(5 \text{ V}) + 1.5 \text{ mV}) = 2.3 \text{ mV}$$

3. Therefore, the total error, programming plus temperature, will be:

$$\pm(1.35 \text{ mV} + 2.3 \text{ mV}) = \pm 3.65 \text{ mV}$$

That means your output voltage will be somewhere between 4.99635 V and 5.00365 V when attempting to set the voltage to 5.0000 V in an ambient temperature of 33°C. Since the 1.35 mV part of this error is temperature-induced, as the temperature changes, this component of the error will change, and the output of the power supply will drift. The measurement drift with temperature can be calculated using the supply's temperature coefficient.

## LEARN MORE



Specifications Guide: *Keysight N6700 Modular Power System Family*





TIP 4

# Dealing with Noise Sensitive DUTs

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## TIP 4 Dealing With Noise Sensitive DUTs

### Two Ways to Minimize Noise

If your device under test (DUT) is sensitive to noise, you will want to do everything you can to minimize noise on the DC power input. The easiest thing you can do is use a low-noise power supply. But if you don't have one, here are a couple of other things you can do.

### Take a Closer Look at your Connections

The connections between your power supply and the DUT can be susceptible to interference, such as noise arising from inductive or capacitive coupling. There are a number of ways to reduce noise, but the most effective is using shielded two-wire cables for load and sense connections. Make sure you connect the shield to earth ground only at one end, as shown in Figure 4. Do not connect the shield to ground on both ends because ground loops can occur. Figure 5 shows a ground loop current that developed because of the difference in potential between the supply ground and DUT ground. The ground loop current can produce voltage on the cabling that appears as noise to your DUT.

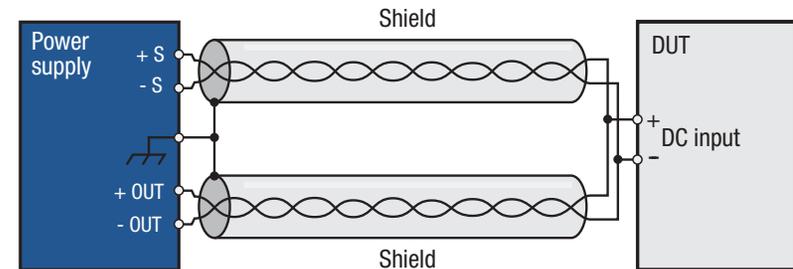


Figure 4: Shield is connected to earth ground only on one end of the cable.

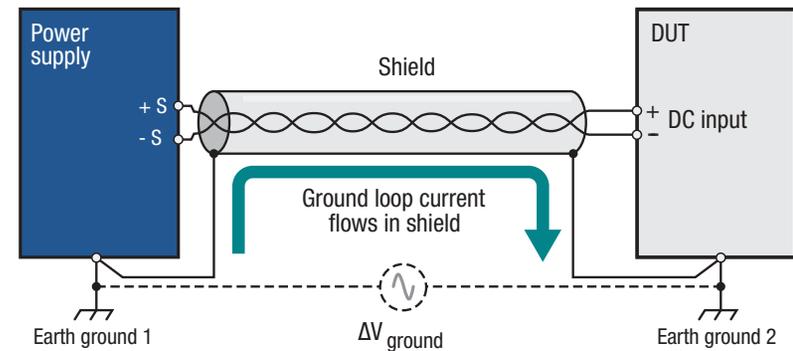


Figure 5: Shield is connected improperly at both ends, which results in ground loop.

## BALANCE OUTPUT TO GROUND IMPEDANCE

Common-mode noise is generated when common-mode current flows from inside a power supply to earth ground and produces voltage on impedances to ground, including cable impedance. To minimize the effect of common-mode current, equalize the impedance to ground from the plus and minus output terminals on the power supply. You should also equalize the impedance from the DUT plus and minus input terminals to ground. Use a common-mode choke in series with the output leads and a shunt capacitor from each lead to ground to accomplish this task.

## LEARN MORE



*App Note: Ten Fundamentals You Need to Know About Your DC Power Supply*



NOISE

## WANT TO LEARN MORE?

# Get Our Guide on Selecting Power Supplies

Whether you need a basic power supply or more sophisticated features for specific applications, this guide helps you select the power supply for your needs. Selecting a power supply with too much power can cause lots of headaches. The most common problems are increased output noise, an inability to set current limits, and less meter accuracy.

## How Much Power?

Evaluate the voltage, current and power for your device upfront and select a power supply that slightly exceeds the device's limits so that you have enough power to handle transient or surge currents which are common when powering up a device. If you are designing a low power device, use a power supply with a low range that can accurately measure current being drawn.

## LEARN MORE



Selection Guide: *Power Product Solutions*

## Built-in Features?

Newer high performance power supplies provide convenient, built-in features to eliminate the need for additional equipment, such as a scope, multimeter or a second power supply. For example, some power supplies come with built-in multimeter level accuracy, or dataloggers that can capture power transients, or even auto-series to cover voltage current combinations that previously required multiple power supplies. Specialized power supplies may include sophisticated features such as dynamic current characterization or the ability to source and synchronize current.

## Form Factor?

Bench power supplies should be small, but have large bright displays and front panel connectors. System power supplies are designed to minimize rack space but their longer depth and loud fans do not belong on a bench!

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