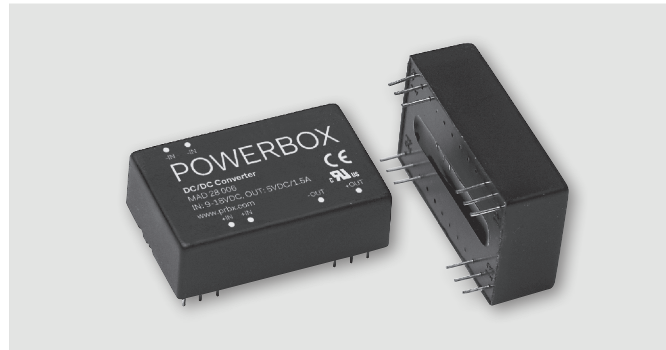
P R
B X

POWERBOX Industrial Line
MAD28 Series
7.5W Single and Dual Output
DC/DC Converter
Manual V10



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1. Introduction

The MAD28 series offer 7.5 watts of output power in a 24 pin DIP and SMD metal package. The MAD28 series has a 2:1 wide input voltage range of 9-18VDC, 18-36VDC and 36-72VDC, and provides a precisely regulated output. This series has features such as high efficiency, 1500VDC of isolation and allows an ambient operating temperature range of –40°C to 85°C (de-rating abov e 71°C). The modules are fully protected against output short circuit. All models are very suitable for distributed power architectures, telecommunications, battery operated equipment and industrial applications.

2. DC/DC Converter Features

7.5W isolated output
Efficiency to 87%
2:1 input range
Regulated outputs
Pi input filter
DIP-24 / SMD metal package
Continuous short circuit protection
Without tantalum capacitors inside
CE Mark meets 2004/108/EC
UL60950-1 approval

3. Electrical Block Diagram

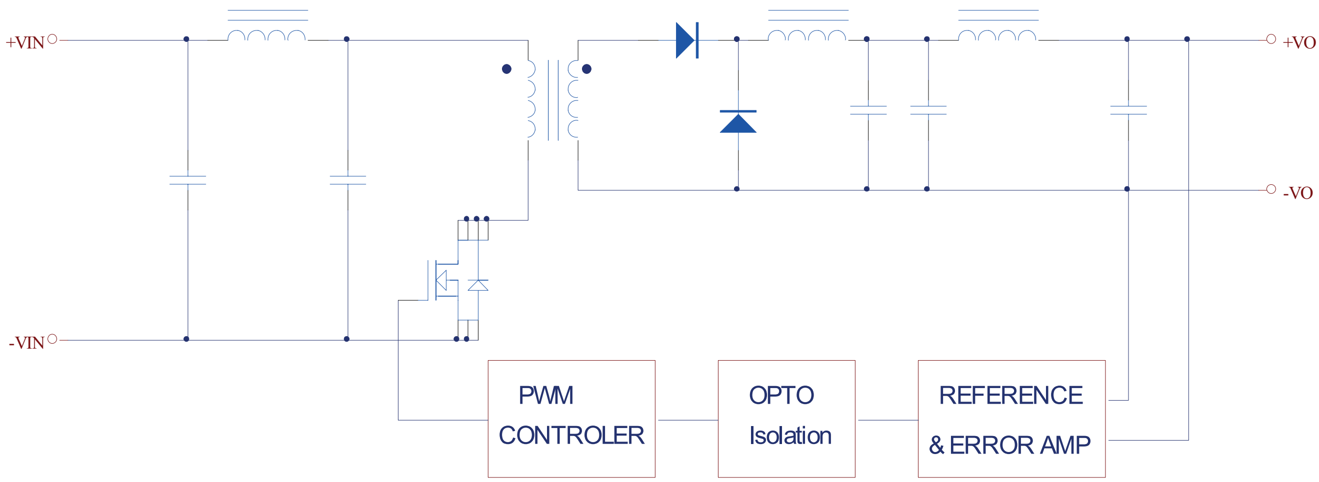


Figure1 Electrical Block Diagram of single output module

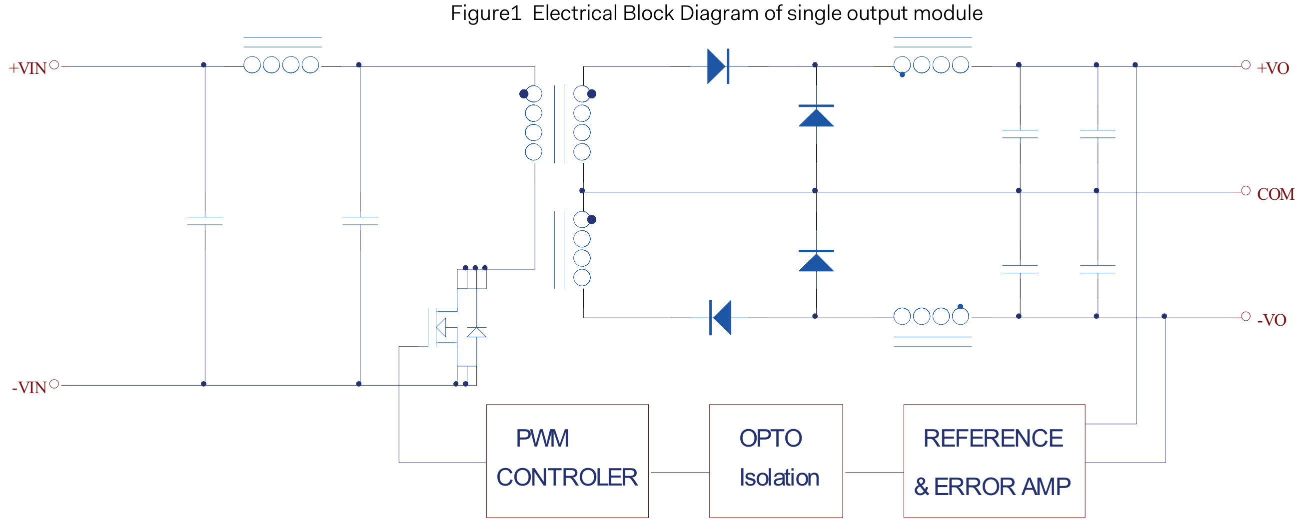


Figure2 Electrical Block Diagram of dual output module

4. Technical Specifications

(All specifications are typical at nominal input, full load at 25°C unless otherwise noted.)

Absolute Maximum Ratings

Parameters	Notes and Conditions	Device	Min	Typical	Max	Units
Input voltage						
Continuous		9-18Vin model	9	12	18	VDC
		18-36Vin model	18	24	36	VDC
		36-72Vin model	36	48	72	VDC
Transient	100 ms	9-18Vin models			20	VDC
		18-36Vin models			50	VDC
		36-72Vin models			100	VDC
Operating ambient temperature	De-rating, above 71 °C	All	-40		+85	°C
Case temperature		All			100	°C
Storage temperature		All	-40		+100	°C
Input/output isolation voltage	1 minute	All	1500			VDC

Input Characteristics

Parameters	Notes and Conditions	Device	Min	Typical	Max	Units
Operating input voltage		9-18Vin model	9	12	18	VDC
		18-36Vin model	18	24	36	VDC
		36-72Vin model	36	48	72	VDC
Maximum input current	Full load, Vin=9V	9-18Vin model		1040		mA
	Full load, Vin =18V	18-36Vin model		500		mA
	Full load, Vin =36V	36-72Vin model		255		mA
No-load input current	Vin=Nominal input	MAD 28 006		25		mA
		MAD 28 009		25		mA
		MAD 28 012		25		mA
		MAD 28 015		30		mA
		MAD 28 018		30		mA
		MAD 28 021		30		mA
		MAD 28 003		25		mA
		MAD 28 023		20		mA
		MAD 28 026		20		mA
		MAD 28 029		20		mA
		MAD 28 032		25		mA
		MAD 28 035		25		mA
		MAD 28 038		25		mA
		MAD 28 041		20		mA
		MAD 28 044		10		mA
		MAD 28 047		10		mA
		MAD 28 050		10		mA
		MAD 28 053		15		mA
		MAD 28 056		15		mA
		MAD 28 059		15		mA
		MAD 28 062		10		mA
Inrush current (I^2t)		All			TBD	A^2s
Input reflected ripple current	P-P thru 1uH inductor, 5Hz to 20Mhz	All		TBD		mA

Output Characteristics

Parameters	Notes and Conditions	Device	Min	Typical	Max	Units
Output voltage set point	Vin=Nominal Vin, Io = Io_max, Tc=25°C	Vo=5VDC	4.9	5	5.1	VDC
		Vo=12VDC	11.76	12	12.24	VDC
		Vo=15VDC	14.7	15	15.3	VDC
		Vo=±5VDC	±4.9	±5	±5.1	VDC
		Vo=±12VDC	±11.76	±12	±12.24	VDC
		Vo=±15VDC	±14.7	±15	±15.3	VDC
		Vo=3.3VDC	3.234	3.3	3.366	VDC
Voltage balance	Vin nominal, Io=Io_max, Tc=25°C	Dual			±1.0	%
Output voltage regulation						
Load regulation	Io=Full Load to 10% load	Single			±0.5	%
	Io=Full Load to 25% load	Dual			±1.0	%
Line regulation	Vin=high line to low line, full load	All			±0.2	%
Temperature coefficient	TC=-40°C to +85°C	All			±0.05	%/°C
Output voltage ripple and noise						
Peak-to-Peak	Vin=nominal input, Io= full load	Vo=5VDC			100	mV
	20MHz bandwidth	Vo=12VDC			100	mV
		Vo=15VDC			100	mV
		Vo=±5VDC			100	mV
		Vo=±12VDC			100	mV
		Vo=±15VDC			100	mV
		Vo=3.3VDC			100	mV
Operating output current range		Vo=5VDC	0		1500	mA
		Vo=12VDC	0		625	mA
		Vo=15VDC	0		500	mA
		Vo=±5VDC	0		±750	mA
		Vo=±12VDC	0		±310	mA
		Vo=±15VDC	0		±250	mA
		Vo=3.3VDC	0		1500	mA
Output DC current limit inception	Output voltage=90% ,nom output voltage	All	120			%
Maximum output capacitance	Full load, resistance	Vo=5VDC			4700	uF
		Vo=12VDC			4700	uF
		Vo=15VDC			4700	uF
		Vo=±5VDC			2000	uF
		Vo=±12VDC			2000	uF
		Vo=±15VDC			2000	uF
		Vo=3.3VDC			4700	uF

Dynamic Characteristics

Parameters	Notes and Conditions	Device	Min	Typical	Max	Units
Start up time						
Start up time, from input	Vin, min to 90%Vo, set	9-36Vin models		15		ms
		Others		20		ms

Efficiency

Parameters	Notes and Conditions	Device	Min	Typical	Max	Units
100% load	Vin=Nominal Vin, Io=Io.max,	MAD 28 006		80		%
		MAD 28 009		83		%
		MAD 28 012		84		%
		MAD 28 015		81		%
		MAD 28 018		83		%
		MAD 28 021		83		%
		MAD 28 003		78		%
		MAD 28 023		83		%
		MAD 28 026		87		%
		MAD 28 029		87		%
		MAD 28 032		84		%
		MAD 28 035		87		%
		MAD 28 038		84		%
		MAD 28 041		78		%
		MAD 28 044		81		%
		MAD 28 047		85		%
		MAD 28 050		86		%
		MAD 28 053		82		%
		MAD 28 056		85		%
		MAD 28 059		85		%
		MAD 28 062		76		%

Isolation Characteristics

Parameters	Notes and Conditions	Device	Min	Typical	Max	Units
Isolation voltage	Input to output 1 minute	All	1500			VDC
Isolation resistance	Input to output	All			1000	MΩ
Isolation capacitance	Input to output	All		560		pF

Feature Characteristics

Parameters	Notes and Conditions	Device	Min	Typical	Max	Units
Switching frequency	Vin=Nominal, Io=Io.max	All		300		KHz

General Specifications

Parameters	Notes and Conditions	Device	Min	Typical	Max	Units
MTBF	Io=100% of Io, max:	Single		TBD		Khours
	Ta=25°C per MIL-HDBK-217F	Dual		TBD		Khours
Weight		All		18.4		grams

5. Main Features and Functions

5.1 Operating Temperature Range

The MAD28 series converters can be operated by a wide ambient temperature range from -40°C to 85°C(de-rating above 71°C). The standard model has a Copper case and case temperature can not over 100°C at normal operating.

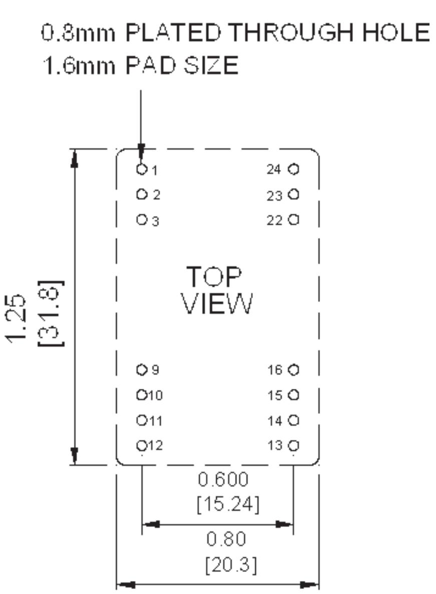
5.2 Over Current Protection

All different voltage models have full continuous short-circuit protection. To provide protection in a fault condition, the unit is equipped with internal over-current protection. The unit operates normally once the fault condition is removed. At the point of current-limit inception, the converter will go into over current protection.

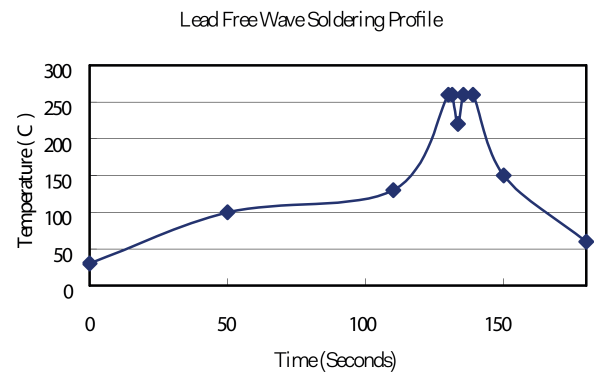
6. Applications

6.1 Recommended Layout, PCB Footprint and Soldering Information

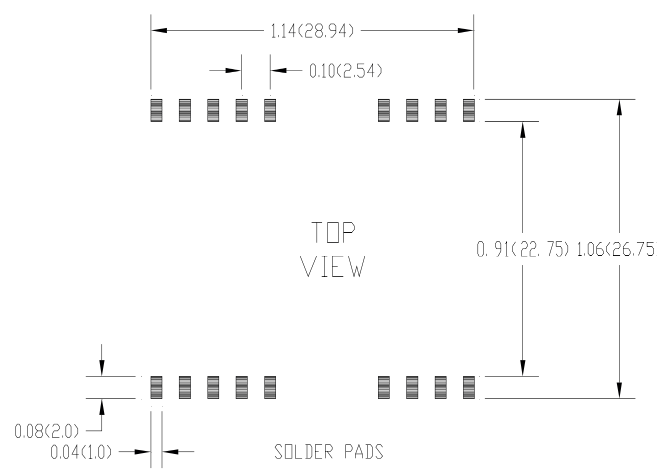
The system designer or the end user must ensure that other components and metal in the vicinity of the converter meet the spacing requirements to which the system is approved. Low resistance and low inductance PCB layout traces are the norm and should be used where possible. Due consideration must also be given to proper low impedance tracks between power module, input and output grounds. The recommended footprints and soldering profiles are shown as Figure 3.

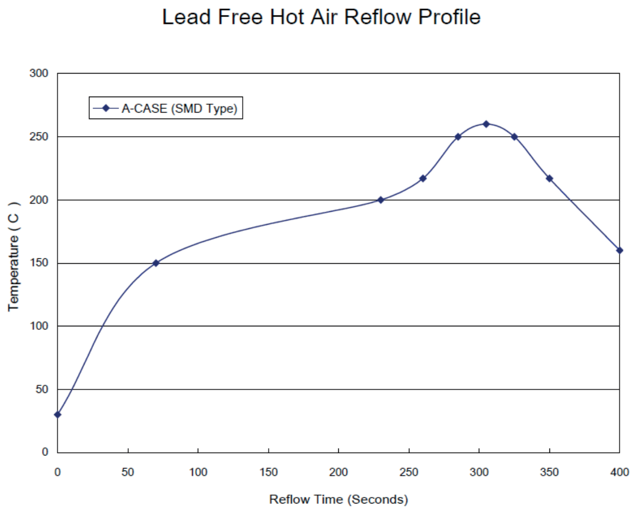


Note: Dimensions are in inches (millimeters)



Note:
1. Soldering Materials : Sn/Cu/Ni
2. Ramp up rate during preheat : 1.4°C/Sec (From 50°C to 100°C)
3. Soaking temperature : 0.5°C/Sec (From 100°C to 130°C), 60±20 seconds
4. Peak temperature : 260°C, above 250°C 3~6 Seconds
5. Ramp up rate during cooling : -10.0°C/Sec (From 260°C to 150°C)



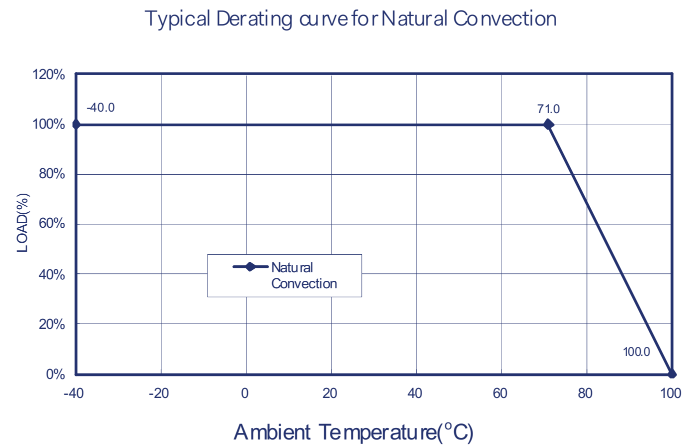


1. Soldering Paste: SHENMAO PF610-P (Sn/Ag/Cu)
2. Ramp up rate during preheat: 1.71°C/Sec (From 30°C to 150°C)
3. Soaking temperature: 0.31°C/Sec (From 150°C to 200°C), 160±10 seconds
4. Ramp up rate during reflow: 0.96°C/Sec (From 217°C to 260°C)
5. Peak temperature: 260°C, above 217°C 90 Seconds
6. Ramp up rate during cooling: -1.2°C/Sec (From 260°C to 160°C)

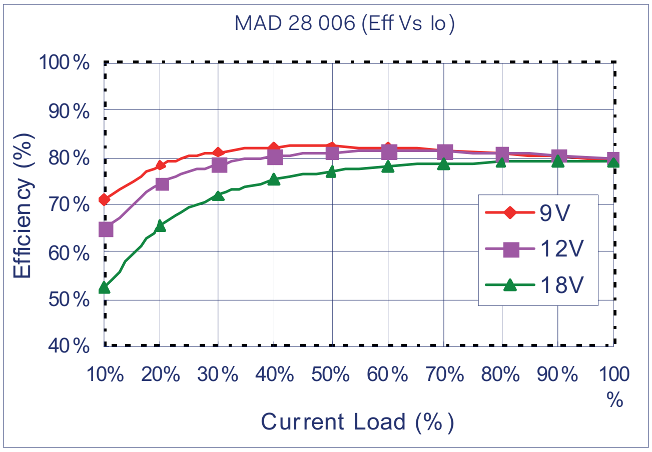
Figure 3 Recommended PCB Layout Footprints and Wave Soldering Profiles for DIP-24 and SMD packages

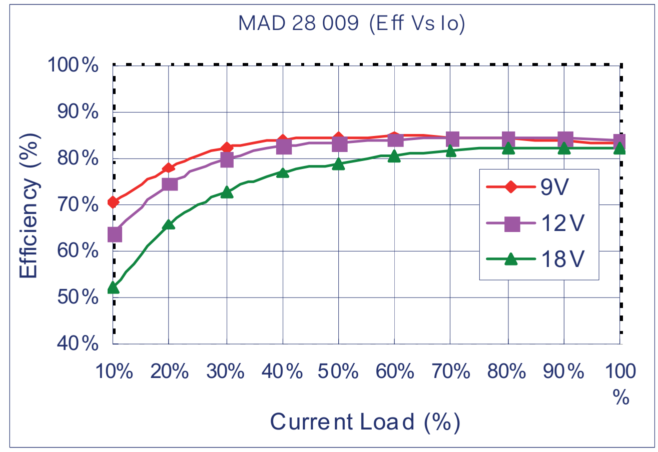
6.2 Power De-Rating Curves

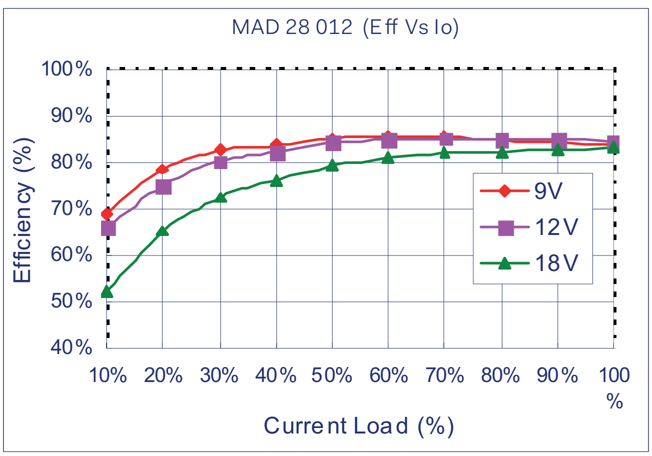
Operating Ambient temperature Range: -40°C ~ 85°C with de-rating above 71°C. Maximum case temperature under any operating condition should not exceed 100°C.

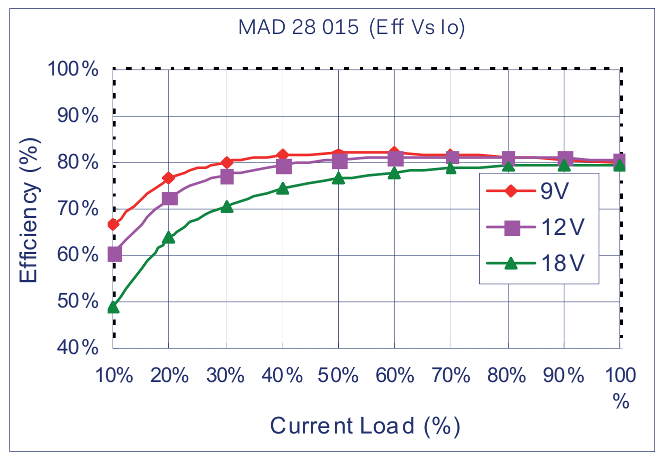


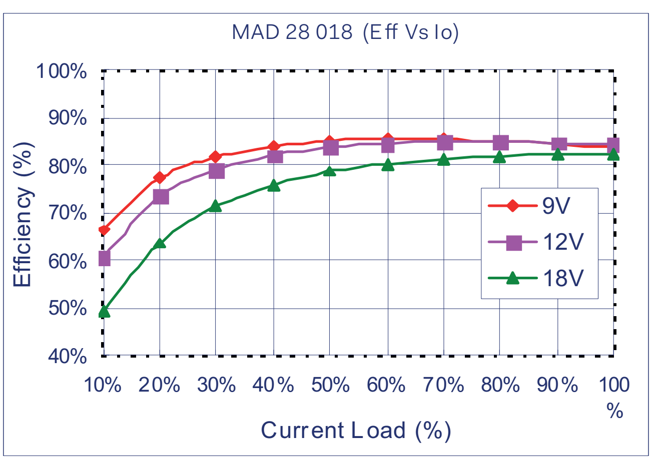
6.3 Efficiency VS. Load

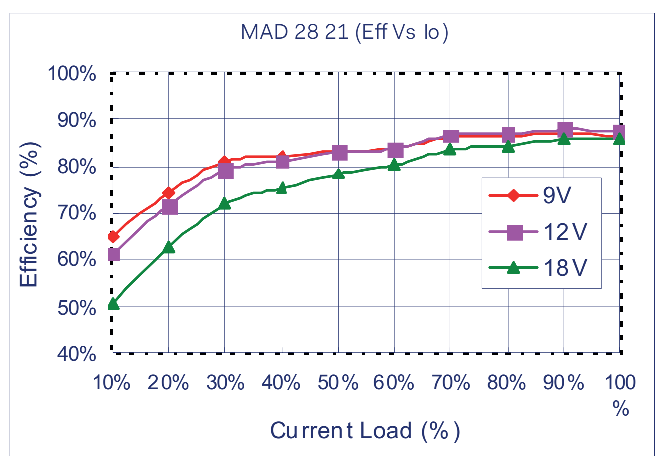


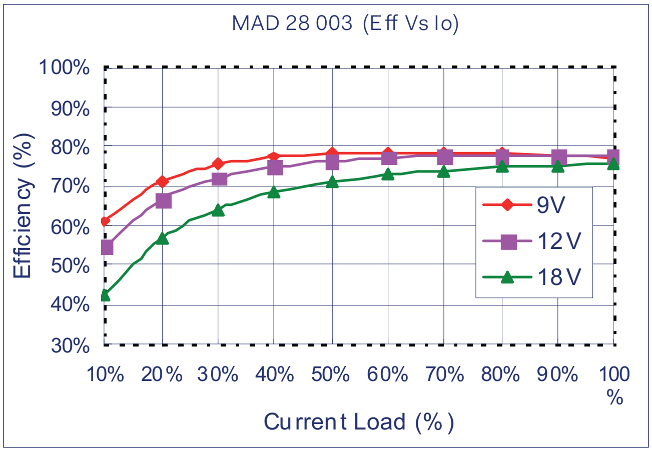


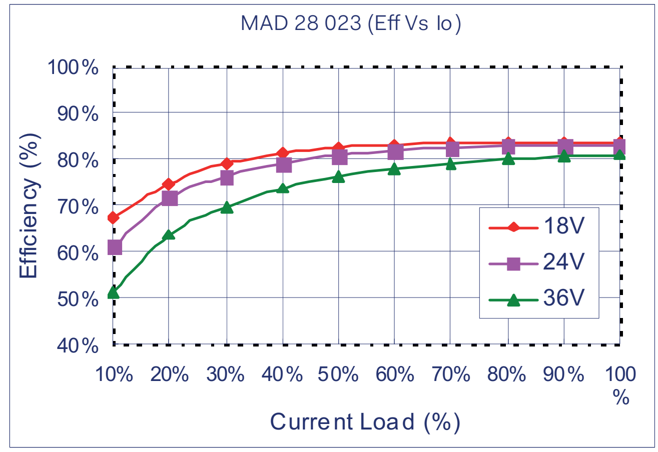


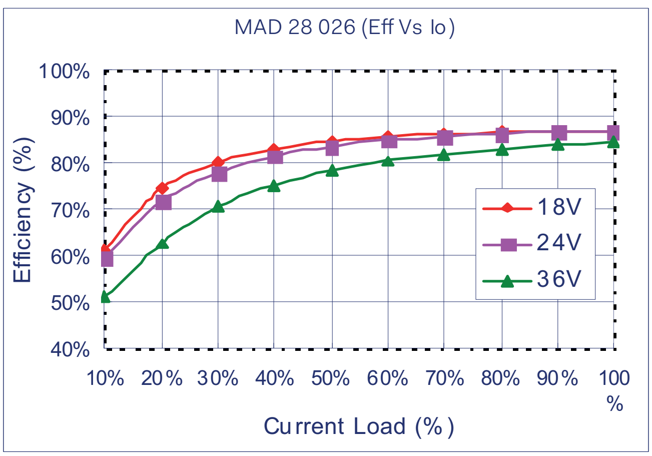


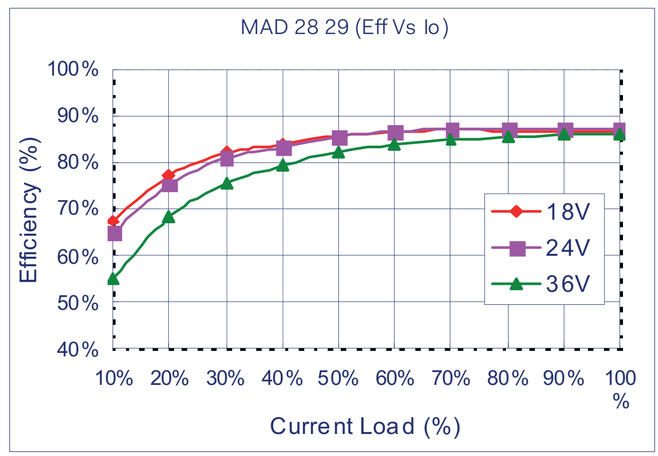


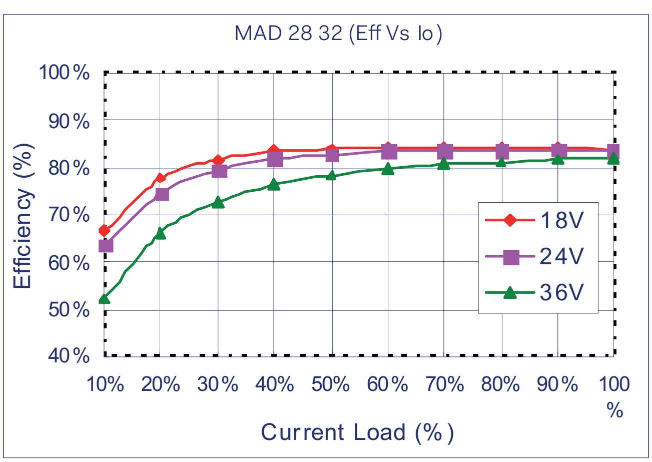


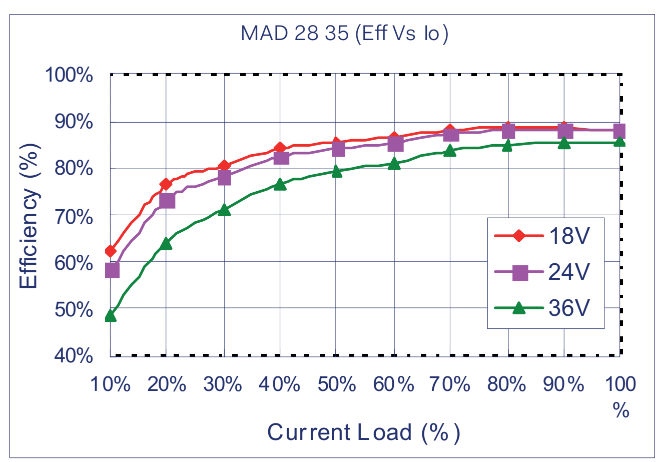

MAD 28 003 (Eff Vs Io)
Efficiency (%)
Current Load (%)
9V
12V
18V

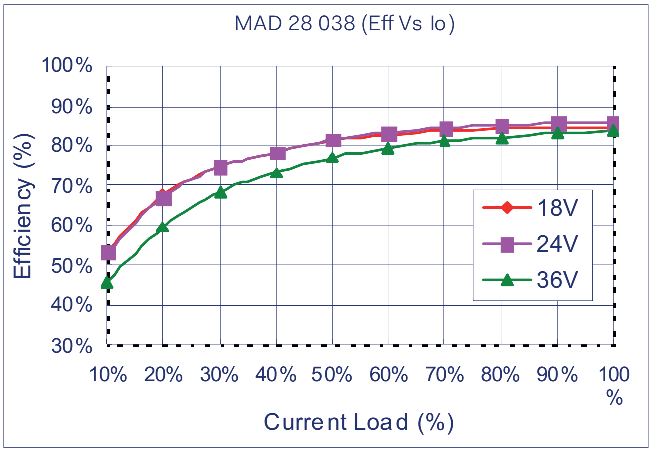

MAD 28 023 (Eff Vs Io)
Efficiency (%)
Current Load (%)
18V
24V
36V

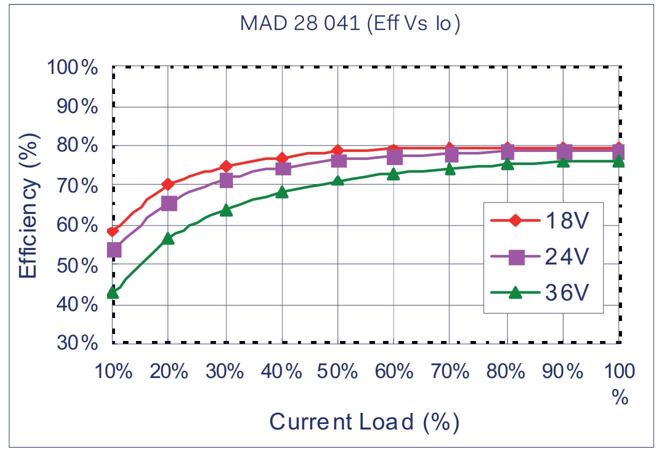

MAD 28 026 (Eff Vs Io)
Efficiency (%)
Current Load (%)
18V
24V
36V

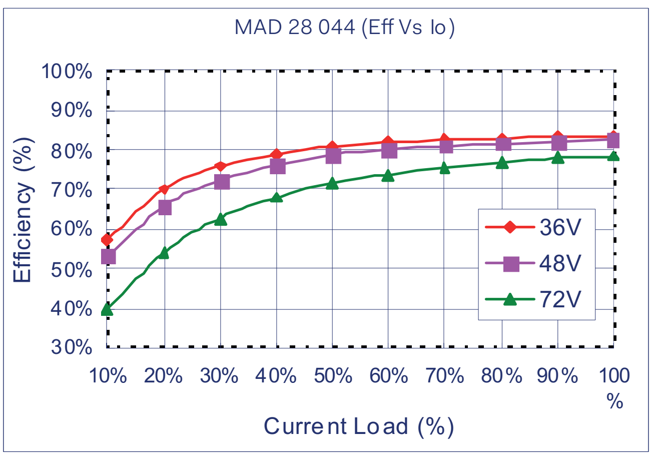

MAD 28 29 (Eff Vs Io)
Efficiency (%)
Current Load (%)
18V
24V
36V

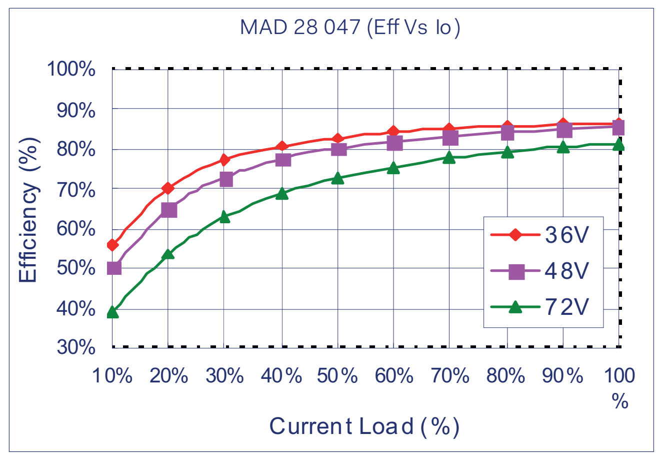

MAD 28 32 (Eff Vs Io)
Efficiency (%)
Current Load (%)
18V
24V
36V

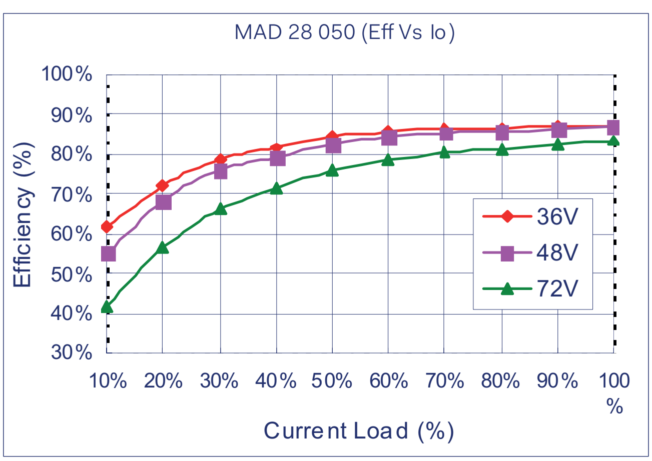

MAD 28 35 (Eff Vs Io)
Efficiency (%)
Current Load (%)
18V
24V
36V

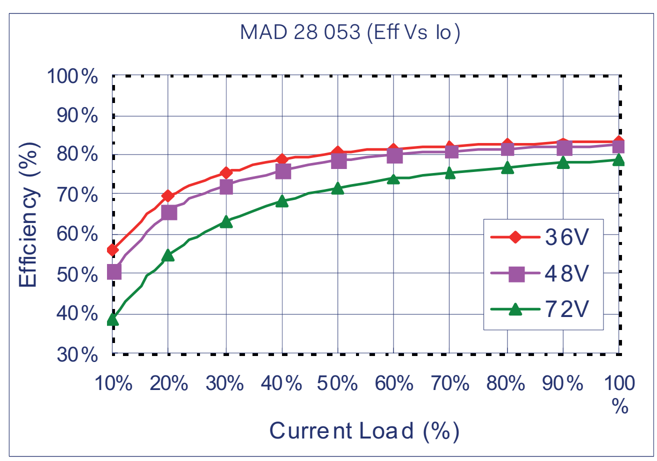

MAD 28 038 (Eff Vs Io)
Efficiency (%)
100%
90%
80%
70%
60%
50%
40%
30%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100 %
Current Load (%)
18V
24V
36V

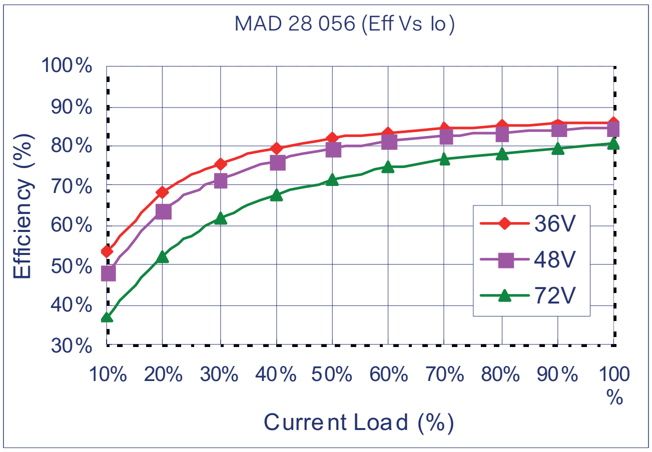

MAD 28 041 (Eff Vs Io)
Efficiency (%)
100%
90%
80%
70%
60%
50%
40%
30%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100 %
Current Load (%)
18V
24V
36V

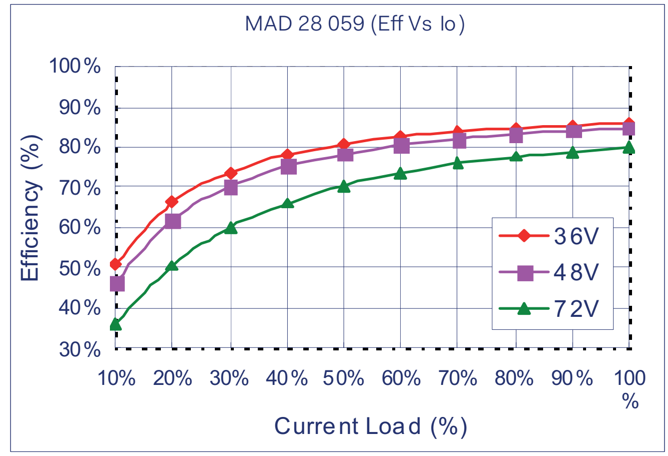

MAD 28 044 (Eff Vs Io)
Efficiency (%)
100%
90%
80%
70%
60%
50%
40%
30%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100 %
Current Load (%)
36V
48V
72V

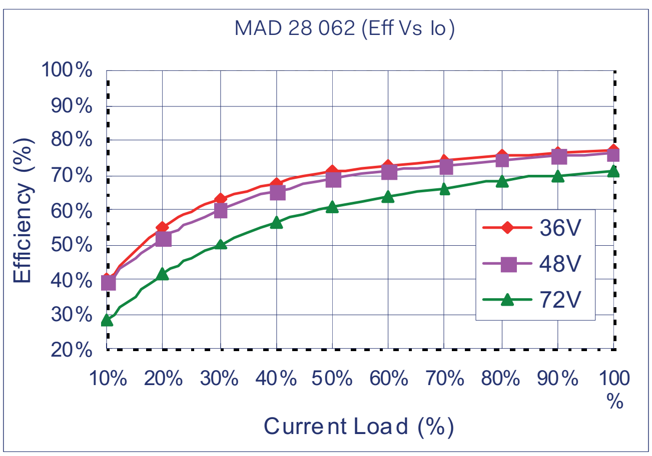

MAD 28 047 (Eff Vs Io)
Efficiency (%)
100%
90%
80%
70%
60%
50%
40%
30%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100 %
Current Load (%)
36V
48V
72V


MAD 28 050 (Eff Vs Io)
Efficiency (%)
100%
90%
80%
70%
60%
50%
40%
30%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100 %
Current Load (%)
36V
48V
72V


MAD 28 053 (Eff Vs Io)
Efficiency (%)
100%
90%
80%
70%
60%
50%
40%
30%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100 %
Current Load (%)
36V
48V
72V

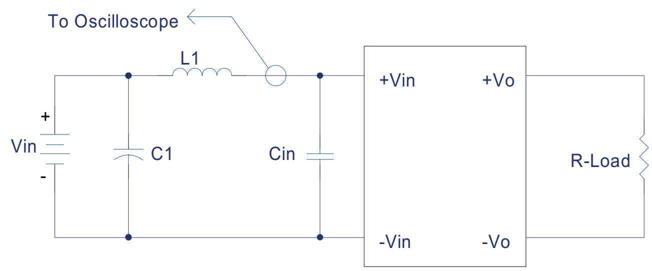

MAD 28 056 (Eff Vs Io)
Efficiency (%)
100%
90%
80%
70%
60%
50%
40%
30%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100 %
Current Load (%)
36V
48V
72V


MAD 28 059 (Eff Vs Io)
Efficiency (%)
100%
90%
80%
70%
60%
50%
40%
30%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100 %
Current Load (%)
36V
48V
72V


MAD 28 062 (Eff Vs Io)
Efficiency (%)
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100 %
Current Load (%)
36V
48V
72V

6.4 Input Capacitance at the Power Module

The converters must be connected to low AC source impedance. To avoid problems with loop stability source inductance should be low. Also, the input capacitors (Cin) should be placed close to the converter input pins to de-couple distribution inductance. However, the external input capacitors are chosen for suitable ripple handling capability. Low ESR capacitors are good choice. Circuit as shown as below represents typical measurement methods for reflected ripple current. C1 and L1 simulate a typical DC source impedance. The input reflected-ripple current is measured by current probe to oscilloscope with a simulated source Inductance (L1).



L1: 12uH.
C1: 220uF ESR <0.1Ω @ 20 , 100KHz.
Cin: None

Figure 4 Input Reflected-Ripple Test Setup

6.5 Test Set-Up

The basic test set-up to measure parameters such as efficiency and load regulation is shown as below. When testing the modules under any transient conditions please ensure that the transient response of the source is sufficient to power the equipment under test. We can calculate the

- Efficiency
- Load regulation and line regulation.

The value of efficiency is defined as:

$$\eta = \frac{Vo \times Io}{Vin \times Iin} \times 100\%$$

Where:
V_o is output voltage,
I_o is output current,
V_{in} is input voltage,
I_{in} is input current.

The value of load regulation is defined as:

$$Load.reg = \frac{V_{FL} - V_{NL}}{V_{NL}} \times 100\%$$

Where:
V_{FL} is the output voltage at full load
V_{NL} is the output voltage at 10% load (Single output)
V_{NL} is the output voltage at 25% load (Dual output)

The value of line regulation is defined as:

$$Line.reg = \frac{V_{HL} - V_{LL}}{V_{LL}} \times 100\%$$

Where: V_{HL} is the output voltage of maximum input voltage at full load.
V_{LL} is the output voltage of minimum input voltage at full load.

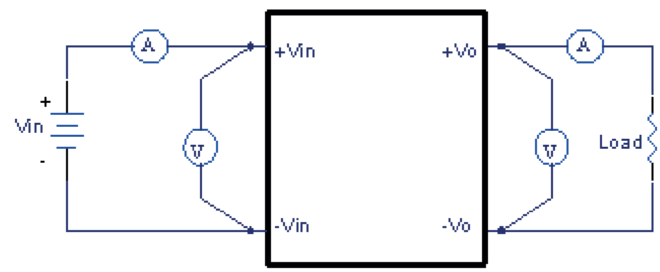


Figure 5 Test Setup

6.6 Output Ripple and Noise Measurement

The test set-up for noise and ripple measurements is shown in Figure 6 and Figure 7. A coaxial cable was used to prevent impedance mismatch reflections disturbing the noise readings at higher frequencies. Measurements are taken with output appropriately loaded and all ripple/noise specifications are from D.C. to 20MHz Band Width.

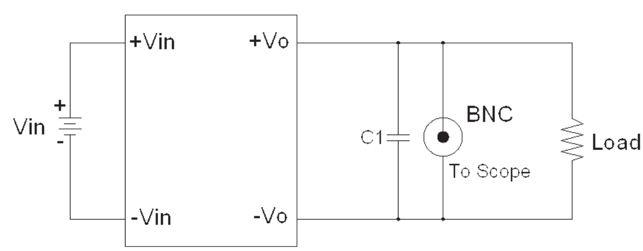


Figure 6 Using BNC to Measure Output Ripple and Noise

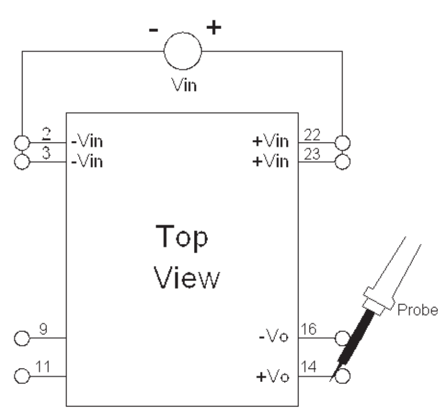


Figure 7 Using Probe to Measure Output Ripple and Noise

6.7 Output Capacitance

The MAD28 series converters provide unconditional stability with or without external capacitors. For good transient response low ESR output capacitors should be located close to the point of load. These series converters are designed to work with load capacitance to see technical specifications.

7. Safety & EMC

7.1 Input Fusing and Safety Considerations

The MAD28 series converters have not an internal fuse. However, to achieve maximum safety and system protection, always use an input line fuse. We recommended a time delay fuse 1.5A for 12Vin, 1A for 24Vin models and 0.5A for 48Vin modules. Figure8 circuit is recommended by a Transient Voltage Suppressor diode across the input terminal to protect the unit against surge or spike voltage and input reverse voltage.

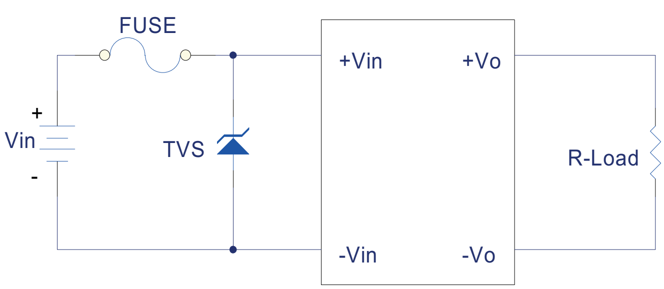


Figure 8 Input Protection

7.2 EMC Considerations

EMI Test standard: EN55022 Class B Conducted Emission
Test Condition: Input Voltage: Nominal, Output Load: Full Load

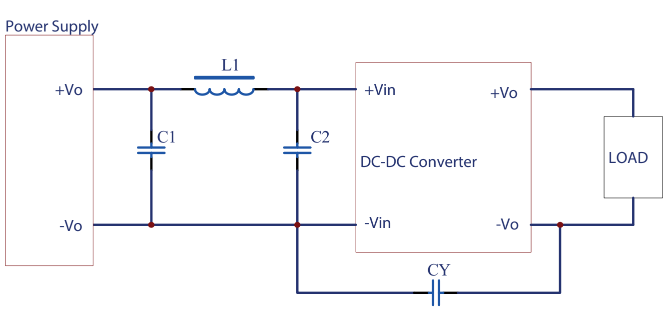


Figure 9 Connection circuit for conducted EMI testing

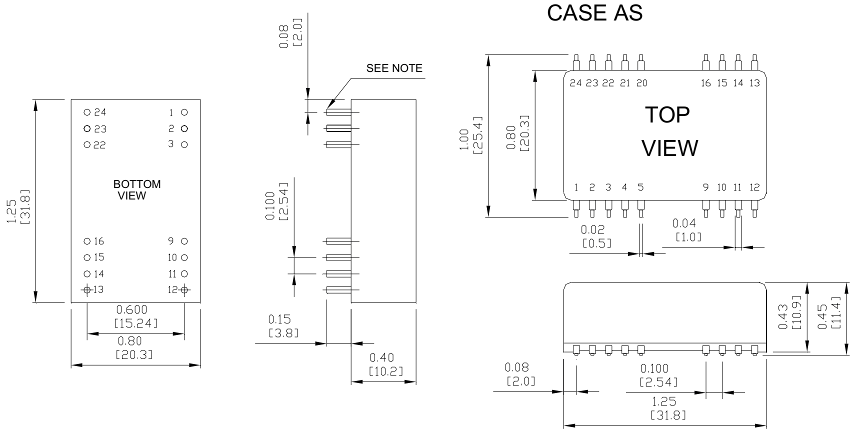
EN55022 Class B

Model No.	C1	C2	CY	L1
MAD 28 006	47uF/50V ESR<0.6	47uF/50V ESR<0.6	NC	3.5uH
MAD 28 009	47uF/50V ESR<0.6	47uF/50V ESR<0.6	NC	3.5uH
MAD 28 012	47uF/50V ESR<0.6	47uF/50V ESR<0.6	NC	3.5uH
MAD 28 015	47uF/50V ESR<0.6	47uF/50V ESR<0.6	NC	3.5uH
MAD 28 018	47uF/50V ESR<0.6	47uF/50V ESR<0.6	NC	3.5uH
MAD 28 021	47uF/50V ESR<0.6	47uF/50V ESR<0.6	NC	3.5uH
MAD 28 0003	47uF/50V ESR<0.6	47uF/50V ESR<0.6	NC	3.5uH
MAD 28 023	47uF/50V ESR<0.6	47uF/50V ESR<0.6	NC	3.5uH
MAD 28 026	47uF/50V ESR<0.6	47uF/50V ESR<0.6	NC	3.5uH
MAD 28 029	47uF/50V ESR<0.6	47uF/50V ESR<0.6	NC	3.5uH
MAD 28 032	47uF/50V ESR<0.6	47uF/50V ESR<0.6	NC	3.5uH
MAD 28 035	47uF/50V ESR<0.6	47uF/50V ESR<0.6	NC	3.5uH
MAD 28 038	47uF/50V ESR<0.6	47uF/50V ESR<0.6	NC	3.5uH
MAD 28 041	47uF/50V ESR<0.6	47uF/50V ESR<0.6	NC	3.5uH
MAD 28 044	22uF/100V ESR<0.66	22uF/100V ESR<0.66	NC	3.5uH
MAD 28 047	22uF/100V ESR<0.66	22uF/100V ESR<0.66	NC	3.5uH
MAD 28 050	22uF/100V ESR<0.66	22uF/100V ESR<0.66	NC	3.5uH
MAD 28 053	22uF/100V ESR<0.66	22uF/100V ESR<0.66	NC	3.5uH
MAD 28 056	22uF/100V ESR<0.66	22uF/100V ESR<0.66	NC	3.5uH
MAD 28 059	22uF/100V ESR<0.66	22uF/100V ESR<0.66	NC	3.5uH
MAD 28 062	22uF/100V ESR<0.66	22uF/100V ESR<0.66	NC	3.5uH

8. Mechanical Specifications

NOTE:Pin Size is 0.02"Inch (0.5mm)DIA
All Dimensions In Inches (mm)
Tolerances Inches: X.XX= ±0.02 , X.XXX= ±0.010
Millimeters: X.X= ±0.5 , X.XX=±0.25

CASE AS



PIN CONNECTION				
Pin	Single Output		Dual Output	
	DIP	SMD	DIP	SMD
1,24	NP	NC	NP	NC
2,3	-V Input		-V Input	
4,5	NP	NC	NP	NC
9	NC		Common	
10,15	NC		NC	
11	NC		-V Output	
12,13	NP	NC	NP	NC
14	+V Output		+V Output	
16	-V Output		Common	
20,21	NP	NC	NP	NC
22,23	+V Input		+V Input	

* NC-NO CONNECTION WITH PIN
* NP-NO PIN