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VCCS300 Droop Mode Current Sharing
APPLICATION NOTE

VCCS300
Single Output Conduction Cooled Power Series

2" x 4" x 1.61"
Small

300W | 600W | 900W
Scalable

Fan-less
Silent

BF-Rated
Output

Cool it your way: Conduction|Convection|Forced Air

OVERVIEW

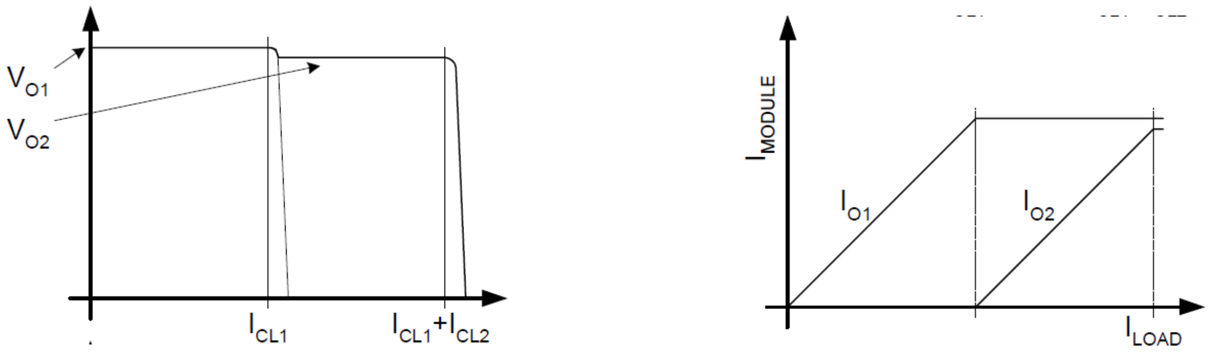
Multiple VCCS300 power supply units can be paralleled to achieve higher power levels. To ensure loading is spread equally between the paralleled units the PSU uses a method called droop current share. This application note provides an insight into issues surrounding the parallel connection of two or more VCCS300 units using droop current sharing. The application note covers the following topics:

- Paralleling without droop current sharing
- Droop current share operation
- Calculation of the current share error
- External influences on accuracy

DETAILS

Paralleling without droop current sharing

When multiple power supplies are connected in parallel without droop current share being activated, the load will not be shared evenly between them. As specified in the datasheet, the initial voltage setpoint (V_{SET}) has a tolerance. If we consider two different units individually, they will have slightly different output voltages (V_{O1} and V_{O2}).
When we connect these two units in parallel, the unit with the highest output voltage will become dominant and will deliver all of the current until it's voltage starts to reduce due to exceeding it's current limit (I_{CL1}). Once this happens, the unit with the next lowest output voltage will begin to deliver the load current while the first unit continues delivering it's maximum current. If the load current increases beyond the summed current limit of both units (I_{CL1} +I_{CL2}), the voltage will reduce to limit the output current. The diagrams below illustrate the behaviour for two paralleled units.

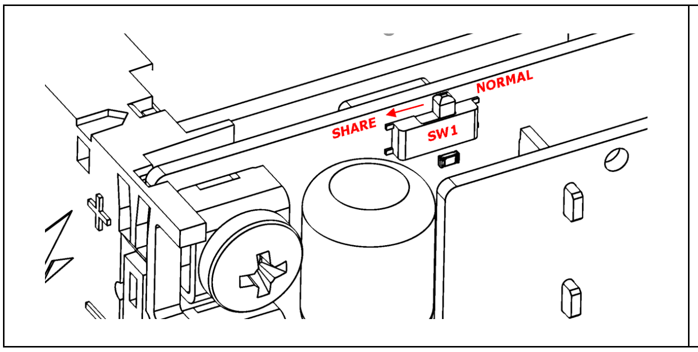


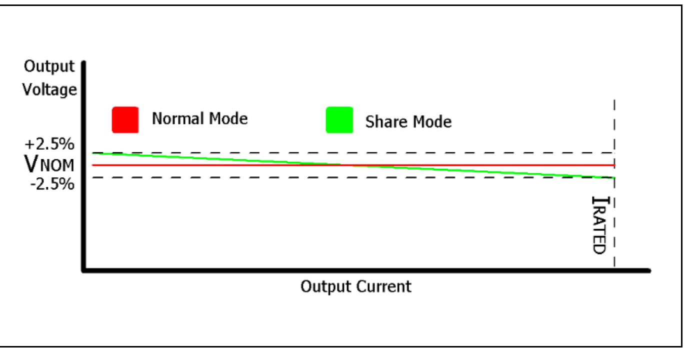
This same process applies when more than two units are connected in parallel. The unit with the highest voltage will deliver all the current until it reaches current limit, then the next lowest output voltage will begin to deliver current until it's current limit is reached and so on until the last paralleled unit with the lowest output voltage.

In this configuration the highest voltage units do most of the work while the lowest voltage units only work intermittently when the load current is very high. As a result, the highest voltage units generate the most heat which leads to lower reliability and reduced MTBF.

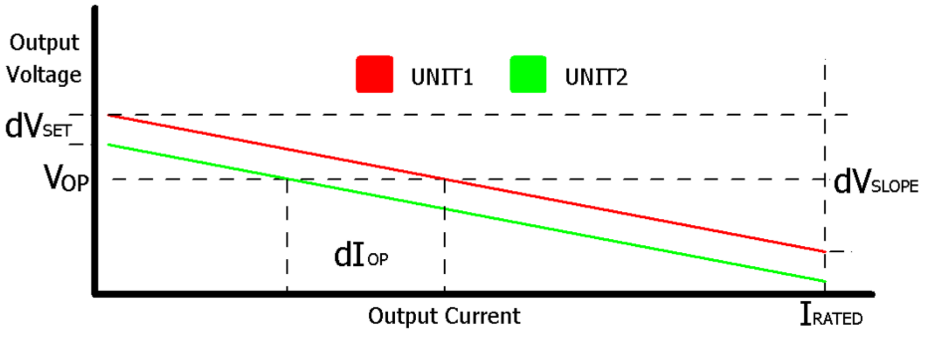
Droop Current Share operation

To overcome the reduced reliability of uneven load sharing in paralleled systems the VCCS300 has the option of activating Droop Current Share (DCS) mode by sliding SW1 towards the output terminals as shown in the diagram below. In Droop Current Share mode, the output voltage of each unit has an artificial voltage drop added that reduces the output voltage as the current increases. At 0% load the voltage is typically V_{NOM}+2.5%, at 50% load it is V_{NOM} and at 100% load it is V_{NOM}-2.5%. (See "Droop Share" specification in the datasheet).





If we consider the load current for paralleled units with an initial setpoint error $\Delta V_{SET} = V_{SET1} - V_{SET2}$ and an output voltage slope of ΔV_{SLOPE} as shown below:



It is possible to calculate the difference of current between the two paralleled units using the following formula.

$\Delta I_{OP} = \Delta V_{SET} / \Delta V_{SLOPE}$ Equation 1.

From this analysis it is observed that initially the highest V_{SET} unit delivers all the output current but as the load current increases above ΔI_{OP} the second unit will also start supplying current to the load. The error ΔI_{OP} effectively remains constant until the OCP limit is reached on the highest V_{SET} unit.

The equation below gives a generalised form for the error ε_{IOP},

$\varepsilon_{IOP} = \Delta I_{OP} / I_{RATED}$ Equation 2.

Substituting equation 1 for ΔI_{OP} gives,

$\varepsilon_{IOP} = \Delta V_{SET} / (\Delta V_{SLOPE} * I_{RATED})$ Equation 3.

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Calculation of the current share error for VCCS300

Using equation 2 and parameters from the datasheet, the worst case expected error for paralleled units can be calculated.

From the VCCS300 datasheets,
$\Delta V_{SET} = \pm 0.01 \times V_{NOM}$ (All Models, -40°C to 125°C) & $\Delta V_{SLOPE} = \pm 0.025 \times V_{NOM} / I_{RATED}$ (All models)

Hence from equation 2, the worst case error is,
$\varepsilon_{IOP} = \pm 0.01/\pm 0.025 = \pm 0.4$ [±40% of individual unit rated current] (All Models, -40°C to 125°C)

It is unlikely that multiple paralleled units will have a large temperature difference and the practical current share error can be more accurately estimated from a statistical analysis of initial voltage setpoint at a specific temperature.

VCCS300 production test data suggests the following parameters,
$\Delta V_{SET} = \pm 0.003 \times V_{NOM}$ (All Models, 25°C, 2 x Standard Deviations) & $\Delta V_{SLOPE} = \pm 0.025 \times V_{NOM} / I_{RATED}$ (All models)

Hence from equation 2, the practical error is,
$\varepsilon_{IOP} = \pm 0.003/\pm 0.025 = \pm 0.12$[±12% of individual unit rated current] (All Models, 25°C)

and the estimated difference in current for any two paralleled units is,
From equation 2 ($\Delta I_{OP} = \varepsilon_{IOP} \times I_{RATED}$),
$\Delta I_{OP} = \pm 0.12 x\ I_{RATED}$

For VCCS300M-12 this would equate to a current difference of ±3A

When paralleling more than 2 units the current share error between any two units in the group will remain within the bounds of the calculated error for any 2 units.

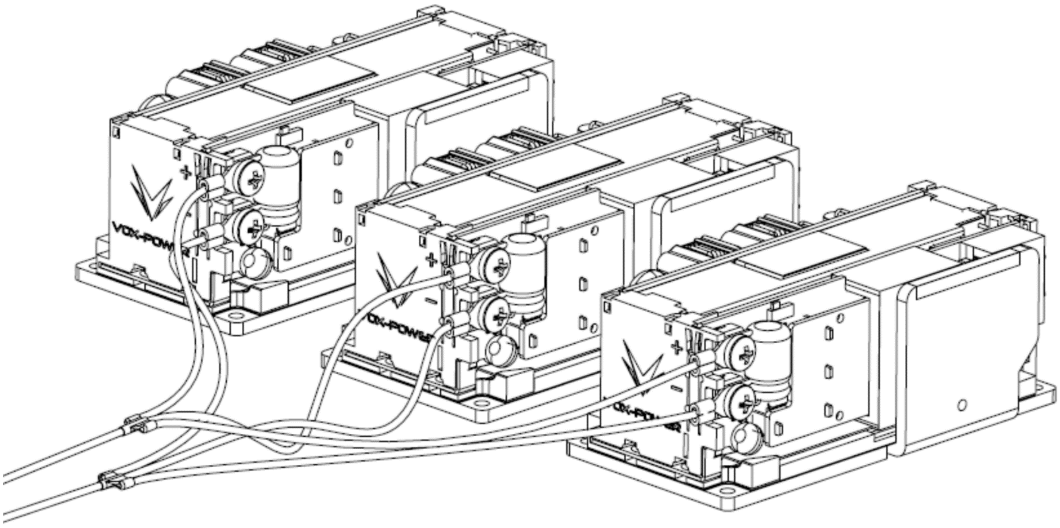
External influences on accuracy

The error estimates calculated previously are based upon parameters within the PSU. External parameters that will also affect the current sharing accuracy are addressed in the following paragraphs.

Cabling

The accuracy of current sharing is highly dependent on external cable resistance as this will affect the slope of voltage drop (ΔV_{SLOPE}) as the output current is increased. To minimise errors, it is important to have equal cable lengths from each output terminal to the common connection point for both positive and negative cables.

Below is an illustration of optimised parallel connection of three units to give 900W of output power.



Thermal Variations

The accuracy of current sharing is dependent on temperature difference between the paralleled units as this will affect the setpoint voltage (ΔV_{SET}) of each unit. To minimise errors, it is important to maintain equal temperatures for all the paralleled units. Mounting all paralleled units to a common thermal plate is usually sufficient.

CONCLUSION

The VCCS300 series of power supplies are very versatile and allow system power flexibility. Series and parallel connection of multiple units allows system power delivery to be scaled as necessary in the end application. This application note explains how to implement Droop Current Share (DCS) mode to improve system reliability. The underlying theory is explained, estimates of sharing accuracy are calculated and external influences are examined.

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