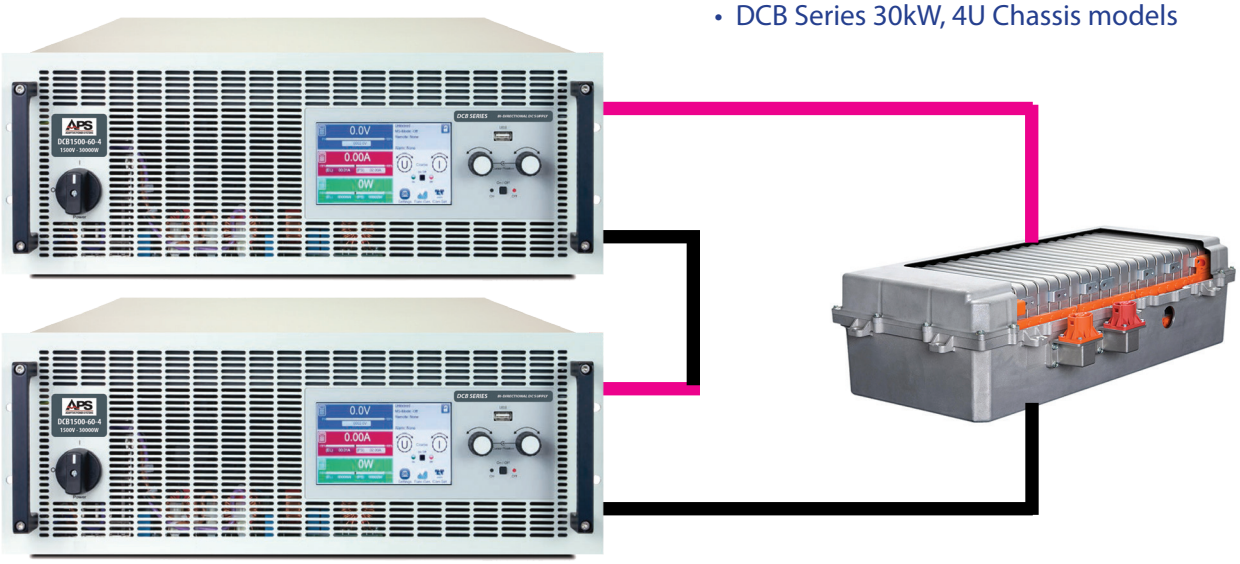
APPLICATION NOTE
DC LOAD SERIES CONNECTIONS

ADAPTIVE POWER SYSTEMS

Series Connections of Electronic DC Loads

Note: This document is only valid for following series

- 6RL Series 30kW, 4U Chassis models
- DCB Series 30kW, 4U Chassis models



Introduction

This document is intended to provide guidance when connecting two 6RL or DCB 30KW units in series. Series connection of electronic loads requires all involved units to have equal internal resistance in order to equally distribute the DC input voltage. Another critical consideration is the potential of the DC input terminals against ground (PE) which is limited by the internal insulation. Electronic loads typically have no protection against overvoltage. In order to safely run in a series configuration, it would require an internal hardware solution than can balance the voltage between the two units, but unfortunately that does not exist. The end user can still connect electronic loads in series and separately control them, but one important factor will always remain: protection from overvoltage.

For this reason the SCB (Serial Connection Box) has been developed The SCB is an externally installed hardware box that is connected to the Share bus and the DC input. It monitors the DC voltage and will shut down the DC input in the event of an overvoltage between DC+ and DC-. It accomplishes that by short-circuiting the Share bus which leads to a Share bus fail (short: SF) alarm, causing all units connected to the SCB to switch off their DC input.

Restrictions

- The SCB is only available for models with a voltage rating of 360 V or higher. 60 V, 80 V and 200 V models are excluded.
- Mixing different voltage models in a series connection is not permissible.
- No master-slave support. All units must be configured and controlled separately, ideally via remote control because of the advantages over manual control.
- The maximum DC voltage allowed in a series connection of electronic loads is 3500 V.
- Certain configurations required to ground the DC input at one point in the line.

General rules

- The number of devices allowed in series connection solely depends on the total potential between their DC minus and DC plus terminals. The float voltage specification is the overall limit.
- Every unit in the series connection requires an SCB installed; so if there are three units then three SCBs are needed.
- The SCB can also be retrofitted and thus a series connection system can be configured whenever needed.

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Example configurations

- **Example 1:** Two units of 750 V in series
- Permissible: Yes
- Grounding required: No
- Restrictions: None

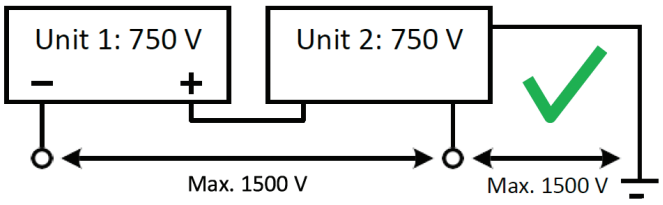

Figure 1

- **Example 2:** Three units of 750 V in series
- Permissible: Yes
- Grounding required: Yes, either between unit 2 and 3 or between 1 and 2
- Restrictions: None

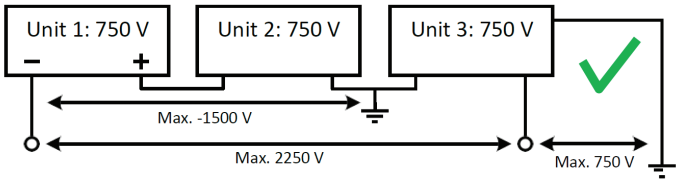

Figure 2

- **Example 3:** Two units of 2000 V in series
- Permissible: With restrictions
- Grounding required: Yes
- Restrictions: total voltage can only be up to 3500 V, so Unit 1 must be limited to 1500 V

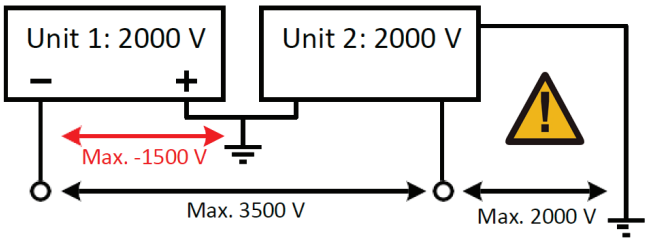

Figure 3

Connection principle with the SCB

Each SCB monitors the input voltage of the device it's attached to. Any SCB which detects an overvoltage, short-circuits the Share bus of the device it's attached to and sends the signal (green line) to any other SCBs to trigger them to do the same. The short-circuited Share bus triggers an alarm which shuts down the DC terminals immediately.

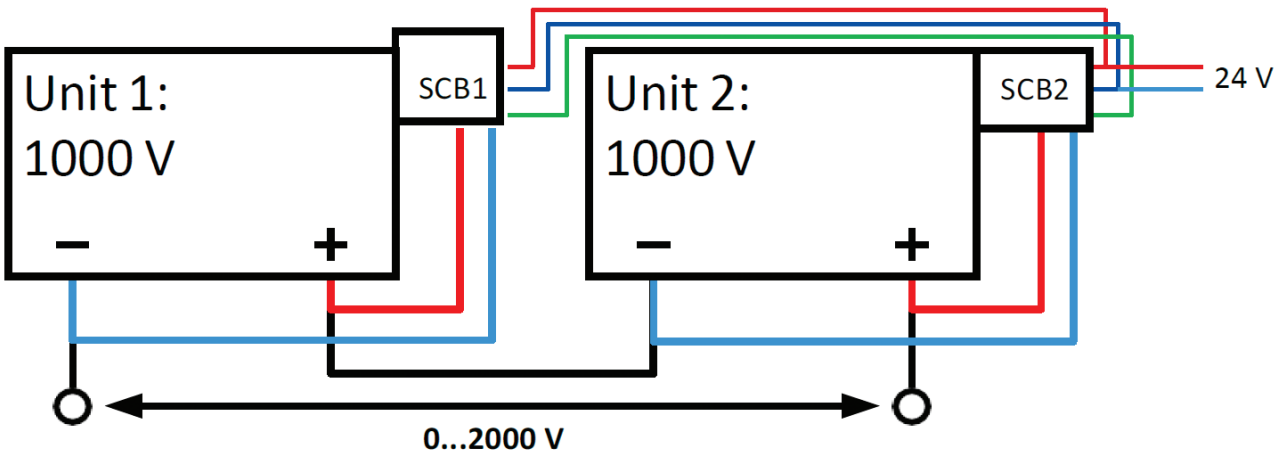

Figure 4

DC LOAD SERIES CONNECTIONS

Ordering information

Model	Voltage Rating	Compatible 6RL Models	Compatible DCB Models
SCB360	360V	6RL-30-240-360	DCB360-240-4
SCB500	500V	6RL-30-180-500	DCB500-180-4
SCB750	750V	6RL-30-120-750	DCB750-120-4
SCB1000	1000V	6RL-30-80-1000	DCB1000-80-4
SCB1500	1500V	6RL-30-60-1500	DCB1500-60-4
SCB2000	2000V	6RL-30-40-2000	DCB2000-40-4

Technical data

Required power supply: 24 VDC (22...26 V) @ 20 mA per SCB

Dimensions (W x H x D): approx. 40 mm (1.6 in) x 72 mm **(2.8 in) x 73 mm (2.9 in) Weight: approx. 150 g (5.3 oz)**

Connection: Standard BNC (50 Ω), 3-pole Phoenix, M6 ring lugs.

Features: Supports series connection and parallel connection.

Transient time (overvoltage detection to shutdown): approx. 25 µs

Views & Dimensions

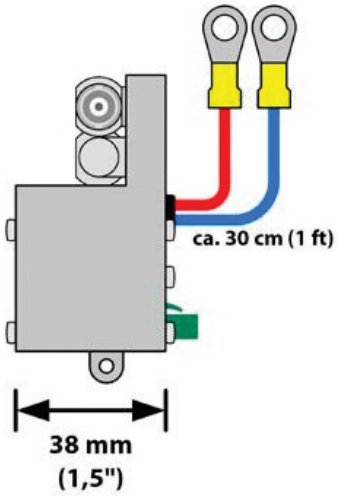

Figure 5 - Rear View

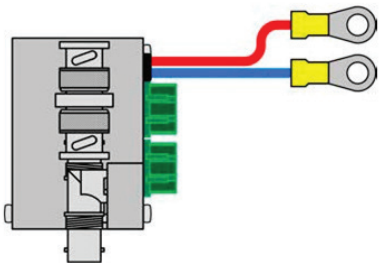

Figure 5 - Top View

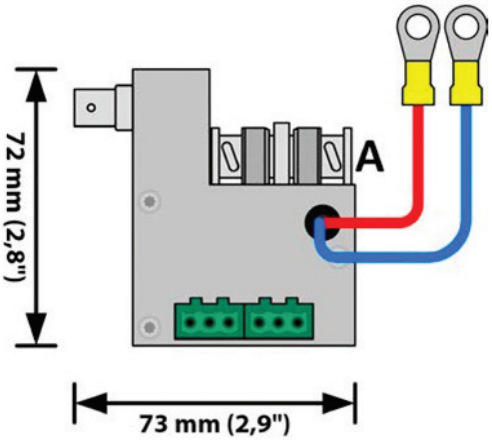

Figure 7 - Side View

Included Components

- 1x SCB module
- 1x Cable for SCB to SCB connection (2x plug 3-pole), ca. 70 cm (2.3 ft)
- 1x Cable for DC supply (1x plug 3-pole)

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Installation + Connection

1. Remove this screw on each unit.

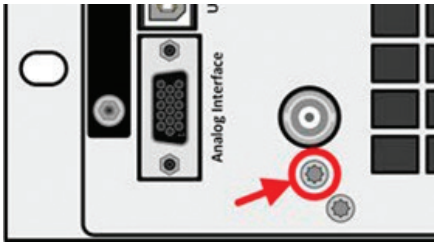

Figure 8

2. Plug the BNC connectors A (see images above) of the SCB modules to the upper Share bus sockets labeled "Share BUS Input". See Figure 9 for the correct placement.
3. Mount the screws from step 1. Firmly tighten them and make sure the included contact disk is put under each screw to ensure good connection to PE.
4. Connect the voltage monitoring cable (red/blue), which comes out of the SCB, to the DC terminal with correct polarity (red = DC+, blue = DC-), as depicted in Figure 9.
5. Connect the SCB link cable (2x green connector) between the SCBs of all units by using any of the two green Phoenix connectors.
6. At one end of the SCB line, whichever one you choose, connect the other cable for 24 V DC supply. Connect a DC power supply to this cable.

WARNING!

- Never connect the Gnd/neg. DC of the 24 V supply to the neg. DC pole of the device!
- The DC side of power supply must be galvanically isolated from all other parts and must have an insulation against PE that is at least as high the DC voltage of the series connection.

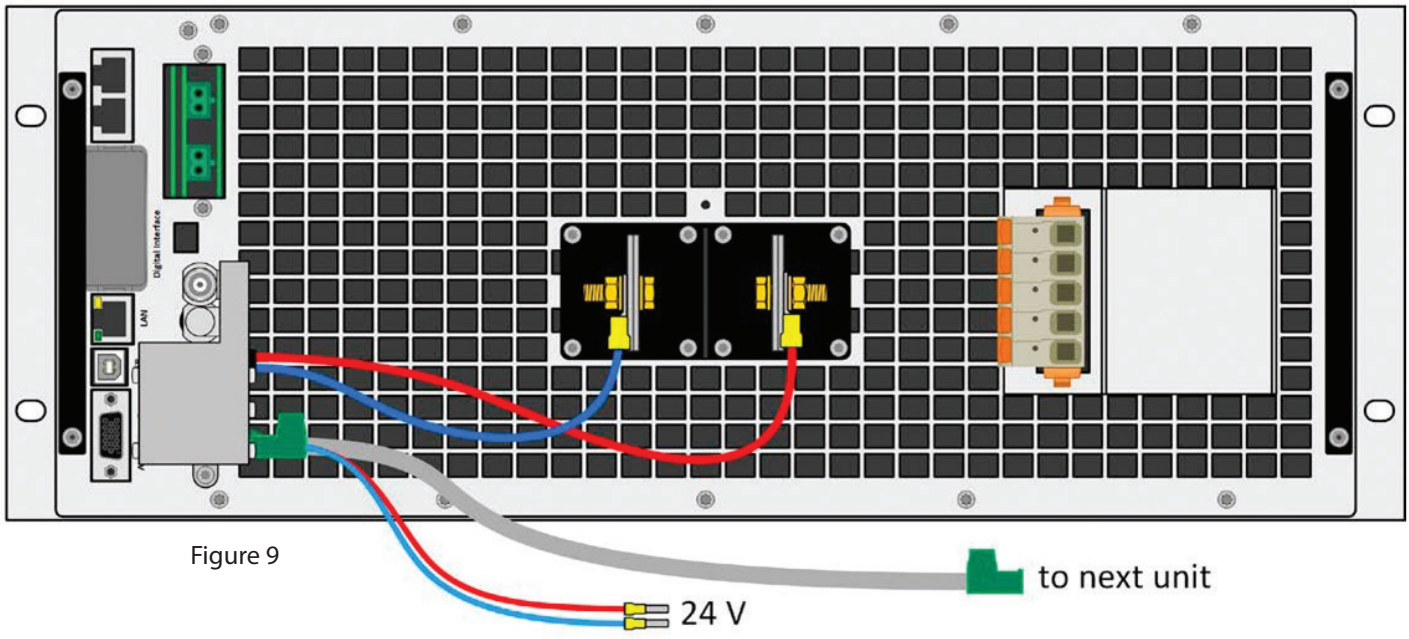

Figure 9

DC LOAD SERIES CONNECTIONS

General rules for operation

- In series connection, the DC inputs of all units must be switched on to have a current flow, even if less power is required.
- Always make sure that the power supply of the SCB modules is running before powering the 6RL/DCB units or at least before applying an external voltage to the DC terminals.

Application

In order to distinguish the units in series connection, the one with the positive DC pole and highest potential against ground is called the "high unit" and the other unit(s) are called the "low unit(s)."

When supplying voltage to the series connection there are basically two methods: either the external voltage is already present and the loads could instantly have an excess voltage on their DC inputs, or the external voltage is 0 V in the moment when the DC inputs are switched on and then the external voltage will be increased to the targeted level, more or less slowly. Both situations have their advantages and disadvantages. It's up to the user to decide which one is best for the application.

Note: the SCB doesn't balance the voltage between the units. For series operation, it's recommended to run the units in CV mode, even electronic loads if possible.

Example: There are three loads in series connection, each rated 500 V. Max. total voltage is 1500 V, no grounding required here. When applying 1500 V to the DC input it must be prevented that any of the units can have more than 500 V on its DC input. One way of achieving that could be to adjust the low unit and the mid unit to max. voltage, i. e. 500 V, and the high unit to 0 V. The series connection would then only start to draw current when the supplied voltage exceeds 1000 V, which is probably not wanted as it narrows down the available voltage range for dynamic tests.

The high unit would be considered as the"boss" of this connection and define the total serial current by setting a specific current set value, while the current set values of the other two units, low and mid, must be set slightly higher than the one of the high unit. In case wider voltage range is required for an application, for example 800 V - 1500 V, only the low unit would be set to 500 V and the mid unit to 300 V etc. As soon as the units start to clip the voltage in CV mode their DC input voltage should balance, or at least not exceed the rating.

A critical situation is when the DC inputs of the units are switched on, especially during manual control. Note: When manually switching on the DC inputs one by one the low unit(s) must be first.

Additional important Information:

- Before initial operation of the series connection, and also in regular intervals, the correct connection and operation of the SCB has to be checked. Correct operation can be checked by intentionally applying an overvoltage to one unit which is 10% higher than the rating, increasing it slowly until the SF alarm occurs.
- Before using the series connection in an actual application, we recommend to "play around" with the devices and the external source to get a feeling about the flow of actions and the required settings for a smooth operation. This is possible without any problem, for example testing 600 V on a series connection of two 500 V models,because the SCB would perfectly protect the devices.
- When using DCB units, due to the voltage on the lower units probably being set to maximum, the lower DCB units could switch into source mode suddenly. In source mode the series connection could generate and supply back a voltage to the external source which is higher than the external source's rating and thus damage it. Accidental source mode can be avoided by setting the set values of power and current for source mode to zero.

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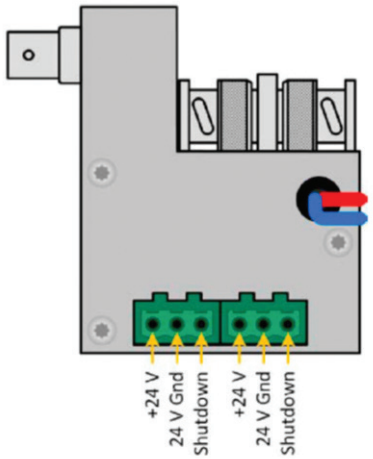
- Alternatively to CV mode, the units could also run in CR mode, but then it would be required to adjust them to the same resistance values at the same time, which can only be achieved in remote control.
- The SCB is designed to trigger the protection at around 110% of the rated voltage of a device. Different models can withstand different overvoltage levels for a few seconds, but the average is approx. 120% of the rated voltage. For example, a 500 V model can take up to approx. 700 V for a few seconds without damage, which is 40% overvoltage. Other models, especially the 2000 V model, can't sustain so much overvoltage. Since the SCB reacts within microseconds, the duration of overvoltage isn't decisive, but the level of overvoltage is.

Note:
The included cables are sufficient for a series connection where the devices are either stacked or closely placed next to each other. In case the length of the cables aren't sufficient, they can be extended. Follow the signal layout below:



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