BTCPower™

Application Notes AN01

DC/DC Converter

Table of Content

Introduction

High current density dc/dc converters are becoming popular in the telecommunication and industrial power systems because of low cost, consistent performance and high reliability. These converters provide a modularity to the design of power supply systems. By using dc/dc converters, complex multiple outputs and custom power supplies can be designed and manufactured in a short time to meet demanding market datelines.

However, high-density brick-type dc/dc converters are considered as building blocks only. These converters should be viewed as components, not as complete power supply units. Additional circuitry such as input filters, output filters, EMI /EMC suppressions, and the use of common mode and differential mode chokes are required to build a complete power system.

Thermal management is also an important part of the system design. Proper cooling and transfer of heat by the module is important for maintaining lower operating temperature. The amount of air-flow and the thermal conductivity of the heat sink will determine the thermal performance of these dc/dc converters. The maximum base-plate temperature rating of the converter can be used to estimate the amount of cooling required. The maximum rating of the output power specified by the manufacturer assumes that proper thermal management is enforced to ensure that the maximum base-plate temperature is not exceeded. Therefore,it is important to maintain the base-plate operating temperature as low as possible in a typical application to have some safety margins.

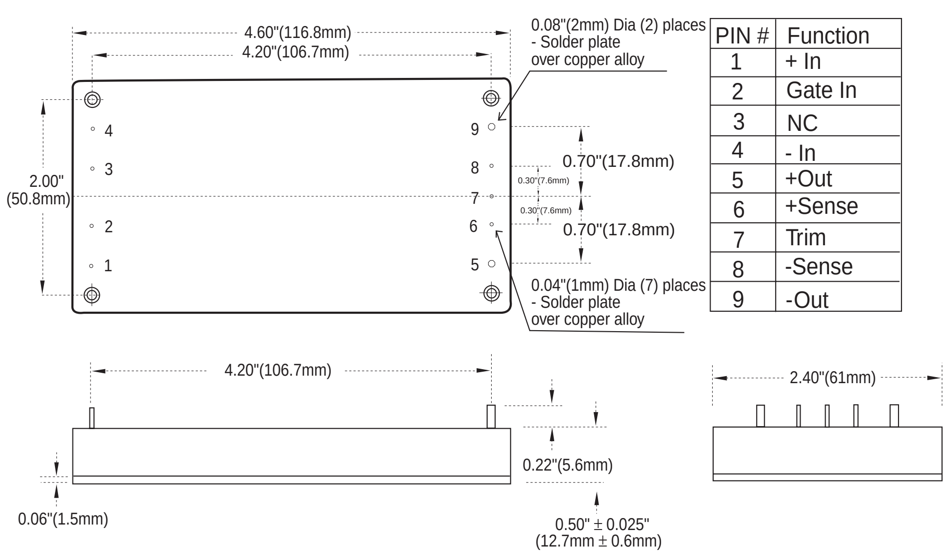
BTCPower's dc/dc converters are available with many built-in features which the end users can configure to achieve the desired functions such as remote digital on/off, remote sensing, and output trimming. The IMT series converters do not have built-in current sharing,however, the current sharing is implemented by the use of external circuits.

The IMT series is also built with protection circuits to ensure that these converters do not blowout when they are misused. These protection circuits consist of over-temperature latched shut down, output over voltage latched shut down, and auto recovery type short circuit and over-current protection. To reset the converter during a latched shutdown, the user needs to re-cycle the input power.

This application note will explain how to use all the features of the IMT series of dc/dc converters, the proper layout and configuration, filtering requirements, and correct methods of measuring the output ripple and noise levels.

Technology

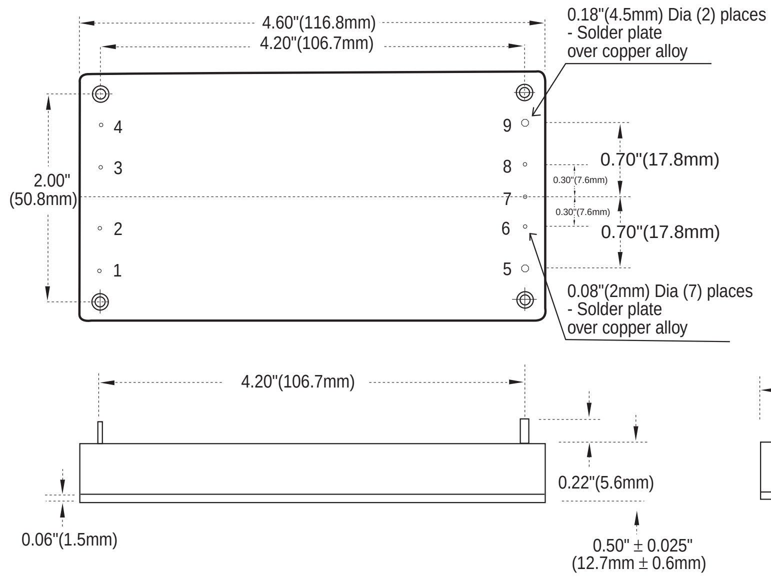
The basic technology used in the IMT series dc/dc converters is a unique flat transformer with a simple push-pull topology. The flat transformer is an ideal technology for products where high output currents is required. Conventional transformer uses a single core with many turns, whereas a flat transformer uses multiple cores with one or minimum number of turns.



PIN #	Function
1	+ In
2	Gate In
3	NC
4	- In
5	+Out
6	+Sense
7	Trim
8	-Sense
9	-Out

Figure 1. IMT-200 mechanical drawing

Broadband Telcom Power, Inc.
250 Briggs Avenue, Costa Mesa, CA 92626 • Tel:714-850-7320 • Fax: 714-850-7321
www.btcpower.com and sales@btcpower.com



PIN #	Function
1	+ In
2	Gate In
3	NC
4	- In
5	+Out
6	+Sense
7	Trim
8	-Sense
9	-Out

Figure 2. IMT-400 mechanical drawing

The use of multiple cores forces equal current sharing through the multiple rectifiers, providing current and heat distributions.

The basic material used for the manufacture of the base-plate consists of Insulated Metal Substrate (IMS). The use of IMS as base-plate material, coupled with the use of parallel equal current sharing rectifiers and multiple transformer cores allows extremely good thermal management of the IMT converters. Under proper thermal management, the maximum internal temperature rise is below 10 °C.

IMS is also used by other dc/dc converter vendors such as Lucent, Astec, etc, however, the use of IMS can cause common mode noise to be coupled to the outputs. Therefore, proper use of by-pass capacitors is necessary for a clean output.

IMT dc/dc Converters

The IMT series of dc/dc converters consists of the full brick 400 watts (IMT400), half brick 200 watts (IMT200), and quarter brick 100 watts (IMT100). The mechanical drawings of IMT200 and IMT400 are shown in Figures 1 and 2. The pin assignments and functions are shown in the mechanical drawings. Photographs of IMT 200 and IMT 400 are shown in Figures 3 and 4.

Figure 3. Photograph of IMT-200

Figure 4. Photograph of IMT-400

General Considerations

Handling

IMT series dc/dc converters are mounted with a UL approved soft epoxy to reduce stress on the internal components that provide a good mechanical integrity and thermal properties. The outer shell is made of fiber glass reinforced ABS material. The outer shell can withstand high temperature variations. The base plate is completely isolated electrically and is made up of aluminum with dielectric layer. This type of base plate is typically called insulated metal substrate (IMS). The IMT converter is therefore very rugged and sturdy.

Nevertheless, the IMT converter should not be mis-handled physically because the aluminum base plate and the input and output pins may be damaged.

Mounting

The typical way of installing the IMT converter is to solder mount it on a PC board (PCB). The mounting holes on the PCB for the converter must be located and aligned with the converter pins to fit properly. After carefully mounting the converter onto the PCB, the pins should be soldered on. When removing the converter from the PCB, care must be taken to ensure that the pins come off easily.

Heat sinks should be assembled onto the dc/dc converter before mounting the converter onto the PCB. If a large heat sink is used to connect to more than one dc/dc converters, make sure that the pins on the converters are aligned accurately.

PCB Layout

A solid copper land pattern should be laid out on both sides of the PCB. See Figure 5. This land pattern will help minimize noise from the converter coupled to other circuits on the PCB. Typically, input and output filter capacitors and chokes are also laid out together at the same time.

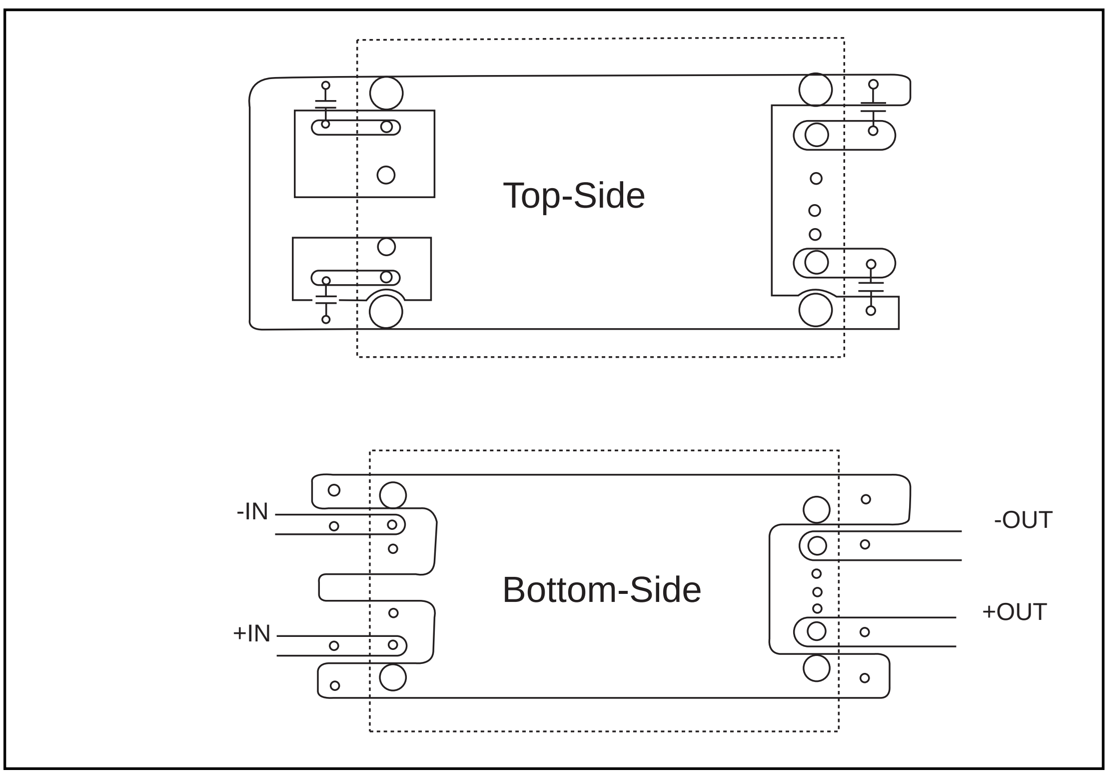


Figure 5. PCB Layout

Broadband Telcom Power, Inc.
250 Briggs Avenue, Costa Mesa, CA 92626 • Tel:714-850-7320 • Fax: 714-850-7321
www.btcpower.com and sales@btcpower.com

Remote Sensing

IMT series of dc/dc converters provide remote sensing so that output voltage regulation is maintained at the load itself, rather than at the output pins. This is achieved by using two sense lines connected from the sense pins of the dc/dc converter to the load which may be located at some distance from the converter. The remote sense can compensate voltage drop of over 0.65v.

These sense lines (one to the load, and one return from the load) will 'sense' the voltage at the load and regulate the dc/dc converter to adjust the output voltage to compensate for the drop in the voltage across the load cables. Remote sense feature is normally used when the load current varies, and hence, the voltage drop is irregular. However, if the load is constant, and the voltage drop is fixed, then, it is recommended that the trim feature be used to compensate for the voltage drop over the load line. This is because trimming is a more efficient way of achieving the voltage compensation.

Please see Figure 6 for connecting remote sense lines to the load.

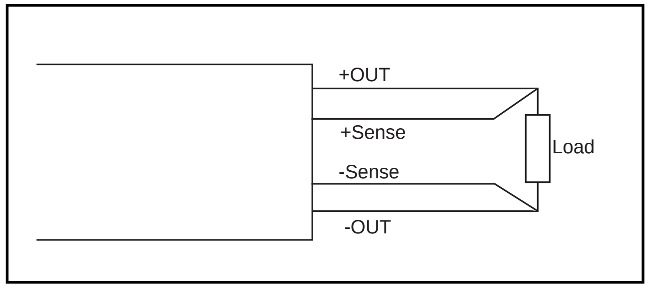


Figure 6. Sense Line Connectivity

The voltage drops between the output pins of dc/dc converter and load is mainly IR in nature. However, when there is substantial inductance between the load cables or circuit traces from the converter to the load, a dynamic L di/dt drop may be significant.

This dynamic L di/dt drop and noise formation can be minimized by connecting a 0.1µF ceramic capacitor in parallel with a 10µF tantalum capacitor at the load. Use of co-axial cables as sense lines is a good method of shielding the sense signal from noise pick up. Twisting the sense cables can also reduce noise pick up. See Figure 7. For different output voltages, please see the capaciator values listed in Table 1.

V_{out}	Power	Ceramic Cap.	Tant. Cap.
2.0	100 watts	3.3µF 10V	330µF 6.3V
3.3	100 watts	1.0µF 10V	220µF 10V
5.0	100 watts	1.0µF 15V	220µF 25V
12	100 watts	0.68µF 50V	100µF 25V
15	100 watts	0.1µF 50V	100µF 35V
2.0	200 watts	3.3µF 10V	470µF 6.3V
3.3	200 watts	2.2µF, 10V	330µF 10V
5.0	200 watts	1.0µF 10V	220µF 15V
12	200 watts	0.68µF 50V	100µF 25V
15	200 watts	0.33µF 50V	100µF 35V
2.0	400 watts	10µF 15V	470µF 6.3V
3.3	400 watts	3.3µF 10V	330µF 10V
5.0	400 watts	1.0µF 15V	220µF 15V
12	400 watts	1.0µF 50V	100µF 25V
15	400 watts	0.68µF 50V	100µF 35V

Table1. Recommended Capacitors for Voltage Out

If the remote sense lines are copper traces on a PCB, it is recommended that the traces be shielded by a ground plane on the other side of the PCB. If noise is coupled into the sense line, the converter may go into oscillation due to its interference on the feedback loop.

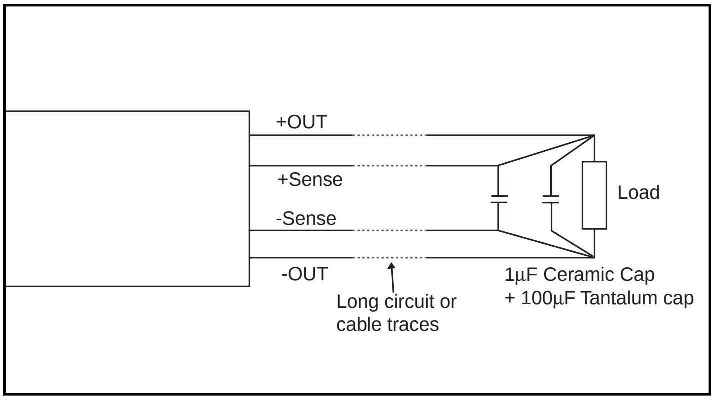


Figure 7. Sense Cable Wiring

The voltage drop (IR) depends on the magnitude of the current (I) and in the case of the dynamic drop, the rate of change of the current (di/dt).

If O-Ring diodes are used in current sharing or N+1 redundancy application, remote sensing can also be used to compensate for the forward voltage drop across the O-Ring diodes. Such a forward drop depends on magnitude of current and the O-Ring diodes junction temperature. Obviously, trimming can also be used to compensate for this drop, if the drop is a known value.

The maximum amount of remote sense voltage compensation is the maximum trim up value, plus the maximum remote sense values as given in the catalog. See Example1. At any rate, the raising of output voltage at the pins as the result of Remote Sensing and Output Trimming MUST NOT exceed the maximum output voltage rating to prevent activating the Over-voltage-Protection.

Example 1: Remote Sense Voltage Compensation

IMT200-300-5. From the specification, the Trimming range is: -6% to +9%. This means that the maximum voltage that can be trimmed up at the output pin is 5v + (5x0.09) = 5 + 0.45v = 5.45v. The specification shows a typical remote sense compensation of 0.1v and a maximum remote sense compensation of 0.15v.

Assuming the converter is not being trimmed, then the maximum sense compensation is 0.15v + 0.45v = 0.60v (0.45v is the maximum trim up value available).

If the converter is trimmed to 5.25v at the output pin, then the maximum remote sense compensation is 0.15v + 0.2v = 0.35v (0.2v is from 0.45v – 0.25v).

If the converter is trimmed down to 4.9v, then the maximum remote sense compensation should be 0.60v.

Broadband Telcom Power, Inc.
250 Briggs Avenue, Costa Mesa, CA 92626 • Tel:714-850-7320 • Fax: 714-850-7321
www.btcpower.com and sales@btcpower.com

Output Voltage Trimming

Output trimming refers to the increase or decrease of the output voltage of a dc/dc converter. It is used for adjusting the output voltage to a different value from those set at the factory. The general range is ±10% of the factory pre-set values. However, the exact trim range values for each model is different, so please refer to the specifications for each model. For example, IMT200-48-12 has a trim range of -8% to +10%, and the IMT-400-48-5 has a trim range of -40% to +10%. These trim ranges are the manufacturer's specifications, but the converters maybe trimmed to a higher range, however, trim ranges outside the manufacturer's specifications are not recommended.

Output trimming can also be used to compensate for the IR drops, if this IR (voltage drop due to cabling) drop value is a known value. For example, if the cable voltage drop from the load to the output pin is known to be 0.2v, then, the output pin can be trimmed up 0.2v to compensate for this drop without the use of extra wiring for the remote sensing. The remote sense can also accomplish this purpose.

Output Trimming: Power and Current specification.

When performing the trimming of the IMT converters, the maximum power and current specifications must not be exceeded. That is, when output voltage is trimmed up, the maximum current specification must be derated to meet the maximum output power specification. When the voltage is trimmed up, the efficiency of the converter will improve and the output ripple as a percentage of the output voltage will decrease.

On the other hand, if the output voltage is trimmed down, the maximum current can remain the same as recommended in the specification. The efficiency of the converter will be lowered, and the output ripple will be higher as a percentage of the output voltage.

When performing trimming, the first step is to estimate the voltage drop across the connection between the load and the output pins of the dc/dc converter. This is simply done by multiplying the resistance of the cable by the expected output current flowing through these cables. Note that both length (the +positive output pin cable and the length of the return cables from the load to the -negative of the output pin) must be taken into account.

Example 2: Output Voltage Trimming Calculation

The dc/dc output is connected to the load using a pair of 12 inches of AWG #12 wire. It carries 50 amp. From the AWG cable chart (Table 2), the voltage drop per 100ft of round trip cable run is 0.324 ohms/100 ft.

Voltage Drop = 3.24/100 x 50 Amp = 162mV.

AWG	Feet/ohm	ohms/100ft	Ampacity*	mm	M/ohm	ohms/100M
10	490.2	.204	30	2.588	149.5	.669
12	308.7	.324	20	2.053	94.1	1.06
14	193.8	.516	15	1.628	59.1	1.69
16	122.3	.818	10	1.291	37.3	2.68

These Ohms/Distance figures are for a round trip circuit.
Specifications are for copper wire at 77 degrees Fahrenheit or 25 degrees Ceisius.

Table 2: Copper Wire Voltage Drop

Example 3: Output Voltage Trimming Calculation

The dc/dc output pins of the circuit board power plane has lengths of 2 cm each, one for +OUT and one for return. The current is 40 Amps. The copper trace is 4 oz per square feet (Thickness = 140 micro-meter).
The maximum voltage drop must be less than 1%.
Resistivity of Copper is 17.5 micro-ohms/mm.
Voltage drop = I x 2 x (resistivity) x 20 / (0.14) x width.
Minimum Width = 40Amp/ 50mV x 2 x 17.5 micro-ohm/mm x 20 /0.14 micro meter = 4 mm.

Trim up and Trim Down

The trimming schematics and the resistor values are shown in Figure 8 and Table 3 respectively . To trim up the output voltage, a trimming resistor is connected to -S (pin 8) and the T (pin 7) . Note that the trim resistor is connected to the sense line, and not to the load itself or the load line.

To trim DOWN the voltage, a suitable resistor is connected between T (pin 7) and +S (pin 6).Figure 9 and Table 4 show the trimming circuit and the resistor values.

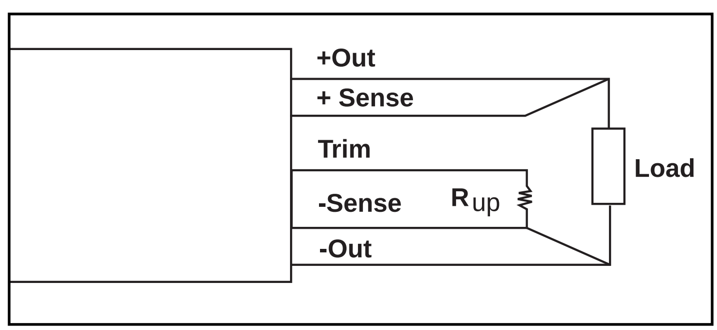


Figure 8. Trim up Circuit

	V nom 2.1V 3	V nom 3V	V nom 5V	V nom 10V	V nom 12V	V nom 15V	V nom 24V
+1%	21.4KΩ	12.2KΩ	5.61KΩ	33.4KΩ	50.9KΩ	78.4KΩ	125.5KΩ
+2%	9.51KΩ	5.41KΩ	2.5KΩ	14.9KΩ	22.6KΩ	34.8KΩ	55.7KΩ
+3%	5.55KΩ	3.15KΩ	1.45KΩ	8.70KΩ	13.2KΩ	20.3KΩ	32.5KΩ
+4%	3.56KΩ	2.03KΩ	936Ω	5.59KΩ	8.50KΩ	13.0KΩ	20.9KΩ
+5%	2.37KΩ	1.35KΩ	623Ω	3.72KΩ	5.66KΩ	8.71KΩ	13.9KΩ
+6%	1.58KΩ	920Ω	415Ω	2.48KΩ	3.77KΩ	5.81KΩ	9.30KΩ
+7%	1.02KΩ	580Ω	267Ω	1.60KΩ	2.42KΩ	3.73KΩ	5.97KΩ
+8%	595Ω	338Ω	156Ω	932Ω	1.41KΩ	2.17KΩ	3.48KΩ
+9%	264Ω	150Ω	69Ω	414Ω	629Ω	968Ω	1.55KΩ
+10%	0.0Ω	0.0Ω	0.0Ω	0.0Ω	0.0Ω	0.0Ω	0.0Ω

Table3. Trimming Up Resistor Values

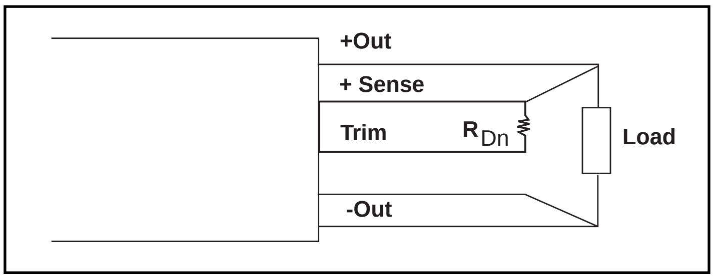


Figure 9. Trim Down Circuit

Model	V nom 2.1V	V nom 3.3V	V nom 5V	V nom 10V	V nom 12V	V nom 15V	V nom 24V
-1%	26.4KΩ	61.7KΩ	28.4KΩ	169.8KΩ	258.0KΩ	397.1KΩ	635.4KΩ
-2%	11.6KΩ	29.8KΩ	13.7KΩ	82.0KΩ	124.5KΩ	191.7KΩ	306.7KΩ
-3%	6.78KΩ	19.1KΩ	8.82KΩ	52.7KΩ	80.1KΩ	123.2KΩ	197.0KΩ
-4%	4.36KΩ	13.8KΩ	6.37KΩ	38.0KΩ	57.8KΩ	89.0KΩ	142.4KΩ
-5%	2.90KΩ	10.6KΩ	4.93KΩ	29.3KΩ	44.5KΩ	68.4KΩ	109.5KΩ
-6%	1.93KΩ	8.51KΩ	3.92KΩ	23.4KΩ	35.6KΩ	54.7KΩ	87.6KΩ
-7%	1.24KΩ	6.99KΩ	3.22KΩ	19.2KΩ	29.2KΩ	45.0KΩ	72.0KΩ
-8%	726Ω	5.85KΩ	2.70KΩ	16.1KΩ	24.4KΩ	37.6KΩ	60.2KΩ
-9%	323Ω	4.96KΩ	2.28KΩ	13.7KΩ	20.7KΩ	31.9KΩ	51.1KΩ
-10%	0.0Ω	4.25KΩ	1.96KΩ	11.7KΩ	17.8KΩ	27.4KΩ	43.8KΩ
-11%	-	3.67KΩ	1.69KΩ	10.1KΩ	15.4KΩ	23.6KΩ	37.8KΩ
-12%	-	3.19KΩ	1.47KΩ	8.78KΩ	13.3KΩ	20.5KΩ	32.8KΩ
-13%	-	2.78KΩ	1.28KΩ	7.65KΩ	11.6KΩ	17.9KΩ	28.6KΩ
-14%	-	2.43KΩ	1.12KΩ	6.69KΩ	10.2KΩ	15.6KΩ	25.0KΩ
-15%	-	2.12KΩ	980Ω	5.85KΩ	8.9KΩ	13.7KΩ	22.0KΩ
-16%	-	1.86KΩ	858Ω	5.12KΩ	7.78KΩ	12.0KΩ	19.1KΩ
-17%	-	1.62KΩ	749Ω	4.47KΩ	6.8KΩ	10.4KΩ	16.7KΩ
-18%	-	1.41KΩ	653Ω	3.9KΩ	5.93KΩ	9.12KΩ	14.6KΩ
-19%	-	1.23KΩ	567Ω	3.39KΩ	5.15KΩ	7.92KΩ	12.7KΩ
-20%	-	1.06KΩ	490Ω	2.92KΩ	4.44KΩ	6.84KΩ	11.0KΩ
-21%	-	911Ω	420Ω	2.51KΩ	3.81KΩ	5.88KΩ	9.36KΩ
-22%	-	774Ω	356Ω	2.13KΩ	3.23KΩ	4.97KΩ	7.96KΩ
-23%	-	648Ω	298Ω	1.78KΩ	2.70KΩ	4.16KΩ	6.66KΩ
-24%	-	532Ω	245Ω	1.46KΩ	2.22KΩ	3.42KΩ	5.47KΩ
-25%	-	425Ω	196Ω	1.17KΩ	1.78KΩ	2.74KΩ	4.39KΩ
-26%	-	327Ω	151Ω	901Ω	1.37KΩ	2.10KΩ	3.37KΩ
-27%	-	236Ω	109Ω	650Ω	988Ω	1.52KΩ	2.43KΩ
-28%	-	152Ω	70Ω	418Ω	636Ω	978Ω	1.56KΩ
-29%	-	73Ω	34Ω	202Ω	307Ω	472Ω	755Ω
-30%	-	0.0Ω	0.0Ω	0.0Ω	0.0Ω	0.0Ω	0.0Ω

Table 4. Trimming Down Resistor Values

Broadband Telcom Power, Inc.
250 Briggs Avenue, Costa Mesa, CA 92626 • Tel:714-850-7320 • Fax: 714-850-7321
www.btcpower.com and sales@btcpower.com
Jan. 2000
Rev. 1.0

Ripple and Noise

Ripple is the output voltage fluctuation associated with the switching of the converter. Each switching transition pumps energy to the output, which causes it to rise a little. The typical switching frequency used in IMT converter is 250 to 350KHz. Therefore, the output noise frequency is in the 500KHz to 700KHz range. Typical value of the ripple is 1% to 2% of output. Noise on the other hand, are higher frequency components, commonly known as 'spikes'. Reduction of these 'spikes' noise can be achieved by adding a 1µF ceramic chip capacitor and a 100µF tantalum capacitor in parallel to the +OUT and -OUT near the load. See Figure 10.

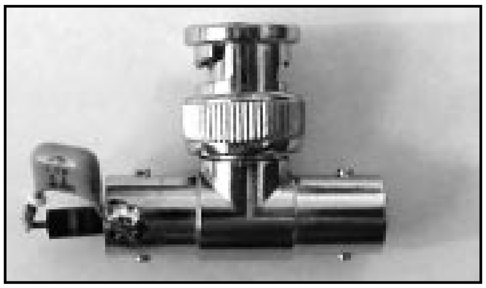


Figure 10.Capacitor in Parallel Connection

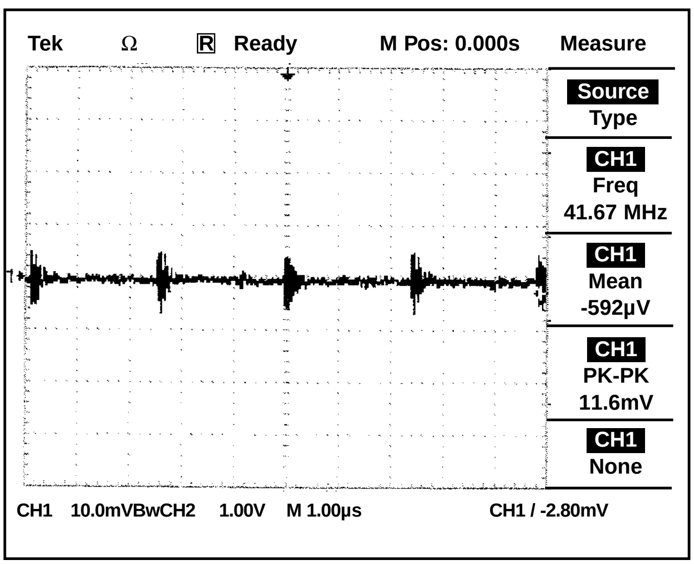


Figure 11. Ripple and Noise Chart

Measuring Output Noise and Ripple

Measuring output noise and ripple requires a basic understanding of the high frequency nature of noise. Very often, 'noise' (as commonly measured) is actually the vector sum of common and differential mode noise.

Common mode noise is common to both outputs (i.e +OUT and -OUT) with respect to chassis or earth ground. Differential mode noise is found at one output with respect to the other.

While the system load can be affected by differential mode noise, it is seldom affected by common mode noise. The common mode noise is often only created in the process of measuring the differential mode noise.

Noise can be measured as root mean square (RMS) or peak to peak. Low frequency noise with a low peak to average ratio is often measured as RMS. High frequency spike noise is measured more accurately with an oscilloscope as peak to peak noise (Figure 11).

Accurate measurement of output noise and ripple requires special attention to equipment used, measuring probes and the understanding of noises. The dc/dc converter switches large amount of output power when compared to the amplitude of the noise being measured. This means that even a few inches of open ground wire in the oscilloscope probe may pick up a fraction of a volt of noise if these probes are not properly connected to the measurement point.

The preferred test to measure noise and ripple includes a custom probe made from a length of RG58A/U coaxial cable. It is connected to the oscilloscope with a BNC 'T' connector, which is terminated with a 47 W carbon composition resistor in series with a 0.68µF Z5U capacitor. The other end of the coaxial is left bare. See Figure 12.

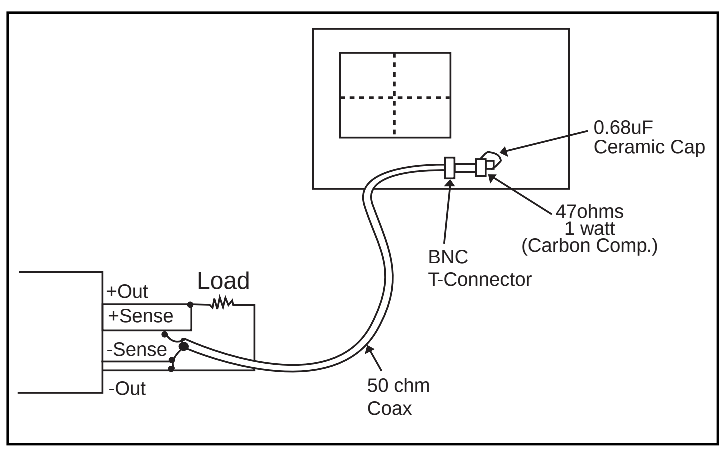


Figure12. Set up for Measuring Noise and Ripple

Measure noise as closely as possible to the converter's output terminals to reduce noise pick up. If an oscilloscope probe must be used, it must be set up for high frequency measurements. The greatest source of error is usually the unshielded portion of the oscilloscope probe. Voltage errors induced by magnetic radiation in the loop can easily suppress the actual values. To reduce measurement errors, keep unshielded leads as short as possible.

To prepare the probe for high frequency measurement, first remove the clip-on ground wire and the probe body fishhook adapter. Then attach a special tip and ground lead assembly as shown in Figure 13.

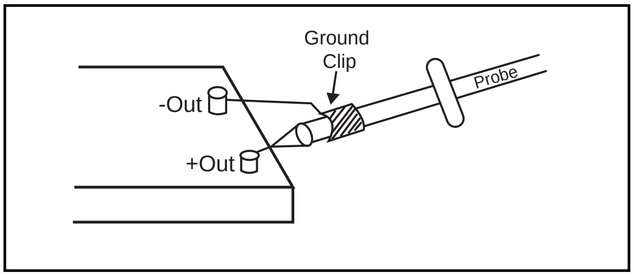


Figure 13. High Frequency Measurement Set Up.

To determine the presence of common mode noise, connect both the tip and the ground lead of the oscilloscope to the -OUT pin. The appearance of waveform on the screen suggests the presence of common mode noise. Such noise may be eliminated or reduced as suggested below:

1) Wrap the oscilloscope probe lead several times around a large diameter Nickel Zinc ferrite toroid (permeability about 1600). This will act as a balun or common mode inductor. It increases common mode impedance without significantly increasing differential mode impedance.
2) Isolate the oscilloscope power source from the line voltage with an isolation transformer.
3) Wrap the power source AC line cord several times around a large diameter nickel zinc ferrite toroid. This will also reduce the common mode current.
4) Do not use the ground lead clipped to most common oscilloscope probes. The loop of wire itself will pick up the high frequency radiated noise and will give erroneous readings.

Measuring Equipment Set up

The power supply to the converter should be mounted about 1" away from the ground shield (or ground plane) which consist of a aluminium or copper sheet. The dimension of the aluminium or copper sheet should be at least as large as the power supply itself. If the power supply is provided with a 'L' bracket, this can be served as the 'ground' plane. Chassis grounding points on the PCB where the converters is mounted, including the 'green wire' terminal for the line input ground lead, should be electrically connected to this shield with a short conductor no more than 2" long. The ground plane should be electrically connected to the conduit or the ground of a 3 prong safety plug.

The set up above is very important to ensure that the noise from the power supply itself does not interfere with the measurement.

Measuring of the noise and ripple is made with the output return connected to the ground plane. If the power supply has more than one return, all the returns should be connected to the ground plane.

Measurement Procedure

A 12" of twisted #16AWG wire with a 47µF capacitor at an appropriate voltage rating and polarity is conencted to an output terminal and return. The noise measurement is taken across the capacitor with a 50 Mhz or greater bandwidth oscilloscope. See Figure 14. The ground lead should be as short as possible, preferrably the type which clips onto the barrel of the probe at one end of the probe body.

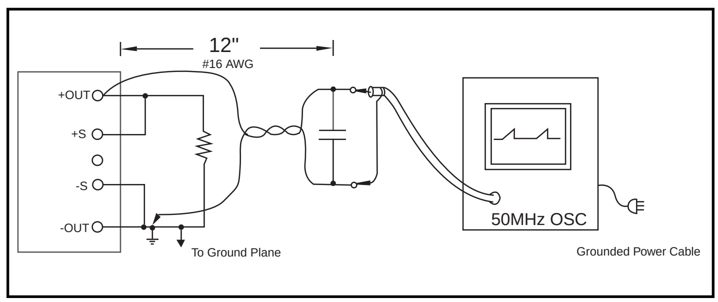


Figure14. Noise Measurement Procedure

Connecting the dc/dc converter

Set up the dc/dc converter as shown in Figure 15.

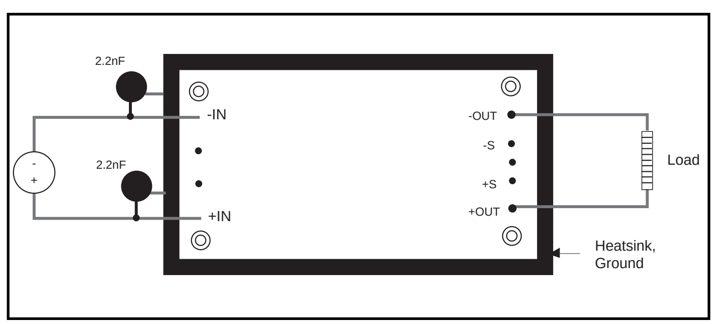


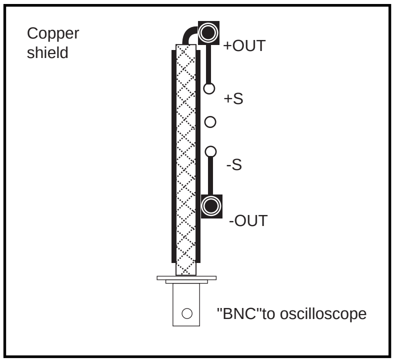
Figure15. Converter Set Up

Broadband Telcom Power, Inc.
250 Briggs Avenue, Costa Mesa, CA 92626 • Tel:714-850-7320 • Fax: 714-850-7321
www.btcpower.com and sales@btcpower.com
Jan. 2000
Rev. 1.0

Two 2.2nF / 250 Vac 'Y' capacitor are connected between each of the inputs (-IN and +IN) to the base plate. The base plate as well as the attached heat sink should have a solid connection to the ground plane. The purpose of the Y-caps is to provide a balanced low impedence path to ground for the common mode noise.

BTCPower has a specially designed fixture for measuring these noise and ripple. This is shown in Figure 16.

Picture16. Special Fixture for Measuring Noise Ripple



This fixture consist of a coaxial like cable with a #16AWG wire inside a cylindrical copper shield. The #16 wire is connected to the +OUT and the copper shield is connected to the -OUT. A 'BNC' connector is used to connect the coaxial cable to the oscilloscope. With this arrangement, minimum loop is obtained and accurate measurements can be achieved. Note that a 47µF capacitor still needs to be connected across the -OUT and +OUT pins.

BTCPower's evaluation boards have the above fixture installed to facilitate easy measurements of the output noise and ripple. Please call the factory to obtain these boards. These board can also be used to evaluate the performance of IMT converters. See Figure17 for Evaluation Boards.

Figure 17. BTC Evaluation Boards

Measuring Noise and Ripple using BTCPower's Evaluation Board.

Obtain a 1:1 coaxial cable with a female BNC connector at each end. A ceramic capacitor of 0.68uF connected in series with the 50 Ohms resister is installed at the BNC located at the oscilloscope end of the coaxial cable. Please see Figure18.

Figure 18. Special Coaxial Cable

The purpose of the capacitor is to block the DC power from dissipating in the resistor. If the DC voltage being measured is less than 5 volts and a 1 Watt carbon composition resistor is used, the capacitor may not be needed. In this case, just a 50 ohm resistor is connected to reduce power dissipation caused by the DC component.

In addition, there is potential for a ground loop to be formed from AC power ground connecting to Oscilloscope probe ground. To check this problem, connect the probe tip and its ground to the -OUT of the dc/dc converter. If there are signals generated on the scope, then the common mode noise due to this ground loop exists. In such a case, an isolation transformer is needed for the oscilloscope. A good isolation transformer must have the primary and secondary on separate bobbin, with ground shield between them.

Alternatively, use a differential probe such as the Tektronix 5200 for accurate measurements.

Remote ON/OFF or Enable

The Remote ON/OFF pin (pin 2) is also called the enable/disable pin or gate pin. This pin is very sensitive to radiated noise, and if not connected properly may cause the converter to intermittenly turn off and on again.

This input pin is used to shut down the converter without disconnecting the DC input power. This is useful in turning the output bus off and on again without discharging the input filter capacitors.

A current sink of 0.5mA at 0.8 volt at GATE-IN (pin 2) with respect to -IN (pin 4) would disable the converter. See Figure19.

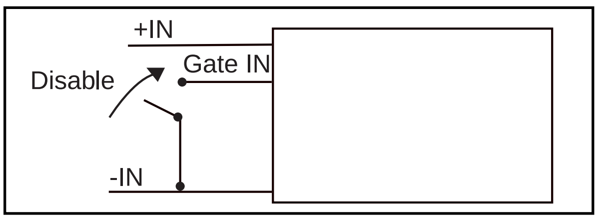


Figure 19. Position to Disable the Converter

Note that raising the GATE-IN pins voltage significantly above -IN (e.g. a +10 volts above –IN) may damage the converter.

The Gate In (pin 2) is internally pulled up with a 10K-ohm resistor to + 5 volt above -IN, and is very sensitive to both radiated and conducted noise levels. The converter is defaulted ENABLED. To minimize noise coupled to the Gate-In pin, it is highly recommended that a Zener diode and a pull up resistor is connected from this pin to the +IN pin (pin 1). See Figure 20. An external pull up of 10K-ohm for 48 volt Input and 100K-ohm for 300 volt input converter clamped by a 6.8 volts Zener may be used as shown.

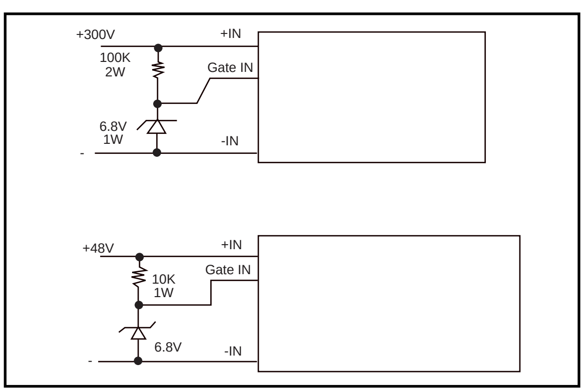


Figure 20. Zener Diode Connection for Noise Reduction

The gate-In pin is used for remote by turning on or turning off the converter, a 0.1µF, 50V ceramic capacitor connected between the Gate-In (pin 2) and -In (pin 4) is highly recommended (Figure 21). Also, a coaxial cable or a twisted pair is recommended for connecting to the Gate-In pins and the -IN pin.

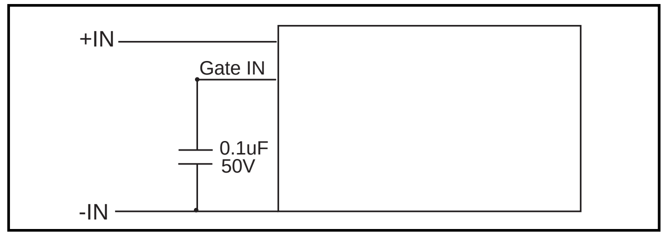


Figure 21. Capacitor Connection for Remote On/Off

In addition, the traces nearby should be sufficiently separated. A recommended spacing of 5 mm from neighboring traces can guard against DC leakage coupled to this pin. This DC leakage can cause the converter to be intermittently disabled.

CAUTION: GATE-IN and -IN pins are at a voltage potential significantly above or below "Ground" in general application. Accidental shorting of this pin to 'ground' will destroy the converter. The voltage potential of the Gate-In pin is referenced to –IN (Pin 4).

If an isolated TTL input control or if controls from the Output side is desired, an opto-coupler can be used. In this case, the opto-coupler separates the TTL ground (or the output ground) from the -IN. Note that a TTL high of +2.0 volts disables the converter. See Figure 22.

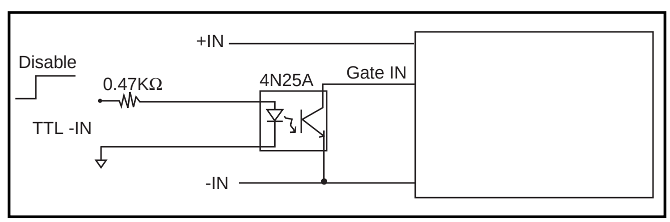


Figure 22. TTL High Circuit to Disable Converter

If a TTL logic low is required to disable the converter, then the circuit shown in Figure 23 can be used.

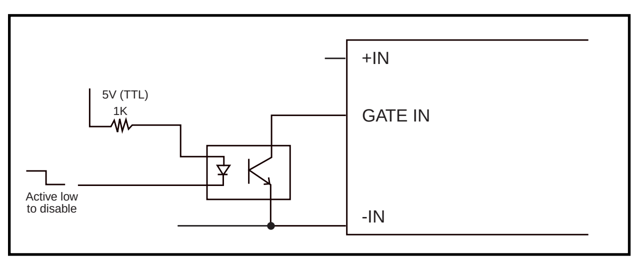


Figure 23. TTL Low Circuit to Disable Converter

Broadband Telcom Power, Inc.
250 Briggs Avenue, Costa Mesa, CA 92626 • Tel:714-850-7320 • Fax: 714-850-7321
www.btcpower.com and sales@btcpower.com

Jan. 2000
Rev. 1.0

Input Ripple Noise and Filtering

The large input supply current to the dc/dc converter causes a rapidly rising current pulse load. Even though there are various by-pass capacitors within the module to buffer such in-rush current pulse, there still will be appreciable amount of current ripple at the input pins.

The input voltage source generally has impedance termed as source ESR. Together with the line impedance denoted here as Line ESR, the ripple current forms a ripple voltage across the input pins as shown in Figure 24.

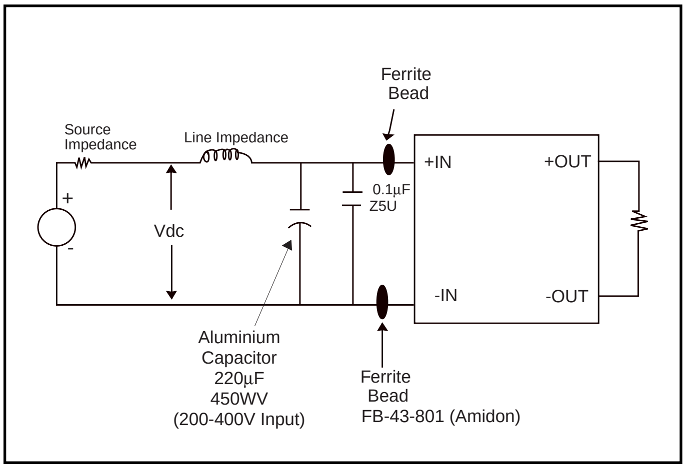


Figure 24. Use of Capacitor and Ferrite Bead to Reduced Current Ripple/EMI

Such ripple current coupled with the line length may become a source of electromagnetic Inteference (EMI). Figure 24 shows the use of a ceramic capacitor and ferrite bead to reduce such potential problem, and an electrolytic aluminum capacitor to buffer transient load response. The dc/dc converters are not considered as complete power supply units. Proper input filtering must be performed to satisfy the electromagnetic compatibility (EMC) requirements. The dc/dc converter switches large amount of energy and generates a significant amount of high frequency noise.

A recommended schematic of the filter circuit is shown in Figure 25 and the component values are listed in Table 5.

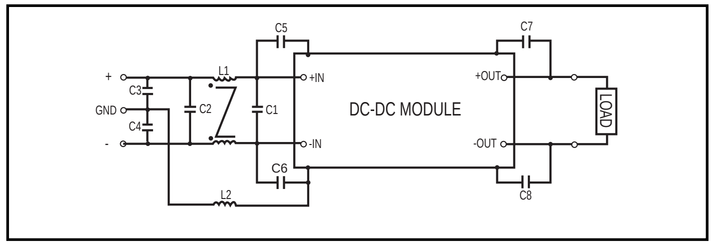


Figure 25. IMT 200 Series Input Filter

Item	Component Value									
	L1	L2	C1	C2	C3	C4	C5	C6	C7	C8
IMT200-48-3.3	3.2mH	500µH	470µF 100V	105pF	471pF	471pF	332pF	332pF	103pF	103pF
IMT200-48-5	3.2mH	500µH	470µF 100V	105pF	471pF	471pF	332pF	332pF	103pF	103pF
IMT200-48-12	3.2mH	500µH	470µF 100V	105pF	471pF	471pF	332pF	332pF	103pF	103pF
IMT200-300-3.3	9.5mH	500µH	47µF 450V	105pF	102pF	102pF	472pF	472pF	103pF	103pF
IMT200-300-5	9.5mH	500µH	47µF 450V	105pF	102pF	102pF	472pF	472pF	103pF	103pF
IMT200-300-12	9.5mH	500µH	47µF 450V	105pF	102pF	102pF	472pF	472pF	103pF	103pF
IMT200-300-15	9.5mH	500µH	47µF 450V	105pF	102pF	102pF	472pF	472pF	103pF	103pF
IMT210-300-2.1	9.5mH	500µH	47µF 450V	105pF	102pF	102pF	472pF	472pF	103pF	103pF

L1 = Common Mode Choke
L2 = Differential Mode Choke
C1 = Electrolytic Capacitor
C2 = X2, MP Capacitor
C3 = Y1, Disc Ceramic Capacitor
C4 = Y1, Disc Ceramic Capacitor
C5 = Y2, Disc Ceramic Capacitor
C6 = Y2, Disc Ceramic Capacitor
C7 = Y2, Disc Ceramic Capacitor
C8 = Y2, Disc Ceramic Capacitor

Table 5. Component Values

The critical decoupling capacitors are those four capacitors that connect to the base plate, two each at the input pins and output pins.

Since IMT converters do not have a base plate pin, the only way to connect the decoupling capacitors is by connecting through the four mounting holes. Note that the mounting holes are threaded with M3 metric screw thread, and a copper trace or sheets can be attached to the mounting screws to provide the contacts. Please see Figure 26.

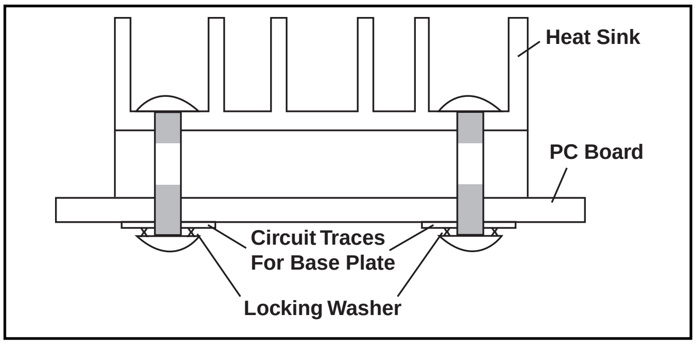


Figure 26. De-coupling Capacitor Connection

Near Field Noise and Layout Radiated Noise.

Within 0.5 inch from the perimeter of the converter, there are strong magnetic and static fields. Circuit traces should not pass underneath the module when laying out the PCB. This should be strongly observed if there are extra sensitive signals such as analog input or high impedance signal traces.

Copper shield (PN:9050-5001) may be needed to wrap around the module and connect to the base-plate. See Figure 27.

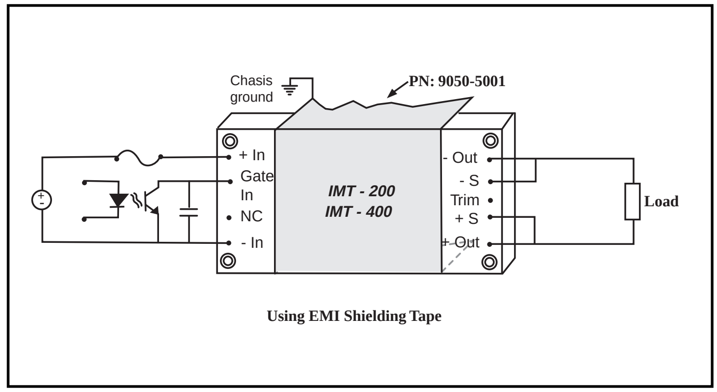


Figure 27. EMI Shielding

As explained earlier, since there is no base-plate pin, the only way to connect the copper shield sheet to the base plate is through one of the mounting holes. This can be achieved by attaching one end of the copper sheet to the mounting screws as shown in Figure 28.

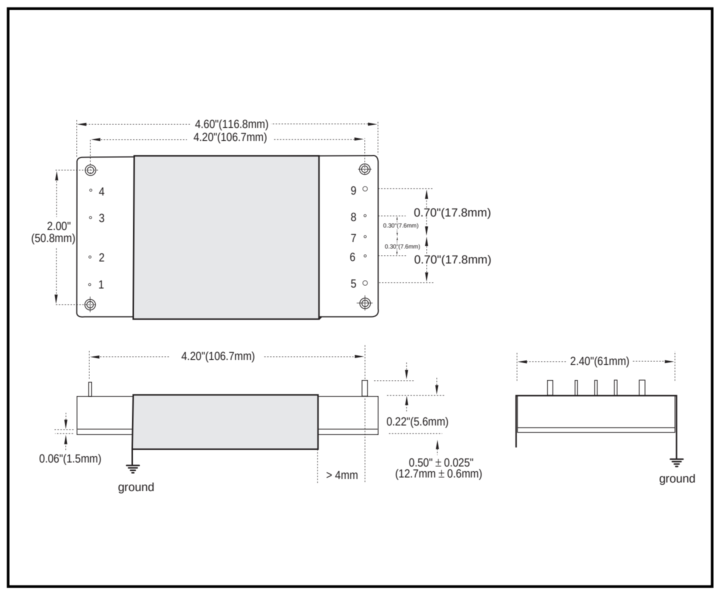


Figure 28. Copper Sheet Connection

Thermal Management

The IMT series dc/dc converters have very low temperature increase above the base plate operating temperature because of the even thermal loading. There are no ‘hot spots’ inside these converters due to the use of flat transformers. However, excess heat still needs to be removed from the converter base plate.This is achieved by means of heat sinks and the use of forced air-cooling.

The most common method of dissipating the heat from the converter is to attach a suitable heat sink. To select the suitable heat sink, the following guidelines may be used:

1) Estimate the thermal resistance between the base plate and the heat sink. If thermal pad or thermal grease is used, a 0.2 °C/watt is a safe number.
2) The thermal resistance of heat sink to air is given by the fllowing equation:

$$Sa = ([Tb-Ta]/P_{diss}) - Bs$$

Where,

Ta	=	worst case operating ambient temperature
Bs	=	0.2 °C/watt
P_{diss}	=	Power dissipation of the converter calculated from the efficiency of the converter
Tb	=	maximum base plate temperature

When attaching heat sink to the module, heat sink compound may be use. The torquing sequence is to start with one screw, go to the diagonal screw, and then tighten the remaining screws. All the four screws may be first hand tightened, and then apply the final torque per specification.

The thermal conductivity of heat sink to air improves significantly even if there is just a 100 linear feet per minute of air flowing through the heat sink.
Below are the thermal characteristics of BTC heat sink for the module:

Table 6. Forced Air Convection of BTC Module Heat Sink.

Air Flow	Thermal Resistance, Base Plate to Air
Free Air	5.0 °C/W
200 LFM	2.7 °C/W
400 LFM	1.7 °C/W
600 LFM	1.4 °C/W
800 LFM	1.2 °C/W

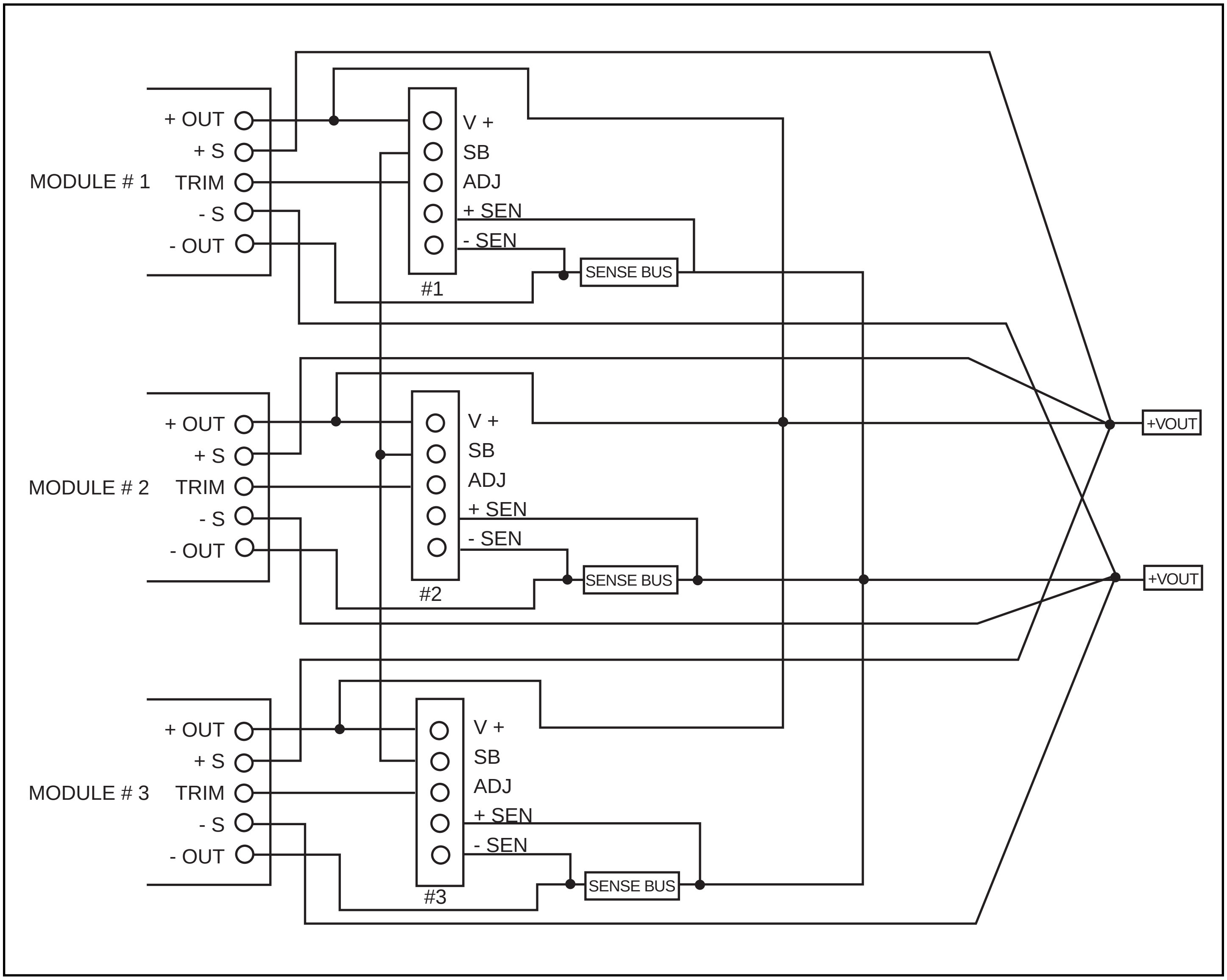
Current Sharing and N+1 Application

Current Sharing is performed externally by a thumb nail size current sharing module with current sensing resistor for each module.

The module compare its sensed current to the sum of current from all modules and sends a signal to 'TRIM' Pin of the corresponding module so that a correct share of the current is driven from the module.

Current sharing examples are described in the following pages.

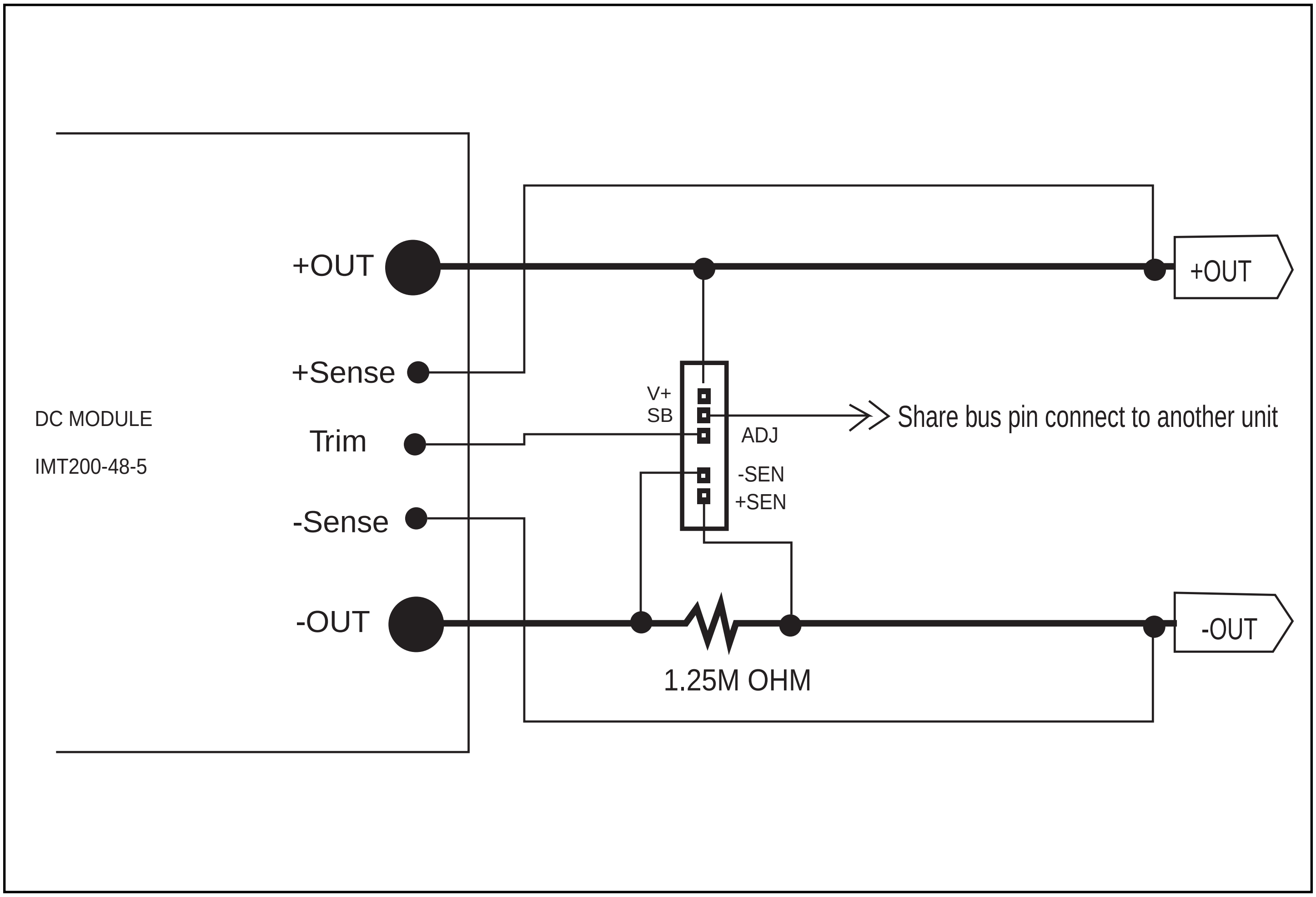
Example: Paralleling — IMT 200-48-5 Paralleling Circuit



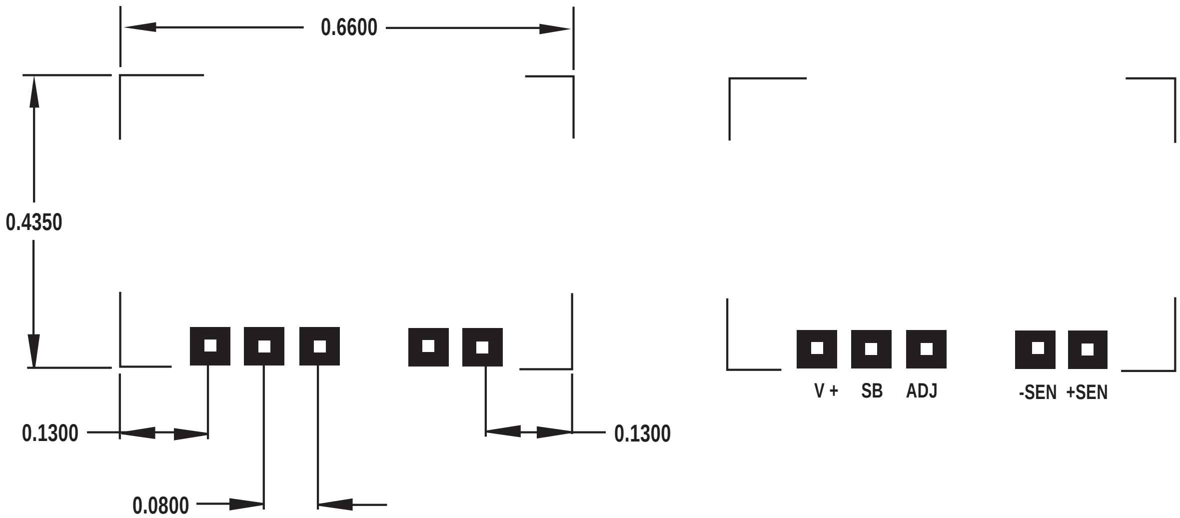
Parallel Modules Configuration

External current share circuit used to parallel IMT 200-48-5 series modules using trim pin.

Broadband Telcom Power, Inc.
250 Briggs Avenue, Costa Mesa, CA 92626 • Tel:714-850-7320 • Fax: 714-850-7321
www.btcpower.com and sales@btcpower.com



IMT200: Current Share Circuit Example



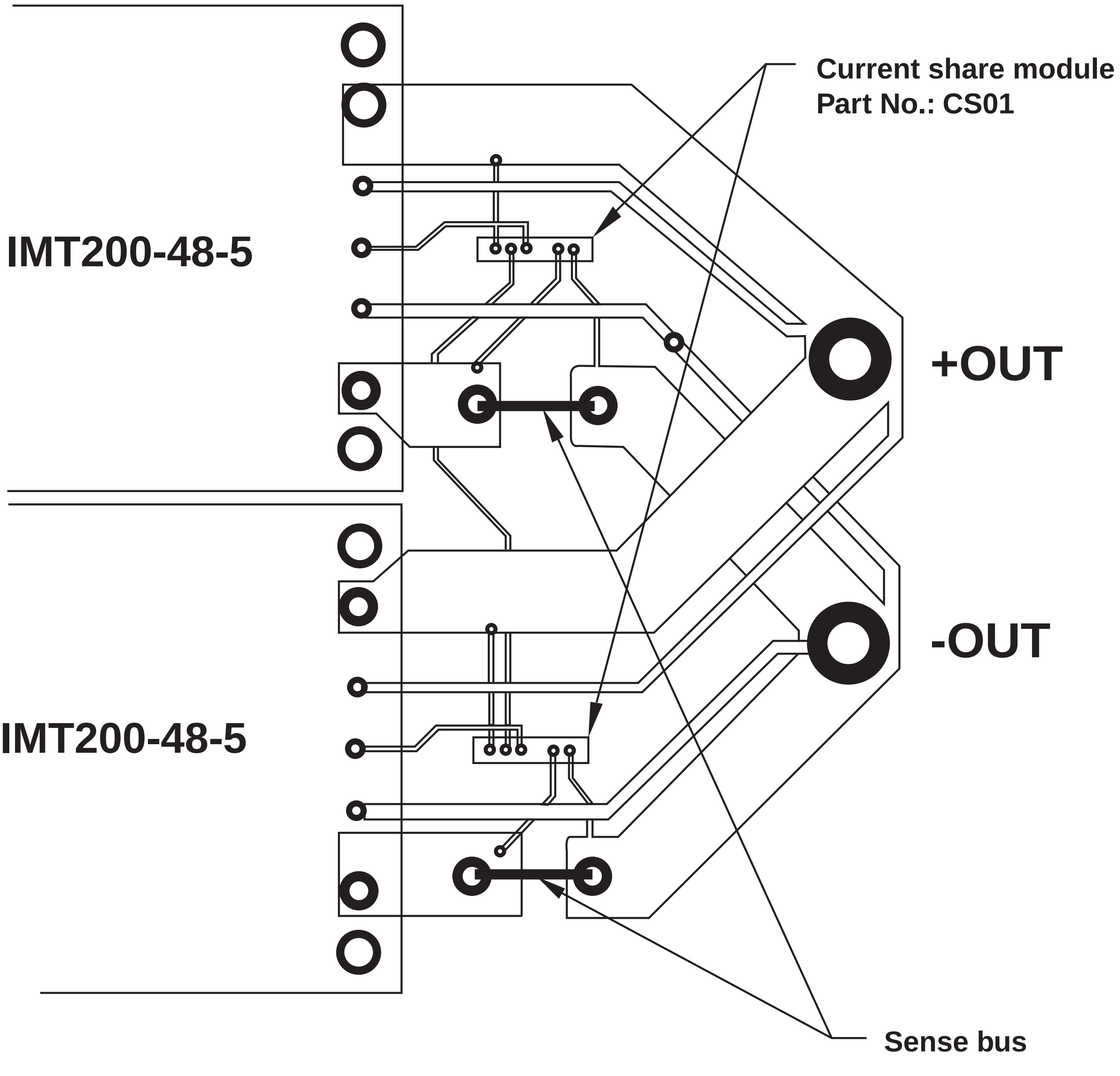
Current Share Circuit Pin Out and Dimension
Part No: CS01

Resistance Value of Sense Bus
Vs.
Different Outputs

Vo	Io	Resistance of Sense Bus
3.3V	50A	0.66mΩ
3.3V	40A	0.825mΩ
5V	40A	1.25mΩ
5V	30A	1.67mΩ
10V	20A	5mΩ
12V	17A	7mΩ
15V	10A	15mΩ

Total power dissipation should not exceed the power rating of sense bus.

Broadband Telcom Power, Inc.
250 Briggs Avenue, Costa Mesa, CA 92626 • Tel:714-850-7320 • Fax: 714-850-7321
www.btcpower.com and sales@btcpower.com
Jan. 2000
Rev. 1.0

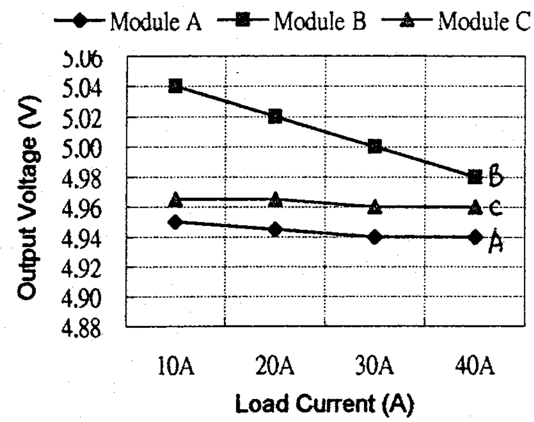


Layout example for current share circuit

Output Voltage of Each Module
Without Using Current Sharing Modufle

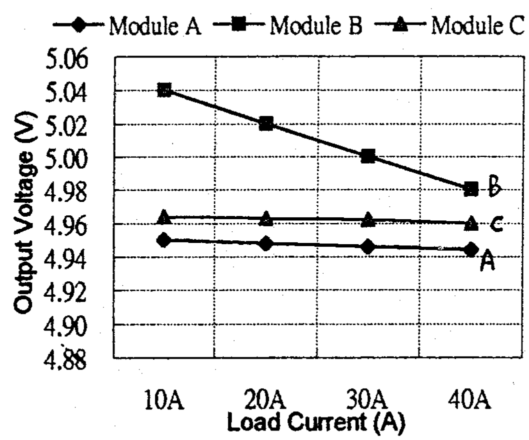
36Vin

Module \ Load	10A	20A	30A	40A
A	4.95	4.945	4.94	4.94
B	5.04	5.02	5.0	4.98
C	4.965	4.965	4.96	4.96



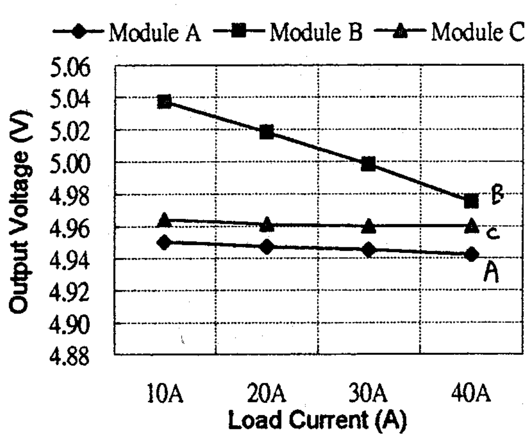
48Vin

Module \ Load	10A	20A	30A	40A
A	4.95	4.948	4.946	4.944
B	5.04	5.02	5.00	4.98
C	4.964	4.963	4.962	4.96



72Vin

Module \ Load	10A	20A	30A	40A
A	4.95	4.947	4.945	4.942
B	5.037	5.018	4.998	4.975
C	4.964	4.961	4.96	4.96



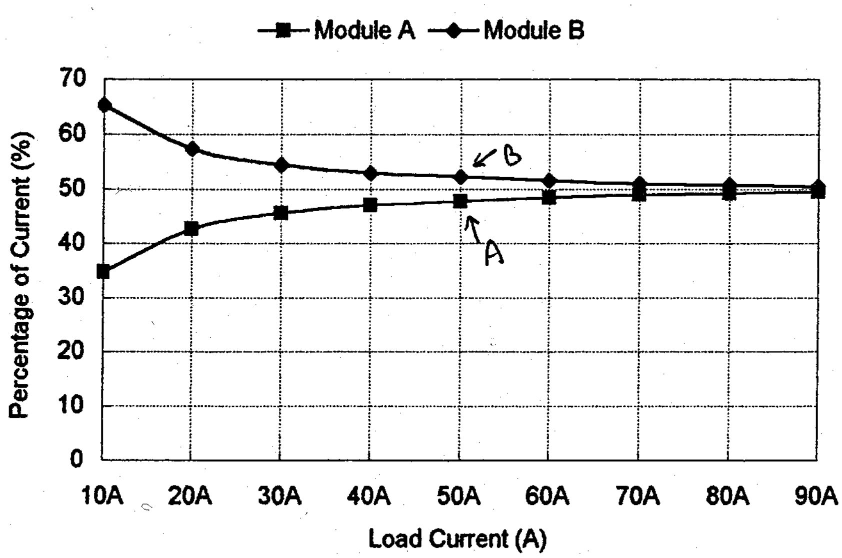
Broadband Telcom Power, Inc.
250 Briggs Avenue, Costa Mesa, CA 92626 • Tel:714-850-7320 • Fax: 714-850-7321
www.btcpower.com and sales@btcpower.com

IMT 200-48-5
Two Modules Paralleling Test Report (A to B), Nominal Input Rail

Vin: 48VDC

※With Current Share Circuit※

Load (A)	Module No.	Sharing Value	%	Different Value(Max)	Vout after Paralleling
10A	A	3.466A	34.66	3.068	5.045V
	B	6.534A	65.34		
20A	A	8.53A	42.66	2.94	5.035V
	B	11.47A	57.34		
30A	A	13.67A	45.57	2.66	5.025V
	B	16.33A	54.43		
40A	A	18.79A	46.99	2.42	5.015V
	B	21.21A	53.01		
50A	A	23.86A	47.72	2.28	5.00V
	B	26.14A	52.28		
60A	A	29.05A	48.41	1.9	4.995V
	B	30.95A	51.59		
70A	A	34.25A	48.94	1.5	4.985V
	B	35.75A	51.06		
80A	A	39.38A	49.22	1.24	4.97V
	B	40.62A	50.78		
90A	A	44.56A	49.52	0.88	4.955V
	B	45.44A	50.48		

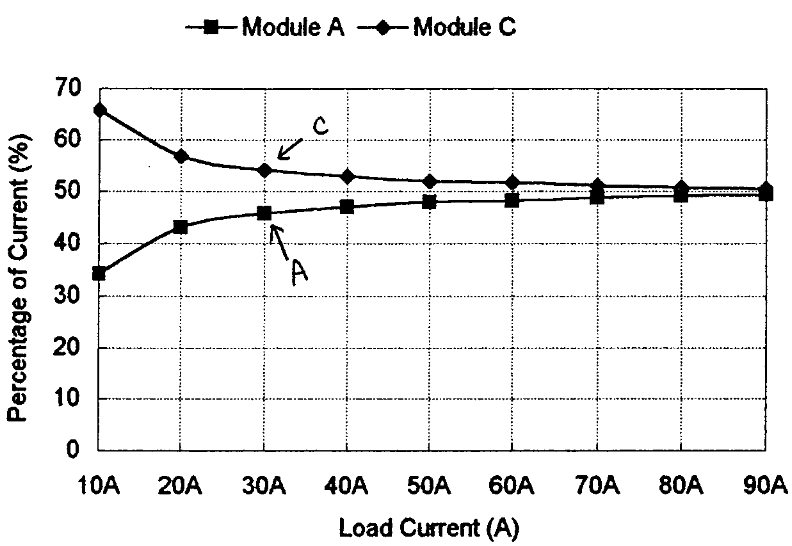


IMT 200-48-5
Two Modules Paralleling Test Report (A to C), Nominal Input Rail

- Vin: 48VDC

※Without Current Share Circuit※

Load (A)	Module No.	Sharing Value	%	Different Value(Max)	Vout after Paralleling
10A	A	3.418A	34.18	3.164	4.965V
	C	6.582A	65.82		
20A	A	8.63A	43.15	2.74	4.965V
	C	11.37A	56.85		
30A	A	13.74A	45.8	2.52	4.963V
	C	16.26A	54.2		
40A	A	18.82A	47.06	2.36	4.963V
	C	21.18A	52.94		
50A	A	23.99A	47.98	2.02	4.962V
	C	26.01A	52.02		
60A	A	28.97A	48.28	2.06	4.96V
	C	31.03A	51.72		
70A	A	34.22A	48.89	1.56	4.96V
	C	35.78A	51.11		
80A	A	39.37A	49.21	1.26	4.96V
	C	40.63A	50.79		
90A	A	44.53A	49.48	0.94	4.958V
	C	45.47A	50.52		

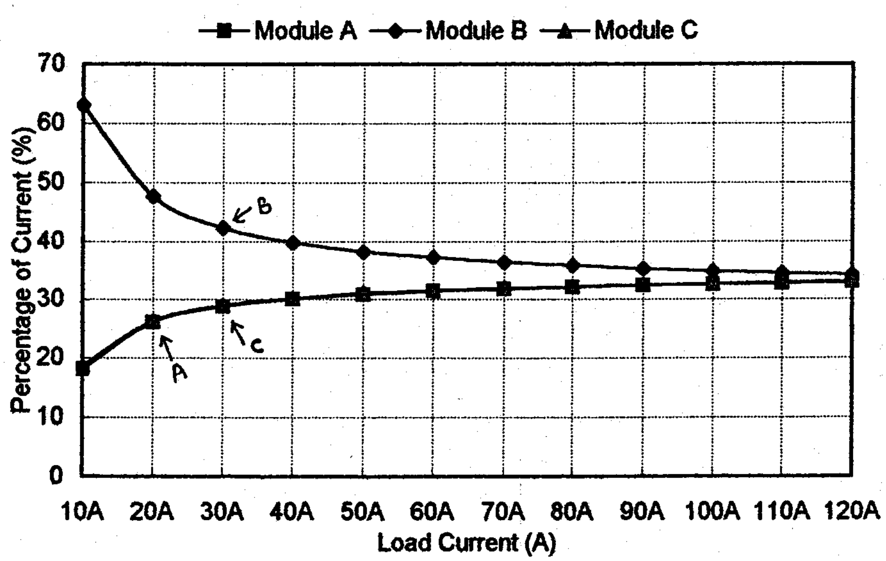


Broadband Telcom Power, Inc.
250 Briggs Avenue, Costa Mesa, CA 92626 • Tel:714-850-7320 • Fax: 714-850-7321
www.btcpower.com and sales@btcpower.com

IMT 200-48-5
Three Modules Paralleling Test Report, Nominal Input Rail
With Current Share Circuit, CS01

Vin: 48V

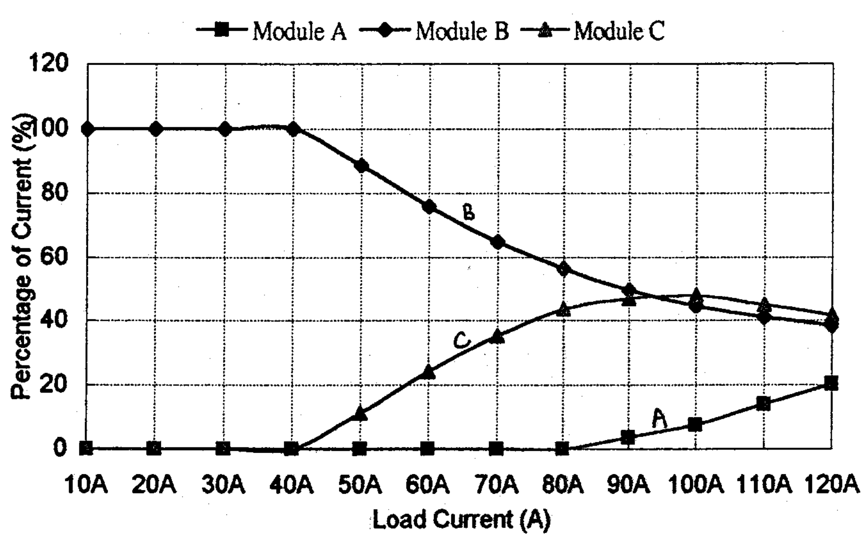
Load (A)	Module No.	Sharing Value	%	Different Value(Max)	Vout after Paralleling	Load (A)	Module No.	Sharing Value	%	Different Value(Max)	Vout after Paralleling
10A	A	1.817A	18.17	4.497	5.045V	70A	A	22.18A	31.68	3.29	5.00V
	B	6.314A	63.14				B	25.47A	36.39		
	C	1.869A	18.69				C	22.35A	31.93		
20A	A	5.22A	26.12	4.3	5.04V	80A	A	25.65A	32.07	3	4.995V
	B	9.52A	47.59				B	28.65A	35.81		
	C	5.26A	26.29				C	25.7A	32.12		
30A	A	8.63A	28.76	4.07	5.03V	90A	A	29.11A	32.35	2.56	4.985V
	B	12.70A	42.32				B	31.67A	35.19		
	C	8.67A	28.92				C	29.22A	32.46		
40A	A	12.01A	30.03	3.91	5.025V	100A	A	32.53A	32.53	2.33	4.98V
	B	15.92A	39.81				B	34.86A	34.83		
	C	12.07A	30.16				C	32.61A	32.61		
50A	A	15.39A	30.79	3.69	5.02V	110A	A	35.91A	32.64	2.06	4.97V
	B	19.08A	38.16				B	37.97A	34.52		
	C	15.53A	31.05				C	36.12A	32.84		
60A	A	18.81A	31.35	3.51	5.01V	120A	A	39.42A	32.85	1.61	4.962V
	B	22.32A	37.20				B	41.04A	34.20		
	C	18.87A	31.45				C	39.53A	32.95		



IMT 200-48-5 Without Use of CS01
Three Modules Paralleling Test Report
Without Current Share Circuit

Vin: 48V

Load (A)	Module No.	Sharing Value	%	Different Value(Max)	Vout after Paralleling	Load (A)	Module No.	Sharing Value	%	Different Value(Max)	Vout after Paralleling
10A	A	0A	0	10	5.038V	70A	A	0A	0	45.36	4.96V
	B	10A	100				B	45.36A	64.80		
	C	0A	0				C	24.64A	35.20		
20A	A	0A	0	20	5.02V	80A	A	0A	0	45.13	4.955V
	B	20A	100				B	45.13A	56.41		
	C	0A	0				C	34.87A	43.59		
30A	A	0A	0	30	4.995V	90A	A	3.17A	3.52	41.42	4.955V
	B	30A	100				B	44.59A	49.54		
	C	0A	0				C	42.24A	46.94		
40A	A	0A	0	40	4.975V	100A	A	7.64A	7.64	40.27	4.95V
	B	40A	100				B	44.45A	44.45		
	C	0A	0				C	47.91A	47.91		
50A	A	0A	0	44.37	4.965V	110A	A	15.42A	14.02	34.1	4.95V
	B	44.37A	88.73				B	45.06A	40.96		
	C	5.63A	11.27				C	49.52A	45.02		
60A	A	0A	0	45.47	4.96V	120A	A	24.20A	20.17	25.68	4.95V
	B	45.47A	75.79				B	45.92A	38.27		
	C	14.53A	24.21				C	49.88A	41.56		



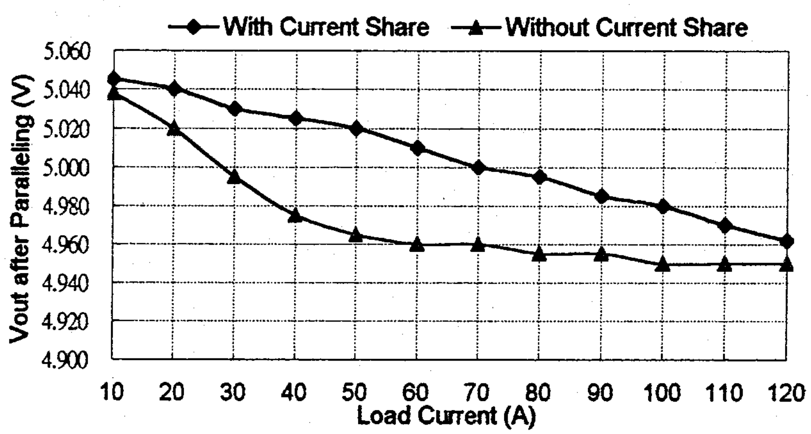
Broadband Telcom Power, Inc.
250 Briggs Avenue, Costa Mesa, CA 92626 • Tel:714-850-7320 • Fax: 714-850-7321
www.btcpower.com and sales@btcpower.com

IMT 200-48-5

Vout after Paralleling

Vin: 48V

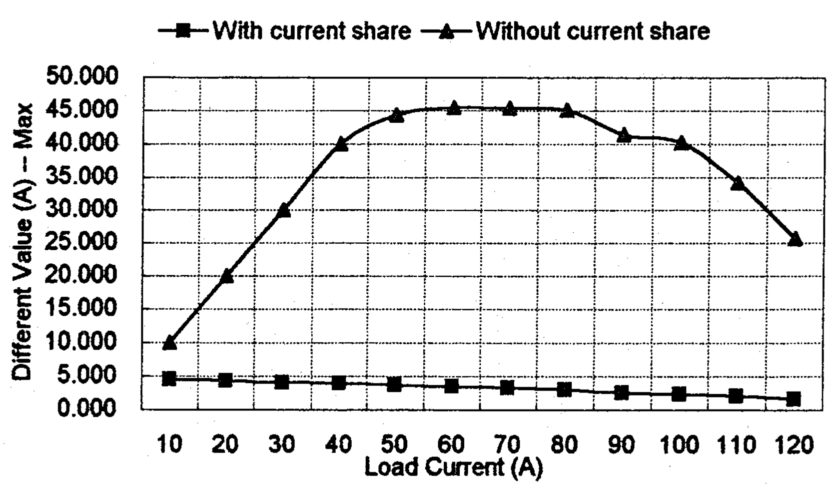
Load (A)	10	20	30	40	50	60	70	80	90	100	110	120
With current share	5.045	5.040	5.030	5.025	5.020	5.010	5.000	4.995	4.985	4.98	4.97	4.962
Without current share	5.038	5.020	4.995	4.975	4.965	4.960	4.960	4.955	4.955	4.95	4.95	4.95



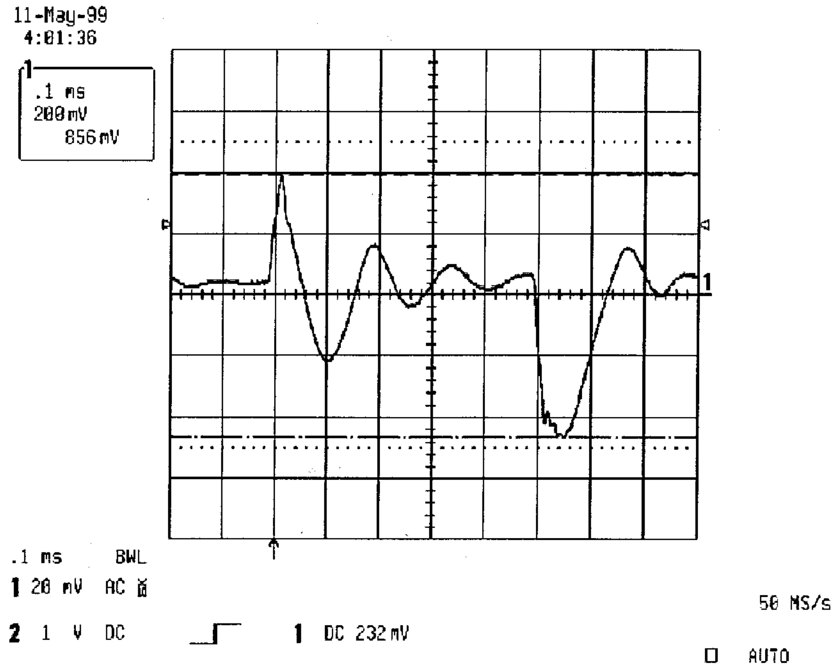
Different Value (A)--Max

Vin: 48VDC

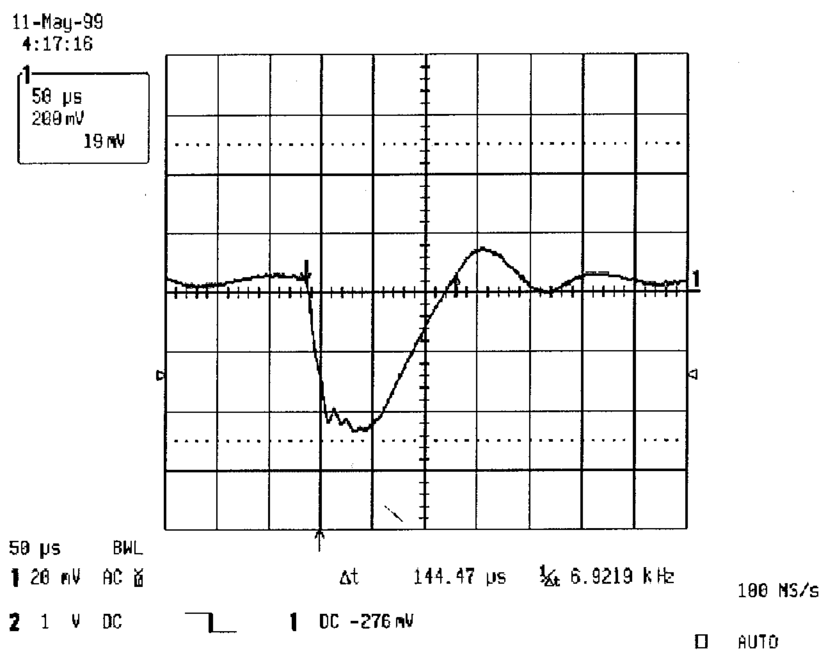
Load (A)	10	20	30	40	50	60	70	80	90	100	110	120
With current share	4.497	4.300	4.070	3.910	3.690	3.510	3.290	3.000	2.560	2.33	2.03	1.61
Without current share	10.00	20.00	30.00	40.00	44.37	45.47	45.36	45.13	41.42	40.27	34.10	25.68



Broadband Telcom Power, Inc.
250 Briggs Avenue, Costa Mesa, CA 92626 • Tel:714-850-7320 • Fax: 714-850-7321
www.btcpower.com and sales@btcpower.com

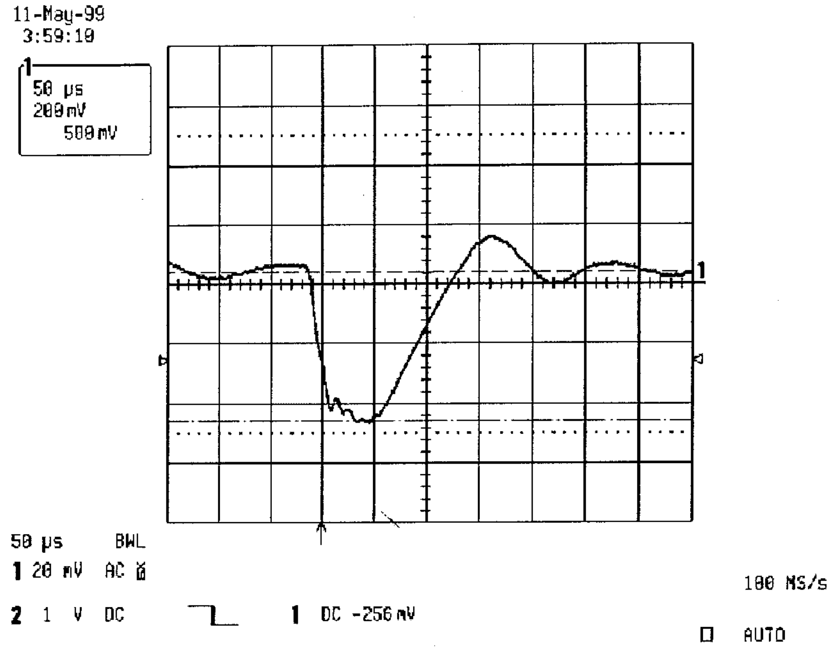


Three modules paralleling transient response picture
(Dynamic, Load= 60A, Slew rate= 2.5A/µs)

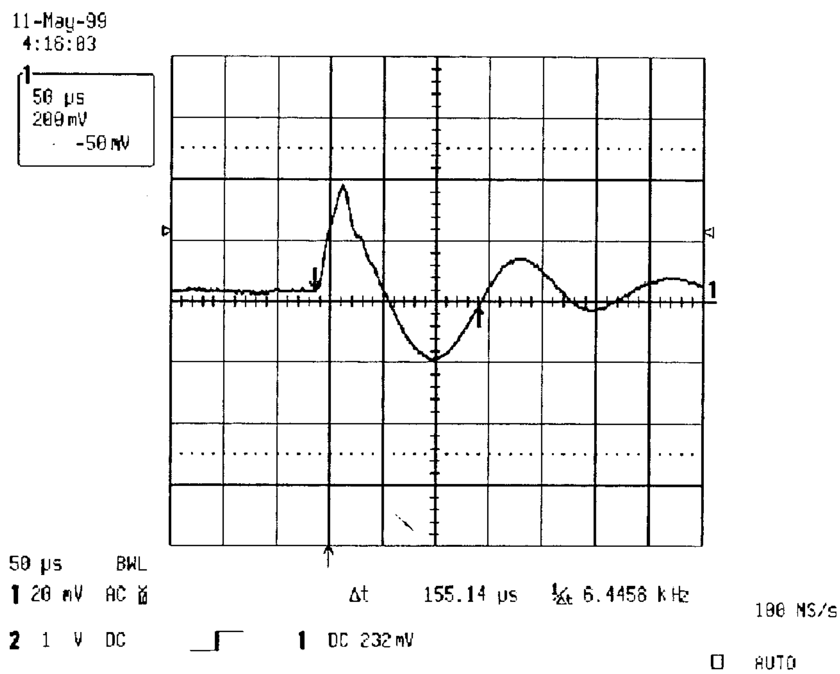


Three modules paralleling transient response time to step in load from 60A to 120A at room temperature and 48V input
(Dynamic, Load= 60A, Slew rate= 2.5 A/µs)

Broadband Telcom Power, Inc.
250 Briggs Avenue, Costa Mesa, CA 92626 • Tel:714-850-7320 • Fax: 714-850-7321
www.btcpower.com and sales@btcpower.com

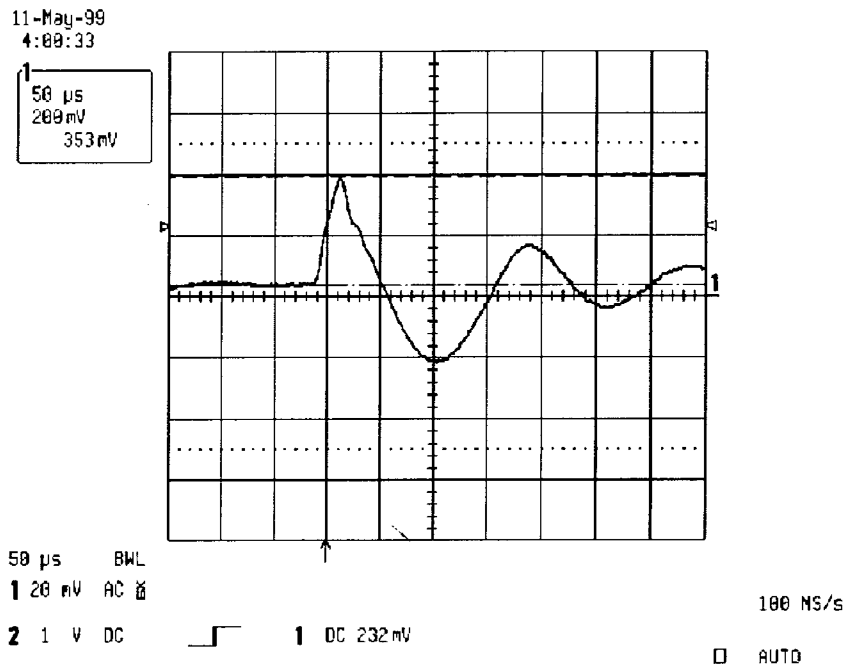


Three modules paralleling transient response voltage to step in load from 60A to 120A at room temperature and 48V input (Dynamic, Load= 60A, Slew rate= 2.5 A/µs)



Three modules paralleling transient response time to step in load from 120A to 60A at room temperature and 48V input (Dynamic, Load= 60A, Slew rate= 2.5 A/µs)

Broadband Telcom Power, Inc.
250 Briggs Avenue, Costa Mesa, CA 92626 • Tel:714-850-7320 • Fax: 714-850-7321
www.btcpower.com and sales@btcpower.com



Three modules paralleling transient response voltage to step in load from 120A to 60A at room temperature and 48V input (Dynamic, Load= 60A, Slew rate= 2.5 A/µs)

Additional Information

For more information or other design examples, please contact our technical support at jlau@btcpower.com or visit our web site at www.btcpower.com

Disclaimer

All statements, information and data given herein are believed to be accurate and reliable, but are presented without guarantee, warranty or responsibility of any kind, expressed or implied. Statements or suggestion concerning possible use of the circuits and components described herein are made without representation or warranty that any such use is free of patent infringement, and are not recommendations to infringe any patents. The use shall not assume that all safety measures are indicated, or that other measures may not be indicated.

Broadband Telcom Power, Inc.
250 Briggs Avenue, Costa Mesa, CA 92626 • Tel:714-850-7320 • Fax: 714-850-7321
www.btcpower.com and sales@btcpower.com