Tektronix® + Elektro-Automatik

Benefits of Connecting DC Programmable Power Supplies in Series or Parallel

Application Note

Benefits of Connecting DC Programmable Power Supplies in Series or Parallel

At its core, a power supply is an electrical device that supplies electric power, a combination of voltage and current, to an electrical load, such as a computer, appliance, consumer electronics or a battery charger, to name a few. Since the primary use of a power supply is to convert electric power from a source, like the utility grid, to the correct voltage, current and frequency to power the load, it is also called an electric power converter. In some loads, like desktop computers, the power supply is built into the equipment. While in some other cases, such as motors or appliances, power supplies are separate standalone pieces of equipment.

There are some applications where the use of a single power supply may not be sufficient to provide the power required by the load. For example, the required voltage may be much higher than that provided by the power supply. Or, the current required by the load may be much higher than the capability of a single power supply unit.

Connecting DC programmable power supplies in series

In those applications where the power required is much higher than a single power supply can provide, the user can connect multiple power supplies in series or parallel, depending upon the requirement. Connecting multiple power supplies in parallel will increase the current and power while the voltage remains constant. Conversely, connecting them in series adds the voltages of the individual supplies resulting in a higher total output voltage while the current remains the same.

This is represented in the equation below.

$$V_{out} = V1 + V2 + V3 + \_\_\_\_\_$$

V_{out} is the output voltage and V1, V2, V3.... are the individual power supplies connected in series. However, there are some dos and don'ts that the user must follow before connecting the power supplies in series. For instance, series connection is only allowed with supplies of the same kind and manufacturer model, i.e., power supplies with similar voltage, current and output impedance ratings. But, most importantly, the current rating should match. Furthermore, series operation of two or more power supplies can be realized only up to the output isolation rating of any one power supply to obtain a higher voltage than that available from a single power supply. In short, the six critical tips suggested by manufacturers for series connections are:

Six critical tips for series connections

1. The voltage setting on each power supply must be identical.
2. Divide the total voltage needed by number of power supplies in series. If using two power supplies, set each to half of total voltage needed. If using three power supplies, set each to one third of total voltage needed. And so on.
3. Make sure current settings match on each power supply.
4. Never exceed the output isolation voltage rating of any of the supply in series.
5. Never subject any power supply to a negative voltage.
6. The power supplies must be controlled individually.

Electronic vehicles: paralleling application examples

Now, where would the user need such series connections? There are applications like electric vehicles (EVs) where manufacturers are moving from 400 V batteries to 800 V. Some key factors motivating car makers to adopt higher voltages are increased EV efficiency, faster charging and weight reduction of other components. Analyst data shows that by increasing the battery voltage to 800 V, the current required to power motors and other devices in the EV is much lower as compared to 400 V, enabling thinner cables and smaller electronic components.

As a result, it reduces the vehicle's weight and minimizes energy losses to heat, thereby increasing overall efficiency and battery range. Plus, this helps the battery to charge much faster, a major factor attracting electric car buyers. Currently, some ten car OEMs, including Tesla (model Cyber Truck), have adopted 800 V architecture. And this number is growing fast.

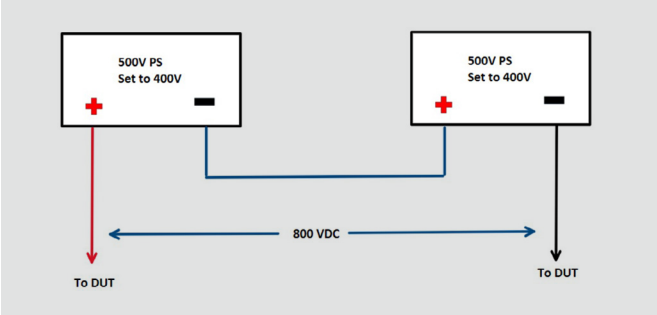

Figure 1. *Two 400 V power supplies connected in series to generate 800 V.*

DC programmable power supplies that provide a variety of output DC voltages

Manufacturers like EA Elektro-Automatik make DC programmable power supplies that provide a variety of output DC voltages. Before embarking on a project, ensure the power supplies have similar ratings before connecting them in series. To generate 800 V supply out of 400 V units, two similar power supplies must be connected in series, as shown in Figure 1. EA makes 500 V units that come closest to 400 V required, such as the EA-PSB 10500-30, a programmable bidirectional DC power supply, and its output can be set to 400 V, as shown in Figure 1.

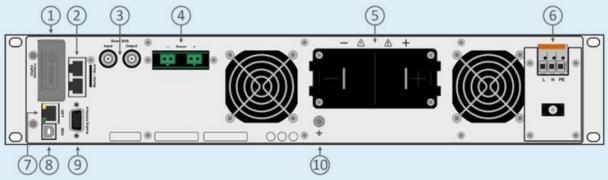

Figure 2. *Rear panel connections of the EA-PSB bidirectional power supply unit.*

1. Slot for interfaces
2. Master-Auxiliary-Bus Interface to set up a system for parallel connection
3. Share Bus Interface to set up a system for parallel connection
4. Output voltage Remote Sense input terminal
5. Output terminal, copper busbar
6. Mains input terminal
7. Ethernet Interface
8. USB Interface
9. Connector (DB15 female) for isolated analog program, monitor and other functions
10. Grounding connection screw

If using a bidirectional power supply as a load, extra measures must be taken. We offer the Serial Connection Box for these applications. See AN023: Series Connections of Electronic Loads.

Benefits of Connecting DC Programmable Power Supplies in Series or Parallel

EA Power Control Software allows control of up to 20 EA devices from one Windows PC

Also, for series connection, the EA power supply does not support Master-Auxiliary mode, meaning each power supply unit must be controlled separately, whether manual or remote (digital or analog). For remote control, the manufacturer recommends using the EA Power Control Software, which is downloadable from the EA website. If desired, users can purchase a one-time license fee to control up to 20 EA devices from a single Windows PC. By selecting the devices that are connected in series, the user can send the same commands to each device almost simultaneously.

Figure 3. *EA-Power Control Software enables easy and precise control of EA programmable DC power supplies products via a Windows PC.*

Other examples require creating plus(+) and minus(-) supplies from a single + power supply, as in aircraft applications. For instance, aircraft use +/-270 Vdc to create 540 Vdc (Boeing 787). In this case, use two EA PSI 10360-240 4U models in series with the middle point grounded, allowing the user to create a +270 Vdc reference and a -270 Vdc reference and providing 60kW of power as shown in Figure 4. For safety and isolation reasons, some restrictions are recommended by the manufacturer, which are explained in the product datasheet.

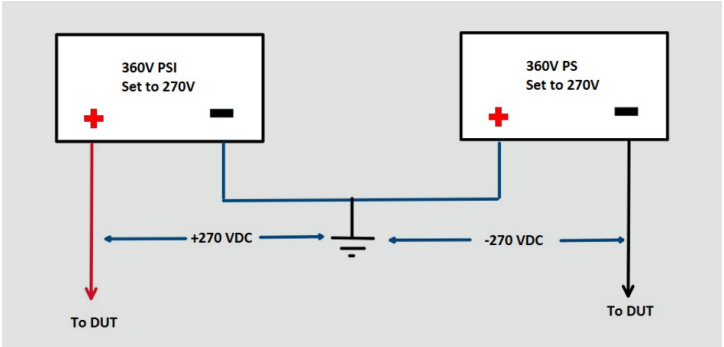

Figure 4. *To create a negative voltage reference, ground the middle point.*

Connecting power supplies in parallel operation

The solution connects two or more power supplies in parallel for applications requiring higher power and current than a single power supply. However, before connecting the supplies in parallel, the user must ensure that the load current is evenly shared between the power supplies. For that, the user must ensure that identical power supplies are used and identical cables or conductors are used to connect the DUT's + and - output connectors. Furthermore, the same wiring length and thickness of cables are used to connect the power supply units to the load. As a result, the voltage drop across the wiring cables is identical, ensuring identical voltage across power supplies and equal distribution of current from each power supply in this operation.

In practice, many power supply manufacturers rate their products, both switch-mode and linear power supplies, as compliant for paralleling. Ideally, for a perfect current share, the various supplies employed in this configuration must present identical output impedances and the output voltage set-up as close as possible. As time passes, this scenario is not guaranteed due to normal dispersion of the output parameters and the impact of aging, including temperature.

For that, makers like EA have incorporated a technique called Master-Auxiliary with a dedicated load-share bus. In this mode, when multiple power supply models of the same series, like the PSI 10000 series, are connected via the Master-Auxiliary bus and Share bus, the entire multi-device system behaves as a single device. With the Master-Auxiliary bus, system data such as total power and total current are collected and shown on the Master device. Warnings and alarms for the auxiliary devices are shown clearly on the display. The Share bus provides an equal load distribution to the individual device.

In short, according to EA (Figure 5), there are three steps to paralleling the company's programmable bidirectional DC power supplies:

Step 1. Physically parallel the +/- outputs

Step 2. Connect the Share bus to ensure units are sharing current equally

Step 3. Connect the master/auxiliary bus to ensure communication between the units

Step 4. Configure each unit as master or auxiliary in the settings menu and set the bias and termination resistors as shown to the right.

Position	Device with KE firmware < 2.08	Device with KE firmware ≥ 2.08
Master (at end of bus)	BIAS + TERM	BIAS + TERM
Master (central in bus)	TERM	BIAS
Aux (at end of bus)	TERM	TERM
Aux (central in bus)	–	–

EA's units are easily paralleled via Cat-5 cable (for communication) and BNC cable (for current sharing).

In summary, manufacturers like EA Elektro-Automatik make power supplies that provide a variety of output DC voltages and currents that can be easily connected in series or parallel, depending on the end requirement, for myriad applications.

For more information on how EA Elektro-Automatik DC programmable power supplies and EA Power Control Software can meet application requirements, visit the EA website or contact us.

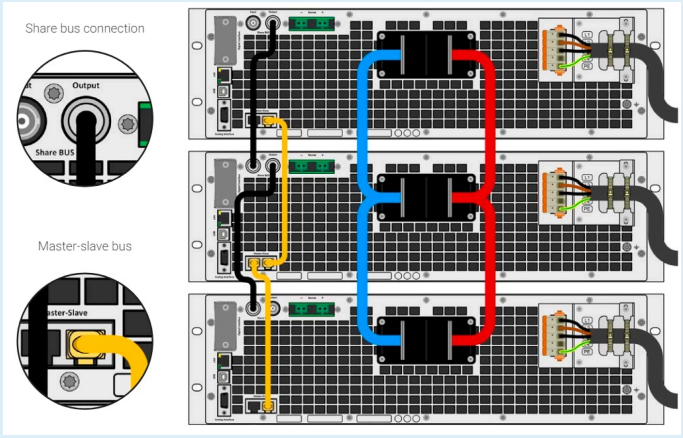

Figure 5. *EA's programmable bidirectional DC power supplies are easily paralleled using Cat-5 cable (for communications) and BNC cable for current sharing.*

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