

# Input Ripple Measurement and Filtering

## General Description

The following discussion pertains to a MicroVerter® UV28 module loaded to 200W. The 370 kHz component of the input ripple is addressed. Higher frequency components, which are usually common mode “spikes,” must be addressed separately.

## Measurement

Measurement of the input ripple current of a high frequency DC/DC converter is not a simple task. Because of the large DC component of the current, many current probes normally used to measure high frequency currents become useless, due to DC saturation. Current shunts, while suitable for accurate measurement of the DC value of the current, are too inductive to give an accurate picture of the AC component of the current.

A low inductance current shunt can be made using a short piece of resistance wire for the purpose of measuring input ripple current. This device, when connected to coaxial cable, and properly terminated, will result in fair accuracy if the resistance wire length is held to an inch or less. The oscilloscope measurement will be greater than the actual IR component of the voltage due to the  $Ldi/dt$  component which, although small, will be present as well.

A more complicated, but more accurate device can be made which is virtually non-inductive by insulating the resistance wire and shielding it with the shield lead from a piece of coaxial cable. Our measurements

were made using this type of device, constructed from three pieces of #18 managing 290, one inch long each, in parallel. The managing wire was kept on sleeved, then shielded with the shield lead portion of a piece of RG 58 A/U coax which is connected to the managing at one end. RG 58 A/U cable was also used to connect the signal to the scope, as was a 50 OHM termination. The resultant DC resistance is 5 milliseconds-Ohms. Of course, there is still some error where the measured current is higher than the actual current due to skin effect. The capacitance of the device is negligible.

## Ripple Current Theory

In Figure 1 below, a MicroVerter module is shown connected to an ideal DC source. Since the ideal source has infinite capacity, the ripple voltage appearing at its terminals is zero, despite the ripple component of the current flowing into the MicroVerter module.

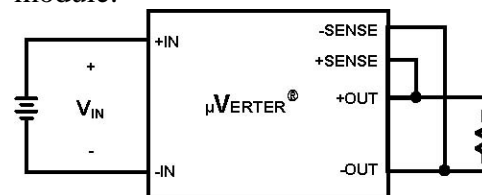


Figure 1 With an ideal input source, the ripple voltage at  $V_{in}$  is zero.

Although the amount of ripple current is small, in practice, a ripple voltage will appear at the input to the MicroVerter module, and at the terminals of the source, which should be treated as two different points. The ripple at the source is a function of ripple current and the source impedance, and the ripple at the input to the MicroVerter

module is a function of these parameters, as well as the line impedance.

The source impedance is generally made up of elements such as battery ESR, capacitor ESR, actual capacitor value, and capacitor or battery ESL. The line impedance is made up of the wire inductance and resistance. Figure 2 illustrates a MicroVerter module connected to a real source, with source impedance and line impedance included. The voltage at the source terminals has been named VDC. The ripple voltages can be calculated if these quantities are known (ripple current, source impedance and line impedance). On the relative magnitudes of the source and line impedances at 400kHz, the source ripple may be highly attenuated. For instance, just a few feet of wire connected between the source and the MicroVerter module input may reduce the ripple at the source to a negligibly small p-p magnitude if the source impedance is small. (A few feet of wire can easily result in 1μH or more of inductance).

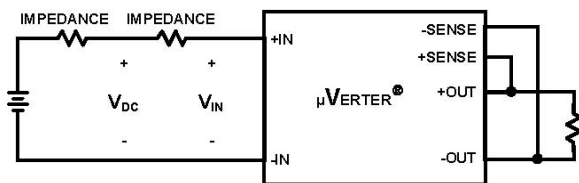


Figure 2 The source voltage and the input to the converter is treated as two different points. They are separated by the line impedance.

There is, of course, a need to keep the ripple that appears at the source reasonably small, since other equipment may be sensitive to ripple at certain frequencies. Since the MicroVerter operates at the affixed 400kHz frequency, keeping the source ripple very low is a simple matter.

## Input Ripple Reduction

The easiest way to reduce the ripple voltage is to use a capacitor at the input to the MicroVerter. This is assuming that the source impedance is suitably low in the first place. The capacitor should be located physically close to the MicroVerter module input, and the connections should be as short as possible between the cap and the input pins to minimize series inductance and resistance. A 22μF, 50V tantalum, or a 3.3μF, 50V MLC, or a 220μF, 50V aluminum will give good results. The same type of capacitor should be added at the source point if the source impedance is not already sufficiently low. The capacitor at the MicroVerter module input terminals reduces both the VIN ripple, and the VDC ripple. Since the line impedance is usually inductive, the capacitor will supply some of the MicroVerter module's input ripple current, thereby reducing the current flowing in the source impedance, and hence the source ripple voltage.

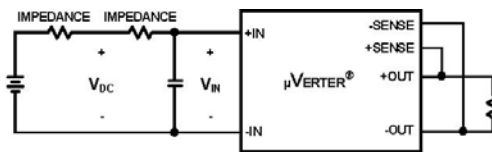


Figure 3 A cap at the converter input has a dramatic effect on the ripple at the source.

The above mentioned capacitors are generally sufficient to reduce the ripple at the MicroVerter module input to less than 100mV p-p. Depending on the relative magnitudes of the source and line impedances at 400kHz, the source ripple may be highly attenuated. For instance, just a few feet of wire connected between the source and the MicroVerter module input may reduce the ripple at the source to a negligibly small p-p magnitude if the source

impedance is small. (A few feet of wire can easily result in  $1\mu\text{H}$  or more of inductance).

For applications where the line impedance is small, the source ripple (VDC ripple) will approach that of the input ( $V_{\text{IN}}$  ripple). In these cases, a small valued inductor can be connected between the VDC and  $V_{\text{IN}}$  points to reduce the VDC ripple to the desired p-p value. The inductor should be used in addition to the capacitor at the input to the MicroVerter module previously described. This is shown in Figure 4.

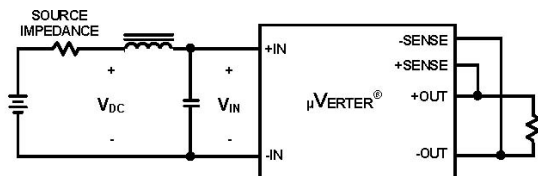


Figure 4 An input choke can be used when the line impedance is small.

Generally, a  $2\mu\text{H}$  choke will be sufficient to reduce the VDC ripple to less than 20mV p-p, assuming 100 milliohm source impedance, and 100 milliohm impedance for the cap at the input of the MicroVerter module.

Attention should be given to the line impedance, since it can play a significant role in determining the ripple at the source, and at the input to the converter. If the line inductance exceeds  $1\mu\text{H}$ , it is recommended that a capacitor be placed at the input of the MicroVerter module as previously described

to prevent the ripple appearing at  $V_{\text{IN}}$  from becoming excessively high, which can result in degraded converter performance or oscillations. Wire, switches, circuit breakers, fuses, and the like will all contribute resistive and more importantly, inductive elements to the impedance of the line. Tables or handbooks, such as F.E. Terman's Radio Engineers' Handbook, McGraw-Hill 1943, may be helpful in determining wire inductances, etc.

## Related Topics

### AP-13 Paralleling with Current Sharing and n+m Redundancy

When paralleling MicroVerter modules, following the recommendations in this note, the result will be much improved performance of paralleled MicroVerter modules, in terms of not only input ripple, but current sharing and output ripple is well. A separate input capacitor, and inductor if necessary, provided for each MicroVerter module, will give best results. The inductor must be connected in the plus leg of the input line to each individual MicroVerter module in order that the - $V_{\text{IN}}$  pins of all the paralleled units may be held at the same potential. In light of this note, it follows that the inductance of the connections between the - $V_{\text{IN}}$  pins of the paralleled MicroVerter modules should be held to a minimum.