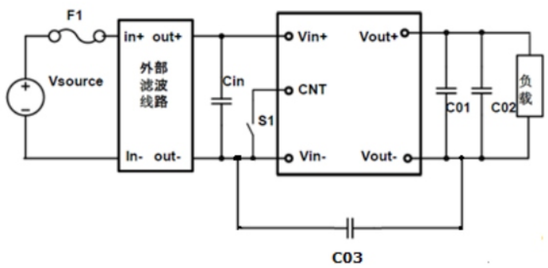
Appendix 1:

Application Notes for DC-DC PowerConverters

Dr.Power Technologies is a China based leader in design and manufacture of high reliable power supply solutions to rugged military and industrial field, and customers have trusted Dr.Power to help them accelerate time-to-market and reduce risk with the highly reliable power conversion products.

This application notes describes how to use the isolated DC-DC power converters of Dr.Power in systems, including typical application structure for DC-DC power module, thermal management, EMI consideration, large capacitive load , paralleling-active current sharing, layout notes, practical evaluation techniques, thermal evaluation. Please contact Dr.Power if there are any more application questions.

Typical Application Sample



F1:25A fuse (fast fuse)
Cin:100μF high frequency low ESR electrolytic capacitor, parallel connect 2.2μF ceramic capacitor
C01: 1μF ceramic capacitor
C02: 470μF E-Cap
C03: 0.01μF /3000Vdc ceramic capacitor. (could paralleling several capacitors

◆ Application Structure For DC-DC Power Module

Figure 1 shown a typical application structure for DC-DC power module. For a DC-DC power module to function properly in a system, the system design should provide a sufficiently low impedance power source (usually the output impedance of power source) to feed the power module, and the output impedance of the power module should be sufficiently low as well for good transient response. Besides the internal design of DC-DC converters and power source, these requirements are usually assured by placing extra capacitors (C1-C4 in Figure1 and figure 2) across the input terminals and the output terminals of the power module.

All standard board-mount DC-DC power modules operate in high frequency switching mode involving fast dv/dt and di/dt, thus generate conducted and radiated EMI. Due to space constraints and ever increasing power density dictated by the system power requirements, there is very limited on-board filtering. For a system to pass EMC regulations, it' s often necessary to add additional filtering components around the DC-DC power module. Except C2, other capacitors are low ESR (equivalent series resistance) and low ESL (equivalent series inductance) ceramic capacitors that provide low impedance loop for high frequency current noises. C1, C3, C4 are differential-mode filter capacitors. C2 represents low ESR and high Capacitance capacitor (such as electrolytic capacitor), the recommended capacitance of C2 for the 36-75V input voltage range (or above range) is 50-100μF per 100W output power. For 18-36V or 18-75V input ranges, the capacitance of C2 shall be significantly higher (such as 200-400μF per 100W) to limit both the power loss in this capacitor and the allowed voltage swing during start-up and load transients. The rating current of C2 should be taken care to meet the requirement of long time operation on high temperature environment and high load. The main function of C2 is to provide sufficiently lower impedance than the input impedance of the power module to keep the power source (line) impedance from interacting the power module input impedance, therefore, secure the stability of the power with module operation. At the same time, C2 provide low impedance loop for input ripple current. C7-C10 are common-mode decoupling capacitors often in the range of 10nF to 0.1μF with voltage rating sufficient to meet the system isolation voltage requirement. In many applications, additional capacitors (C4) are used at the output of DC-DC power modules, often in the range of several hundred to tens of thousands micro-farad (μF). Increasing capacitance of C4 will help to reduce the switching ripple at the output, and reduce the voltage variation during load or input transients. These are also low ESR capacitors (such as ceramic capacitors) .

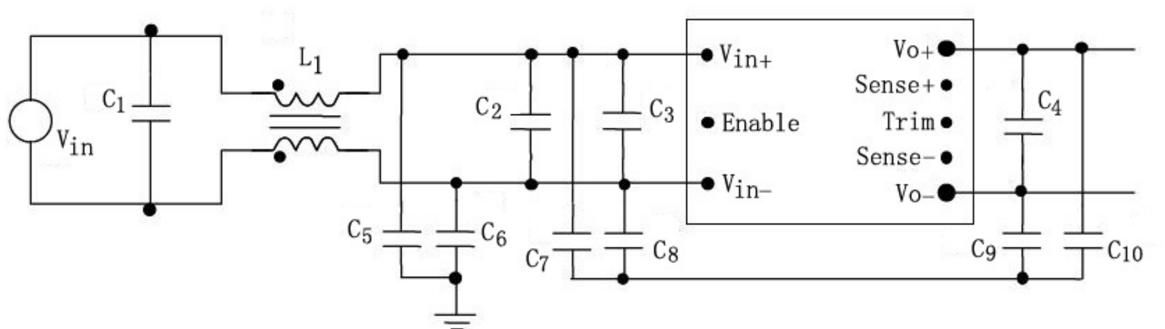


Figure 1 Typical application structure for DC-DC power module

SENSE(+) and SENSE(-) pins should be connected to the point where high precious regulation is desired(usually close to the load). The TRIM pin allows the user to adjust the output voltage set point, the output voltage adjustment range is usually 80% to 110% (some models 10% to 110%) of its specified nominal output voltage. The converter can be turned on and off by changing the voltage between the ON/OFF pin and Vin(-). When remote ON/OFF controlling is not required, the ON/OFF pin should be connected to Vin- (for negative control logic) or left floating (for positive control logic).

Thermal Management

The thermal management of DC-DC power modules is one of the most important application issues as more and more applications demand high power and high current in smaller packages and require the modules to operate under increasingly stringent environment, such as high temperature and low wind speed.

The key factors affecting the thermal performance of a given DC-DC power module are:

- Airflow and Orientation
- Ambient Temperature
- Heat transfer path

Available airflow and its orientation with reference to the power module have great impact on the module's thermal performance. It is recommended that customers place the converter at a location where it receives the maximum available airflow and in the preferred transverse orientation (refer to the thermal derating curve).

The thermal derating curves in the product datasheets provide a guideline for application. The derating curves are based on the data obtained in wind-tunnel tests conducted by power module manufacturers. The derating curves of Dr.Power are generated using industry standard of 125 °C power semiconductor junction temperature. The junction temperature is calculated based on semiconductor's thermal resistance and surface temperature.

Although the derating curves are supposed to be very important for system designs, the performance of a power module in a system often cannot be well represented by these curves, and evaluation at the system level is necessary. The detailed evaluation considerations are illustrated in "Thermal Evaluation" under "Practical Evaluation Techniques" section.

Based on open-frame design, the baseplate and other encapsulation options available on Dr.Power modules provide customers the flexibility in their designs to deal with extreme environments. Dr.Power module's high efficiency, balanced thermal design make sure better performance on extreme environment applications. A baseplate by itself is able to improve the thermal performance of the module. The higher the airflow speed, the more improvement a baseplate will bring. Additional heatsink can be added to some baseplates for enhanced thermal performance.

EMI Consideration

All standard board-mount DC-DC power modules operate in high frequency switching mode involving fast dv/dt and di/dt, thus generate conducted and radiated EMI. Radiated EMI is also affected by the converter's mechanical structure. General the converters apply snubber to reduce the high frequency vibration.

For the metal baseplate converter, connect the baseplate to ground or stable voltage point will bring about a certain shielding effect.

The conducted EMI can be separated into differential-mode (DM) noise and common-mode (CM) noises. The differential mode noises appear between the positive and the negative leads at both input and output terminals, mainly at input. Switch mode or PWM is the root cause of such kind of "noise".

The common mode noises appear between the converter input/output terminals to ground and the system, which are affected by many internal and external factors. Dr.Power's converters have internal input differential -mode L-C filter.

Additional external EMI filter is primarily for suppressing conducted EMI, though it also helps to reduce radiated EMI by containing the radiated EMI sources in a local area. EMI is a system problem, which is affected by many factors outside the converters, such as cabinet design, application PCB layout, etc.

So the external filter's structure and component's parameter may be different according to the different application system.

For Dr.Power converters, the single-stage filter in Figure 1 is generally good for power modules below 150W. For power level above 150W, the two-stage filter structure shown in Figure 2 is recommended.

C1，C2，C3，C4 are differential-mode filter Capacitors. C2 represents low ESR and high capacity capacitor (such as electrolytic capacitor) at the input of the power module and is primarily for holding the energy to keep the stiffness of the input voltage source, thus the proper stability and large signal behaviors of the power module. C1, C3, C4 are low ESR (equivalent series resistance) and low ESL(equivalent series inductance) Cap for EMI filtering and fast load transients, and they should be a combination of ceramic and tantalum types. These capacitors have low ESR and low ESL for good filtering results. The reason of suggesting a combination of ceramic and other types of capacitors is because of the extremely low ERS of the ceramic capacitors, when no other type of relatively higher ESR capacitors present, could cause instability of some power modules.

The recommended capacitance of C2 for the 36-75V input voltage range (or above) is 50-100μF per 100W output power. For 18-36V or 18-75V input ranges, the capacitance of C2 shall be significantly higher (such as 200-400μF per 100W) to limit both the power loss in thiscapacitor and the allowed voltage swing during start-up and load transients. The rating current of C2 should be taken care to meet the requirement of long time operation on high temperature environment and high load. The main function of C2 is to provide sufficiently lower impedance than the input impedance of the power module to keep the power source (line) impedance from interacting with the power module input impedance, therefore, secure the stability of the power module operation. If the power source (line) impedance is low and converter is close to power source, a lower capacitance C2 can be used. Besides securing stability, C2 also provide the loop for the input ripple current.

C7-C10 are common-mode decoupling capacitors often in the range of 10nF to 0.1μF with voltage rating sufficient to meet the system isolation voltage requirement. C7 and C8 are also common-mode decoupling capacitors when the connection to system ground is available.

In many applications, additional capacitors (C4) are used at the output of DC-DC power modules, often in the range of several hundred to tens of thousands micro-farad (μF). Such external output capacitors help to reduce the switching ripple at the output, and reduce the voltage variation during load or input transients. When large amount of ceramic capacitors are used at the output of a power module, it could cause the power module to become unstable due to the very low ESR of these capacitors. This is a complicated matter as it is related to small signal analysis of converter designs, the system board designs, and the characteristics and locations of the capacitors used.

The current mode control scheme adopted in most of Dr.Power's designs makes power modules' stability insensitive to the ESR of the load capacitors. For a robust system design when using large amount of load capacitance, a combination of ceramic capacitors and capacitors with moderate ESR such as tantalum, polymer or electrolytic capacitors often provide satisfactory results.

L1, L2 should be selected based on practical input current and system EMC request, the value varied from several tens of μH to several hundreds of μH. L1, L2 are common-mode inductor. The common-mode inductance and the common mode capacitors together provide the containment of the common-mode noise. The common-mode inductance of L1，L2 are usually below 1mH（several tens of μH to several hundreds of μH）considering its current rating, EMC request and physical size. The leakage inductance of L1, L2 serve as the inductance for differential-mode filtering.

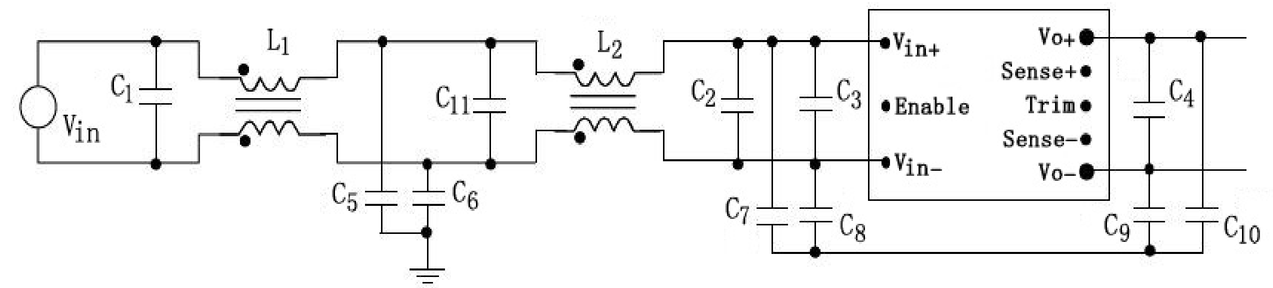


Figure 2 Two-Stage EMI filter structure

The filer structures shown in figure 2 is designed to meet electromagnetic compatibility (EMC) requirements for radiated and conducted EMI per FCC part 15J (47 CFR part 15B) in USA and/or EN55022 (equivalent to CISPR 22) in Europe without considering the system. Considering that module is only part of the application system and both input and output wires/trace are short and lay inside the system, system designs may suppress EMI through proper bypassing, shielding, grounding and system level filter. So the filter structure could be simpler compared to Figure 2.

Large Capacitive Load

In many applications, additional capacitors are used at the output of DC-DC power modules, often in the range of several hundreds to several thousands micro-farad (μF), some application demand even larger capacitance to tens of thousands of μF . Such external output capacitors help to reduce the switching ripple at the output, and reduce the voltage variation during load or input transients. The controlling schemes of DC-DC converters include voltage mode control and current mode control. When large amount of ceramic capacitors are used at the output of a power module, the voltage mode control DC-DC converters could easily be caused to become unstable due to the very low ESR of these capacitors as well as large amount of output capacitance. The current mode control scheme adopted in Dr.Power's designs makes power modules' stability insensitive to the ESR of the load capacitors. Moreover, the voltage overshooting of Dr.Power's modules are only no more than 5% on the specified maximum output capacitance. Customer can change parameter of the application board components to solve the power up failure caused by ultra large amount of output capacitance and can also contact Dr.Power for further support.

Paralleling- Active Current Sharing Notes

1. SHARE pin is noise sensitive and high-impedance network. SHARE pins of converters in parallel shall be tied together with possible shortest wire/trace, it is suggested to have corresponding ground plane on the application board to shield SHARE pin for reducing the ground noise impact on the current share accuracy. The ground plane shall be placed under the converters in parallel to make sure that the current share signals of these converters have the same referencing point. Minimize the loop formed by the current share signal traces and the above mentioned ground plane. Minimize the distance among the converters in parallel.

2. The input capacitor should be as close as possible to the input pin. For 18V-36V input range model, it is recommended to select input capacitor according to 1uF / W. For high input voltage model, it is recommended to select the input capacitor according to 0.5uF / W.

3. Vin (-) is used as the reference ground of the current sharing pin, Vin (-) on each converter should be connected together and don' t need any more components.

4. Y-Cap (value of tens to hundreds of nF) are recommended to add among Vin (-), Vout (-) and ground to improve the EMC performance with voltage rating sufficient to meet the system isolation voltage requirement. These capacitors should have good high frequency performance, such as ceramic capacitors. The trace of Y-Cap should be short and thick. At the same time, the layout trace spacing is recommended to be no less than 2mm.

5. If there is any filter on input side, Vin (+)/Vin (-) of the modules in parallel must be connected accordingly before connecting to filter.

6. If there is any filter on output side, Vout (+)/Vout (-) of the models in parallel must be connected accordingly before connecting to filter.

7. Try to use symmetrical input and output current paths.

8. Ceramic capacitors are recommended to add between Vout (+) and Vout (-) to minimize output ripple and noises.

9. If converters in parallel require to be turned on/off at the same time, it is recommended to use remote ON/OFF pin to control (add optocoupler on controlling if the converters don' t have the same ground reference).

10. Try to arrange the positions of the power converters or the airflow paths so that all converters in parallel can obtain similar airflow and running under similar thermal environment. Make sure the temperature of the case below 100℃.

11. Connect Sense (+) to Vin (+) and connect Sense(-) to Vin (-) for each converter. If system need to accurately regulate the load voltage, the output remote sense leads of all converters in parallel shall be connected to the point where the voltage regulation is required.

12. Leave the TRIM pin floating. If output voltage need to be trimmed up/down, each converter should connect a trim resistor separately. It may cause abnormal operating if all converters connect the same trim resistor.

13. Parallel application is very complicated. Please provide below application information if need the design support from Dr.Power.

Model Name	
Quantity of Converters in Parallel	
Total Output Power	
Is Dynamic Load(Y/N)	
Dynamic Load Parameter（Minimum Load/Duration Time, Maximum Load/ DurationTtime, Interval time(Cycle), Current Slope ）	
Output capacitance	

Email: support@drpower.com.cn

Layout

The system designers shall keep the following guidance in mind when doing system board layout:

▲ The layout (component placement and trace routing) of EMI filter

The component of filter, especially the capacitors should be place as close as possible to the module. Run the positive and negative power paths (both input and output of the power module) as close as possible and better in parallel in a multiple layer PCB, minimizing the loop area and inductance because any loop area will either pick up noise and turning them into conducted noise or radiated noise to pollute other part of the system. This will also provide lower impedance than the input impedance of the power module to secure the stability of the power module operation. It is especially important when the power sourcing is far from the module.

A copper plan should be placed under the power module and coupled to the input and output terminals of the power module through ceramic capacitors of proper voltage rating. These ceramic capacitors also include the components of filter, such as C7-C10 in Figures 1 and figure 2.This helps to contain the radiated noise from the fast dv/dt and di/dt inside the power module. This copper plan should be buried in an internal layer of the system board to prevent possible violation of isolation spacing distances between input and output.

Avoid the coupling of a noisy trace and a quiet trace. This suggests place the filter components and the power module in a straight flow.

Use short paths and minimize loops for capacitor branches in the filter to avoid the trace impedance defeating the purpose of low impedance of the high frequency capacitors. Therefore C3 and C4 in Figure 1 should be placed as close to the power module as possible.

▲ High Current Capacity of the Application Board

As the module's power and current capabilities increasing, it is becoming more and more important to understand the current-carrying capabilities of application boards, especially the current-carrying capabilities of high output currents.

Consideration on current carrying capacity

1. The influence of the voltage drop on the application board trace. When a current of 100A flows through a 2mΩ resistor, a voltage drop of 200mV will be generated. Such a voltage drop may have a great impact on the low-voltage load. The module's remote sense can be used to compensate for such voltage drops, but it should be noted for the compensate range.

3.The temperature rise of the application board caused by high current. The temperature rise allowed by the application board is related to the ambient temperature and the material of the application board. For high reliability designs, the temperature rise should generally not exceed 20 ° C. The thermal characteristics of multi-layer PCBs are quite complicated.

Generally speaking, the IPC-2221 standard can be used as the starting point for analysis reference, the standard includes curves of the several inner/outer trace temperature rise relative to the cross-sectional area and current. According to these curves, temperature rise is 20 ° C for the outer layer of 0.16 mm2 carrying 10A current, while temperature rise is also 20 ° C with the same cross-sectional area of the inner trace carrying 5A current. It means that the inner trace carrying current capacity is about half of the outer trace.

3. Safety considerations. According to the requirements of UL, CSA, TUV and VDE, the primary to secondary side, primary side to ground, and secondary side to Ground must meet a sufficient minimum air separation distance and minimum insulation distance; the specific requirements are determined by the operating voltage, isolation design of primary and secondary sides connected parts, and whether the primary and secondary sides are grounded. In most DC-DC modules applications, if basic isolation is required, the air isolation distance is at least 0.71mm; the insulation isolation distance is at least 1.42mm

DC-DC Practical Evaluation Techniques

Evaluating DC-DC power modules for a specific application is a quite complex and errorprone process, and requires a thorough understanding of the power module and the application environment. To assist customer perform the test, Dr.Power supplies module evaluation board as shown in Figure 3. This board contains practical application circuit similar to that shown in Figure 1. In addition to the connection terminals and test points, there are also probe socket of oscilloscope. Customers can order the evaluation board from Dr.Power. More important tests should be performed on this board or similar devices to ensure the correct results. Below discussion are related to the most commonly and important tests.

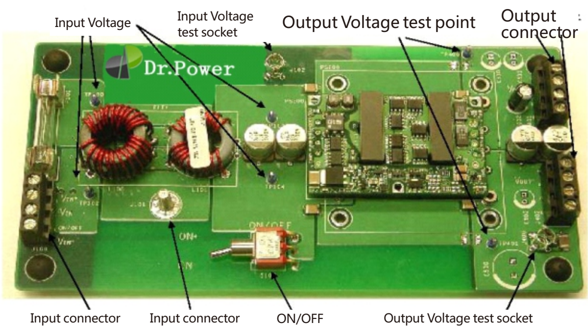


Figure 3 Dr.Power's evaluation board

▲ Efficiency Measurement

Conversion efficiency is a key parameter that is used in evaluating power modules. It's essential to achieve high efficiency so heat generated inside a moduleis low.

Measuring the efficiency correctly is challenging. Since a 1% discrepancy in efficiency measurement means a significant change in terms of the losses, the accuracy of the measurement about input/output current and voltage becomes critical for any meaningful result.

Below points should be paid attention:

1. If the power converter is plugged into sockets, the contact resistance between the pins and the sockets especially at the output terminals varies with many factors, and can cause significant power losses. Therefore, when using sockets the output voltage readings shall be taken at the pins right above the sockets, not on the system or evaluation board.

2. The input and output currents shall be measured with high-accuracy shunts (accuracy 0.1%). The rated current of the shunts should be defined by the current of the input and output.

3. The multi-meters shall have at least 5-digit accuracy. Since all variables determining the efficiency are dc values, it's important that the meters' reading is not sensitive to the ac ripples that inevitably present in a switched-mode power supply.

4. Such a shunt has a small and well defined resistance to convert a current into a voltage signal normally in the range of mV. However, the measurement of such low amplitude signal is susceptible to switching noises, especially the common-mode noise. Filter capacitors may be used to achieve valid readings (refer figure 1 and figure 2). If good grounding and filtering is not possible, it's recommended to connect an input terminal (usually Vin-) to an output terminal(usually Vo-) together through a short wire or a capacitor to minimize common-mode noise.

5. The typical efficiencies published by Dr.Power as well as most other power module manufacturers are measured at room temperature while the converter is in cold state. For the purpose of comparing the measurements with the published efficiency, the measurement shall be taken quickly once the converter is powered up. In general, the efficiency drops while the component temperature rises. One should use the "hold" button of the multi-meters to hold all four numbers within a few seconds apart.

▲ Output Ripple and Noise Measurement

Output ripple is referring to the voltage swing caused by charging and discharging the output capacitors at the switching frequency; while noise is about the ringing at much higher frequencies caused by the turning on and off of the power switches. To separate the ripple and the noise, the output ripple voltage measurements are conducted by limiting the oscilloscope bandwidth to 20-25MHz, while the output noise measurements are taken with full bandwidth of the oscilloscope. The ripple and noise measurement results are sensitive to the measurement setup since extra noise pickup, common-mode noise, and ground-loop noise can easily get into the measurements.

To obtain a correct accurate measurement, special attentions should be paid to these below issues:

1. Ground connection: sometimes poor grounding could cause a lot of noise. A complex grounding loop can be formed by the grounding connections of the power source, the module, the load and the oscilloscope, and also the parasitic capacitive coupling inside the power module. Often, single-point grounding is not easy to obtain at high frequencies. The best way to avoid this problem is to use differential probes. An isolation transformer can also be used to isolate power source to the power converter and the oscilloscope. Resistive load shall be used since it doesn't have any ground connection.

2. A loose connection between power module pins and the sockets or between oscilloscope probes and the test points may cause the measured ripple much higher or lower than it really is. Whenever possible, a soldered connection should be used.

3. A ceramic cap should always be connected at or close to the points where the probe is attached. The probe (probes) should be arranged to minimize extra noise pickup.

4. The scope bandwidth is another factor affecting the readings. The published ripple waveforms by almost all manufacturers are obtained with 20-25MHz bandwidth. For measuring noise, the oscilloscope should be set to full bandwidth to catch the very high frequency components at the input /output terminals.

5. It's highly recommended to measure output ripple voltage with a setup similar to actual application and with filter attached. The filter can reduce the common-mode noise and ground interaction in the measurement. The output voltage ripple is a differential signal by definition, but common-mode noise and ground interaction can distort the measurement. If good grounding and filtering is not possible, it 's recommended to connect an input terminal (usually Vin-) to an output terminal (usually Vo-) together through a short wire or a capacitor.

6. Output ripple voltages could also vary significantly with the input voltage changing. Customers should check the ripple at low, nominal, and high line conditions.

7. Use a BNC connector if possible because oscilloscope probe leads can easily pick up radiated noise to yield misleading readings. If wire connection is used for connecting the BNC to the test point, make sure the two wires are twisted and as short as possible.

▲ Output Voltage Startup Waveform

Today's complex electronic systems often require their ICs to follow a given sequence during power-up. To accommodate the tolerance of the IC threshold voltages, power modules need to provide a monotonic and fast-rising output voltage during a start up process. There are 2 kinds of start up for the module on application board: 1. Setting remote ON/OFF pin to ON, module will be turned on with lowest input start up voltage. 2. Setting remote ON/OFF pin to OFF and with normal input, module will be turned on with remote on/off change to on.

Please note that load capacitance and load current have significant impact on this waveform. Two extreme corner conditions should be checked: minimum load with minimum output capacitance and maximum load with maximum output capacitance.

Pre-biased start up is another commonly concerned characteristic. In today's electronic systems, multiple voltages are required. Some sophisticated ICs require multiple voltages to power chip. There is often a required sequence for these different voltages to be established for these ICs to work properly. It's often the case that lower voltages are required to be established sooner than the higher voltages. When a lower voltage is established, it could go through some internal paths in an IC or circuits on the system board to pre-charge the output of a higher voltage rail. When the power module for the higher voltage rail starts, its output voltage should be monotonically rising other than dropping down before rising up.

▲Thermal Evaluation

Thermal performance of a power module determines how much current or power it can supply reliably. In many applications power modules are required to operate at a challenging environment. To achieve good thermal performance, a module needs to have high efficiency to reduce its power loss and thus heat generated. The module must also have good heat distribution across the module, as well as a good mechanism to remove the heat out of the module. A module's thermal performance is characterized by its thermal derating curves often found in datasheets.

Thermal derating curves define how many amperes of current a power module can output under various airflow speeds / orientations and ambient temperatures. The derating curves are based on the data obtained in wind-tunnel tests conducted by power module manufacturers.

Among power module manufacturers there are differences in temperature measurement method and location, airflow measurement method and location, construction of the test fixtures, spacing board design and pitch, etc. These differences have significant influence on the resulted derating curves. Because of these differences, the derating curves published by different suppliers cannot be directly compared to determine whether one module is better or worse than another module from a different vendor. It is strongly recommended to evaluate the module's thermal performance in actual systems, or in a condition closely simulating the actual application.

If a thermal coupler is used to measure the temperature on that component, the wire connecting the thermal coupler should be much smaller than the component itself to avoid unintended heat transfer through the wire. Also, the thermal coupler should not be attached to places with high voltage, such as the drain leads of primary power MOSFETs. If an infra-red temperature meter is used, the measurement area of the meter should be significantly smaller than the device's area for meaningful results. A better way to evaluate a power module is to obtain a thermal image of the whole module because such image gives the user much more information than a point on the derating curve. One example image of Dr.Power's modules is shown in Figure 4.

Even if the power module manufacturer has done everything correctly in generating the thermal derating curves, it's very likely that the application environment is different from the supplier's test environment. The user needs to evaluate the module's thermal performance in the system under differen conditions, include some abnormal operating conditions such as fan failure. Performing thermal tests in an early stage is of great value and could save a lot of time and effort later. If the actual thermal environment and/or the maximum load current were unknown, it would be beneficial to select the power module that has effective options for thermal performance enhancement, such as the ability to add a baseplate and/or heatsink.

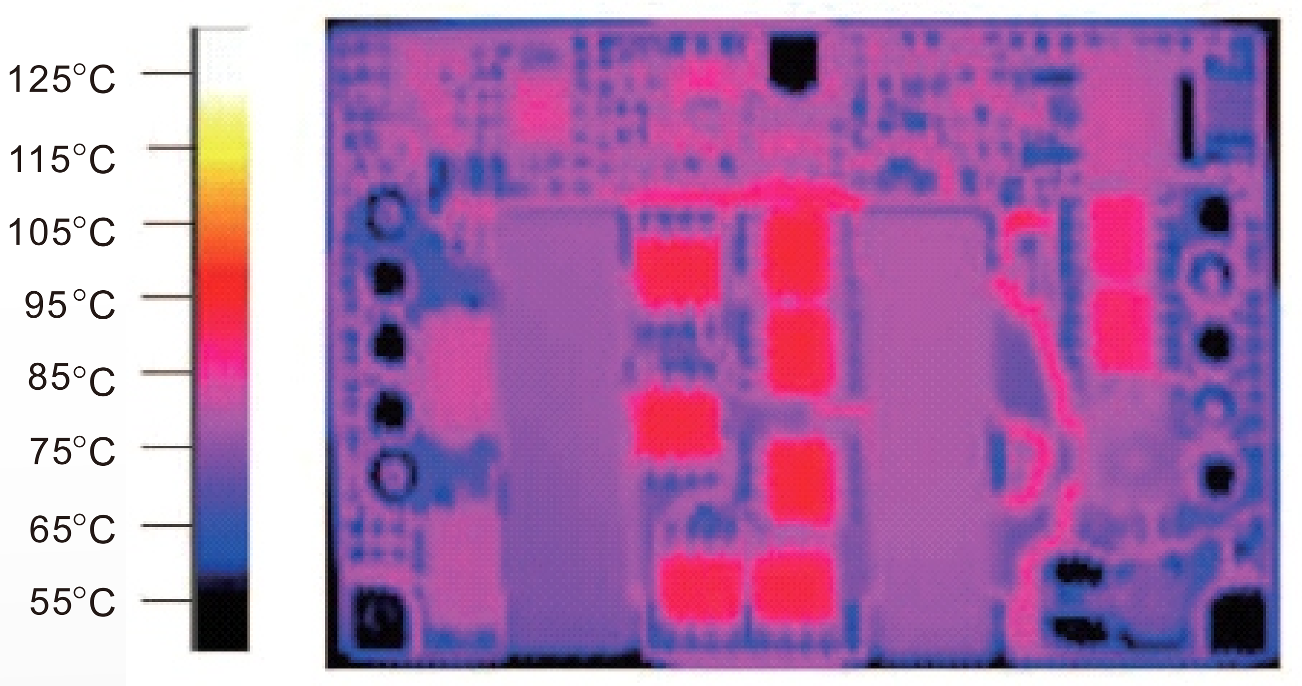
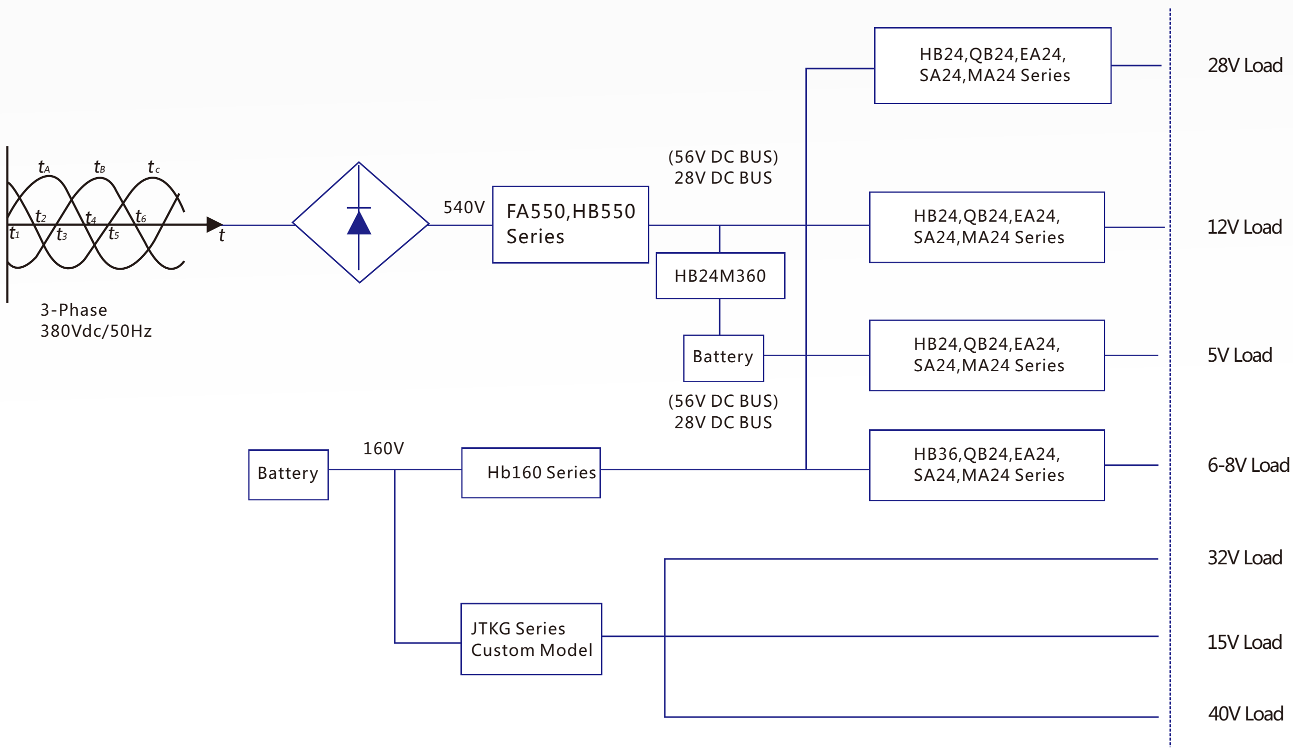


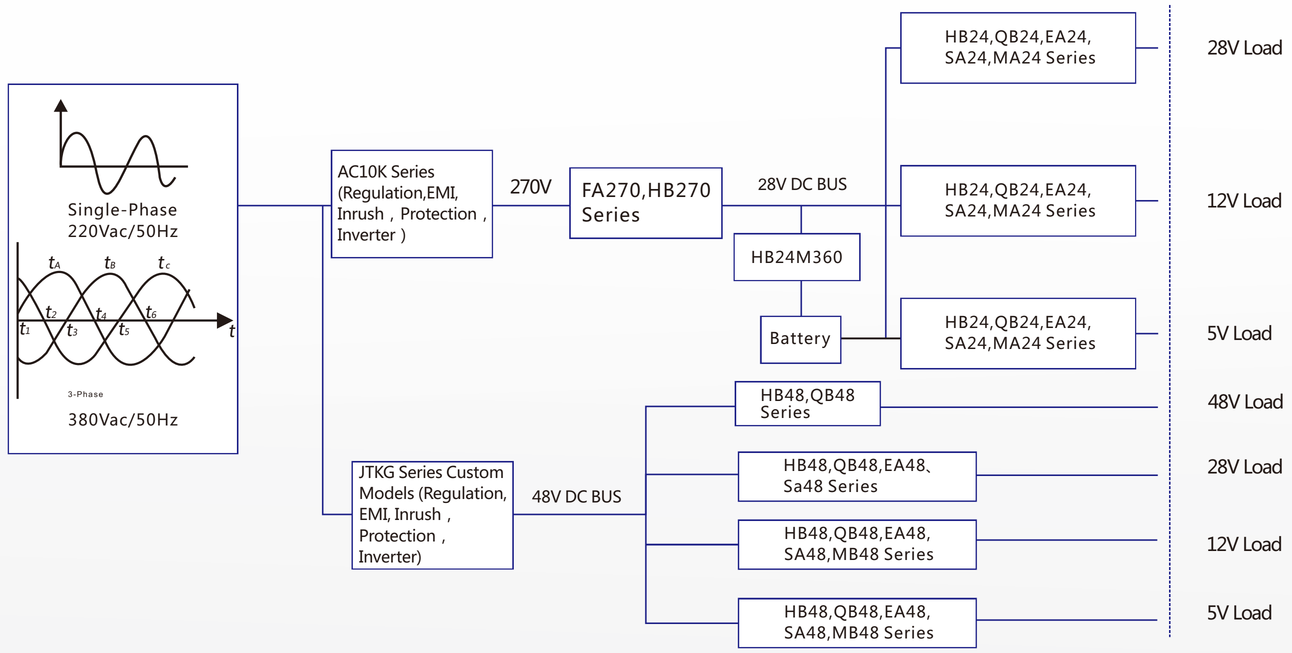
Figure 4 Example thermal image of Dr.Power's module

Appendix 2 :

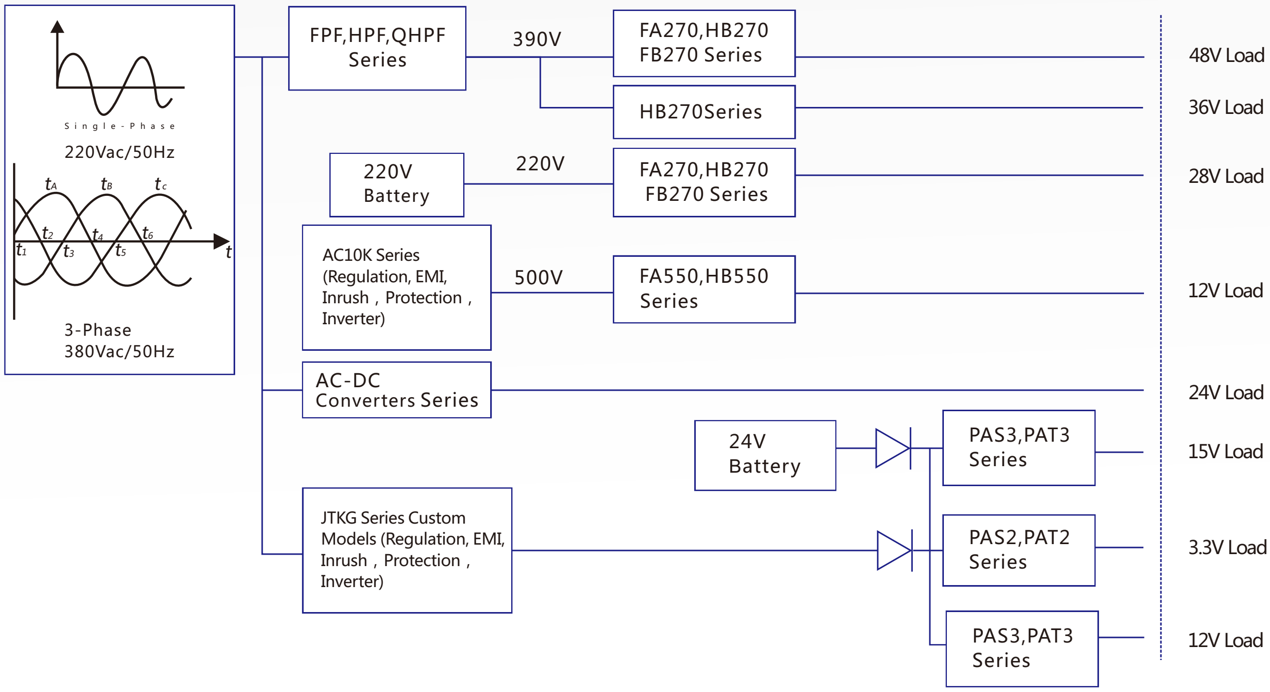
Application Example 1-MissileBorne



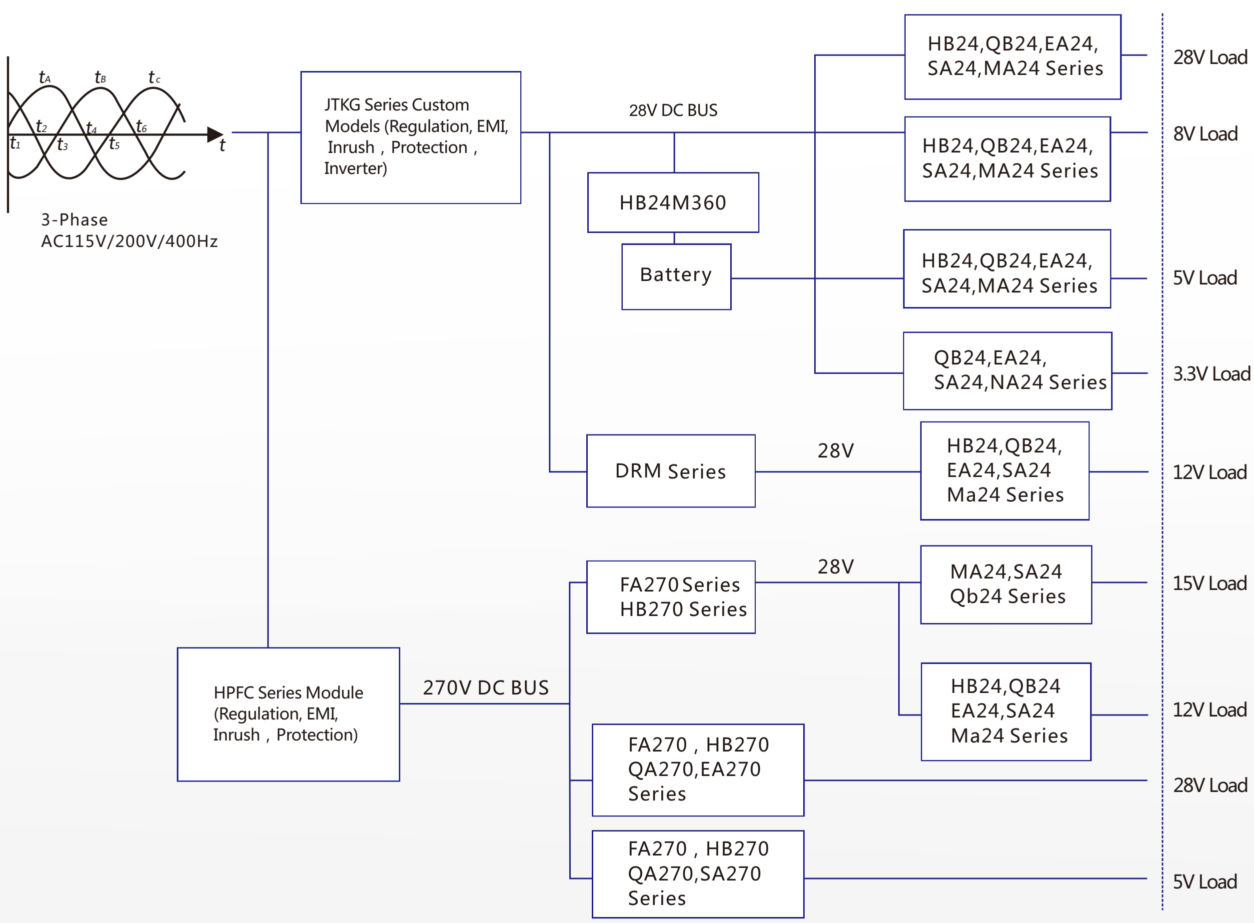
Application Example 2- Vehicle



Application Example 3- Shipborne



Application Example 4- Airborne



Appendix 3：

Products Weight

Series	Open-frame	Baseplate	Encapsulated	Flanged Baseplate
1/32 Brick	9.5±2g	14.5±2g	23±5g	23±5g
1/16 Brick	16±5g	23±5g	35±5g	40±5g
1/8 Brick	27.5±5g	38.5±5g	65±5g	70±5g
1/8 Brick with Fixed Pin	-	-	76±5g	-
1/4 Brick	45±15g	65±15g	100±10g	105±10g
1/4 Brick with Fixed Pin	-	-	115±10g	-
1/2 Brick	73±5g	105±15g	165±10g	-
1/2 Brick Pentagon Plastic Package			130±10g	
FA Series Full Brick	145±15g	-	310±15g	-
Brick Pentagon Plastic Package	-	-	260±15g	-
FB Series Full Brick	92±15g	-	210±15g	-

Notes: Please refer datasheets for detailed information

Dimension (Please refer datasheets for detailed information)

LengthxWidthxHeight (mm)

		Open-frame	Baseplate	Encapsulated	Flanged Baseplate
1/32	MA	23.6x19.3x10.7	25.9x19.3x12.7	26.19x21.7x12.7	37.9x22.1x12.7
	MB	23.6x19.3x10.7	25.9x19.3x12.7	26.19x21.7x12.7	37.9x22.1x12.7
1/16	SA	33.3x23.1x9.7	33.3x23.1x12.7	35.3x25.1x12.7	39.0x37.5x12.7
1/8	EA	58.4x22.8x10.4	58.4x22.8x12.7	61.0x25.2x12.7	64.5x37.5x12.7
	EC	58.4x22.8x10.4	58.4x22.8x12.7	61.0x25.2x12.7	64.5x37.5x12.7
1/4	QA	58.2x37.1x10.2	58.2x37.1x12.7	60.6x39.4x12.7	64.3x51.7x12.7
	QB	58.2x37.1x10.2	58.2x37.1x12.7	60.6x39.4x12.7	64.3x51.7x12.7
	QC	58.2x37.1x10.6	58.2x37.1x12.7	60.6x39.4x12.7	64.3x51.7x12.7
1/2	HB	61.2x58.2x10.1	61.2x58.2x12.7	64.0x61.0x12.7	-
Full Brick	FA	113.3x57.9x10.1	-	116.8x61.2x13.7	-
	FB	112.0x40.9x10.0	-	-	116.9x55.9x12.7