PowerWatt ™

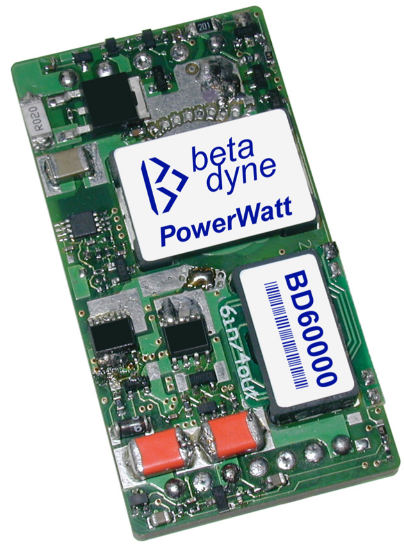
BD60000

60W Dual DC/DC Converter

18–36V_{IN}, 5.5V_{OUT}@7A & 3.5V_{OUT}@6A

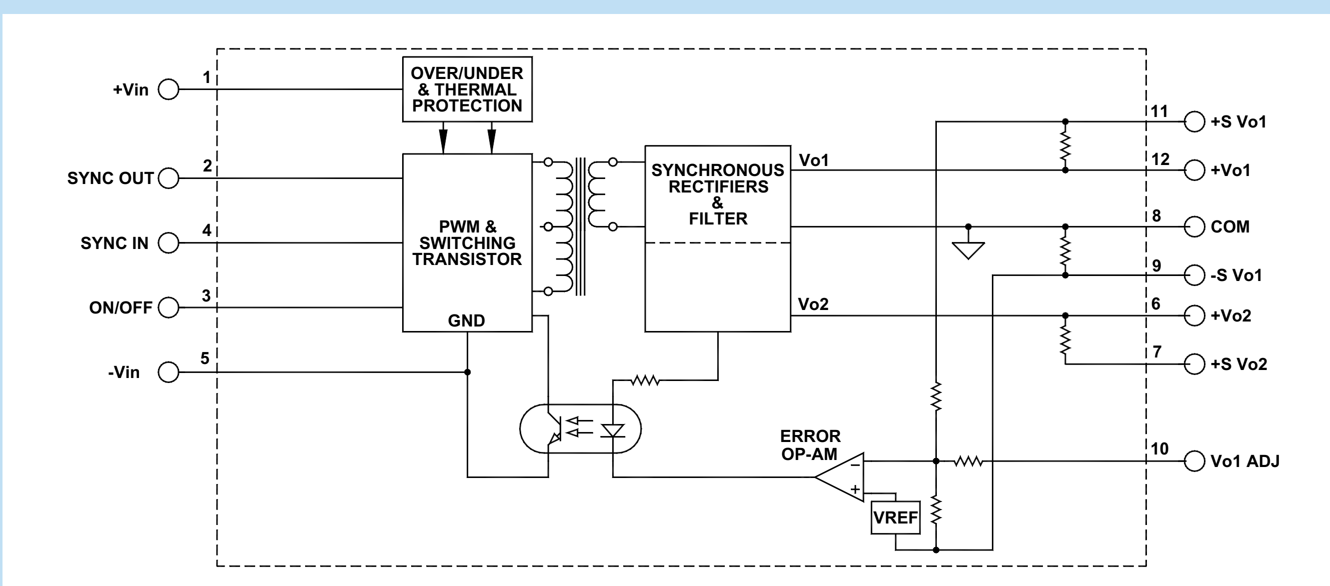
Key Features

- Efficiency up to 86%
- 50µS transient response time
- 500µA off state current
- Output synchronous rectification
- Industry standard pins
- 2:1 input voltage range
- Input-to-output isolation
- Soft start
- Multiple converter synchronization
- Short circuit protection
- Thermal protection
- Under/overvoltage protection



Functional Description

The BD60000 is a 60W dual output DC/DC converter in a 2.3×1.2×0.4-inch package. Its high efficiency and density is a result of patented designs utilizing improved synchronous rectification techniques and planar magnetics. The converter accepts 18V_{IN} to 36V_{IN} and provides 5.5V_{OUT}@7A and 3.5V_{OUT}@6A. The main output can deliver the full power of 60W, while V_{O2} is current limited to 10A of I_{O2}. High efficiency, coupled with a multilayer PCB and thermal management, minimizes power dissipation and allow the converters to operate without an external heat sink. The through-hole pins allow for low-cost installation and act as an integrated heat sink for the converters.



Typical Block Diagram

Electrical Specifications

Unless otherwise specified, all parameters are given under typical ambient temperature of +25°C with an airflow rate = 400LFM. With the given power derating, the operating range is -40°C to +125°C. Specifications subject to change without notice.

ABSOLUTE MAXIMUM RATINGS

PARAMETER / VALUE / UNIT
Input Voltage
Non-operating... 100Vdc continuous
Operating... 75Vdc contnuous
Input/Output Isolation....................................... 1500Vdc
Operating Temperature.................................. -40 to +125°C
Storage Temperature..................................... -55 to +125°C
Voltage at On/Off Input Pin............................ +12/-1Vdc
Semiconductor Junction Temperature.......... 150°C
PCB Operating Temperature........................ 150°C
Connector Pins Current Rating.....................
Output Capacitance.. 20,000μF

INPUT SPECIFICATIONS

PARAMETER	CONDITION / NOTE	MIN	TYP	MAX	UNIT
Input Voltage Range		18	24	34	Vdc
Input Startup Voltage		17	18		Vdc
Input Overvoltage Protection		34	36		Vdc
Reverse Polarity	External series-blocking diode				
Reflected Ripple			150		mA_{PP}
No Load Input Current			110		mA
Full Load Input Current			2978		mA
Input Surge Current (20μS Spike)				10	A
Short Circuit Current Limit	See Short Circuit Protection		150		% I_{IN}
Off State Current			500		μA
Remote ON/OFF Control					
Supply ON	Pin 3 Open (Open circuit voltage: 12V max.)				
Supply OFF		0		0.8	Vdc
Logic Input Reference	-Input for ON/OFF, SYNC IN and SYNC OUT				
Logic Compatibility	TTL Open Collector or CMOS Open Drain for ON/OFF				
Sync, High	See External Synchronization, Figures 3 & 4	2		6	Vdc
Sync, Low	See External Synchronization, Figures 3 & 4	0		0.8	Vdc

[1] Measured with 22μF capacitor for $48V_{IN}$ and 100μF capacitor for $24V_{IN}$ at the input power pins in series with 3.3μH inductor for $48V_{IN}$ and 1μH for $24V_{IN}$ (see Figure 7). See also Figure 1.

[2] Full load current in this column is given for V_{O1}+V_{O2} fully loaded. The maximum input current at any given input range measured at minimum input voltage is given as $1.6*I_{NOMINAL}$. Nominal input current is the typical value measured at the input of the converter under full-load room temperature and nominal input voltage (24Vdc and 48Vdc).

OUTPUT SPECIFICATIONS

PARAMETER	CONDITION / NOTE	MIN	TYP	MAX	UNIT
Output Voltage, V_{O1}			5.5		Vdc
Output Voltage, V_{O2}			3.5		Vdc
Output Voltage Accuracy	V_{O1}, V_{O2}		±1	±2	%
Outuput Current, V_{O1}			7		A
Outuput Current, V_{O2}			6		A
Ripple & Noise			1	2	$\%V_{PP}$ of V_{OUT}
Line Regulation	Both outputs		±0.05	±1	%
Load Regulation	Both outputs		±1	±2	%
Temperature Coefficient @ FL			0.02		%/°C
Transient Response Time	50% FL to FL to 50% FL		50	100	μS
Short Circuit Protection					
Output Adjust Range	See External Trimming of Output Voltages	±5		±10	%

GENERAL SPECIFICATIONS

PARAMETER	CONDITION / NOTE	MIN	TYP	MAX	UNIT
Efficiency			82		%
Isolation Voltage (1 min.), Input to Output			1500		Vdc
Isolation Resistance			10^9		Ω
Isolation Capacitance			2700		pF
Switching Frequency, V			400		kHz
Switching Frequency, V			300		kHz
Turn On Delay	See Figure 1		7	10	mS
Soft Start Time	See Figure 1		7	15	mS

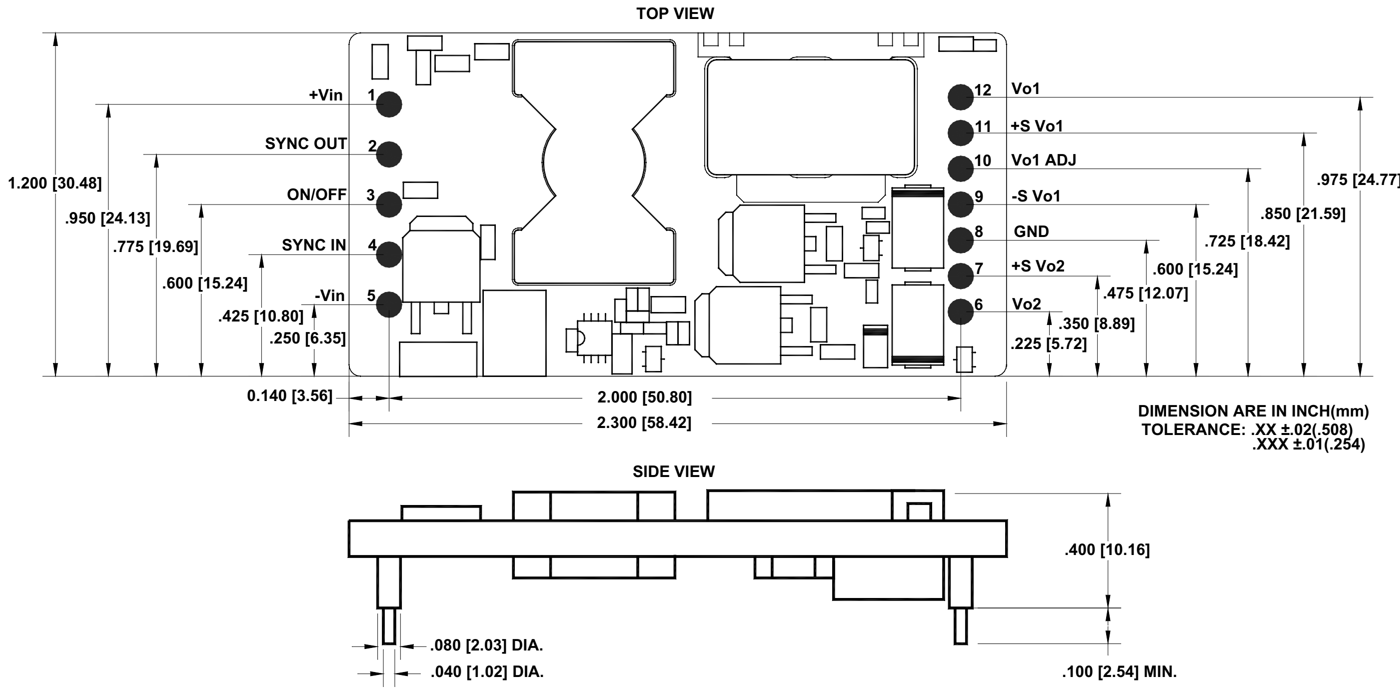
ENVIRONMENTAL SPECIFICATIONS

PARAMETER	CONDITION / NOTE	MIN	TYP	MAX	UNIT
Operating Temperature Range , Commercial	Contact factory for Industrial	-40		+71	°C
Storage Temperature Range		-55		+125	°C
Overtemperature Protection			115	125	°C
Thermal Hysterisis		20	30		°C
Maximum Operating PCB Temperature				125	°C
Derating	See Figure 8				
Cooling	See Figure 8				
MTBF	per MIL-HNBK-217F (Ground benign, +25°C)		670,000		hours

PHYSICAL CHARACTERISTICS

PARAMETER	CONDITION / NOTE	MIN	TYP	MAX	UNIT
Dimensions (L×W×H)	2.30×1.20×0.40 in. (58.42×30.48×10.16mm)				
Weight	1.3 oz. (37g)				

MECHANICAL SPECIFICATIONS



Pin	Function	Pin	Function
1	$+V_{IN}$	6	$+V_{O2}$
2	SYNC OUT	7	$+S\ V_{O2}$

APPLICATION CONSIDERATIONS

Pin Functions

$+V_{IN}$ (Pin 1): For positive input power supply connections.

SYNC OUT (Pin 2): Output-driving signal of the PWM.

ON/OFF (Pin 3): Turns converter off when pulled to ground through an open collector or open drain transistor. Maximum voltage at this pin is 12V minus a diode drop. Can be parallel connected with the ON/OFF pins of multiple converters or any Beta Dyne converter that may reside in the system. Leave this pin open for continuous operation.

SYNC IN (Pin 4): Input synchronization signal to the PWM. A TTL level input signal with a minimum pulse width of 300nS and period of 2.5µS is required to synchronize the converter.

$-V_{IN}$ (Pin 5): For negative input power supply connection (or input ground).

$+V_{O2}$ (Pin 6): Positive V_{O2} voltage.

$+S\ V_{O2}$ (Pin 7): Positive V_{O2} output sense; to be connected at the positive V_{O2} output at the load.

COM (Pin 8): For both V_{O1} and V_{O2} outputs.

$-S\ V_{O1}$ (Pin 9): Negative output voltage sense for V_{O1}; to be connected to the negative output at the load only.

V_{O1} ADJ (Pin 10): Output voltage adjust for V_{O1} only; to be used for an output voltage adjustment. Bypass this pin with a 0.01µF to 0.10µF capacitor.

$+S\ V_{O1}$ (Pin 11): Positive output voltage sense for V_{O1}; to be connected to the positive output voltage at the load only.

$+V_{O1}$ (Pin 12): Main positive output voltage.

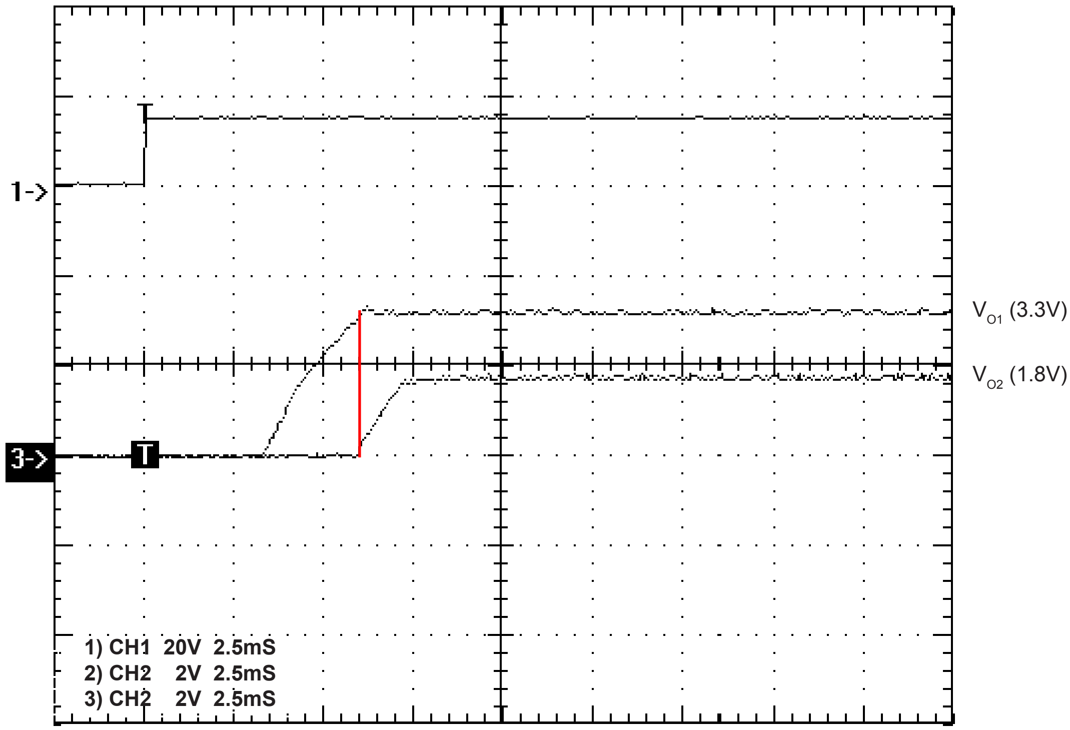


FIGURE 1. Turn on delay (60D3.3-1.8/48)

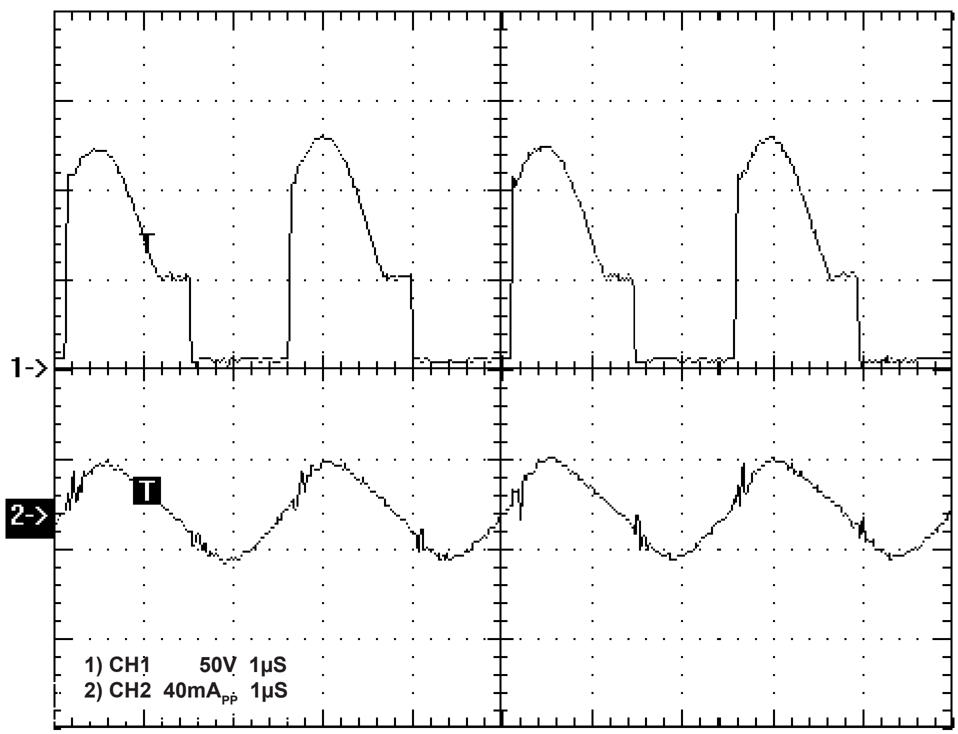


FIGURE 2. Reflected ripple (60D3.3-1.8/48)

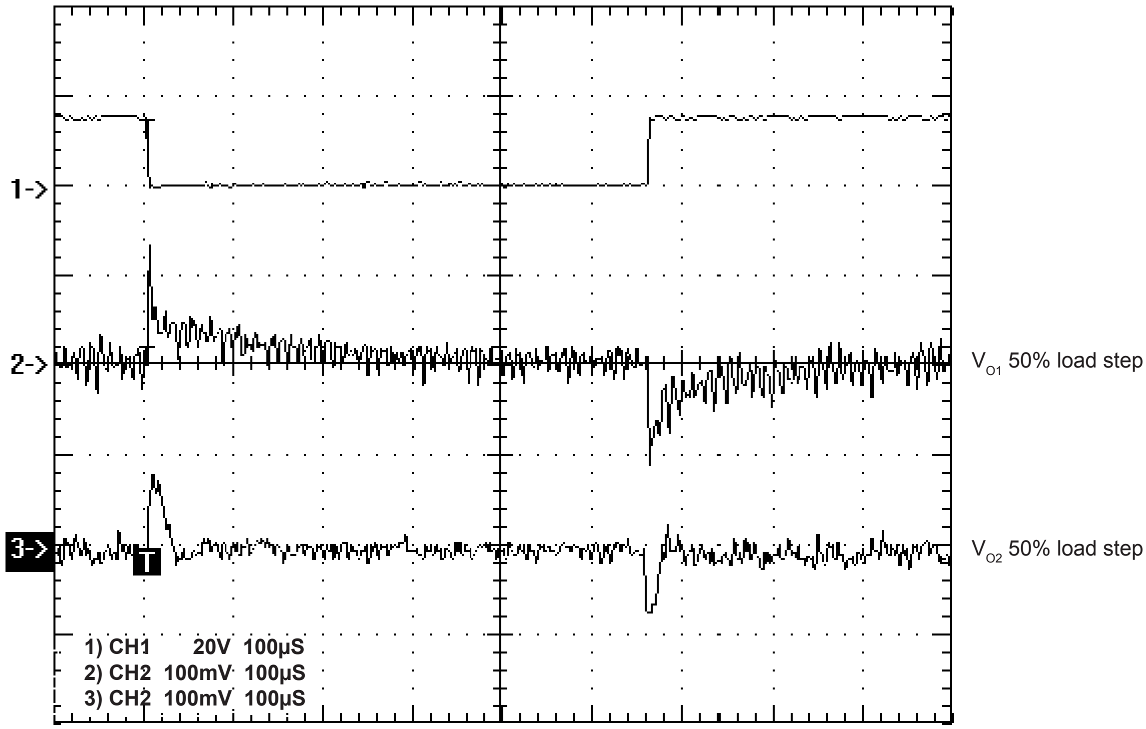


FIGURE 3. Transient response (60D3.3-1.8/48)

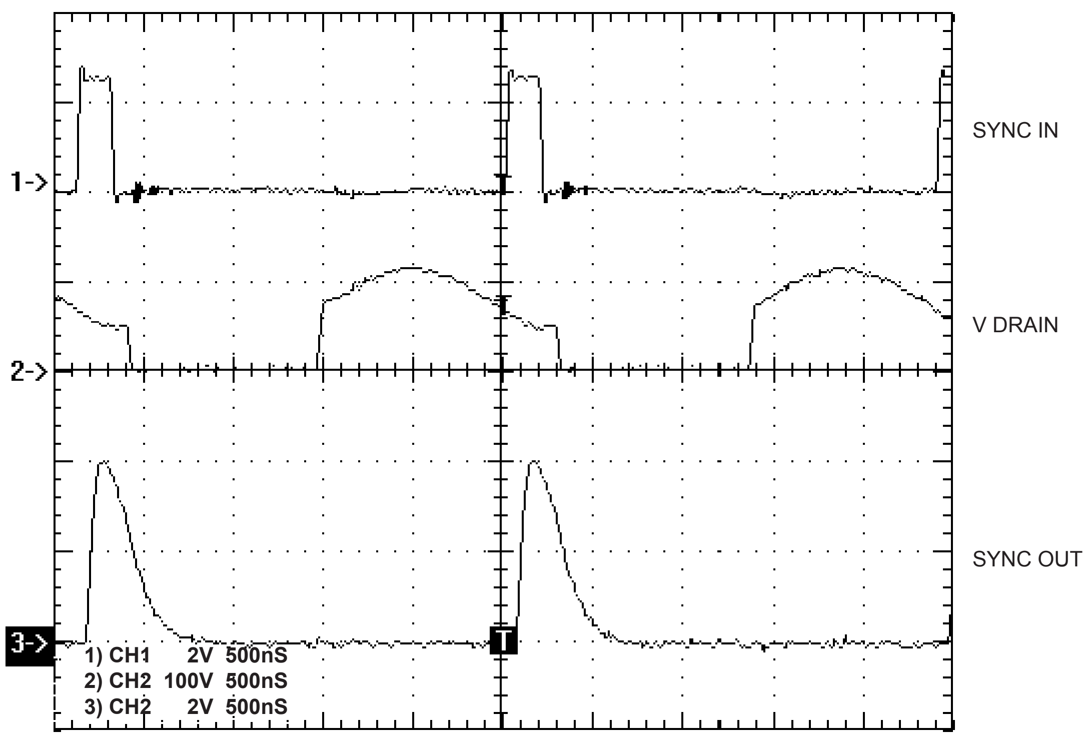


FIGURE 4. Input/output synchronization signals

SYNC OUT: An internal current source driven by the PWM oscillator provides the Sync Out. It can source a 10mA TTL pulse between 300nS to 500nS. If it is not used, the 2kΩ pull-down resistor (see Figure 6) is not required.

EXTERNAL SYNCHRONIZATION

A TTL signal applied at the SYNC pin of the converter will synchronize the switching frequency of the converter to that of the TTL input signal. The external (TTL) frequency must be equal or higher than the converter's frequency. At the positive-going edge of the applied pulse, the internal power-switching transistor turns off and the PWM discharges its timing capacitor. At the negative-going edge, the PWM resumes normal operation. The minimum positive pulse width of the TTL signal must be 300nS and its frequency between 370kHz and 430kHz.

NOTE: Higher frequencies will reduce the efficiency of the converter and wide TTL pulses will force the PWM to follow the external TTL width modulation, which may effect regulation. A high TTL signal at the SYNC pin of the converter will turn the converter off. An internal pull-down resistor will keep this pin low when it is not used. A pulse differentiator (see Figure 6) can be used to shape a square wave sync signal as shown in Figure 5. To avoid noise pickup, place a 5kΩ resistor from Pin 4 to GND as close as possible to the converter.

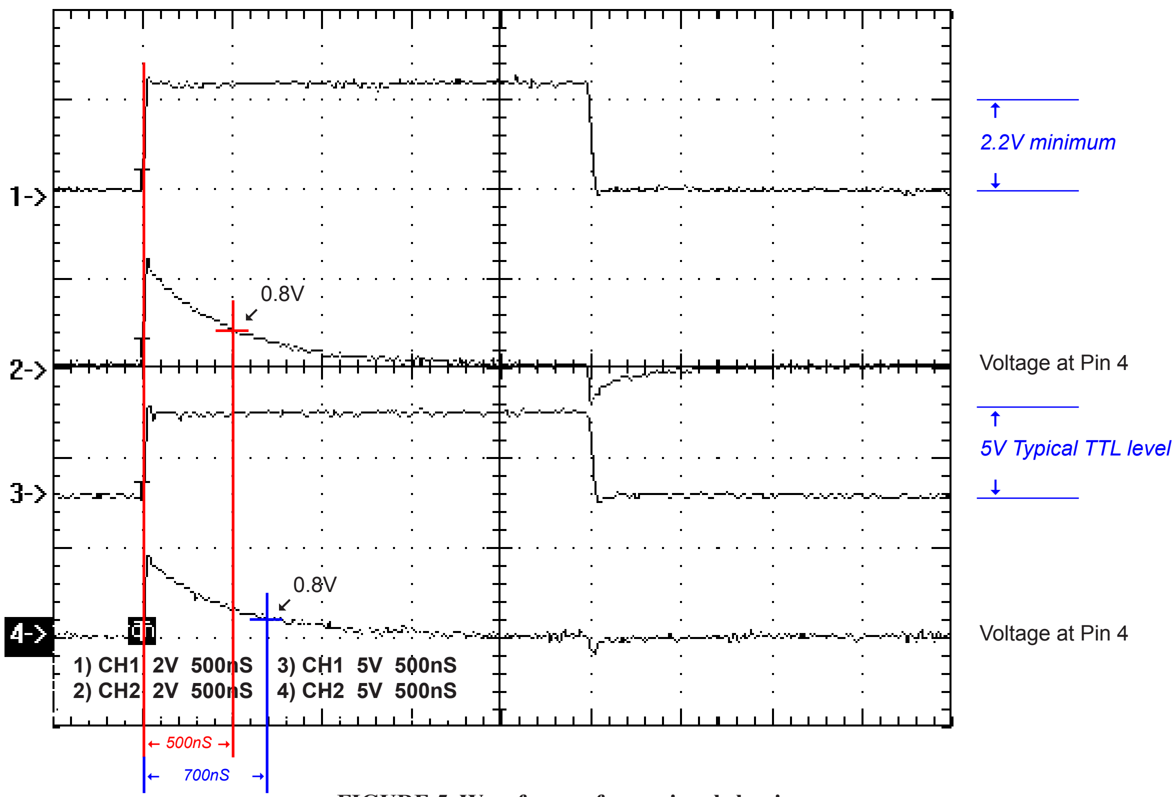


FIGURE 5. Waveforms of sync signal shaping

SYNC SIGNAL SHAPING

As described in External Synchronization, the PWM of the 60W converter requires a TTL signal of 0.8 to 2Vdc minimum amplitude and minimum duration of 300nS. When such a signal is not available (through one shot multivibrator or other pulse-shaping circuits) a C-R differentiator, such as the one in Figure 6, can be used to shape a square wave TTL signal. As is shown by the oscillogram in Figure 5, the positive edge of the sync pulse must be 2V minimum and the decaying exponential must reach the low 0.8Vdc in 300nS minimum from the positive edge. The parallel diode with the resistor is a small signal switching diode or a Schottky signal diode with 0.3 to 0.5V forward drop, it is used to clamp the voltage at Pin 2@-0.5Vdc.

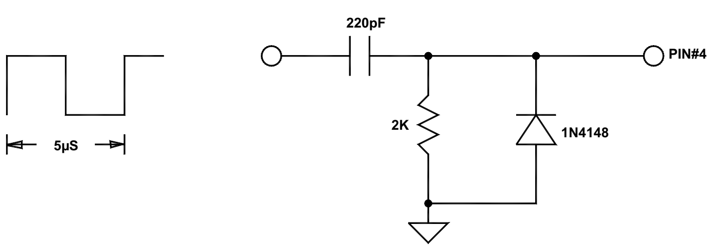


FIGURE 6. Suggested pulse-shaping circuit

SHORT CIRCUIT PROTECTION

The 60W dual PowerWatt™ series has a dual short circuit protection feature. At the input side of the converter, two short circuit current comparators are used to monitor the input current of the converter. They are biased at different voltage levels; the lower threshold (LTH) comparator provides the power limiting function of the converter. Under normal operating conditions, the LTH comparator limits the output power of the converter when the maximum output power is exceeded. When a hard short is applied across the output of the converter and the input current exceeds the set threshold of the second comparator, the converter goes into shutdown mode, the overcurrent latch is set and the converter is turned off. The converter will turn on again when its input voltage is recycled (OFF—ON) or if the ON/OFF pin is used to turn the converter on and off. The time required for the ON/OFF pin to be held low is between 100mS and 800mS. Even though it is not recommended, the ON/OFF pin will reset the thermal protection circuit when it is activated. Output V_{O2} has its own current limit and thermal protection.

EXTERNAL TRIMMING OF OUTPUT VOLTAGES

To trim the output voltage DOWN, connect a 5% ¼W 10kΩ resistor between the $+V_{O1}$ (Pin 12) output and trim pin of the converter. To trim the output voltage UP, connect a 5% ¼W resistor between GND (Pin 8) output and trim pins of the converter. For UP/DOWN trimming capability, connect a 10kΩ potentiometer between the $+V_{O1}$ and $-V_{O1}$ pins, with the wiper arm connected to the trim pin.

The trim resistors/potentiometer can be connected at the converter output pins or the load. However, if connected at the load, the resistance of the runs becomes part of the feedback network which improves load regulation. The second output can be adjusted higher only by inserting a series resistor between $+SV_{O2}$ and $+V_{O2}$ (see Figure 7). A maximum of 100mW higher than V_{O2} nominal is obtained when $+SV_{O2}$ is left open.

See our application notes:
DC-001: Testing Transient Response in DC/DC Converters
DC-004: Thermal Consideration for DC/DC Converters

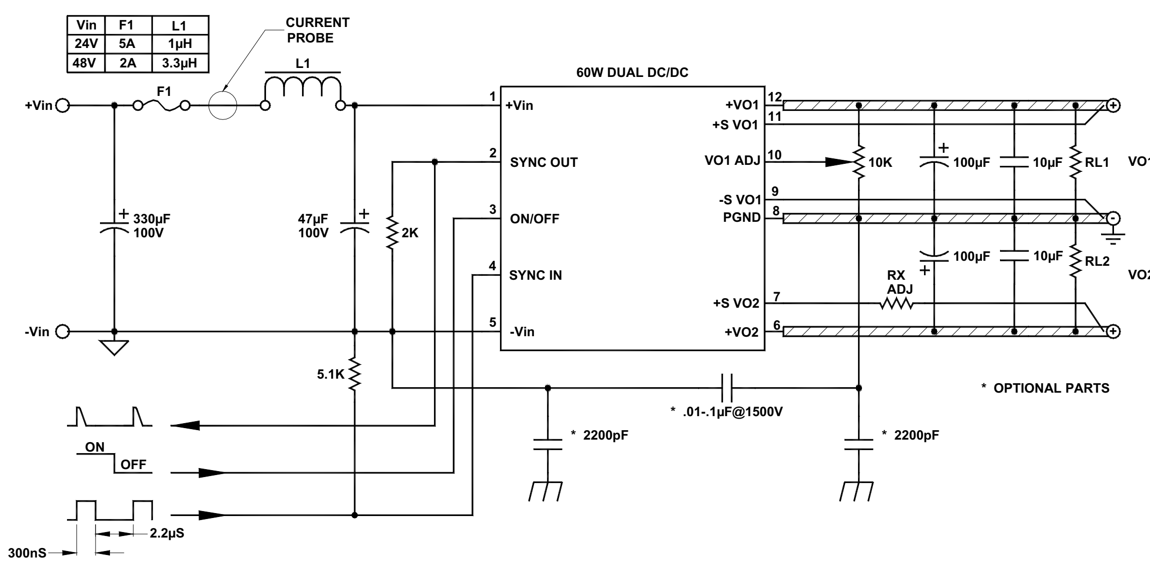


FIGURE 7. Typical connection diagram

DESIGN CONSIDERATIONS

The PowerWatt 60W Dual DC/DC Converter is based on the patented PowerWatt forward converter design. The main output can deliver all the output power to the load when needed. For the auxiliary output (V_{O2}), a high efficiency synchronous rectifier step-down converter is used. The maximum current V_{O2} is limited to 10A and it has its own thermal protection circuit.

Input Source Impedance

The input of the converter should be connected to a low AC-impedance source. To reduce the impedance of a potentially high-inductive DC source, use a low ESR electrolytic capacitor (ESR < 0.6W@400kHz) mounted as close to the input pins as possible to ensure stability of the converter. As suggested in Figure 6, an electrolytic capacitor (22µF for $48V_{IN}$ or 47µF to 100µF for $24V_{IN}$) in parallel with an SMD 2.2µF ceramic capacitor will ensure stability under any line or load condition. The 330µF capacitor before the input inductor L1 will reduce both reflected ripple and any long wire impedance from the DC source.

Output Filter Impedance

The impedance of an output filter may also affect the stability of a converter when additional low-pass filters are used. If additional output ripple reduction is required, avoid installing series inductors at the output. Instead, try to maximize output capacitance. The inductor of the output copper strips and a 1000µF capacitor will be enough for most applications. Low ESR electrolytic or tantalum capacitors can be used for additional output ripple reduction in parallel with ceramic capacitors for high-frequency attenuation. We recommend Vishay Sprague 594D Solid Tantalum Chip Capacitors.

Load Regulation

The output ground (Pin 4) carries both return current of V_{O1} and V_{O2} output. Because V_{O1} has sense pins any voltage drop in the power pin and copper trace is automatically compensated. The load regulation of V_{O1} is typically 0.5% to 1%. V_{O2} has only one sense pin and the PWM for V_{O2} cannot compensate for the voltage drop due to the $-V_{O2}$ (GND) and it will affect the load regulation of V_{O2}. A 50mV drop is observed at V_{O2} (NL to FL) when both outputs are fully loaded. With only V_{O2} loaded, the voltage drop (NL to FL) is approximately 25mV.

Output Ripple

The output ripple at the main output V_{O1} is the combination of the output ripple of V_{O1} and the reflected ripple of V_{O2}. Due to different switching frequencies, the V_{O1} output ripple appears to be AM modulated.

EFFICIENCY MEASUREMENTS

Using the setup given in Figure 7, measure the input and output voltage at the pins at the top of the multiplayer PCB and use these values to calculate the efficiency. It should be understood that in a still air environment, the efficiency will decrease over time due to the increase of the semiconductor resistance. The worst case efficiency of the converter is observed when V_{O1} has no load and V_{O2} is fully loaded.

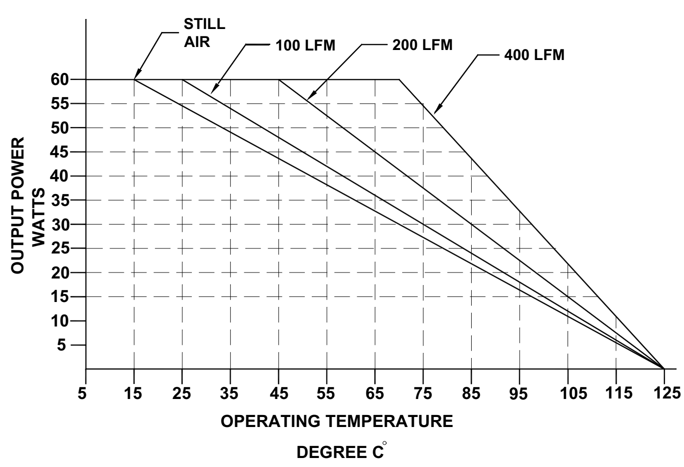


FIGURE 8. Derating curves

THERMAL CONSIDERATIONS

Under full load, the 60W PowerWatt™ converters dissipate between 6W to 12W of power (depending on the model). The generated heat is transferred to the ambient by air conduction. At room temperature without any air movement, the operating environment of the converter is higher than room temperature, 30°-60°C higher, due to the fact that air around the converter heats up.

To measure the actual operating environment of the converter in a still air environment, place a thermocoupler a half-inch above the top center of the converter. Perform the same temperature measurement in a forced air convection system and use those temperature values for your thermal calculations. Do not assume the temperature is constant throughout a forced air cooling system! Surrounding components and the load can cause the converter to go to thermal shutdown.

The minimum junction temperature of all semiconductors is 150°C and the maximum operating temperature of the PCB is 150°C. When the temperature of the PCB reaches approximately 125°C, the converter will turn off. The thermal hysterisis of 20°-30°C will allow the converter to cool off and resume operation once it reaches approximately 95°C. If there is not enough air circulation due to air fan failure of the system or very high environmental temperatures, the converter will stay in this so-called "hiccup" (ON/OFF) thermal mode indefinitely.

In a forced air environment, allow the air to pass over and under the converter. When airflow is restricted to a single side (top or bottom), the thermal conductivity of the converter is reduced by 50%. When the airflow is restricted to the bottom side, the V_{O2} output may go into thermal protection if the bottom side PCB temperature reaches 125°C while V_{O1} is operating. Under these conditions a differential of 5°-10°C can be observed between the top and bottom PCB surfaces.

LAYOUT CONSIDERATIONS

The maximum output current of the converter is 25A and is carried to the load through 25A-rated pins. When the converter is installed in a double-sided PCB, use both sides to connect the high current pins and use 2-3oz. copper for the plated through holes and/or power pads.

DO NOT use sockets in production. For lab testing, we recommend MILL-MAX sockets (P/N: 7406-0-15-01-18-01-04-0) or any other socket that offers a maximum conductive surface to the pins.

If possible, maximize the surface area on the board for the power pins and DO NOT install a solder mask. A solder mask will trap the heat inside the PCB and will not allow for maximum heat transfer even in forced-air cooling systems.

Please note that in a multilayer PCB the inner layers do not contribute much in reducing the thermal resistance of the power component, they only reduce the resistance to the load. If the top and bottom layers of your PCB can be plated up to 3-4 oz., you do not have to use a multilayer PCB for the converter.

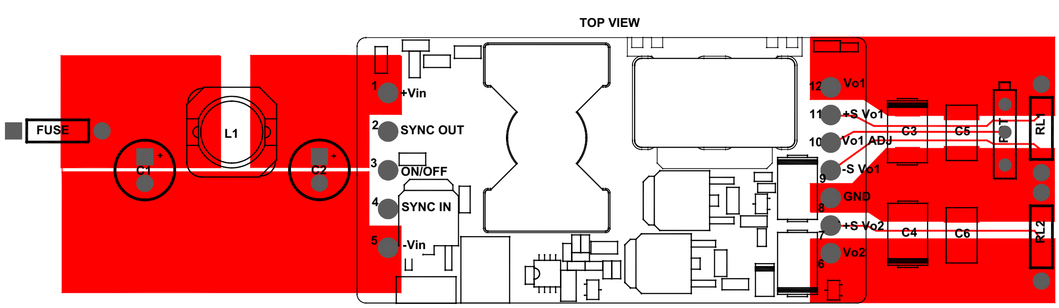
Also, the PCB resistance from the converter pin to the load is given by:

$$R_T = \rho * \frac{L}{W * th}$$

where

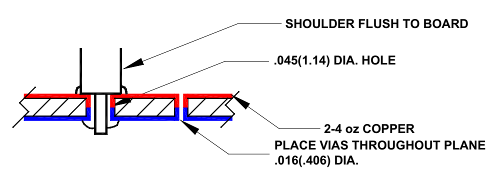
ρ = resistivity of copper (μΩ-mil)
(For one ounce of copper, ρ = ~718μΩ-mil)
L = length (mils), W = width (mils), th = thickness (mils)

If the sense run length exceeds 2 inches, the sense pins may have to be bypassed at a point close to the converter. Keep in mind to bypass to their respective polarity. Avoid running digital signal lines parallel to the sense pins. If more than one power device or converter is used per system board, use a star ground connection



SUGGESTED PARTS

	24Vin	48Vin
FUSE	PICO II 4A@125V S.B.	PICO II 4A@125V S.B.
L1	10μH SUMIDA PT#CDRH104R-100	10μH SUMIDA PT#CDRH104R-100
C1&C2	47μF-100μF UNITED CHEMI-CON	22μF-47μF@100V UNITED CHEMI-CON
C3&C4	220μF@6.3V OR 470μF@6.3V SPRAGUE	220μF@6.3V OR 470μF@6.3V SPRAGUE
C5 & C6	10μF CERAMIC UNITED CHEMI-CON	10μF CERAMIC UNITED CHEMI-CON



NOTES:
1. DIMENSIONS ARE IN INCH(mm).
2. TOLERANCE: .XXX ± .005

FIGURE 9. Suggested layout of 60W PowerWatt series

EMI/RFI IN OPEN-FRAME DC/DC CONVERTERS

All switching AC/DC and DC/DC converters generate noise due to high-voltage, high-current internal switching. Conducted noise is the noise that appears at the point of conduct (pins) of the converter. Radiated noise is the electromagnetic noise transmitted to the environment from the power source. Conducted noise can be reduced to acceptable levels by an input/output low-pass filter.

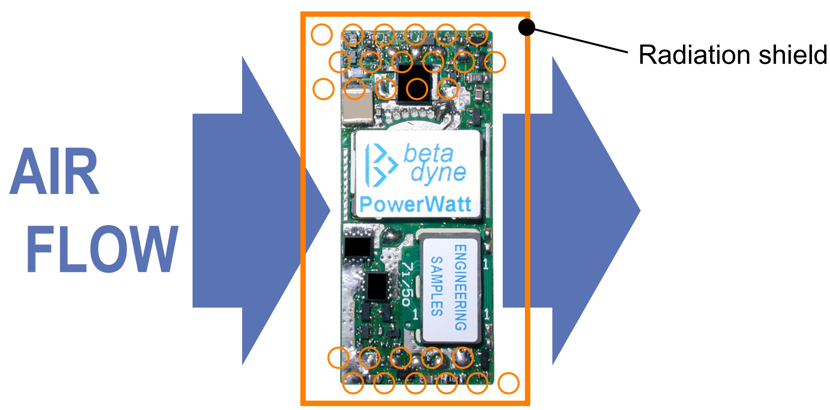
In the past, manufacturers used metal cases and conductive headers to provide six-sided shielding to prevent radiated noise. Open-frame converters, on the other hand, have no shield and all the high-voltage, high-current switching points radiate noise. Open-frame, high-density DC/DC converters use forced air cooling. Most of the switching transistors are placed at the top of the converter to allow for better air circulation. Also, these switching transistors and power magnetics will produce square current/voltage waveforms that are full of harmonics. Most open-frame converters use fixed switching frequencies from 200kHz to 1MHz. The high switching frequencies can generate harmonics from 1MHz up to several hundred MHz.

converter is necessary.

The shield must allow the forced air to pass freely over the converter (see Drawings A, B & C). A metal screen can be considered. The holes in the screen must be less than the wavelength of the noise. If the converter is placed far from the load, make sure thick PCB runs are used (2–3 oz. copper is sufficient.)

When noise creates problems in a system, it is very difficult to identify the source of the problem. A poor layout with ground loop can not only create noise it can also affect the stability of the converter or randomly trigger an event. A common problem in high frequency and high power density DC/DC converters is the so-called "common-mode noise," which is the noise generated from parasitic capacitors, leakage inductance, etc. in the converter.

Common-mode noise (CMN) can be bypassed to chassis with small capacitors between input and output grounds to chassis and input and output ground. Assuming the layout is correct and the converter still generates noise, the question then becomes why



DRAWING A

Effective placement and orientation of the converter in a system with forced air cooling can reduce the case temperature by 5–15°C (depending on the air flow (LFM)). When the converter is placed at the entrance and air passes over it as shown in Drawing A—from Pin 5–1 and 6–10—the lowest case temperature can be obtained.

Therefore, open-frame converters require special consideration in three critical areas—layout, radiation and cooling—that may create conflicts. We stress the importance of these critical areas:

LAYOUT
RADIATION
COOLING

When an open-frame converter is used to power digital circuits, radiation shielding can be implemented via the system shielding. When the load is an analog circuit—for example, A/D, D/A, RF amplifier, etc.—and these components are placed close to the converter, the radiated noise may affect signal integrity.

High impedance summing points of operational amplifiers or other components with poor power supply rejection ratio (PSRR) may be affected. In this case, local radiation shielding around the

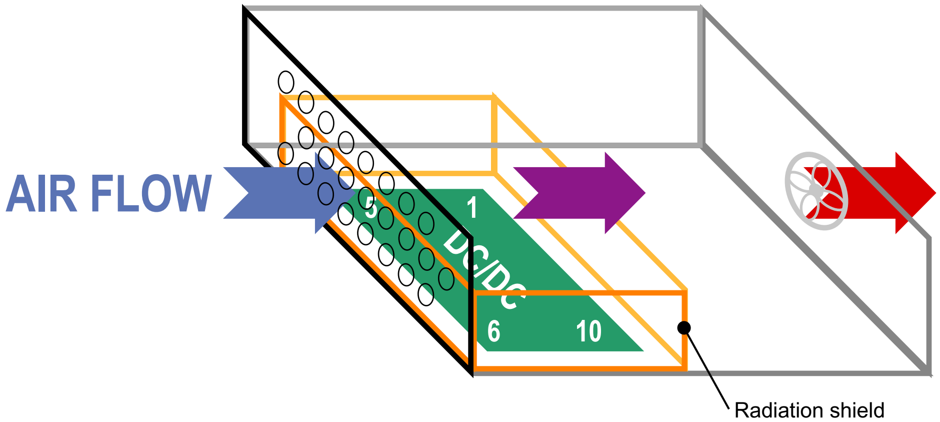
does the system not exhibit a noise problem when a linear voltage source is supplied?

The answer comes from the process of elimination. Replacing a switching power source of 500kHz with another one switching at 50–60Hz is not the solution. Using the "noisy" DC/DC converter, one may try the following: First, if possible, shield the converter with six-sided shielding. If the problem is still in the system, then radiated noise is not the problem! Conducted noise or poor layout are the more likely causes. As was mentioned earlier, the use of a component with poor PSRR—e.g. BICMOS, CMOS, rail-to-rail OPAMS—may be the cause of the problem.

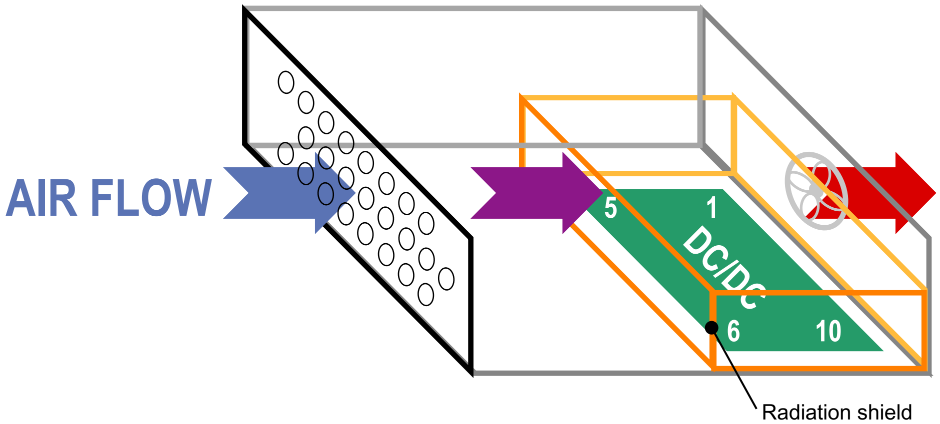
Do not use a converter with 50mV to 100mV output ripple to power a 12-bit A/D converter. Also keep in mind that CMOS, OPAMs, A/D, and S/H may offer low power, but the parasitic capacitor from drain to gate, drain to source, and gate to source will couple any V_{DD} and V_{SS} supply noise into your signal.

Better filtering in the input or output will reduce conducted noise if they are the cause of the problem. When both radiated and conducted noise are reduced, the last potential cause is ***layout***. Also, use ground plain under the converter for shielding and avoid passing signal lines under it.

In conclusion, open-frame DC/DC converters offer high efficiency, power density, and low cost, but radiate a wide band of noise. For any application where the system layout is critical, select the appropriate converter(s) for the application and completely test your system during the prototyping phase. DO NOT ASSUME all is well.



DRAWING B



DRAWING C