Application Notes - DC/DC Converter

■ Circuit Test Drawing

Basic usefully circuit

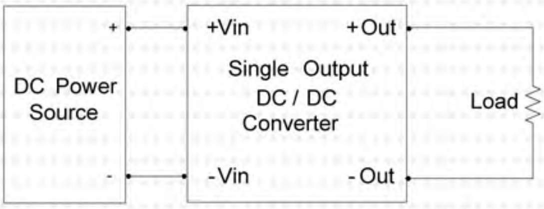


Figure 1

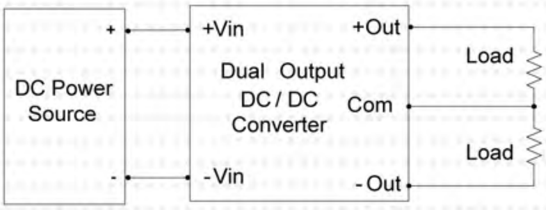


Figure 2

■ General Test Set-Up

Figure 3 shows a general equipment set-up for testing DC/DC converters. Except where otherwise required, the following conditions should be applied:

- Nominal DC input voltage
- +25°C ambient temperature
- Full rated output load

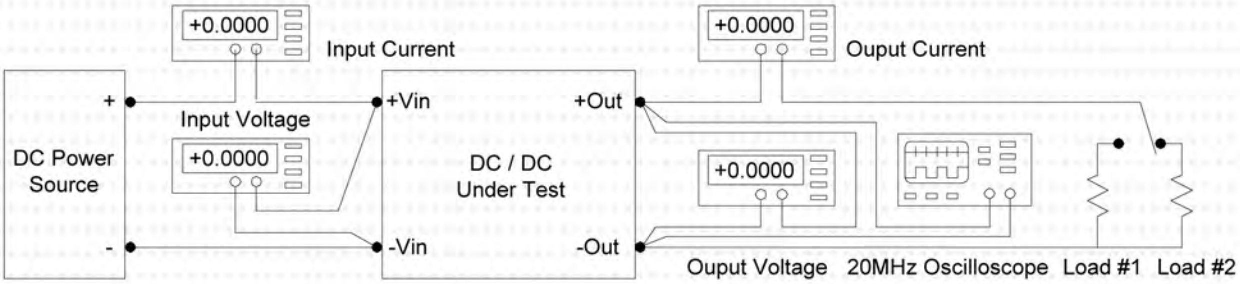


Figure 3

■ Measurements

All connections to the converters should be made with great care, especially to the output pins. Standard four-terminal or Kelvin, measurement practices should always be observed in making DC/DC converters measurements.

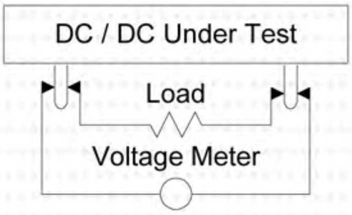


Figure 4

Figure 4 shows a voltage measurement being made from the output terminals of a DC/DC converter by means of separate contacts that do not carry load current. If contacts carrying load current are used for measurement, an erroneous reading of many millivolts can be resulted.

► Output Voltage Accuracy

Make and record the following measurements:

1. Output voltage at nominal input voltage (V_{ON})	Output Voltage Accuracy = $\frac{V_{ON} - V_O}{V_O} \times 100\%$ V_O is output voltage specified in the data sheet.
2. Output voltage accuracy is derived by the formula.	

Example: $V_O = 5.0V$ $V_{ON} = 4.9V$

$$\text{Output Voltage Accuracy} = \frac{4.9V - 5.0V}{5.0V} \times 100\% = -2\%$$

► Line Regulation

- Regulated

Make and record the following measurements:

1. Output voltage at nominal input voltage (V_{ON}).	Line Regulation = $\frac{V_D - V_{ON}}{V_{ON}}$ V_D is maximum output voltage deviation measured.
2. Output voltage at maximum input voltage (V_{OH}).	
3. Output voltage at minimum input voltage (V_{OL}).	
4. Line regulation is derived by the formula.	

Example: $V_{ON} = 11.98V$ $V_D = 12V$

$$\text{Line Regulation} = \frac{12V - 11.98V}{11.98V} \times 100\% = 0.17\%$$

- Unregulated

Make and record the following measurements:

1. Output voltage at nominal input voltage (V_{ON}).	Line Regulation = $\frac{\Delta V_O}{\Delta V_I} = \frac{(V_{ON} - V_{OL}) \div V_{ON}}{(V_{IN} - V_{IL}) \div V_{IN}}$
2. Output voltage at minimum input voltage (V_{OL}).	
3. Line regulation is derived by the formula.	

Example: $V_{IN} = 12V$ $V_{IL} = 10.8V$ $V_{ON} = 14.95V$ $V_{OL} = 13.4V$

$$\text{Line Regulation} = \frac{(14.95V - 13.4V) \div 14.95V \times 100\%}{(12V - 10.8V) \div 12V \times 100\%} = 1.036\%$$

▶ Load Regulation

Make and record the following measurements:

1. Output voltage at full load (V_{OF}).	Load Regulation $= \frac{V_{OM} - V_{OF}}{V_{OF}} \times 100\%$
2. Output voltage at minimum load specified in the data sheet (V_{OM}).	
3. Load regulation is derived by the formula.	

Example: V_{OF}=4.95V V_{OM}=5.0V

$$\text{Load Regulation} = \frac{5.0V - 4.95V}{4.95V} \times 100\% = 1\%$$

▶ Output Voltage Balance (Dual Output)

1.Positive Output voltage measured of nominal input voltage(+Vo).	Output Voltage Balance $= \frac{\lvert +V_O \rvert - \lvert -V_O \rvert}{\frac{\lvert +V_O \rvert + \lvert -V_O \rvert}{2}} \times 100\%$
2.Negative Output voltage measured of nominal input voltage(-Vo).	

Example: +Vo = +12.01V -Vo = -11.99V

$$\left(\frac{|+12.01V_{DC}| - |-11.99V_{DC}|}{\frac{|+12.01V_{DC}| + |-11.99V_{DC}|}{2}} \right) \times 100\% = 0.166\%$$

▶ Efficiency

Make and record the following measurements:

1. Output voltage at nominal input voltage (V_{ON}).	Efficiency $= \frac{P_O}{P_I} = \frac{V_{ON} \times I_O}{V_{IN} \times I_{IN}} \times 100\%$ V_{IN} is nominal input voltage and IO is output current.
2. Input Current at nominal input voltage (I_{IN}).	
3. Output voltage at minimum input voltage (V_{OL})	
4. Efficiency is derived by the formula.	

Example: V_{IN} = 24V I_{IN} = 506mA V_{ON} = 4.98V_{DC} Io=2A

$$\text{Efficiency} = \frac{4.98V \times 2A}{24V \times 506mA} \times 100\% = \frac{9.96W}{12.144W} \times 100\% = 82\%$$

▶ Output Ripple & Noise

This is an AC measurement at the output of a power converter at rated load and +25°C ambient temperature. The Measurement is made in either millivolts RMS or millivolts peak-to-peak. Figure 5 shows the typical voltage waveform.

In the case of DC/DC converters, the output ripple voltage is a series of small pulses with high frequency content and for this reason, it is almost always specified as peak-to-peak rather than RMS value. A 50 millivolts peak-to-peak output ripple from a DC/DC converter can have a very low RMS value—perhaps just 5V – but this type of specification would be of questionable value to the designer who must specify the power supply for his system.

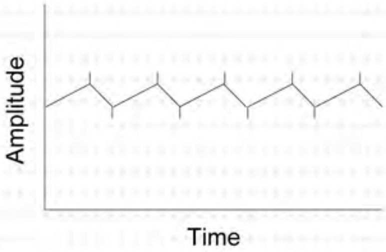


Figure 5

Because of the high frequency content of this ripple, special measurement techniques must be employed so that correct measurements are obtained. First, a 20MHz bandwidth oscilloscope is normally used for the measurementso that all significant harmonics of the ripple spikes are included. The actual ripple voltage measurement must be carefully made in order not to induce error voltages in the test equipment. Therefore, the conventional ground clip on an oscilloscope probe (see Figure 6) should never be used in this type of measurement. This clip, when placed in a field of radiated high frequency energy, acts as an antenna or inductive pickup loop, creating an extraneous voltage that is not part of the output noise of the converter.

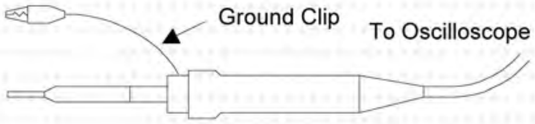


Figure 6

This noise pickup is eliminated as shown in Figure 7 by using a scope probe with an external ground band or ring and pressing this band directly against the output common terminal of the power converter while the tip contacts the voltage output terminal. This makes the shortest possible connection across the output terminals.converter.

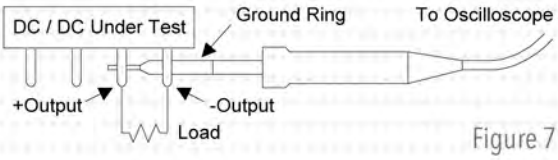


Figure 7

Another method of measuring the output voltage ripple & noise that is specified for many switching power supplies is shown in Figure 8. A 30cm twisted pair of no. 20 AWG copper wire is connected to a 10uF capacitor of proper polarity and voltage rating. The oscilloscope probe ground led should connect right to the ground ring of the probe and be as short as possible. The oscilloscope bandwidth should be at 20MHz and connected to AC ground.

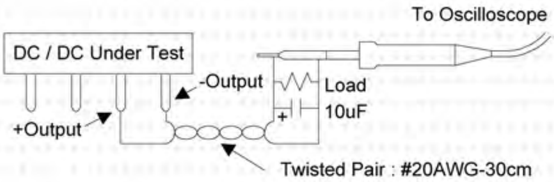


Figure 8

▶ Transient Recovery Time

The time required for return to value of stabilization when a load in a step change cause output voltage of skew.

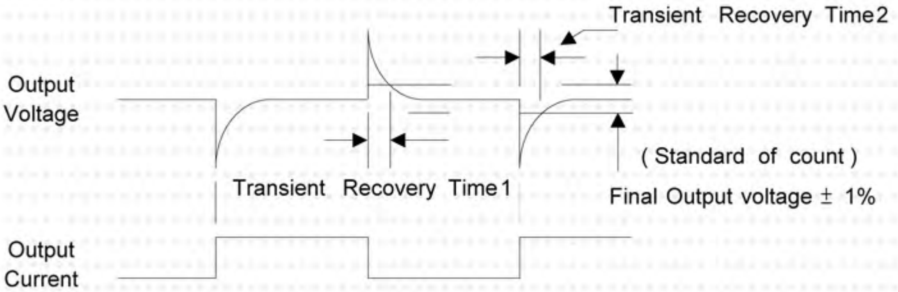


Figure 9

▶ Transient Response Deviation

When a load was change in a very short time, the percentage of transient response amount is in output voltage.

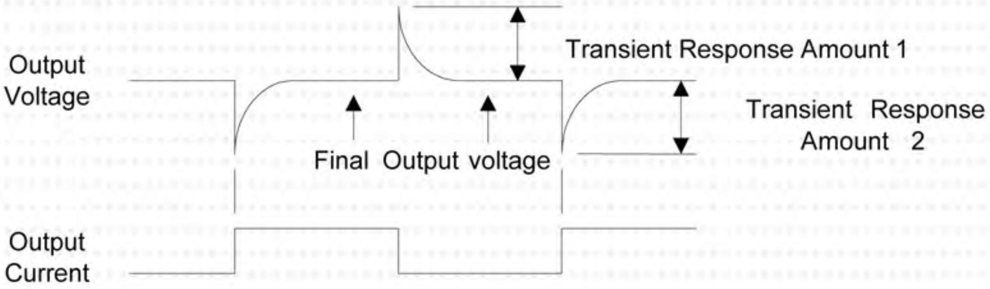


Figure 10

▶ Peak-to-Peak Output Noise Measurement Test

Use a Cout ceramic capacitor. Please refer to capacitor value of every series. Scope measurement should be made by using a BNC socket, measurement bandwidth is 0-20 MHz. Position the load between 50 mm and 75 mm from the DC/DC Converter.

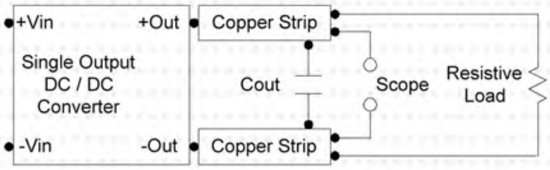


Figure 11

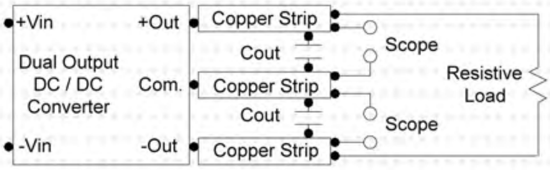


Figure 12

Input Source Impedance

The power module should be connected to a low ac-impedance input source. Highly inductive source impedances can affect the stability of the power module. In applications where power is supplied over long lines and output loading is high, it may be necessary to use a capacitor at the input to ensure startup.

Capacitor mounted close to the power module helps ensure stability of the unit, it is recommended to use a good quality low Equivalent Series Resistance (ESR < 1.0Ωat 100 KHz) capacitor, please refer to capacitor value of every series.

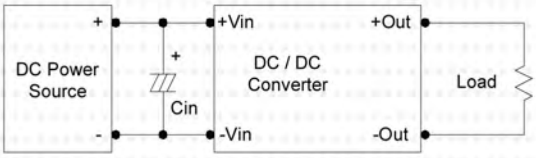


Figure 13

Output Ripple Reduction

A good quality low ESR capacitor placed as close as practicable across the load will give the best ripple and noise performance. To reduce output ripple, it is recommended to use reference of every series capacitors at the output.

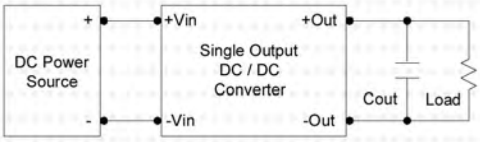


Figure 14

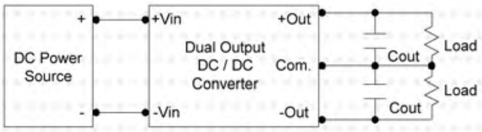


Figure 15

▶ Absolute Maximum Ratings

Exceeding the specified absolute maximum ratings may severely damage the module. These ratings are intended as guidelines for absolute worst case operating conditions and are not to be interpreted as recommended operating condition.

▶ Fusing Considerations

Encapsulated DC/DC module can be used in a wide variety of applications, ranging from simple stand-alone operationto an integrated part of a sophisticated power architecture. To preserve maximum flexibility, internal fusing is not included. However, to achieve maximum safety and system protection, DC inputs should always be fused.

In general, use a slow-blow fuse with 150% to 200% of the maximum input current.

Whether a fast or slow-blow fuse is required depends upon the application. Generally, a slow blow fuse will provide adequate protection and the module's internal circuitry will handle any short period transient faults. A fast blow fuse is recommended for redundant systems to prevent a failed unit from shorting the input bus.

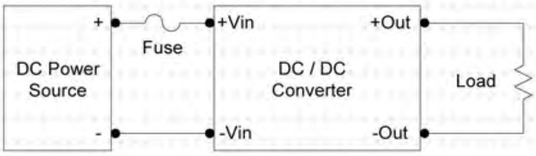


Figure 1

▶ Maximum Operating Temperature

The maximum operating temperature for a power converter is determined by the internal temperature rise of its components. In a DC-DC converter, a small proportion of the input power is not converted to output power, but is dissipated as heat inside the module. The amount of power dissipated depends on the efficiency of the converter, defined as the ratio of useful output power to supplied input power. At an ambient temperature of 71°C the internal temperature of some components may be over 100°C.

The internal temperature of any component must never exceed its maximum operating temperature, and for this reason many DC/DC converters specify derated outputs power at higher operating temperatures. In other cases the power converter is specifically designed with special components and thermal techniques to allow operation at full load to 71°C with no derating.

Whether or not the unit is derated at higher temperatures, it is a good idea to provide additional cooling above 50°C ambient temperature. Is not just to keep a power converter operating within its specified operating area, but to increased reliability.

However, for normal operation the modules should not be run at the maximum allowable temperature, since the Mean Time Between Failures (MTBF) will reduce sharply as temperature increases.

▶ Power Line Transients

Power line transients can cause damage to the DC/DC converter. If voltage transients in a given application can exceed the maximum rated input voltage of a DC/DC converter, it may be necessary to provide external protection devices.

Figure 2 shows transient protection methods commonly used. An DC/DC converter input is protected by a fuse and TVS (or power zener diode). The TVS effectively absorbs and dissipates transient voltages above its breakdown voltage.

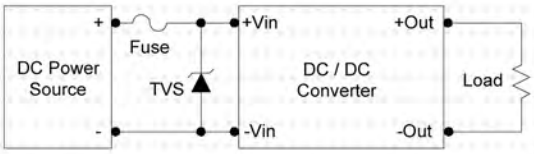


Figure 2

▶ Series Connection

One frequent application of the series connection is in using a dual output power converter as a higher voltage single output converter as shown in Figure 3.

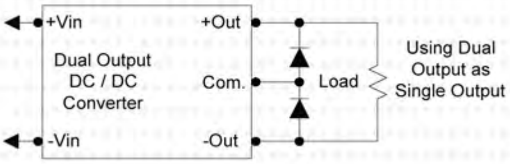


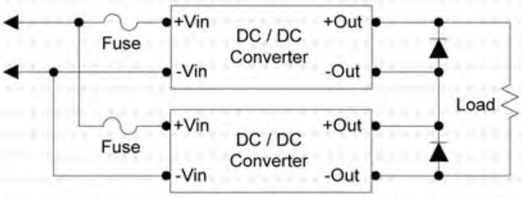
Figure 3

The outputs are already series connected by means of the common output terminal, so it is only necessary to float the common and connect the load directly across positive and negative output terminals as shown. In this manner 24, 30, or 36V outputs can be realized from ±12, ±15, or ±18 dual output power converters respectively.

In general, DC-DC converters can be operated with outputs connected in series. Note there will be an addition of ripple voltage at the outputs since the power converters in general will not have synchronous ripple voltages.

The only other limitation on series connection is that the total output voltage should not exceed the working breakdown voltage of any one of the power converters. This may be substantially less than the dielectric test voltage.

A common practice in the series connection of power converters is to connect reverse biases diodes across the output of each series connected power supply as shown in Figure 4. Diodes placed on the outputs of the modules ensure that on start-up the modules are protected against reverse polarity. This can occur when the modules do not begin delivering power to the load simultaneously.



Series Connection With Reverse Voltage Protection Diode

Figure 4

▶ Parallel Connection

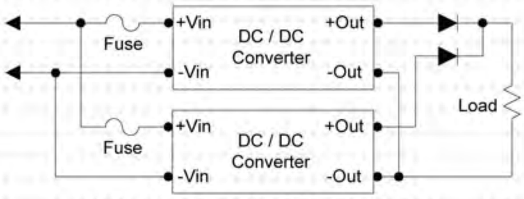
The parallel connection of DC-DC converter outputs is a much more difficult problem than series connection. In fact, as a general rule it should not be done unless the power converters are specifically designed for parallel operation or the manufacturer says it can be done.

The problem with parallel operation it that it is nearly impossible to get equal load sharing between two power converters. First of all, two output voltages from fixed-output DC/DC converters will not be exactly equal. The converter with the larger output voltage will tend to provide the entire load current.

Even if the outputs can be adjusted so that they are precisely equal, a difference in output impedance and also drift with time and temperature will cause the loads to become unbalanced.

▶ Redundancy

A good reason for parallel operation of power converters is in providing power redundancy. In Figure 5, two power converters have their outputs connected in parallel through two diodes. For 100% redundancy each power converter must be capable of supplying the total load.
In this case, it does not matter whether the load current is shared equally, however it is desirable for each output to provide at least part of the load current. A diode should be fitted to the output of each of the paralleled units in order to isolate the modules from the output bus in the event of a failure.



Redundant Parallel Connection With Diode

Figure 5

▶ Maximum Output Power

(1) Definition

The maximum guaranteed output power that the power supply can provide continuously.

(2) Output Power Measuring Circuit

The maximum output power is the maximum output current multiplied by the rated output voltage (Vo x Ao) measured at terminals + and - .

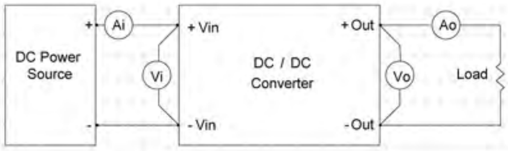


Figure 6

(3) Note

The maximum output power is Vo x Ao. When the output voltage Vo is increased, Ao should be decreased to ensure that the output power does not exceed the maximum. If Vo is decreased then the output current can not be increased to more than the maximum output current value.

For example, if a 5V-power supply has a maximum output current of 2A then the maximum output power will be 10W. If the output voltage is increased at 5.5 volt to use, the allowable maximum current shall be decreased to 1.5A for the output power to remain less than to the maximum of 10W for this power supply (5.5 x 1.5=8.25W). However, if the output voltage is decreased to 4.5V, the output current remains at the maximum of 2A of the output power.

▶ No Load Operation

The problem with no load operation of unregulated DC/DC converter is the output voltage will exceed specified tolerance, maybe +20% or more. In fact, output voltage is undefined when loading below 10% of maximum output current.

Keep 10% loading on the output to ensure the output voltage remains within a specified tolerance. However, to achieve maximum safety, 2% loading is necessary.

▶ Isolation

Isolation：The electrical separation between the input and output of a power converter (see Figure 7).

Normally determined bye transformer characteristics and component spacing, isolation is specified in values of resistance (typically mega ohms) and capacitance (typically pico farads).

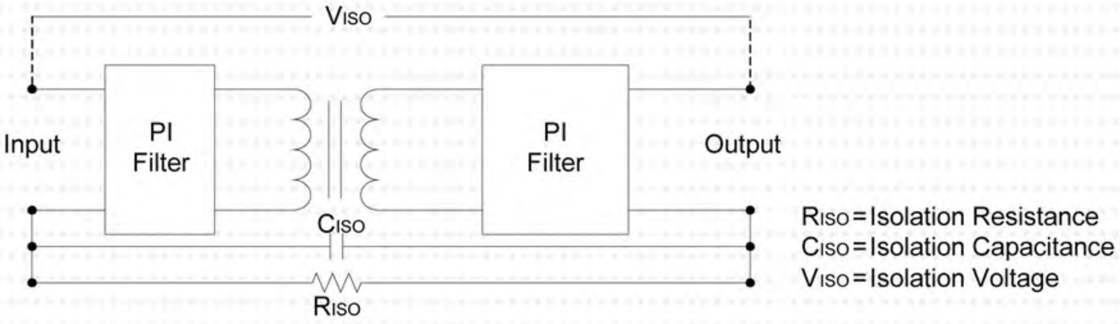


Figure 7

About instruction of measurement point:

(1) Output to Input: Put the test pencil to touch whatever pin of input and whatever pin of output respectively.

(2) Input to Case: Put the test pencil to touch whatever pin of input and case respectively.

(3) Output to Case: Put the test pencil to touch whatever pin of output and case respectively.

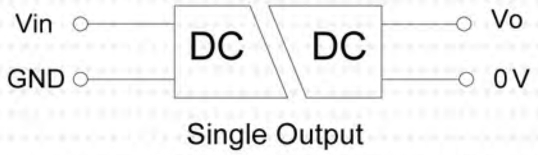


Figure 8

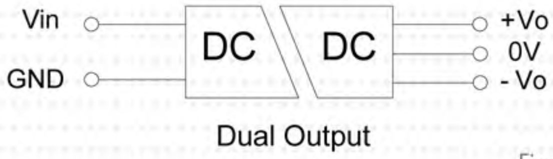


Figure 9

▶ PI Filter

A commonly used filter at the input of a switching supply or DC/DC converter to reduce reflected ripple current. The filter usually consists of two parallel capacitors and a series inductance.

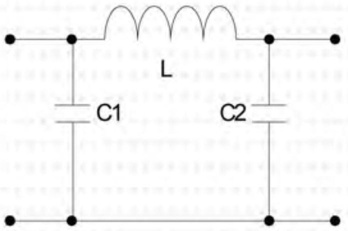


Figure 10