COMMUNICATION PROTOCOL FOR POWER SHARING IN VICOR CONVERTERS

There are several methods of sharing power distribution among multiple power converters connected to the same power supply and the same load. Usually, power converters are operated in parallel either to increase output power, fault tolerance or both.

One method is based on artificially adjusting the output impedance. While functional, most loads require very low source output impedance. Multiple cases of instability have been reported as non-zero output impedance forms an unwanted feedback system with certain loads (1). This method decreases the output voltage with increasing current, which forces other parallel converters to provide more current. This method is simple and can work with any topology.

Another method is to have dedicated driver/booster arrays. The driver module sets the output voltage and boosters are used to supply current to the output node. It should be noted that this method is not fault tolerant – if the driver module fails, no other converter can regulate output voltage.

The VICOR power modules are based on a quasi-resonant topology. In a nutshell, two additional elements are added to a standard PWM converter – an inductor and a capacitor. Together they create a resonant network which enables zero-voltage switching (ZVS) or zero-current switching (ZCS), thus increasing the overall efficiency. Voltage regulation is controlled by variable frequency switching as the converter transfer the same amount of energy per switching cycle. Some disadvantages are higher conduction loss (switch current is not constant and follows a sine wave) and higher voltage stresses.

Below is a picture of my setup. One converter is set up as a driver and the other one is a dedicated booster. The output voltage is trimmed down to about 16 V from 24 V to provide an inherent overvoltage protection provided the external two-state power control fails. The PR (parallel) pins are tied together.

Measurement Setup

The VICOR modules are all connected in parallel. The driver and all boosters communicate through one channel referenced to the negative input terminal. I was curious about their communication protocol: Is the communication digital or analog? Do they use frames? Do booster modules acknowledge the power command?

We can just take a guess at the power transfer properties of the converter – but we know that the voltage transfer ratio depends on switching frequency and load. Reciprocally, the switching frequency is dependent on the voltage ratio and the load. Assuming constant load, the switching frequency is dependent only on the voltage ratio (neglecting conduction & switching losses). The exact relationship depends on the topology.

Here are my **findings**:

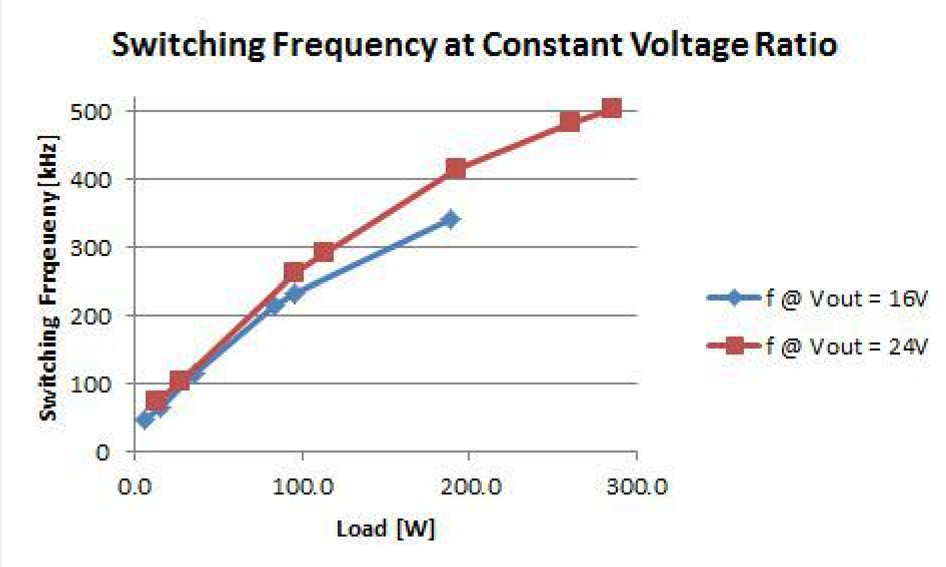
- The driver transmits a digital signal binary signal (40 ns pulse) to all receivers.
- The booster module behaves as a simple receiver. It does not transmit any signal.

- The pulse frequency is based on the power level and input voltage. The higher the power required, the higher the frequency of the driver pulse train.
- Output currents are well regulated among multiple converters within 100 mA, which is about 0.7% of the maximum current limit. When the converters reach their current limit, maximum difference was about 300 mA, with the driver module supplying more current than the booster module.
- The driver signal most likely has the same frequency as the switching. Thus, the booster modules most likely synchronize their switching frequency to the driver module.

Conclusion:

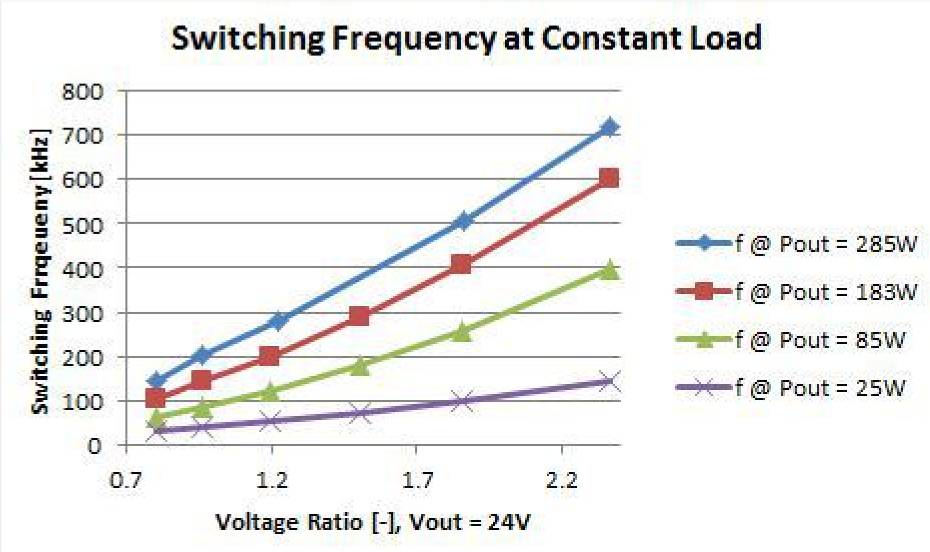
I hoped to find and analyze a more intricate communication scheme than a simple gate signal output. However, the method works and resulting current sharing is spectacular!

The switching frequency is strongly dependent on the output power.



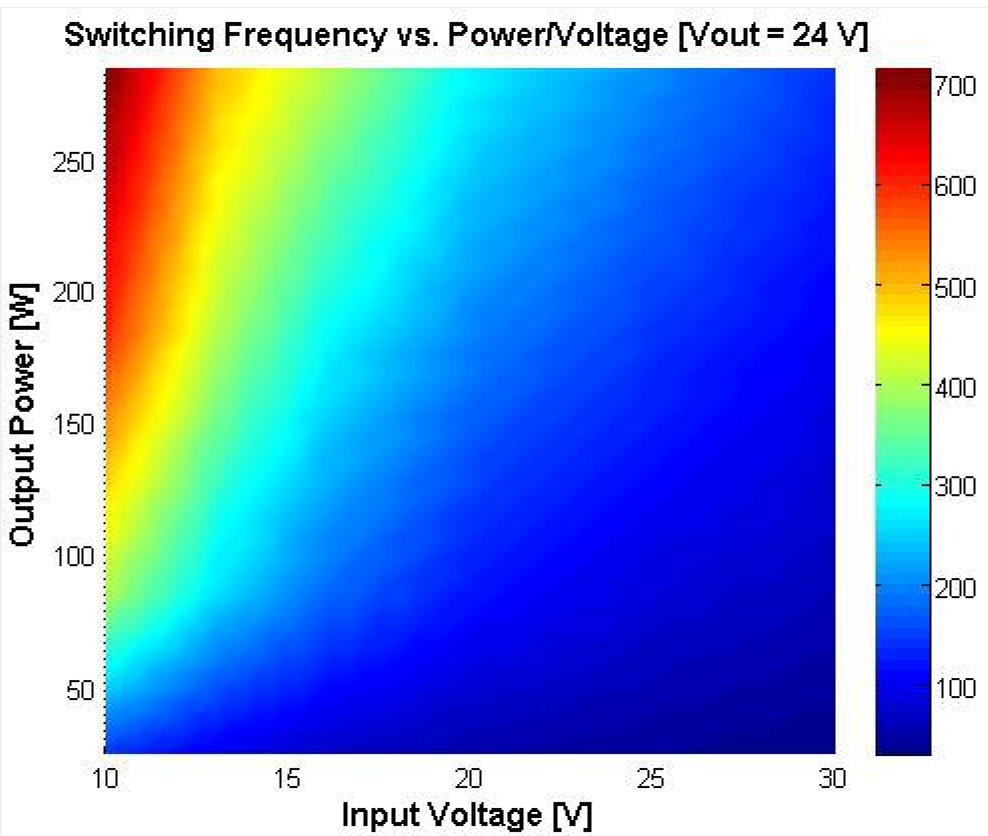
Switching Frequency at Constant Voltage Ratio

And is also dependent on the voltage ratio!



Switching Frequency at Constant Load

Below is a nicely interpolated colormap.



Switching Frequency vs. Power & Voltage Ratio

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