

Preface

To let our new employees and distribution partners have basic understanding about switching power supply, Mean Well published this “Switching Power Supply Technical Manual” based on our 22-year experiences in designing, manufacturing, and selling switching power supplies as well as the latest safety regulations and textbooks.

This manual includes basic information for switching power supply, general specifications, safety regulations, EMC standards, CE, reliability, operation notes, technical Q&A, and notes on failure correction. The contents emphasize on description of facts but not formulas or mathematical issues which is very suitable for people without S.P.S. technical background. Readers should get the big picture about switching power supply’s specification, application, and safety issues in the short time.

This manual was originated from “Switching Power Supply User Manual” published in February 1996 and was revised many times during these years. This edition strengthens the explanation portion by using photos, diagrams and tables which is more friendly to readers without technical background. Besides, the safety and EMC portion are also revised based on the latest standards that can help readers get more insight understanding about these regulations.

Finally, I would like to thank our editing committee that share their experiences in technical, research, engineering, quality assurance, repair, safety, and EMC fields to all of us. Since they are not professional writers, there might be some topics still unclear or hard to understand because of the “engineer-style writing”. Please kindly give us your precious opinion so that we can improve the drawbacks in the next edition. Hope that we can provide more complete and valuable information in our future edition of technical manual.

Jerry Lin / President
Mean Well Enterprises, Co. Ltd.
Sep. 2nd, 2003

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Chapter 1

Introduction To Power Supply

1.1 Introduction To Linear Power Supply

The topology of a conventional linear power supply, as shown figure 1.1, uses a low-frequency transformer comprising a core made of silicon steel sheet to convert AC mains to a desired voltage, and rectifies and filters the voltage to a DC level. Since general equipments require stable DC voltage, the rectified and filtered DC level should be regulated through a power regulator. The power regulator clamps excessive voltage at the predetermined level and dissipates unwanted voltage in the form of heat. In order not to greatly reduce the efficiency, linear power supplies should put a limit to the variable range of the AC input voltage. The concept of linear power supplies is to clamp the unwanted voltage along with ripple voltage and dissipate them in the form of heat, which result in quite small ripple voltage. Due to linear topology, there will be no problems of ripple noise and EMI in linear power supplies.

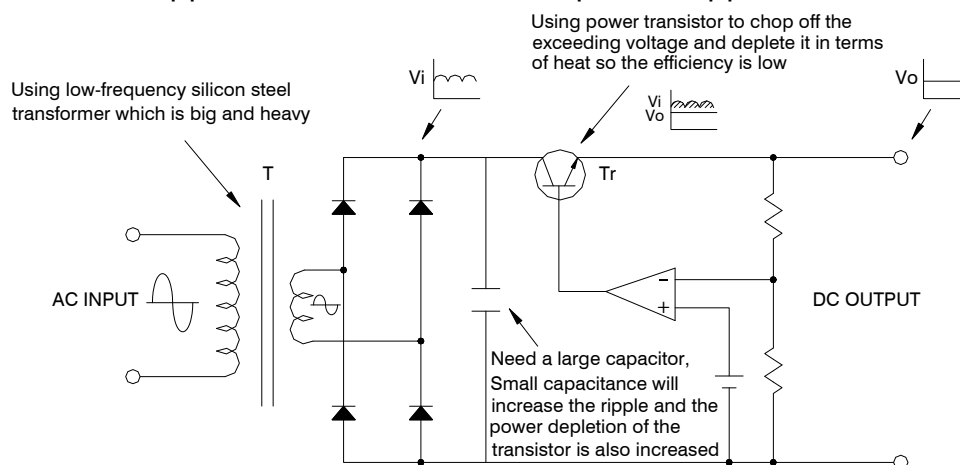


Figure 1.1: The principle diagram of a typical linear (serial) power supply

1.2 Introduction to Switching Power Supply (S.P.S.)

(1) Switching power supplies mainly improve the weaknesses such as the huge volume, the heavy weight, and the low efficiency in linear power supplies. The topology of a switching power supply, as shown in figure 1.3, rectifies and filters the voltage directly from AC mains (off-line) without using a low-frequency transformer. The capacitance of the bulk capacitor can be quite small due to the high rectified voltage.

Switching power supply uses a high-frequency transistor to chop the high DC voltage (rectified from AC source) into high AC voltage and converts it into a desired voltage by a high-frequency transformer, and then rectifies and filters the voltage to a DC level. The high-frequency switching of the transistor and diodes results in generation of ripple noises at the transient of switching.

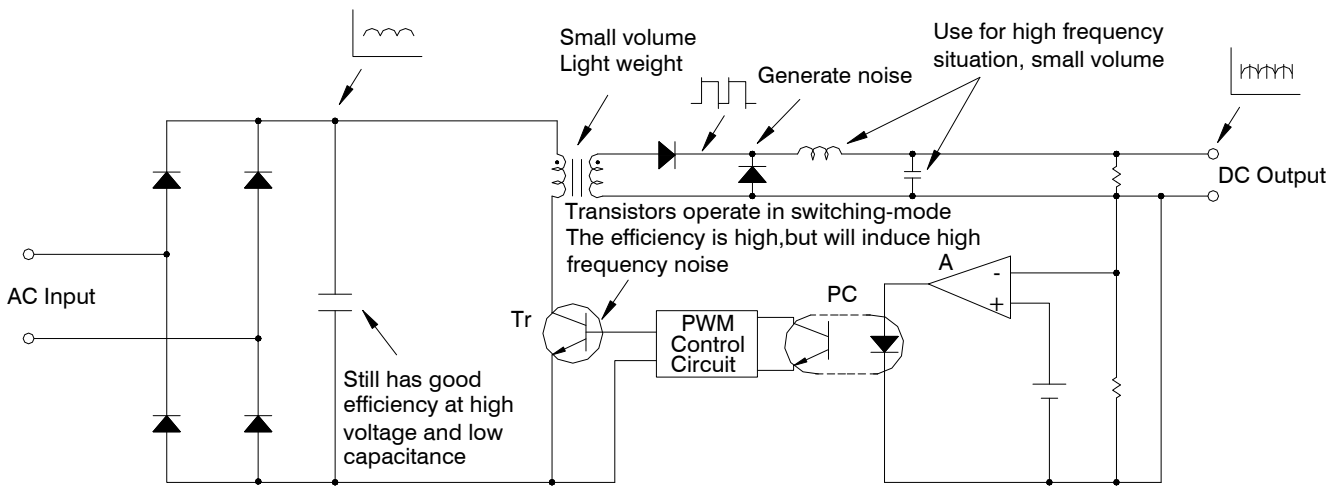


Figure 1.2: The principle diagram of a typical switching power supply

(2) The block diagrams along with their description in a switching power supply are as follows:

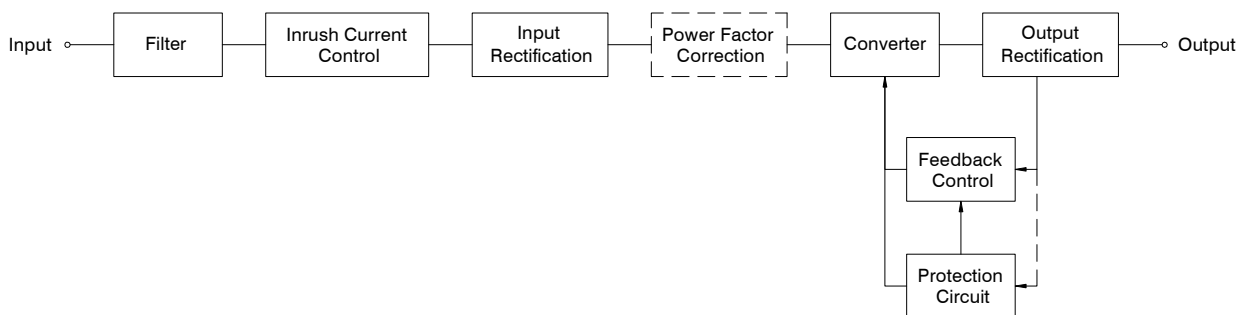


Figure 1.3 Block diagrams of a typical S.P.S.

- (a) EMI Filter: The built-in filter reduces the EMI generated from the S.P.S.
- (b) Inrush Current Suppressor: Inrush current occurs at the time of power-on of the S.P.S. If the inrush current is too large, the S.P.S. might be damaged, and the power distribution system could be adversely influenced. Thus, an inrush current suppressor is installed inside each S.P.S. to limit the high current.
- (c) Input Rectifier: It rectifies the AC input voltage to a DC level.
- (d) Power Factor Correction (PFC): The active/passive PFC circuit upgrades the power factor (PF) figure and approximates the waveform of input current to a sine wave, so as to be compliant to the harmonic current regulation and reduce reactive power.
- (e) Converter: It converts the DC voltage to high-frequency signal, and the signal is increased or decreased by a high-frequency transformer.

- (f) Output Rectifier: It rectifies the DC pulses to a steady DC level.
- (g) Feedback Control: It regulates the output voltage to a steady level to respond to variation of loads and AC input voltage.
- (h) Protection Circuit: When in abnormal situations, the S.P.S. will shut down or go into other protection modes by activating protection circuits. The protection circuits consist of over voltage, over temperature and over current (overload) protections, and etc.

For further explanation, refer to section 1.5

1.3 Comparison Between Switching Power Supply and Linear Power Supply

- (1) Compared to linear power supplies, switching power supplies possess the advantages of high efficiency and light weight. The advantages correspond to the contemporary demands of being light and handy, and energy saving. Thus S.P.S. has gained much popularity in field applications.

(2) The following table is the comparison between S.P.S. and linear power supply:

Items	Linear Power Supply	Switching Power Supply
Efficiency	Low (25 ~ 50%)	High (65 ~ 97%)
Size	Large (big transformer and heat sink)	Small (1/4 ~ 1/10 of linear power supply)
Weight	Heavy (heavy transformer and heat sink)	Light (1/4 ~ 1/10 of linear power supply)
Circuit	Simple (transformation, rectification, and stabilization)	Complicated (rectification, conversion, pulse-width control, transformation, rectification, feedback control and regulation)
Stability	High (0.001 ~ 0.1%)	Normal (0.1 ~ 3%)
Ripple(P-P)	Small (<10mV)	Large (10mV ~200mV)
Transient Response	Fast(10us ~ 1ms)	Normal (0.5 ~ 10ms)
Input Voltage Range	Efficiency greatly reduced with wide range of input voltage. DC input prohibited.	Wide range of input voltage. 100V/200VAC full range. DC input is allowed
Cost	Low for small power rating; high for high power rating.	Normal (difference of each topologies is decreasing rapidly)
Reliability	High reliability due to fewer parts. But reliability decreases as the temperature rise on parts.	Reducing temperature rise to improve reliability.
EMI	No	Yes (Can be reduced by filters)
Applications	Power source of low voltage tolerance, programmable power source, power source below 10W, variable power sources for lab. application	Power source built in all kinds of machine, device with DC input, power source requiring small size and high efficiency
Assembly	Transformer too big to be fit onto P.C.B.	Small components; all parts of S.P.S. with power rating up to thousands of wattage being able to be fit onto P.C.B.

1.4 Applications Of Switching Power Supply

Switching power supplies have gradually taken the place of linear power supplies and been widely used in every kind of electronic equipments such as the source for module application, driving circuit, uninterruptible power supply (UPS), and battery charger, etc.. Applications of switching power supplies can be divided into industrial and commercial usage, which are listed specifically in the following table:

Industrial machine	Information product	Electronic calculator, CPU, memory device, industrial PC
		Peripheral of computer, terminal device, I/O device, display device
	Communication product	Wired communication equipment, electronic switching system, fax machine, indoor device
		Wireless communication equipment, broadcasting system, car phone
	Office equipment	Word processor, PC
		Photocopier, printer
	Control equipment	Factory automation, robot, power control system, air conditioner
		Vending machine, CD, ATM
Electronic testing instrument	Oscilloscope, Oscillator, frequency spectrum analyzer	
Electrical equipment	CNC, textile machine, mechanical automatic control machine	
Others	Medical equipment, automobile application, test equipment, charger	
Commercial machine	Video equipment	TV, video game machine, set-top box
		VTR、VCD、DVD
	Audio equipment	Digital audio, VCD
		Recorder, compact audio
Others	Adapter, LED lighting, home equipment, others	

1.5 Circuit Principle of Switching Power Supply

(1) Introduction

Among all DC-to-DC converters, S.P.S. is to be divided into 3 basic circuit topologies based on input voltage, output voltage and polarity:

- (a) Step-down or buck converter: Used for output voltage lower than input voltage.
- (b) Step-up or boost converter: Used for output voltage higher than input voltage.
- (c) Inverter or buck-boost converter: Used when the output polarity is reversed from the input one. It can also be used in either step-up or step-down application.

If the input side needs to be isolated from the output side, the above 3 basic converters would be inappropriate. Instead, the converter topologies, which are Forward, Flyback, Half-bridge, Push-pull, or Full-bridge, derived from the 3 basic ones would be the right ones to use. There are various methods of generating switching signal, one is to use self-oscillation whose oscillation frequency depends on input voltage and output loading, and the other is to use PWM IC whose oscillation frequency depends on the control IC.

(2) Circuit Principle

▲ Non-isolated Type

(a) Buck Regulator

When the switch (MOSFET) is ON, the energy is transferred to the load (RL) through L1 and stored in L1 at the same time; when the switch is OFF, the energy stored in L1 supplies the load through D1 and L1.

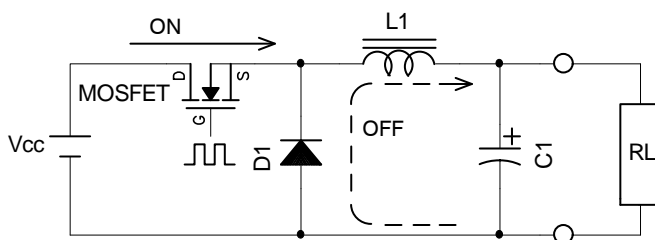


Figure 1.4: Buck Regulator

$$V_o = \frac{V_{cc} \times t_{on}}{T}$$

V_{cc} : Input voltage
 V_o : Output voltage
 t_{on} : ON period of the MOSFET
 T : Cycle
 t_{on}/T : S.P.S. duty cycle

(b) Boost Regulator

When the switch (MOSFET) is ON, the energy is stored in L1; when the switch is OFF, the energy stored in L1 is transferred to the load (RL) through L1 and D1. Output voltage can be higher than the input due to the summation of the voltage pre-stored in L1 and V_{cc} . The topology is popular in PFC application.

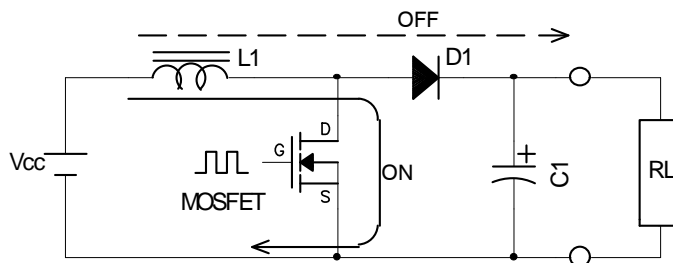


Figure 1.5: Boost Regulator

$$V_o = \frac{V_{cc}}{1 - \frac{t_{on}}{T}}$$

(c) Buck-Boost Regulator

When the switch (MOSFET) is ON, the energy is stored in L1. When the switch is OFF, the energy stored in L1 is transferred to the load (RL) through L1 and D1.

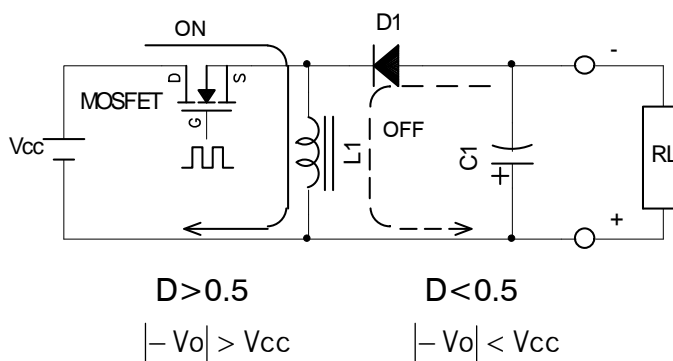


Figure 1.6: Buck-Boost Regulator

$$V_o = \frac{V_{cc} \times \frac{t_{on}}{T}}{1 - \frac{t_{on}}{T}}$$

▲ Isolated Type

(a) Flyback Converter

When the switch (MOSFET) is ON, the energy is stored in the transformer; when the switch (MOSFET) is OFF, the energy in the transformer is transferred to the load (R_L) through $D1$.

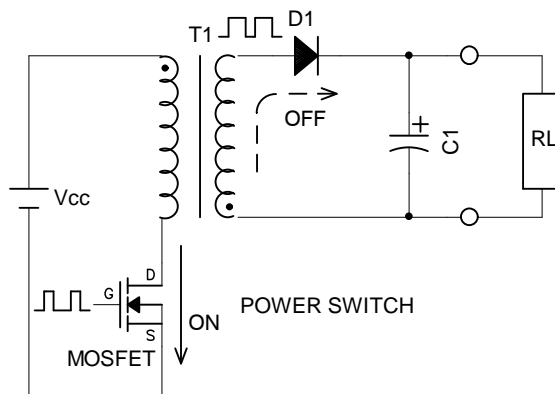


Figure 1.7: Flyback Converter

(b) Forward Converter

When the switch (MOSFET) is ON, the energy is transferred to the load (R_L) and stored in $L1$ through $D1$ and transformer. When the switch is OFF, the energy stored in $L1$ is transferred to the load through $D2$. The topology of using two MOSFETs (Double-end) can reduce the voltage stress on the switches.

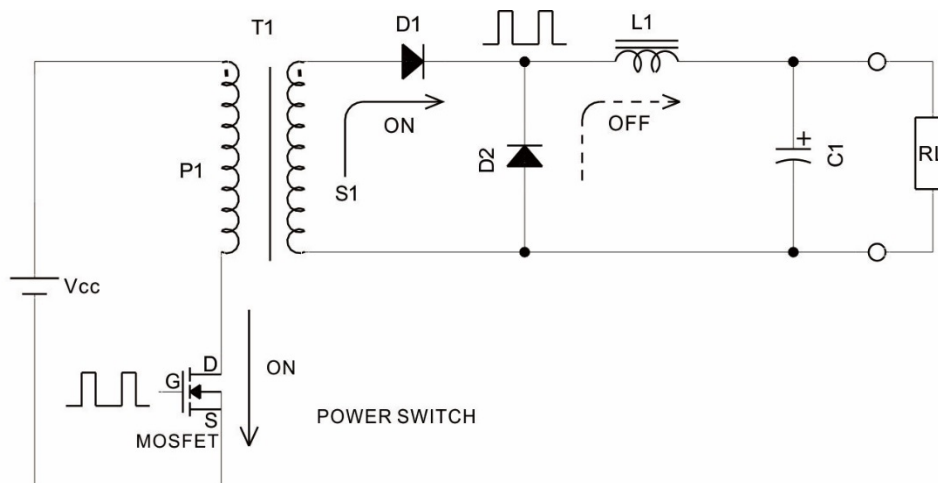
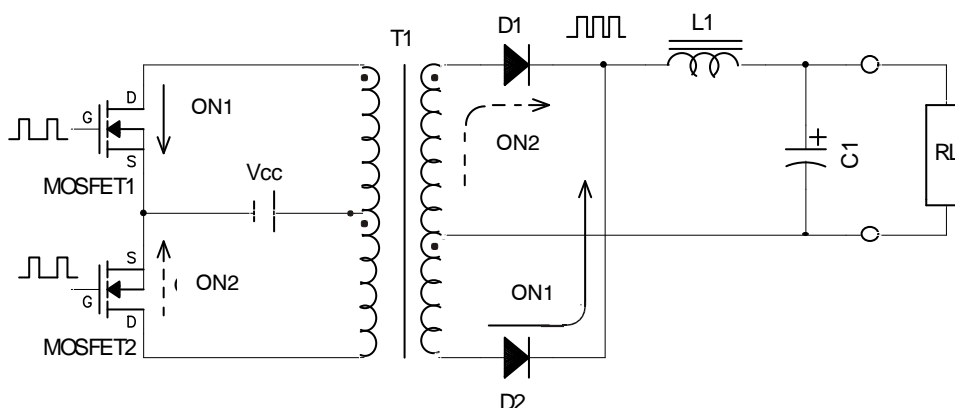


Figure 1.8: Forward Converter

(c) Push-Pull Converter

When switch 1 (MOSFET 1) is ON and switch 2 (MOSFET 2) is OFF, the energy is transferred to the load (R_L) through transformer and $D2$; when switch 2 is ON and switch 1 is OFF, the energy is transferred to the load through transformer and $D1$.



(d) Half-Bridge Converter

When switch 1 (MOSFET 1) is ON and switch 2 is OFF, the energy is transferred to the load (RL) through transformer, C2, and D1; when switch 2 is ON and switch 1 is OFF, the energy is transferred to the load through transformer, C1, and D2. The Asymmetric Half-Bridge Converter (commonly used in S.P.S. with PFC) derived from it can achieve higher efficiency.

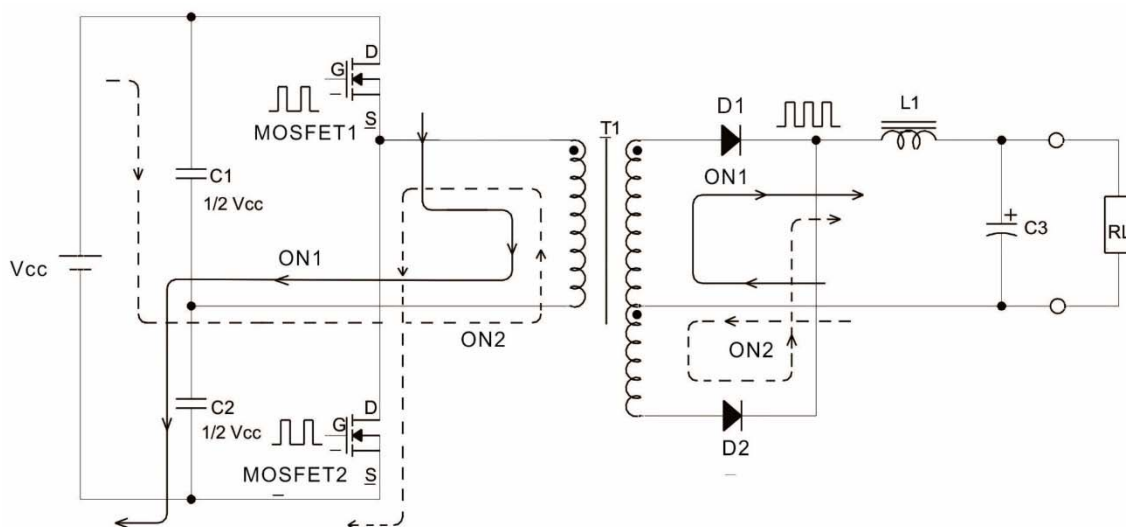


Figure 1.10: Half-Bridge Converter

(e) Full-Bridge Converter

When switch 1, 4 (MOSFET 1, 4) are ON and switch 2, 3 (MOSFET 2, 3) are OFF, the energy is transferred to the load (RL) through transformer and D2; when switch 2, 3 are ON and switch 1, 4 are OFF, the energy is transferred to the load through transformer and D1. The collocation of this topology and phase-shift control is commonly used to achieve high-efficiency Zero Voltage/Current Transition (ZVT/ZCT).

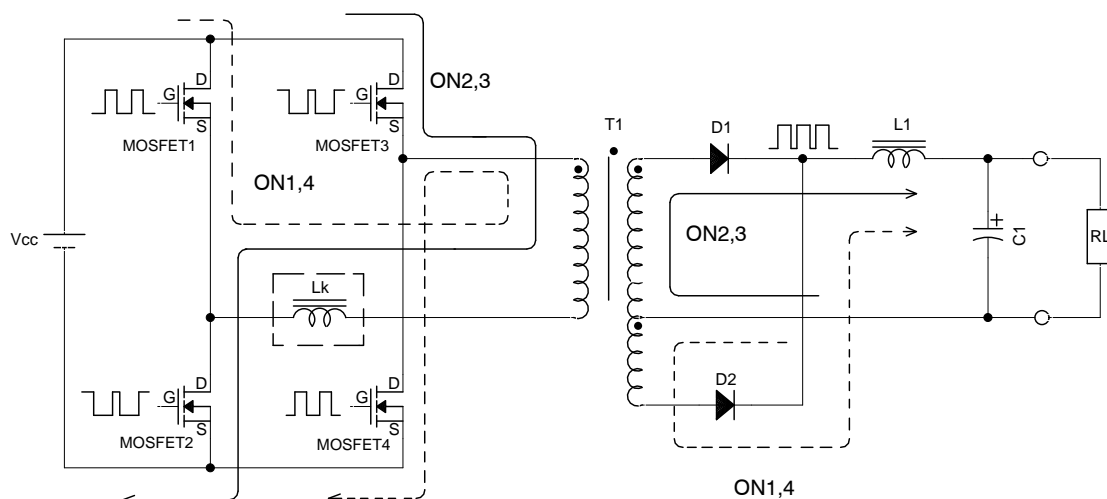


Figure 1.11: Full-Bridge Converter

(f) LLC Half-Bridge Resonant converter

When switch 2 is turned off, C_r , L_k and L_m resonate in the resonant tank, and the Q1 Body diode turned on. At this period, the switch 1 achieve ZVS and the energy is transmitted from V_{cc} to the load through the resonant tank (C_r , L_k , L_m) via the transformer and D1. When switch 1 is turned off, the resonant tank continue resonates, and the Q2 Body diode is turned on. At this period, switch 2 achieve ZVS, and energy is transmitted from C_r to the load through the resonant tank (C_r , L_k , L_m) through the transformer and D2. This architecture is mostly used together with PFC circuit, which capable to achieve high efficiency.

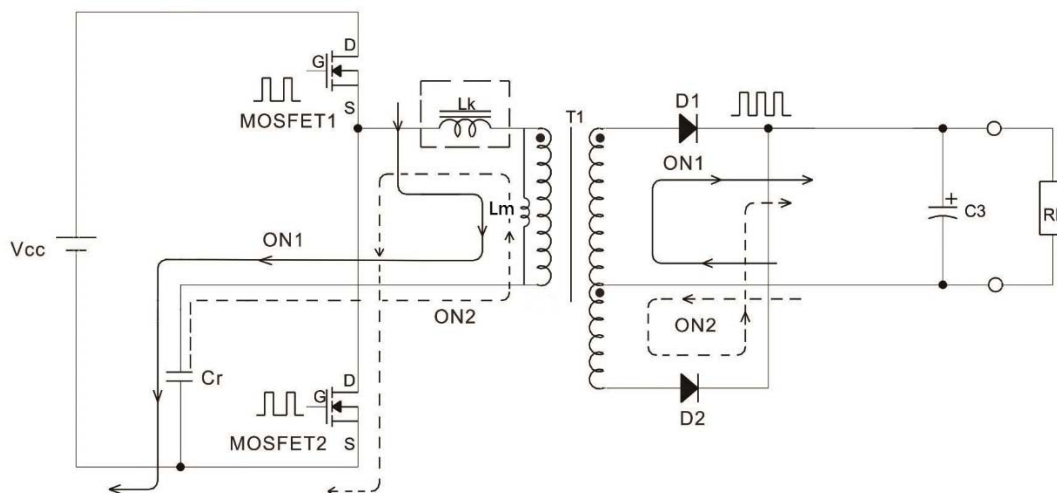


Figure 1.12 LLC Half-bridge resonant converter

1.6 The Characteristics and Applications of Hard Switching Converters in S.P.S.

Existing varieties of topology in S.P.S. can be used to meet all types of demand. In theory, S.P.S. only has conduction loss and is without switching loss since it operates only at the ON/OFF period of the switch (MOSFET). However, in reality, the leakage inductance and the capacitance effect in components lead to the existence of switching loss, which is an obstacle to improving efficiency. The converters with switching loss are of the hard switching topology.

Type	Topology	Characteristics	Selection Notes
Non-Isolated	Buck	<ol style="list-style-type: none"> 1. Complicated driving circuit 2. Output voltage lower than input voltage 3. Non-isolated converter. 	<ol style="list-style-type: none"> 1. Used for application requiring good regulation on several outputs 2. Used in application of stepping down the high DC voltage to low stable DC level
	Boost	<ol style="list-style-type: none"> 1. Simple driving circuit 2. Output voltage higher than input voltage 3. Non-isolated converter 	<ol style="list-style-type: none"> 1. Used in application of stepping up low DC voltage to high DC level 2. Commonly used for PFC application
	Buck-Boost	<ol style="list-style-type: none"> 1. Semi-complex driving circuit 2. Output voltage can be higher or lower than input voltage 3. Non-isolated converter 4. Polarity of output voltage opposite from input voltage 	Used in application of non-isolation and requiring output voltage of reversed polarity from input voltage.
Isolated	Flyback (PWM Control)	<ol style="list-style-type: none"> 1. Simple topology 2. Transformer also used as energy-storage inductor which contributes to larger transformer size 3. High output ripple current 4. Capable of operating in either continuous or discontinuous mode without storage inductor 5. Balanced distribution in parallel application 6. Voltage rating of switch must be 1.5~2 times higher than max input voltage 7. Simple driving circuit 	<ol style="list-style-type: none"> 1. lesser components 2. Application of high power rating only suitable for high output voltage with low output current due to high ripple current 3. Application of low output voltage commonly used for power rating below 150Watt
	Forward	<ol style="list-style-type: none"> 1. Simple driving circuit 2. Complicated topology compared to flyback 3. Voltage rating of switch must be 1.5~2 times higher than max input voltage 4. Application of higher power rating 	<ol style="list-style-type: none"> 1. More components. 2. Suitable for application of power rating below 500W 3. Lower ripple current, good for low output voltage and high output current 4. Available for application of Single MOSFET or Dual MOSFETs
	Push-Pull	<ol style="list-style-type: none"> 1. Simpler driving circuit due to common negative ends of two switches 2. Voltage rating of switch must be 1.5~2 times higher than max input voltage 3. Similar topology to double-end Forward converter 	<ol style="list-style-type: none"> 1. More components 2. Application of low input voltage 3. Prevent transformer from magnetic saturation
	Half-Bridge	<ol style="list-style-type: none"> 1. Complicated driving circuit 2. Voltage rating of switch same as input voltage 3. High utility rate of transformer 	<ol style="list-style-type: none"> 1. Application of high input voltage 2. Suitable for high power rating (above 500Watt) 3. Asymmetric type used in PFC circuit to achieve high efficiency
	Full-Bridge	<ol style="list-style-type: none"> 1. More components 2. Complicated driving circuit 3. Voltage rating of switch same as input voltage 4. High utility rate of transformer 	<ol style="list-style-type: none"> 1. Application of high input voltage 2. Suitable for high power rating (above 1000 W) 3. Collocation with phase-shift control to upgrade efficiency

1.7 The Characteristics and Applications of Soft Switching Converters in S.P.S.

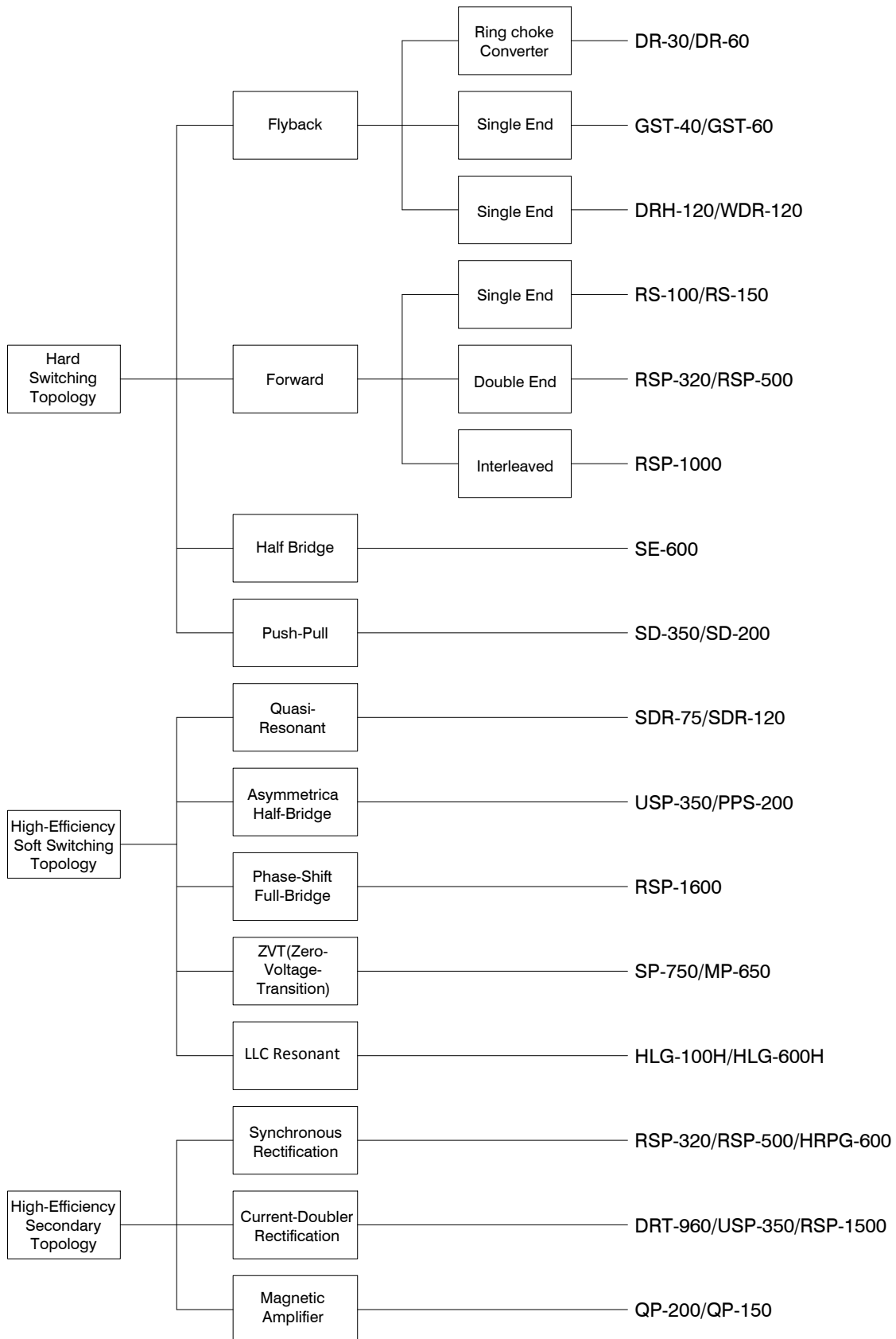
Soft switching technique is to reduce the switching loss coming from hard switching converters. By adding auxiliary and resonant circuits, switching transitions only take place either under zero-voltage or zero-current status. With significant decrease in switching loss, not only efficiency can be upgraded, but the temperature rise on switches can be reduced. Thus, plus the downsized heat sink, the power supply of new generation with minimized size and high power density is realized.

Type	Topology	Characteristics	Selection Notes
Soft Switching , Isolated	Quasi-resonant	<ol style="list-style-type: none"> 1. Complicated driving circuit 2. Various types: quasi-resonant, voltage resonance, current resonance 3. Resonance achieved by using the inductance and capacitance from the circuit or components 4. With advantages of soft switching; reducing switching loss 	<ol style="list-style-type: none"> 1. Strict limitation on selections of inductors and capacitors 2. Suitable for application of low or middle power rating 3. High efficiency and low power consumption are achievable
Soft Switching , Isolated	LLC resonant	<ol style="list-style-type: none"> 1. Half bridge circuitry 2. high efficiency with both ZVS and ZCS 3. High power density 4. low EMI 	<ol style="list-style-type: none"> 1. applicable is fan less design 2. suitable for high wattage application 3. higher current ripple, multi-capacitor is necessaried. 4. narrow adjustment range of output voltage
	ZVS	<ol style="list-style-type: none"> 1. More components 2. Complicated driving circuit 3. Requiring collocation with complicated circuit for auxiliary switch 4. High efficiency; low switching loss 	<ol style="list-style-type: none"> 1. Design of high efficiency and free-air convection 2. Suitable for application of middle or high power rating 3. Complicated control circuit; low reliability 4. Strict limitation on selections of active components

1.8 The Characteristics and Applications of High-Efficiency Secondary Topologies in S.P.S.

Type	Topology	Characteristics	Selection Notes
High-Efficiency Secondary Circuit	Synchronous Rectification	<ol style="list-style-type: none"> 1. Variety of driving circuits 2. Capable of collocation with all types of primary topology 3. Reducing power consumption on rectifiers by taking advantage of low conduction resistance of MOSFETs 	<ol style="list-style-type: none"> 1. Application of low output voltage with high output current 2. Variety of circuits available for different cost demand 3. Commonly used for DC-to-DC and AC-to-DC application
	Magnetic Amplifier	<ol style="list-style-type: none"> 1. Complicated driving circuit 2. Using magnetic components able to operate with saturated magnetization 3. Variety of cores available for all kinds of output voltage 4. Compared to regulator IC, higher efficiency on application of multi-output with low voltage tolerance 	<ol style="list-style-type: none"> 1. Wide adjustable range of output voltage 2. Suitable for application of multi-output and high output current requirement 3. High power consumption for application of high output voltage
	Current-Doubler Rectifier	<ol style="list-style-type: none"> 1. Double the output inductance of general rectifier topology 2. Difficulty in transformer winding 3. Providing higher output current 4. Effectively upgrading efficiency for application of high output current 	<ol style="list-style-type: none"> 1. suitable for application of high output current 2. Application requiring high power density and low height 3. High performance on transformer and output components

1.9 Circuit Classification of Mean Well's Products



1.10 Example of a Typical Switching Power Supply

Figure 1.13 shows a typical Forward circuit with PFC and PWM. The functionality of each block is as follows:

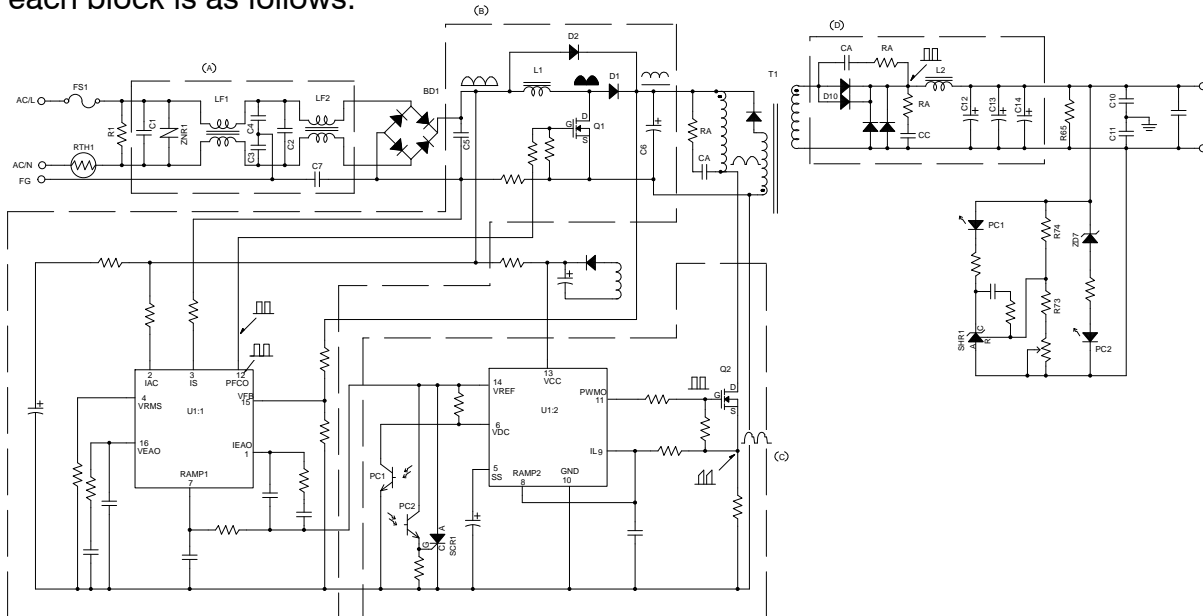


Figure 1.13 PFC+PWM Forward circuit

- (1) Inrush Current Limiting - RTH1 (thermistor) suppresses the inrush current during cold start. Thermistor is a resistor whose resistance changes in indirect proportion to temperature, which is why it is called a NTC (Negative Temperature Coefficient) Thermistor. At cold start, the high resistance suppresses inrush current; after starting up for a while, the resistance decreases to reduce power consumption in normal operation. S.P.S. of middle/high power rating uses a circuit comprising TRIAC and relay to have lower conduction loss. Please refer to Section 2.3 for detailed information.
- (2) Anti-Lightning Surge – ZNR1 (transient/surge absorber) is a resistive component. Part number 471, commonly used in our products, it possesses high resistance at normal condition. As the voltage across it increases, its conductivity also increases; the resistance decreases greatly when the voltage across it reaches 470VDC or 332VAC, and the conductive current is around 1mA. With that characteristic, the transient/surge absorber is able to bypass the abnormal surge voltage so as to effectively inhibit the surge voltage from entering the S.P.S.
- (3) EMI filter – As show in block (A) of figure 1.13 (excluding ZNR1, the surge absorber), this module of EMI filter is commonly used at the input side of our products to filter out noises interference. Basically, it consists of three types of components, which are X capacitor, Y capacitor, and common-mode choke. The functionality of each component in block (A) is as follows:

C1 and C2 (X capacitor) suppress differential-mode noise.

C3, C4, and C7 (Y capacitor) suppress common-mode noise.

LF1 and LF2 (common-mode choke) suppress common-mode noise.

- (4) Input Rectification – BD1 (bridge rectifier) rectifies AC input voltage to DC level with twice frequency of AC main(Ex: $60\text{Hz} \times 2 = 120\text{Hz}$)
- (5) PFC (Boost) Circuit - Block (B) in figure 1.13 consists of Q1, D1, L1, and U1:1 (PFC controller) boosts the voltage to 380VDC. The main function of the block is for power factor correction, to approximate the waveform of input current to sine wave, and to reduce harmonic current to correspond to the demand of CE regulations. Either active or passive PFC circuits can be used. Passive PFC circuit uses a low-frequency transformer comprising a core made of silicon steel sheet to upgrade power factor figure from 0.5 to 0.7; active PFC circuit upgrades it to 0.95.
- (6) PWM Control at Primary Circuit – Block (C) consists of U1:2 (PWM controller) and Q2 (main power transistor) converts DC voltage from PFC circuit to high-frequency pulse train signal, so as the high-frequency transformer can increase/decrease it to get lower conversion of output voltage.
- (7) Isolation Transformer – Its (T1) main functions are isolation and decreasing voltage level. Temperature rise and the ability to meet withstand voltage rating of safety regulations are the main considerations when designing the transformer.
- (8) Output Rectification – Block (D), consisting of D10, L2, and C12~C14, rectifies and filters the high-frequency DC pulses to a steady DC level.
- (9) Feedback Control Loop – The loop, consisting of R74, PC1, etc., senses the divided output voltage to compare with the reference voltage of SHR1, and feedback the signal to PWM control IC (U1:2) through PC1 to regulate the duty cycle of PWM to achieve the purpose of output voltage control.
- (10) Over Voltage Protection Circuit – It consists of ZD7, PC2, etc. When the output voltage exceeds the specified value (ZD7), PC2 conducts to activate SCR1 to pull the reference voltage of PWM IC (U1:2) to ground to cease operation of PWM IC, so as to protect the S.P.S or users' system from damage.
- (11) Snubber Circuit: RA and CA, located in primary side of T1 and secondary rectifiers (D10), are mainly to reduce the high-frequency spikes and oscillation coming from switching transitions of switches or rectifiers, such as Q2 and D10. It also improves EMI performance and decreases withstand voltage on components.

Chapter 2

Explanation of Switching Power Supply Specification

2.1 Input Voltage / Frequency

S.P.S. has been used in various field applications all over the world. Depending on type of product, input source of either alternating current (AC) or direct current (DC) is acceptable. Prior to operation of the power supply, users should confirm the following: the type of input voltage (AC or DC), the range of input voltage, and other conditions written on specification sheet. Input voltage exceeding the operating range would cause damage to the power supply. Also, input voltage with distorted waveform, even within the operating range, could also lead to malfunction of the power supply.

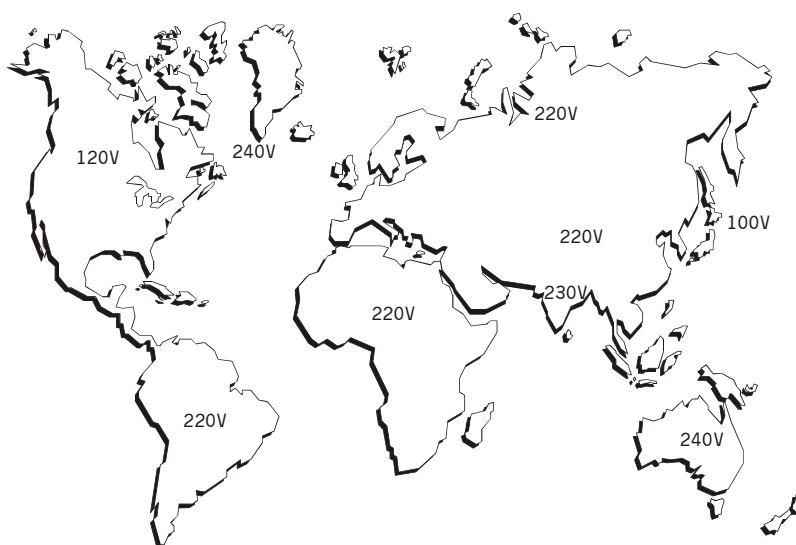


Figure 2.1: Electricity around the world

- (1) If input voltage is of DC or square wave, its maximum value should be equal to 1.4 ($\sqrt{2}$) times of the peak value of sine wave. For example, input voltage of 85~264VAC can be replaced with DC voltage of 120~370V. (Please refer to specification for the input range).
- (2) Input source of DC or square wave is not acceptable for S.P.S. with function of input voltage manual-switch.
- (3) Input Frequency:
The frequency of AC mains for S.P.S. is generally 50Hz or 60Hz. Taking into account deviation of ± 3 Hz from power plants, S.P.S. is designed to accept input frequency within the range of 47~63Hz. For special applications, such as for boats or ships, the frequency of 440Hz is acceptable, but users should be aware of the increased leakage and decreased PF.
- (4) The input range for products with safety approvals is available on model labels of the casings.

2.2 Input Current/Power Factor

It is common in S.P.S. designs to connect a bulk capacitor right after the bridge rectifier. This leads to charging of the filtering capacitor at the peaks of the input sine wave. Apparent power becomes high due to high RMS current and this leads to low PF. Current meters with “True RMS” function are required for measurements of input current. PF for typical S.P.S. falls within the range of 0.4~0.6; for S.P.S. with PFC function, PF can be above 0.95. The relation among input current, output power, input voltage, power factor, and efficiency is as follows:

$$\text{Input Current} = \frac{\text{Output Power}}{\text{Input Voltage} \times \text{Power Factor} \times \text{Efficiency}}$$

2.3 Inrush Current

When AC is initially powered ON, a peak current is required to charge the empty bulk capacitor. This momentary peak is also called the inrush current.

The magnitude of the inrush current varies according to the type of current limiting circuit used. S.P.S. commonly uses a thermistor to limit inrush current. The high resistance of the thermistor limits inrush current at cold start of S.P.S.; the low resistance of the thermistor reduces power consumption after power-on. Thus, in order not to accumulate inrush current do not turn the power supply ON and OFF rapidly. Generally, after turning-off, a delay of few seconds before turning-on is suggested.

Compared to the input current in steady state, the inrush current could be several to tens of times higher. Be aware that application with multiple S.P.S. leads to accumulate inrush current. In this case, the ability of input wiring, external fuses, and switches to withstand transient current should be taken into consideration.

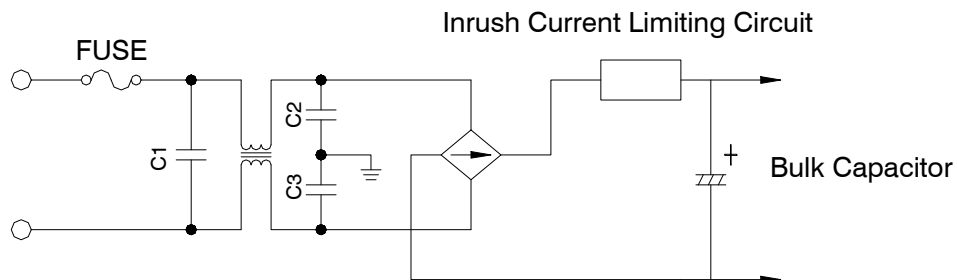


Figure 2.2: Circuit of input rectification and filtering

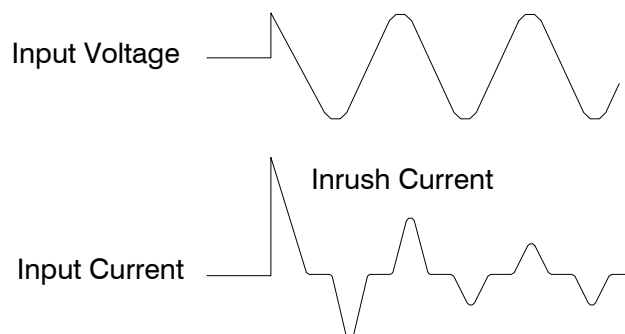


Figure 2.3: Waveform of inrush current

2.4 Line Regulation

The variation in output voltage, corresponding to change in input voltage, is called the line regulation (measurement done with full load at output). Although the effect of line change, within specified range, on output voltage would not be significant, minimizing length of input wiring and limitation on the amounts of units connected to the same AC source is recommended.

$$\text{Line Regulation (\%)} = \frac{V_{\max} - V_{\min}}{V_{\text{nor}}} \times 100\%$$

V_{\max} : Maximum output voltage measured while input varies within the range

V_{nor} : Output voltage measured while input is at nominal level

V_{\min} : Minimum output voltage measured while input varies within the range

2.5 Leakage Current

Leakage current is the current flowing from the protective earth (PE) conductor, such as metal enclosure, of equipments to frame ground (FG). Due to EMI requirements in S.P.S., there are Y capacitors (C2 and C3 in Figure 2.2) connected in between AC L/N and PE conductor. A low current will flow through the Y-caps to FG. In reality, leakage current should be regulated to comply with safety standards. In regulations of safety for IT products, leakage current should be less than 3.5mA for portable Class I equipment, 0.75mA for hand-held Class I equipment, and 0.25mA for Class II equipment.

2.6 Output Voltage/Tolerance/ Adjustment Range

The measurement of output voltage is defined to be at the output terminal of S.P.S. If voltage is measured at the load end, the measurement would deviate due to voltage drop on wiring. The voltage tolerance is the biggest voltage variation measured during simultaneous line and load change. In general, the tolerance accounts for line regulation, load regulation, cross regulation and setup tolerance. For compensating voltage drop, output voltage is factory set a little bit higher. Most products have a built-in variable resistor for output voltage adjustment. However, there are some important requirements to be followed:

- (1) Rated power should not be exceeded. If output voltage is set higher, output current must be decreased accordingly.
- (2) Rapidly decrease in output voltage with no load or light load would lead to momentary malfunctions of S.P.S.
- (3) Output voltage would be unable to be set higher with low input voltage.
- (4) Increasing the main output voltage of a multi-output model could have adverse effects on output voltage of auxiliary outputs such as extra power loss on auxiliary outputs (for auxiliary outputs adopting linear regulator or step down regulator).
- (5) In addition to the built-in VR, high end models might also have the voltage trimming function using external resistors or voltage signal.

2.7 Maximum Output Current/Power

Maximum output power equals to $V_{out} \times I_{out}$. I_{out} should be decreased to keep output power within rated value when V_{out} is increased. For instance, a model with rated voltage of 5V and maximum output current of 10A, the maximum allowed output

current would be 9A while output voltage is set at 5.5V. Please note that the maximum allowed output current would remain at 10A even though output voltage is set at 4.5V. Some channels of multi-output models would be allowed to deliver at the maximum value of output current range, but the total output power should not exceed rated value. For example, take RD-60A with outputs of 5V/8A & 12V@4A, and maximum output power of 58W. If we use 5V output at 6A, and 12V output at 4A, the total output power would be 88W which exceeds the maximum value. Consequently, either output current of 5V or 12V should be decreased to keep output power equivalent to or less than 66W.

2.8 Ripple Noise

An AC waveform can be identified on the DC output of a S.P.S., which is shown in Figure 2.4.

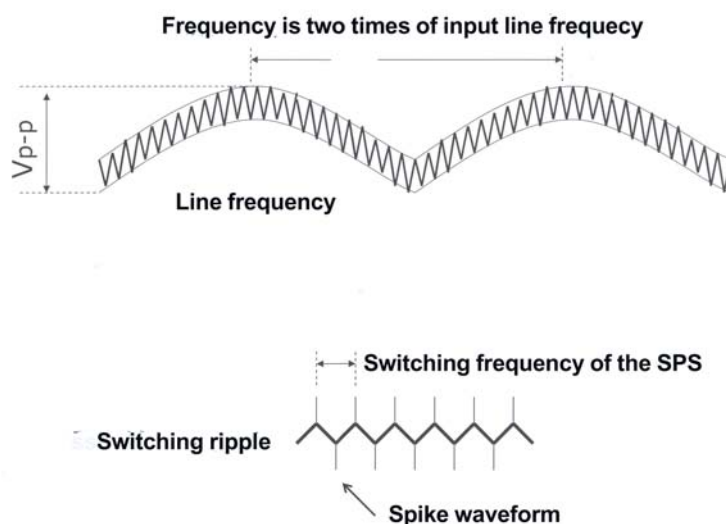


Figure 2.4: Ripple and noise on the output voltage of a S.P.S.

There are two AC components, also known as Ripple and Noise (R&N), on the DC output. The first one, coming from sine wave rectification, is at a low frequency which is 2 times of the input frequency; the second one is at high frequency which is from the switching frequency. For measuring high frequency noise, configurations of an oscilloscope with a bandwidth of 20MHz, a scope probe with shortest ground wire possible, and adding 0.1uF and 47uF capacitors in parallel with test point for filtering out noise interference are required to be made.

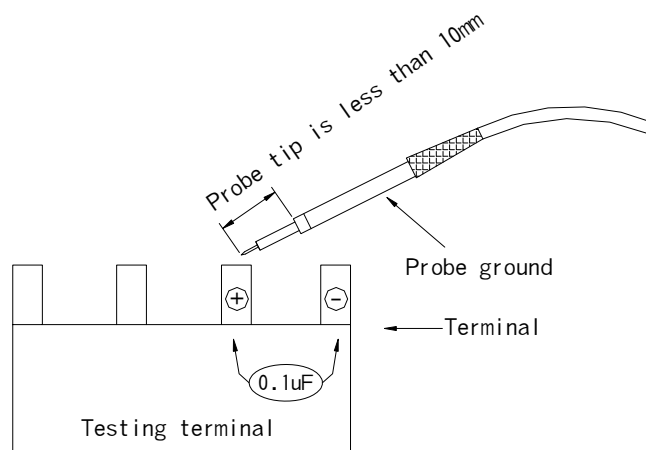


Figure 2.5: Configurations of R&N measurement

2.9 Load Regulation

The variation in output voltage, corresponding to change in output load between minimum value and full value, is called load regulation. In general, high output current would lead to slight voltage drop at the output terminal.

$$\text{Load Regulation (\%)} = \frac{|V_{\text{min}} - V_{\text{fl}}|}{V_{\text{cent}}} \times 100\%$$

V_{min} : Output voltage at minimum load

V_{cent} : Output voltage at 50% load

V_{fl} : Output voltage at full load

2.10 Cross Regulation

For power supplies with two or more channels, cross regulation stands for the variation in output voltage of the channel under test which is loaded with 60% of its rated load, while the load of other channels varies between 20% and 100%.

2.11 Efficiency

The ratio of output power to real input power in terms of percentage.

$$\text{Efficiency} = \frac{P_o}{P_{\text{in}}} \times 100\% = \frac{V_o \times I_o}{P_{\text{in}}} \times 100\%$$

P_{in} : Real input power equivalent to $V_{\text{in}} \times I_{\text{in}} \times \text{PF}$

2.12 Set Up, Rise, Hold Up Time

Set up time (t_{on}): The time from power on to 90% of rated output voltage, or from AC powered on to operation of S.P.S.

Rise time (t_r): The time it takes for output voltage to rise from 10% to 90% of rated value. It is usually within 50ms. Longer period than that might lead to malfunction of system.

Hold up time (t_h): The time from power off to 90% of rated output voltage. The general requirement is at least 16ms to allow sufficient time for UPS to take over.

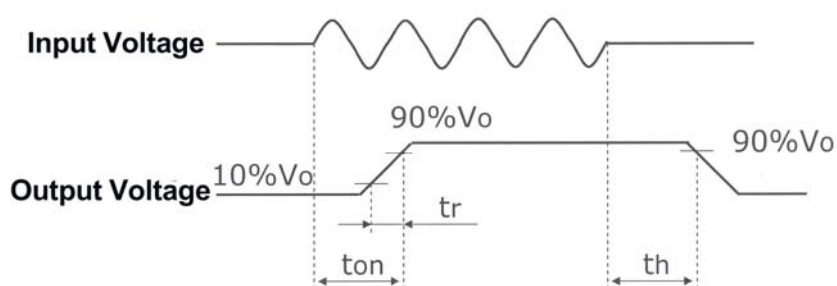


Figure 2.6: t_{on} , t_r , t_h

2.13 Overshoot, Undershoot

The deviation of output voltage to tolerance value prior to steady state after AC is powered on.

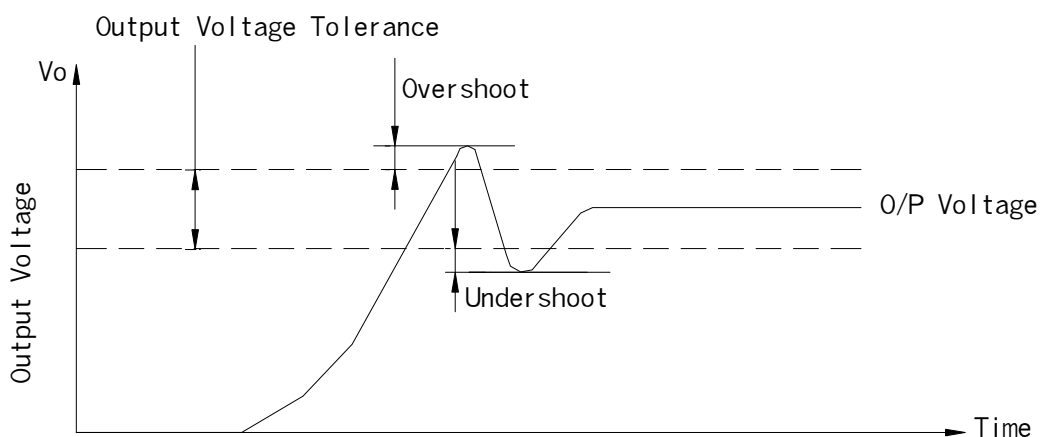


Figure 2.7: overshoot \ undershoot

2.14 Transient Recovery Time

The time required for output voltage to settle within specified tolerance value while output load is in drastic change. The general requirement is 500us at most.

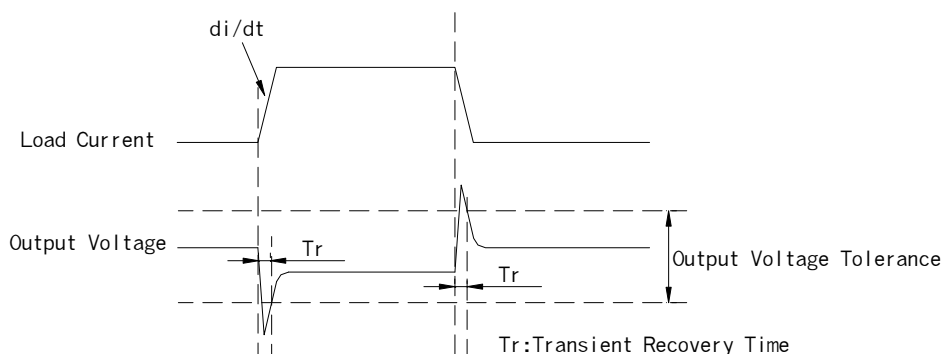


Figure 2.8: transient recovery time

2.15 Temperature Coefficient

It stands for the variation in output voltage due to change in ambient temperature. The unit is in terms of %/°C. Measurements are usually made after burn-in of half an hour.

$$\frac{\Delta V}{V_o} / \Delta T \times 100\%$$

ΔV : Variation in output voltage while temperature varies

V_o : Output voltage measured prior to test conduction

ΔT : Variation in temperature

2.16 Over Current Protection (O.C.P)/ Overload Protection (O.L.P)

When the output power or current reaches the range of O.L.P. /O.C.P. (typically 105%~150% of rated power/current), the S.P.S. would be protected by decreasing or cutoff of output power. The protection modes for over current/overload are categorized into the following types:

Protection Types:

(1) Foldback Current Limiting

Output current is folded back to 20% or less of rated load current (curve (a) in figure 2.9).

(2) Constant Current Limiting

Output current remains constant and within the specified range while the output voltage drops to a low level (curve (b) in figure 2.9).

(3) Over Power Limiting

Output power remains constant. As output load increases, output voltage decreases in proportion (curve (c) in figure 2.9).

(4) Hiccup Current Limiting

Output voltage and current keep pulsing ON and OFF repeatedly when protection is activated. The unit automatically recovers when fault condition is cleared.

(5) Shut Off

Output voltage and current are cut off when output load reaches protection range.

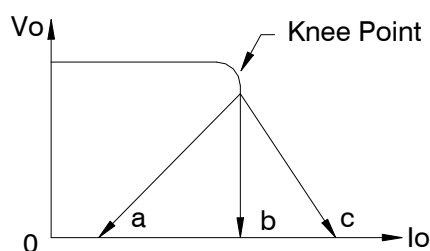


Figure 2.9: O.C.P./O.L.P.

Recovery Methods:

- (1) Auto Recovery: S.P.S. recovers automatically when over current/overload condition is removed or over.
- (2) Re-power on: S.P.S. restarts by manual AC re-power on after over current/overload condition is removed or over.

Cautions: Please prevent from long-term overload or short-circuit, or it could lead to decreased lifetime or damage of S.P.S. Some models are designed with two-stage protection for overload or short-circuit. When in the protection mode, S.P.S. is either foldback current limited or over power limited, and then goes into shutdown or hiccup current mode after a predetermined period of time.

2.17 Over Voltage Protection (O.V.P)

When output voltage functions abnormality (e.g. lost of regulation), it could exceed the rated value. In consequence of that, O.V.P. is triggered to protect end equipments from damage. The protection modes for over voltage are categorized into the following types:

Protection Types:

(1) Shut Off

S.P.S. restarts by manual AC re-power on of after fault condition is removed or over.

(2) Hiccup Voltage Limiting

Output voltage keeps pulsing ON and OFF repeatedly when protection is activated. The unit automatically recovers when fault condition is cleared

Basically, there are two kinds of O.V.P. detection:

(1) Secondary detection circuit feeds back signal to disable PWM IC from operation.

(2) Short circuiting output by using a Crowbar circuit. This would in turn trigger OLP.

2.18 Over Temperature Protection (O.T.P)

This protection is to prevent internal components of S.P.S. from overheating and damage, or to prevent decrease in lifetime due to high ambient temperature, overloading, or malfunction of S.P.S. (e.g. damaged cooling fan). The fault conditions needs to be cleared then S.P.S. would recover automatically or restarts by manual re-power on after internal temperature drops below activating temperature. In general, it would take a few to tens of minutes.

2.19 Vibration Test

The test simulates the usage of S.P.S. in high vibration environment, and verifies the S.P.S.'s capability of operating under this situation. It is conducted with a single unit or an entire carton in the X, Y, and Z axes, and with sine wave acceleration of specified amplitude, frequency in each of the three axes at specified period of time.

The relation between amplitude and frequency to constant G is as follows:

$$G=0.002 \times d \times f^2$$

G: gravity, d: amplitude, f: frequency

For example, if gravity is of 2G and d= 3mm, then f= 18 Hz



Figure 2.10: Instruments for vibration test

2.20 Hi-Pot Test

- (1) Hi-pot testing is made on behalf of safety regulation, and is one way to verify the effectiveness of primary-to-secondary isolation of S.P.S., so as to confirm that the SPS can withstand high voltage without breakdown. The test voltage should be gradually increased from 0V to preset level and remains at preset level for 60 seconds. In mass production, the test period could be reduced to 1 second. If the leakage current flowing through the isolation material increases rapidly after applying test voltage, it indicates ineffectiveness of isolation (dielectric breakdown). Corona effect/discharge or transient electrical arc is not considered as a failure.
- (2) When AC test voltage is applied, Y capacitors are the main cause of leakage current. A 4.7nF capacitor can cause leakage current of 5mA. According to regulations of UL-554, the Y capacitors should be removed for Hi-Pot test, which is not practical for mass production. The only solution is to increase the leakage current setting, typically 25mA, of test instrument. Presently, the criteria of leakage current are not defined in safety regulations.
- (3) According to regulations of safety, DC test voltage can be substituted when there are bridging capacitors coupled between primary and secondary circuits, so as to solve the problem of leakage current.

2.21 Isolation Resistance

It is to determine the dielectric strength of insulation materials by applying DC voltage. The unit is expressed in $M\Omega$ (mega-ohms). The tests are to verify the isolation resistance of transformers, PCB, and etc. The criteria of isolation resistance are not defined in regulation of safety.

2.22 Power Good (P.G.)/ (Pok/DC OK) and Power Fail (P.F.) Signal

When S.P.S. is powered on or off., PG/Pok, or PF signals are sent out for status monitoring.

P.G.: A TTL (+5V) signal will be sent out with a delay of 10~500ms after output voltage reaches 90% of rated value.

P.F.: The TTL signal will be turned off at least 1ms before the output voltage drops to 90% of rated value.

Pok: A TTL signal is sent out in synchronization with output voltage. It is without functionality in time sequence.

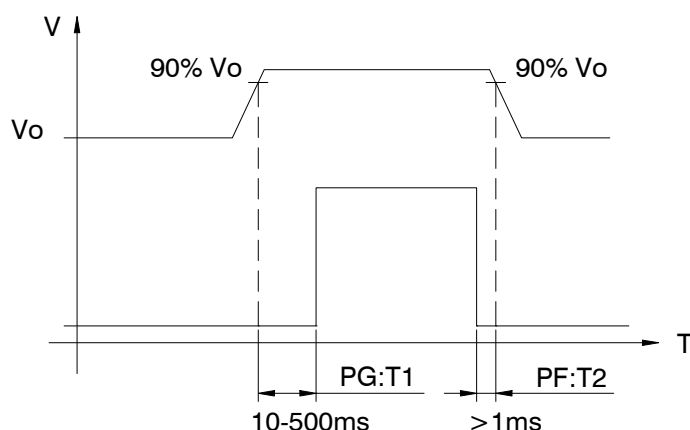


Figure 2.11: P.G. and P.F. signals

2.23 Alarm

The two contacts provided by S.P.S. are short-circuited when output voltage reaches specified voltage level. On the contrary, the contacts are open-circuited.

- (1) The contacts of this alarm functions typically derives from solid-state semiconductor components. In addition to limitations on withstand voltage and current, polarity needs to be aware of.
- (2) Some alarm functions use relays as the contacts. Since relays are just mechanically open/close contacts, it is free of polarity problem.

- (3) Alarm functions could malfunction when the total output load is below 10% of rated current in parallel application of S.P.S.

2.24 Auxiliary Power

Auxiliary may design together with switching power supply. Not only provides energy to remote control or alarm circuit, but also for convenience of application, or powered surrounding equipment. Auxiliary power outputs individually, and commonly isolated from other outputs. For detail, please refer to the specification.

- (1) The auxiliary power source is designed based on isolation concept, and independent of other power sources in the unit.
- (2) The auxiliary power source is only for applications of control functions in S.P.S. It should not be used as power source for other end equipments.

2.25 Noise

The common noise sources of power supplies can be divided into three types:

1. Fan noise from the fan built-in model.
2. Due to energy consumption requirements, IC are mostly equipped with burst mode function, which is to reduce switching frequency during light load. When the switching frequency is reduced to a frequency of 20Hz ~ 20kHz, it become audible to human ears. Leading the noise from inductive component will be heard sound.
3. Under dynamic load, high-frequency of sound from transformer will be heard. Because noise may cause uncomfot to end-user, although the parameter does not define in Spec, but QE still defines its requirements for noise in internal functional tests. Please refer to the following definition.

Definition: regarding to the noise that is produced by the PSU, under normal input / output conditions

Condition: I / P: Low / Normal / High (range defined by SPEC)
O / P: Min Load-Full Load

Note: This test is performed with power place on a table at a distance of 30Cm. QE is in charge of the test. If there is a dispute, it can be judged with a noise meter separately.

Chapter 3

Introduction To Safety

3.1 Introduction to Safety








To insure the safety of life and property, safety inspection of products becomes increasingly more important. UL/CSA/TUV safety standards are used to verify that the products meet safety requirements. Soundness of design, component selection, and overall quality are also checked at the same time. These safety standards mainly try to prevent the occurrence of the following seven kinds of hazards: (1) Electric shock (2) Energy related hazards (3) Fire (4) Mechanical hazards (5) Radiation hazards (6) Chemical hazards and (7) Thermal hazards

3.2 Introduction to Regulations

Product Category	UL	TUV	IEC
Audio/video, information and communication technology equipment	UL62368-1	EN62368-1-1	IEC62368-1
Medical Equipment	ANSIAAMI 60601-1	EN60601-1	IEC60601-1
Household Appliance	UL60335-1	EN60335-1	IEC60335-1
LED driver	UL8750	EN61347-1 EN61347-2-13	EN61347-1 EN61347-2-13

Note: Audio, Video Equipment(60065) will combine with communication technology equipment(60950-1) on 2020, by new regulation of 62368-1.

3.3 Safety Marks found on MW products

- (1)  Considered as a component to be installed in a complete system. The File NO. E127738 is equivalent to compliance of UL1012.
- (2)  Considered as a component to be installed in a complete system. This mark represents universal certification. Both UL/CSA standards are met.
- (3)  Categorized as final product. This mark represents universal certification. Both UL/CSA standards are met.
- (4)  Based on the safety standard CSA C22.2 NO.60950, the file number issued to MEANWELL is LR109657. This mark represents universal certification, meaning UL/CSA/IEC/EN standards are met.
- (5)  Considered as a component. Meets TUV requirements.
- (6)  Categorized as final product. Meets TUV requirements.
- (7)  Class II equipment.

3.4 Safety Related Terminology

(1) CB (Certification Body Scheme)

CB scheme is a global organization in which reports issued by any member nation is mutually recognized by all. Currently, there are 35 members from the European Union. CB reports and certificates can be issued by any one of the 82 national certification bodies (NCB). All certification bodies follow the same standards set by the IEC (International Electrotechnical Commission).

(2) LVD/ Low Voltage Directive (73/23/EEC) (93/68/EEC)

As early as 1973, the low voltage directive (73/23/EEC) was being followed by many countries in Europe. It regulates low voltage products between the range of AC 50V~1000V or DC 75V~1500V. Member countries individually authorized Safety lab to verify LVD on their behalf. On July 22, 1993, the EC organization announced that beginning in January 1, 1995 the CE mark (93/68/EEC) will be used to replace all safety marks previous certified by members of the EC.

(3) Equipment Classification:

a. Class I Equipment:

Equipment where protection against electric shock is achieved by using basic insulation and also providing a means of connecting to the protective earth conductor in the building where by routing those conductive parts that are otherwise capable of assuming hazardous voltages to earth ground if the basic insulation fails.

b. Class II Equipment:

Equipment in which protection against electric shock does not rely on basic insulation only, but in which additional safety precautions, such as double insulation or reinforced insulation are provided, there being no reliance on either protective earth or installation conditions.

c. Class III Equipment:

This type of equipment draws power from a SELV source which means hazardous voltages does not exist in its circuitry.

(4) Clearance Distance:

The shortest distance between two conductive parts or between a conductive part and the bounding surface of the equipment as measured through air. Please refer to Figure 3.1.

(5) Creepage Distance:

The shortest path between two conductive parts or between a conductive part and the bounding surface of the equipment as measured along the surface of the insulation. Please refer to Figure 3.1.

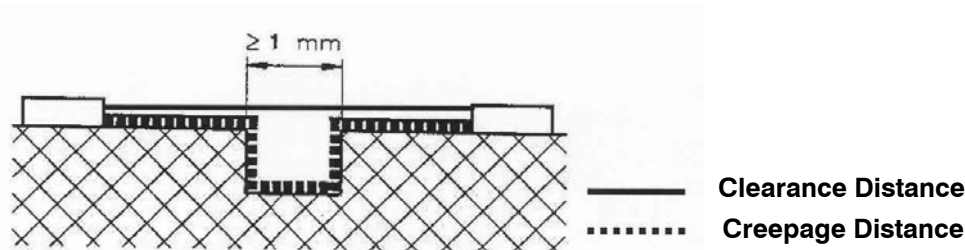



Figure 3.1 - Clearance Distance and Creepage Distance

3.5 Category of Safety Tests (Refer to IEC-62368-1, including all S.P.S. related tests)

(1) Input Test

The steady state input current of the equipment shall not exceed the rated current by more than 10% under normal load.

(2) Marking

- a. Rated voltage(s) or rated voltage range(s), in volts. (Should add on the "≡" symbol for DC input).
- b. Rated current, in milli-amperes or amperes.
- c. Rated frequency or rated frequency range, in hertz.
- d. Manufacturer's name, trademark or identification mark.
- e. Manufacturer's model or type reference.
- f. Symbol  for Class II equipment only.
- g. For equipment intended for connection to multiple rated voltages, the method of adjustment should be fully described beside the switch.
- h. Marking of fuse identification should be located adjacent to each fuse or fuse-holder and specify the fuse's voltage rating, current rating and fusing characteristics.
- i. Symbol for grounding: \perp (IEC417 NO5017) or \oplus (IEC419 NO5019).
- j. Neutral conductor of the AC main supply shall be indicated by the capital letter N. Additional markings are permitted, provided that they do not give rise to misunderstanding.

(3) Capacitance Discharge Test for Audio/video, information and communication technology equipment

Equipment shall be designed that at an external point of disconnection of the AC mains supply, the risk of electric shock from stored charge on capacitors connected in the primary circuit is reduced. Usually, there will be discharging resistors across the X-capacitors and decay their voltage to lower than 60V of their original value within 2 second.

(4) Humidity Test for Audio/video, information and communication technology equipment

For insulating materials that their insulating characteristics may vary under different humidity, the humidity test should be made. Humidity test is carried out for 48 hours in acabinet or room containing air with a relative humidity of 91%~95%. The temperature of the air, at all places where samples can be located, is maintained within 1°C between 20°C and 30°C such that condensation does not occur. And then the hi-pot test will be executed in this environment, also, tightened inspection might be required for certain countries.

(5) Working Voltage Measurement

Parameters such as clearance distance, creepage distance, and value of hi-pot test derives from working voltage measurements.

(6) Limited Current Circuit Measurement for Audio/video, information and communication technology equipment

Limited current circuits shall be so designed that under normal operating conditions and in the event of a single failure within the equipment, the voltage should not exceed 42.4V peak or 60Vdc within the touchable region for repairing. So, as long as connecting to the limited current circuit, components with dangerous voltage will not harm human beings if the user accidentally touches it. For frequencies not exceeding 1 KHz, the steady-state current drawn through a non-inductive resistor of $2K\Omega \pm 10\%$ connected between any two parts of a limited current circuit, or between any such part and earth, shall not exceed 0.7mA peak, or 0.2mA DC. For frequencies above 1 KHz, the limit of 0.7mA is multiplied by the value of the frequency in KHz but shall not exceed 70mA peak.

(7) Grounding Test for Audio/video, information and communication technology equipment

The purpose of grounding test is to make sure that the resistance between Protective Earth Conductors and grounded components does not exceed 0.1Ω . The test voltage should not exceed 12V. The requirement for TUV is 32A for 1min. As for UL, it is 40A for 2min.

(8) Clearance Distance Measurement for Audio/video, information and communication technology equipment

Minimum clearance distance is decided based on working voltage and insulation level. The test is conducted by applying a force of 10N to the internal components and a 30N force to the case to reduce the distances. We have to make sure that in the worst case scenario, the clearance distances are still within the regulated values.

CLEARANCES in mm															
PEAK WORKING VOLTAGE ^a up to and including V	MAINS TRANSIENT VOLTAGE														
	1 500 V ^c					2 500 V ^c					4 000 V ^c				
	Pollution degree														
	1 and 2 ^b			3			1 and 2 ^b			3			1, 2 ^b and 3		
	F	B/S	R	F	B/S	R	F	B/S	R	F	B/S	R	F	B/S	R
71	0,4	1,0 (0,5)	2,0 (1,0)	0,8	1,3 (0,8)	2,6 (1,6)	1,0	2,0 (1,5)	4,0 (3,0)	1,3	2,0 (1,5)	4,0 (3,0)	2,0	3,2 (3,0)	6,4 (6,0)
210	0,5	1,0 (0,5)	2,0 (1,0)	0,8	1,3 (0,8)	2,6 (1,6)	1,4	2,0 (1,5)	4,0 (3,0)	1,5	2,0 (1,5)	4,0 (3,0)	2,0	3,2 (3,0)	6,4 (6,0)
420	F 1,5 B/S 2,0 (1,5) R 4,0 (3,0)											2,5	3,2 (3,0)	6,4 (6,0)	
840	F 3,0 B/S 3,2 (3,0) R 6,4 (6,0)														
1 400	F/B/S 4,2 R 6,4														
2 800	F/B/S/R 8,4														
7 000	F/B/S/R 17,5														
9 800	F/B/S/R 25														
14 000	F/B/S/R 37														
28 000	F/B/S/R 80														
42 000	F/B/S/R 130														

The values in the table are applicable to FUNCTIONAL INSULATION (F) if required by 5.3.4 a) (see 2.10.1.3), BASIC INSULATION (B), SUPPLEMENTARY INSULATION (S) and REINFORCED INSULATION (R).

Table 3.1 - Minimum clearances for insulation in primary circuits and between primary And secondary circuits

MAINS TRANSIENT VOLTAGE						
1 500 V ^c				2 500 V ^c		
Pollution Degrees 1 and 2 ^b	Pollution Degree 3	FUNCTIONAL ^a BASIC OR SUPPLEMENTARY INSULATION	REINFORCED INSULATION	Pollution Degrees 1, 2 and 3 ^b	FUNCTIONAL ^a BASIC OR SUPPLEMENTARY INSULATION	REINFORCED INSULATION
PEAK WORKING VOLTAGE up to and including V				PEAK WORKING VOLTAGE up to and including V		
210 (210)	210 (210)	0,0	0,0	420 (420)	0,0	0,0
298 (288)	294 (293)	0,1	0,2	493 (497)	0,1	0,2
386 (366)	379 (376)	0,2	0,4	567 (575)	0,2	0,4
474 (444)	463 (459)	0,3	0,6	640 (652)	0,3	0,6
562 (522)	547 (541)	0,4	0,8	713 (729)	0,4	0,8
650 (600)	632 (624)	0,5	1,0	787 (807)	0,5	1,0
738 (678)	715 (707)	0,6	1,2	860 (884)	0,6	1,2
826 (756)	800 (790)	0,7	1,4	933 (961)	0,7	1,4
914 (839)		0,8	1,6	1 006 (1 039)	0,8	1,6
1 002 (912)		0,9	1,8	1 080 (1 116)	0,9	1,8
1 090 (990)		1,0	2,0	1 153 (1 193)	1,0	2,0
		1,1	2,2	1 226 (1 271)	1,1	2,2
		1,2	2,4	1 300 (1 348)	1,2	2,4
		1,3	2,6	(1 425)	1,3	2,6

The additional CLEARANCES in the table apply if required by 2.10.3.3 b).
The values in parentheses shall be used:
- if the values in parentheses in Table 2K are used; and
- for FUNCTIONAL INSULATION if required by 5.3.4 a).
For voltage values above the PEAK WORKING VOLTAGE values given in the table, linear extrapolation is permitted.

(9) Creepage Distance Measurement for Audio/video, information and communication technology equipment

Working voltage measurement in conjunction with insulation level can be used to find out what is the minimum creepage distance based on Table 3.3.

CREEPAGE DISTANCES in mm									
RMS WORKING VOLTAGE up to and including	Pollution degree								
	1 ^a	2	1 ^a	2			3		
	Printed boards			Other materials					
	I, II, IIIa, IIIb	I, II, IIIa	I, II, IIIa, IIIb	I	II	IIIa, IIIb	I	II	IIIa, IIIb (see Note)
10	0,025	0,04	0,08	0,4	0,4	0,4	1,0	1,0	1,0
12,5	0,025	0,04	0,09	0,42	0,42	0,42	1,05	1,05	1,05
16	0,025	0,04	0,1	0,45	0,45	0,45	1,1	1,1	1,1
20	0,025	0,04	0,11	0,48	0,48	0,48	1,2	1,2	1,2
25	0,025	0,04	0,125	0,5	0,5	0,5	1,25	1,25	1,25
32	0,025	0,04	0,14	0,53	0,53	0,53	1,3	1,3	1,3
40	0,025	0,04	0,16	0,56	0,8	1,1	1,4	1,6	1,8
50	0,025	0,04	0,18	0,6	0,85	1,2	1,5	1,7	1,9
63	0,04	0,063	0,2	0,63	0,9	1,25	1,6	1,8	2,0
80	0,063	0,10	0,22	0,67	0,9	1,3	1,7	1,9	2,1
100	0,1	0,16	0,25	0,71	1,0	1,4	1,8	2,0	2,2
125	0,16	0,25	0,28	0,75	1,05	1,5	1,9	2,1	2,4
160	0,25	0,40	0,32	0,8	1,1	1,6	2,0	2,2	2,5
200	0,4	0,63	0,42	1,0	1,4	2,0	2,5	2,8	3,2
250	0,56	1,0	0,56	1,25	1,8	2,5	3,2	3,6	4,0
320	0,75	1,6	0,75	1,6	2,2	3,2	4,0	4,5	5,0
400	1,0	2,0	1,0	2,0	2,8	4,0	5,0	5,6	6,3
500	1,3	2,5	1,3	2,5	3,6	5,0	6,3	7,1	8,0

Table 3.3 - Minimum creepage distances

(10) Power Source Test for Audio/video, information and communication technology equipment

When an electronic circuit is powered by a PS1 or PS2 power source. Output current and power are under the limitation shown in Table 3.4, the risk of fire can be reduced significantly. So, the safety distances and flammability rating of components can be much lower. Leading plastic material of the HB level can be use for its enclosure to reduce costs.

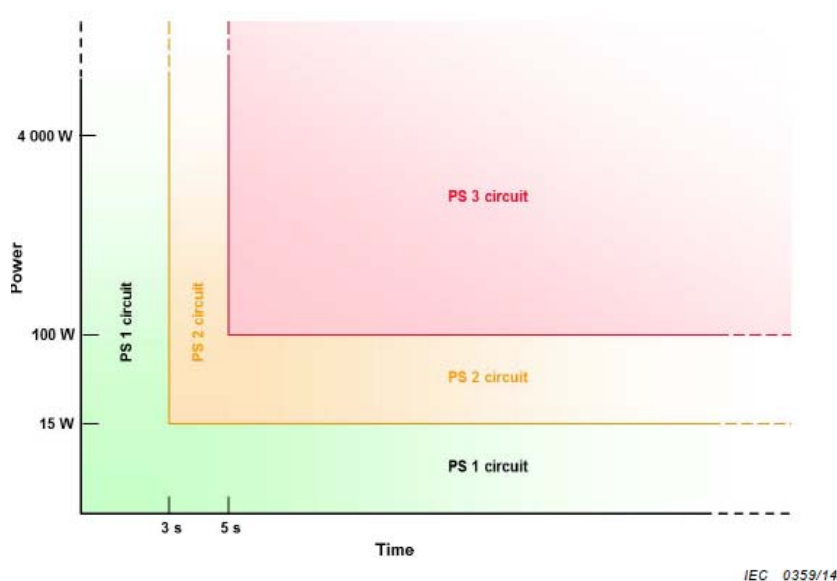


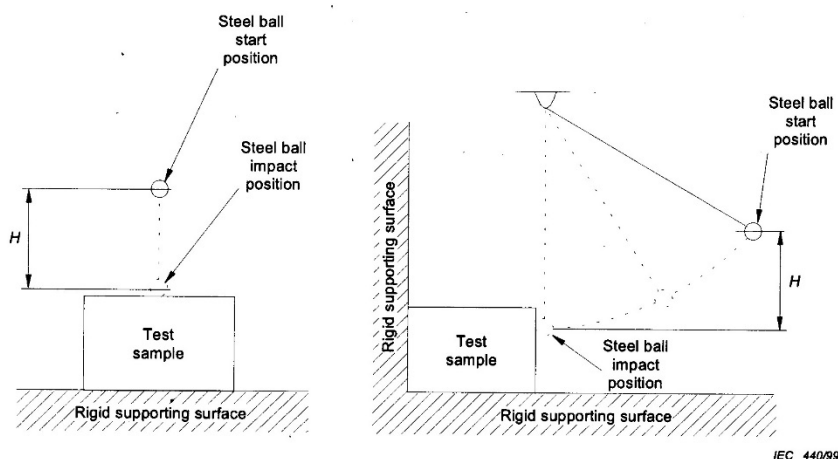
Figure 3.2 - Illustration of power source classification

(11) Stability Test for Audio/video, information and communication technology equipment

The test unit shall remain balanced when tilted to an angle of 10° from its upright position. This is to make sure that this condition will pose no danger to the user or repair personnel.

(12) Impact Test for Audio/video, information and communication technology equipment

A product consisting of complete enclosure should pass the impact test. A solid smooth steel ball, approximately 50mm in diameter and with a mass of $500\text{g} \pm 25\text{g}$, is permitted to fall freely from rest through a vertical distance of 1.3 meter. After test completion, the product must not be capable of inducing danger or show insufficient insulation.



(13) Drop Test for Audio/video, information and communication technology equipment

For hand-held and direct plug-in equipments, a sample of the complete equipment is subjected to three impacts resulting from being dropped onto a horizontal hardwood surface. The drop height should be 1 meter and the sample can't induce any danger or show insufficient insulation after testing. However, it is not required that the sample can still function properly.

(14) Mold Stress Relief Test for Audio/video, information and communication technology equipment

Enclosures of molded or formed thermoplastic materials shall be so constructed that any shrinkage or distortion of the material due to release of internal stresses caused by the molding or forming operation does not result in the exposure of hazardous parts or in the reduction of creepage distances or clearance distances below the minimum requirement. The test temperature is 70°C or 10°C higher than the surface temperature measured during the Heating Test. The test duration is 7 hours.

(15) Heating Test for Audio/video, information and communication technology equipment

- ① The first step is attaching thermocouplers to test components.
- ② Apply 90% and 110% of rated input voltage.
- ③ Full Load connected at output terminal.
- ④ The test should stop only after the temperature is stable.

The maximum allowable temperature for each component is as follow:

(A) General electronic components: the rated operating temperature for that component.

(B) Transformer: Class A → 90°C Class E → 105°C

Class B → 110°C

(C) Case: Metal 70°C; plastic 94°C. (if the time period of contact is less than 1s)

(16) Ball Pressure Test for Audio/video, information and communication technology equipment

This test is mainly for plastic material. Using a solid smooth steel ball, approximately 5mm in diameter and applying a 20N force on the test surface. Both items are placed in a heating cabinet at 125°C for 1 hour. It is then taken out of the cabinet and allowed to cool down to room temperature. The diameter of the indentation can't exceed 2mm. If the material is Phenolic, the Ball Pressure Test can be omitted.

(17) Leakage / Touch Current Test for Audio/video, information and communication technology equipment

Test voltage is 1.1 times of the rated voltage and the leakage current can't exceed the limits of 0.707mA_{PK}

(18) Electric Strength Test for Audio/video, information and communication technology equipment

The purpose is to make sure that the insulation materials in the equipment have enough electric strength. Two portions of the sample will be tested: isolating transformer and switching power supply. The voltage applied is gradually raised from zero to the prescribed voltage and held at that value for 60 seconds. Insulation breakdown is not allowed during the test. The general standard is $4kV_{DC}$ or $4kV_{PK}$ for primary to secondary.

(19) Abnormal Test for Audio/video, information and communication technology equipment

Equipment shall be designed so that the risk of fire or electric shock due to mechanical or electrical overload or failure, or due to abnormal operation or careless use (fan lock, open or short of MOS, diode, or capacitor), is limited to a minimum. After abnormal operation, the equipment shall remain safe for an operator, but it is not required that the equipment should still be in full working order. There's no specific time duration for this test, however, we can stop the test only after one of the following situations occur:

- ① The fuse is open.
- ② The outcome is clear.
- ③ The test has been made for 7 hours.
- ④ The input current or temperature has reached equilibrium situation.
- ⑤ Flame or the melting metal has been spreading outside the case.

(20) Output Power Overload Test for Audio/video, information and communication technology equipment

While testing, input voltage is at the maximum rated input voltage and the output load for each channel is increased gradually until over load protection occurs. Following conditions are not allowed during the test:

- ① Flame has spread outside the equipment.
- ② The case changes its shape and influences safety.
- ③ Temperature of the transformer exceeds the limitation: Class A - $150^{\circ}C$; Class B - $175^{\circ}C$.

3.6 Comparison between regulations

Category		IEC62368-1	IEC60601-1		IEC61558	EN60335-1		
Creepage/clearance distances Working voltage: Max.250Vrms	Basic insulation	2.5mm/1.5mm	4mm/2.5mm		2.6mm/2.5mm	2.5mm/2mm		
	Reinforced insulation	5mm/3mm	8mm/5mm		5mm/4.7mm	5mm/4mm		
Electric strength test	Basic insulation	2500V _{PK}	1500Vac		2100Vac	1000Vac		
	Reinforced insulation	4000V _{PK}	4000Vac		420Vac	3000Vac		
Isolation resistance	Basic insulation	NA	NA		2MΩ	NA		
	Reinforced insulation	NA	NA		4MΩ	NA		
Leakage current	CLASS I	5mA _{PK}		Normal condition	Abnormal condition	2mA	Hand held	0.75mA
			Ground leakage current	0.3mA	1mA		Stationary	0.75mA
			Case leakage current	0.1mA	0.3mA			
	CLASS II	0.707A _{PK}	Case leakage current	Normal condition	Abnormal condition	0.55mA	0.25mA	
			0.1mA	0.3mA				
Number of fuse		1	2		1	1		
Minimum ambient temperature		Determined by manufacturer	40°C		Determined by manufacturer	Determined by manufacturer		

3.7 Reference data

(1) EU website : Search for CE directives.

<http://ec.europa.eu/growth/>

(2) UL website : Search for UL certificate and Introduction to regulations.

<http://www.ul.com/>

(3) TUV website : Search for TUV certificate and newsletter.

<http://www.twn.tuv.com/>

(4) CSA website : Search for CSA certificate and Introduction to regulations.

<https://www.csagroup.org/services-industries/product-listing/>

(5) JET website (Japan) : PSE-Mark and S-Mark introductions.

<http://www.jet.or.jp/en/>

(6) FIMKO website : Search for FIMKO certificate.

<http://www.fimko.com/>

(7) VDE website : Search for VDE certificate.

<http://www.fimko.com/>

Chapter 4

Introduction To EMC

4.1 Introduction of EMC

EMC (Electromagnetic Compatibility) is divided into two sections, which are EMI (Electromagnetic Interference) and EMS (Electromagnetic Susceptibility).

By definition, EMI refers to emissions of electromagnetic energy from a device or system that interferes with the normal operation of another device or system. On the other hand, EMS refers to the ability of a device or system to function without error in its intended electromagnetic environment.

4.2 Regulations and Explanations of EMI

(1) If the functionality of an electrical device is interrupted by external voltage/current sources, and the device cannot function as intended. Then, we can conclude this device is being interfered by electromagnetic wave. For example, the picture on TV may distort when a nearby PC is starting up; a radio may send out noises if a motorcycle is starting while the radio is operating. These phenomena are considered as electromagnetic interference. There are two ways that un-intentional external voltage/current sources causes interference: The first one is Conducted Emission – this source of noise interferes with other systems through power cord, plug, and dispatching system; the second one is Radiated Emission - this source of noise interferes with other systems through the radiation of its electromagnetic field. That is, radiates unwanted electromagnetic wave through free space.

(2) The most popular EMI regulations are CISPR32/EN55032, and the limits are listed on the Table 4.1.

Table 4.1: Limit for Conducted Emission of class B equipments

Range of frequency MHz	Limit in dB (uV)	
	Q.P	AVG
0.15-0.5	66-56	56-46
0.5-5	56	46
5-30	60	50

Note: The frequency band in between 0.15MHz and 0.5MHz, the limit decreases linearly with respect to the logarithm value (Figure 4.1).

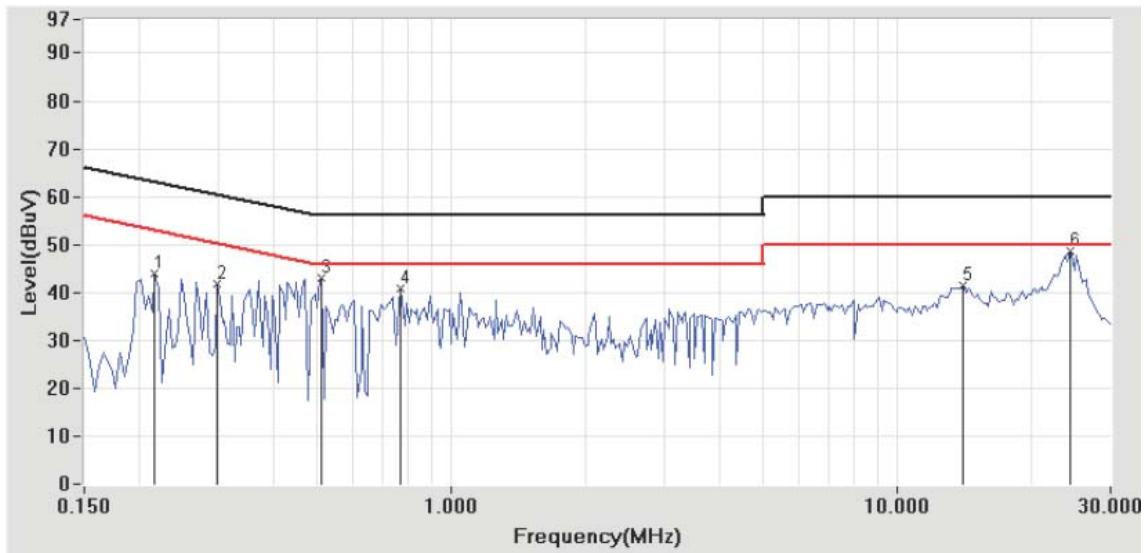


Figure 4.1 : CISPR22 / EN55022 Class B (Conduction Limit)

Table 4.2: Limit for Radiated Emission of class B equipments measured at 10 meters away

Range of frequency MHz	Q.P. dB(uV/m)
30~230	30
230~1000	37

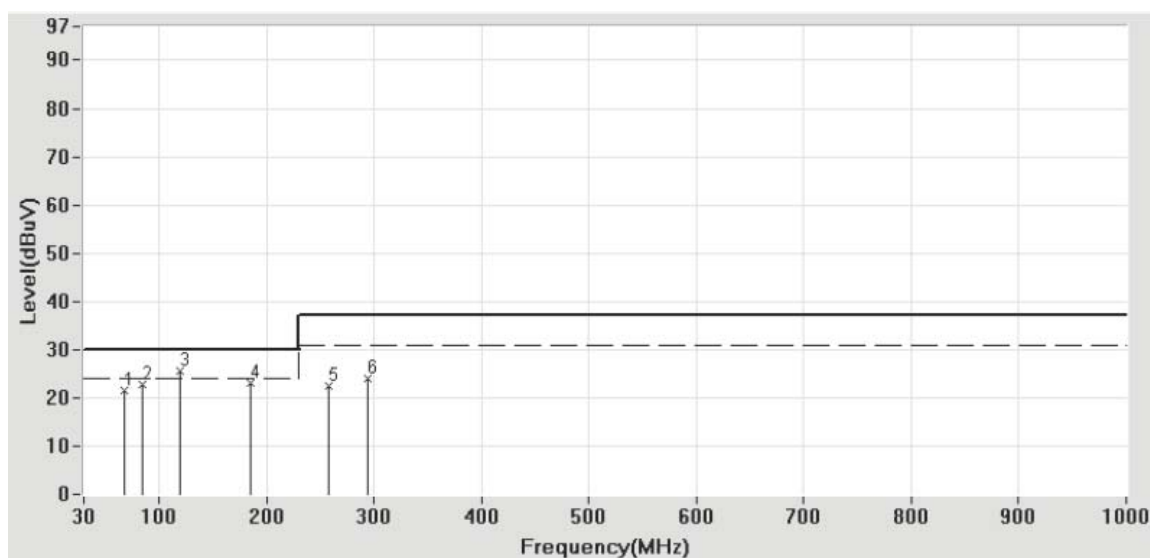


Figure 4.2 : CISPR22 / EN55022 Class B (Radiation Limit)

4.3 Definition of Harmonic Current and Related Regulations

- (1) For a traditional AC/DC converter, there is a bridge rectifier and bulk capacitors which charges/discharges in a very short period of time. Hence, a high current pulse is introduced at AC input line and generates harmonic current noises through the power line. The un-intentional harmonic current noise could interfere with other electrical devices and also reduce the Power Factor (See Figure 4.3). In order to prevent interference with other equipments, PFC (Power Factor Correction) circuit should be used on the switching power supply that makes the current waveform more sinusoidal (Figure 4.4), and improves the quality and efficiency of the AC power source.

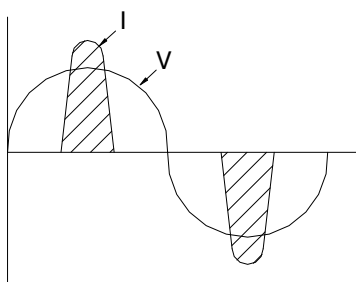


Figure 4.3
Non-PFC: Typical $Pf < 0.6$

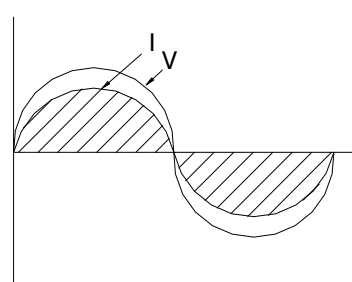


Figure 4.4
PFC: Typical $Pf > 0.9$

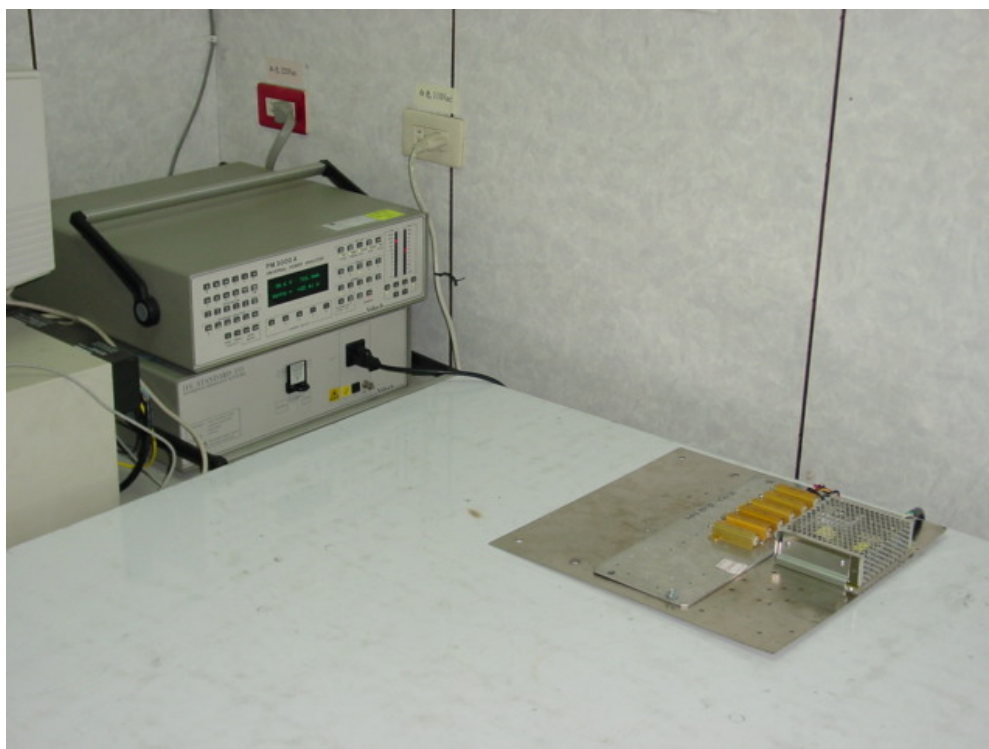


Figure 4.5: Equipment set-up for harmonic testing

(2) Since, harmonic current pollution on power distribution network is becoming more and more serious. CENELEC announced the latest standard EN61000-3-2:2000 to regulate harmonic current. All members of the European Union began to execute the regulation on July 1st, 2001, and official enforcement of this regulation commences after Jan 1st, 2004. This regulation divides all applicable products into four categories:

Class A : ① Balanced three-phase equipment

② Household appliances excluding equipment identified as class D

③ Tools, exclude portable tools

④ Dimmer for Incandescent lamp

⑤ Audio equipment

⑥ Equipment not specified as class B, C and D

Class B : ① Portable tools

② Non-professional Arc welding equipment

Class C : Lighting equipment

Class D : Equipment having a specified power according to 6.2.2 less than or equal to 600 W, of the following types. personal computers and personal computer monitors, television receiver and refrigerators and freezers having one or more variable-speed drives to control compressor motor(s). The rest which excluded, are specified as class A.

(3) If MW power supply is not used in Class D equipments, than any products with input power <150W are able to meet Class A Limit (Table 4.3) without the PFC circuit. For input power >150W, power supply will need PFC circuit in order meet Class A and Class D limits.

Table 4.3 : Limits for Class A equipment

Harmonic order n	Maximum permissible harmonic current (A)
Odd harmonics	
3	2.30
5	1.14
7	0.77
9	0.40
11	0.33
13	0.21
$15 \leq n \leq 39$	$0.15 \cdot 15/n$
Even harmonics	
2	1.08
4	0.43
6	0.30
$8 \leq n \leq 40$	$0.23 \cdot 8/n$

Table 4.4 : Limits for Class D equipment

Harmonic order n	Maximum permissible Harmonic current per watt (mA/W)	Maximum permissible Harmonic current (A)
3	3.4	2.30
5	1.9	1.14
7	1.0	0.77
9	0.5	0.40
11	0.35	0.33
$13 \leq n \leq 39$ (odd harmonics only)	$3.85/n$	Refer to Table 4.3

4.4 Explanation of EMS

EMS (Electro-Magnetic Susceptibility) refers to the correct operation of electrical equipments in the presence of electromagnetic disturbances. The most common electromagnetic interferences are listed on the following table.

EN Regulation	Content of tests	Explanation
EN61000-4-2 (ESD)	ESD (electrostatic discharge)	Simulating the influences of static on human body to electronic products
EN61000-4-3 (RS)	Radiated RF	Simulating RF power radiated through antenna radiation and we need to test electronic products' susceptibility to the RF power
EN61000-4-4 (EFT)	EFT (Electrical Fast Transient)	Simulating the influence of the switching transient of inductive components such as relay to electronic products
EN61000-4-5 (Surge)	Lightning / Surge	Simulating the influence of lightning shock to electronic products
EN61000-4-6 (CS)	Conducted RF	Simulating the influence of conducted RF power that directly injects into electronic products through power cord or signal line
EN61000-4-8 (PM)	Power frequency magnetic field	Simulating the influence of the magnetic field induced from the current flowing through the power line to electronic products
EN61000-4-11 (Dip)	Voltage Dips, short Interruptions	Simulating how voltage dips, interruptions or variation of the AC source affect the electronic products

4.5 Introduction to EMC Regulation:

- (1) Currently, most countries implement their own EMC regulations. In general, all the regulations are based on the standards issued by international committees, such as IEC (International Electrotechnical Commission), and CISPR (Committee International Special des Perturbations Radioelectraque). Individual countries adapt these international standards, and modify it to include the actual need for that particular environment.
- (2) Following are the EMC standards issued by European Union for each product category:

Product Category	EMI Standard	EMS Standard
Industrial Scientific and Medical (ISM) equipment	CISPR11 (EN55011)	EN61000-6-2/EN60601-1-2
Information Technology equipment	CISPR32 (EN55032)	CISPR24 (EN55024)
Household appliances, electric tools and similar apparatus	CISPR14-1 (EN55014-1)	CISPR14-2 (EN55014-2)
Power supply DC output (stand alone)	CISPR32 (EN55032)	EN61204-3
TV/Audio Broadcasting Receiver & its Auxiliary	CISPR13 (EN55013)	CISPR20 (EN55020)

4.6 EMC Standards for ITE Products

(1) EMI Standards

Conduction/Radiation	EN55032 (Class B)
Harmonic Current	EN61000-3-2
Voltage Fluctuations and Flicker	EN61000-3-3

(2) EMS Standard (EN55024/EN61204-3)-ITE/Power Supply

Test Item	ESD	RS	EFT	Surge
Standard	IEC61000-4-2	IEC61000-4-3	IEC61000-4-4	IEC61000-4-5
Spec of Test	4KV(Contact discharge) 8KV(Air discharge)	80-1000MHz 3V/m 80%AM 1KHz modulation	1KV/0.5KV 5/50ns 5KHz	1. 2/50us 1KV(line to line) 2KV(line to earth)
Class Judgment	B	A	B	B
Test Item	CS	Power-frequency Magnetic field(PM)	Voltage dips/interruptions	
Standard	IEC61000-4-6	IEC61000-4-8	IEC61000-4-11	
Spec of Test	0.15~80MHz 3Vrms 80%AM 1KHz modulation	50Hz 1A/m	Dip > 95% 0.5 cycle Dip > 30% 25 cycle interruptions > 95% 250 cycle	
Class Judgment	A	A (NA for EN61204-3)	Dip > 95% B Dip 30% C interruptions 95% C (EN61204-3 follows the same standard as EN61000-6-2)	

(3) EMS Standard (EN61000-6-2)-Heavy industry

A numbers of MW products are certified according to Heavy industry standard, due to operating environment and customer application requirement. The test procedures are the same as ITE (EN55024); however, the test levels are different (see below).

Item	ESD	RS	EFT	Surge
Test Level	4KV (Contact) 8KV (Air)	10V/m	2KV/1KV	2KV (Line to Line) 4KV (Line to Earth)
Item	CS	PM	Voltage dips/interruptions	
Test Level	10Vrms	30A/m	Dip 100%, 1 cycle Dip 60%, 10(50Hz)/12(60Hz) cycles Dip 30%, 25(50Hz)/12(60Hz) cycles Dip 100%, 250(50Hz)/300(60Hz) cycles	

*Remark:

Criterion A: The function of equipment under test is not influenced or only deviates within a certain range during or after the test.

Criterion B: The function of equipment under test is influenced or even loses its function during test conduction. However, it will recover automatically after the test is over.

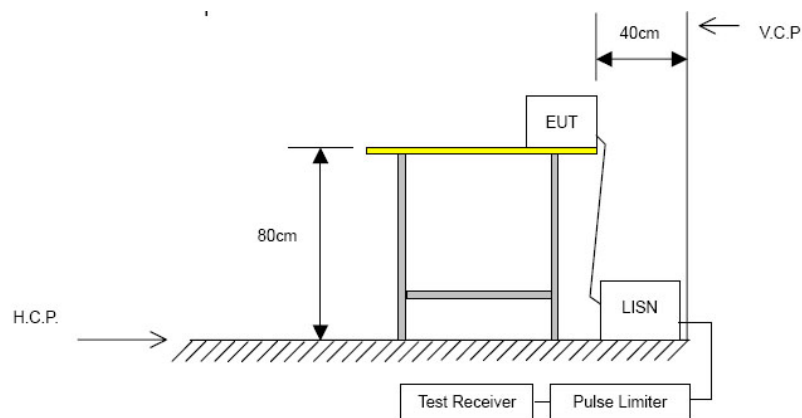
Criterion C: The equipment loses its function during test conduction or after testing. It can't recover automatically and need to be manually re-powered ON.

Criterion D: The equipment loses its function during or after the test and it can't recover even by manual re-power ON.

4.7 EMC Tests: Procedure And System Allocation

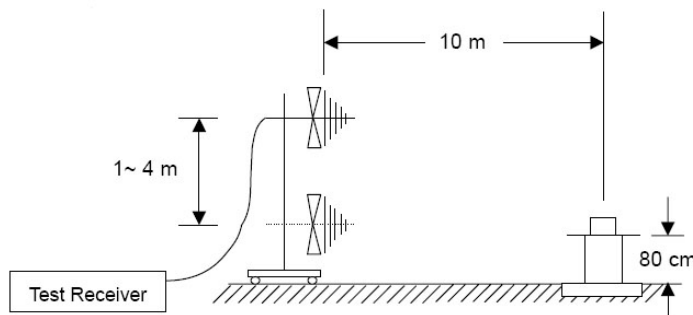
Refer to CISPR32, IEC61000-4 regulation, and Meanwell EMC reports for detailed information.

(1) Conduction Emission



1. If the power cord can not be shrunk to a suitable length, so that it is 40cm above the metal plane. The excess wires should be bundled to a length of 30~40cm.
2. Simulated resistive network should be attached to the ground plane before connection to the EUT.
3. Simulate connection to external environment through I/O cables.
4. Auxiliary devices should be placed 10cm apart.
5. Auxiliary and control equipment should be placed 10cm apart. The power cord should be 1m long with no shielding.

(2) Radiation Emission

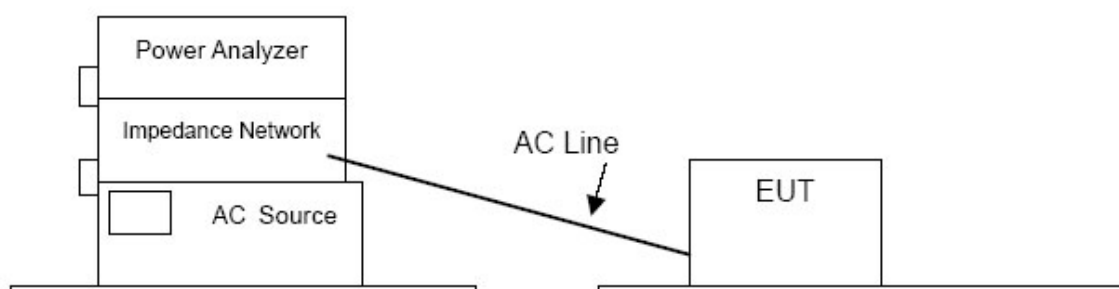


1. If the power cord can not be shrunk to a suitable length, so that it is 40cm above the metal plane. The excess wires should be bundled to a length of 30~40cm.
2. The power box should be installed on a metal plane and parallel to ground. The simulated resistive network should be placed under the horizontal metal plane.
3. The power cord should be laid flatly on the ground before connecting to the power outlet. Extension cord should not be used.

Test procedure

1. According to CE directive, EUT should be placed on a rotating table 10m from the antenna (power cord shall hang loosely from the longer side of the table). It will be rotated in 360 degrees to pick out angles with the strongest radiation. The antenna will also be raised between 1~4m to pick out the highest radiation.
2. Antenna must be adjusted for horizontal and vertical testing.
3. The test frequency is between 30~1000 MHz.

(3) Voltage Fluctuations and Flicker

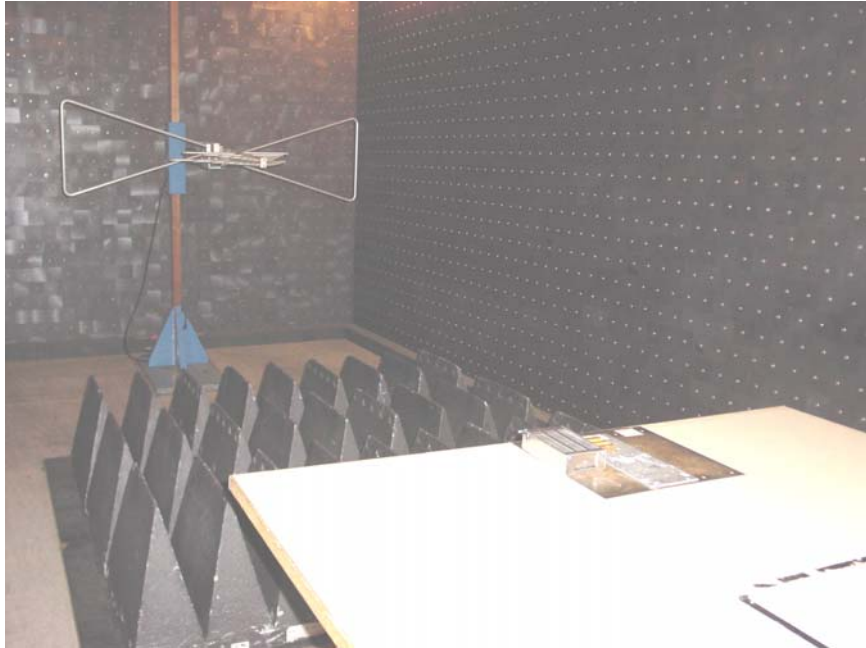


1. Set the output of Power Analyzer to 230V/50Hz
2. Testing periods are 1) Short time $T_p=10\text{min}$ and 2) Long time $T_p=2\text{hrs}$
3. Power Analyzer will collect all the measured data and reports the result.

(4) ESD (Electrostatic Discharge)**Test Procedure**

Apply ESD to EUT's conduction and coupling surface.

1. The EUT shall to subject to 200 contact discharge. 100 times each for negative and positive discharge.
2. Pick four test points.
3. Center of EUT and side of HCP should be subjected to contact discharge of 50 times.
4. Other 3 points should be tested 50 times each.
5. If there are no conductive surface to make contact discharge, test can be done on the coupling plane (HCP, VCP). 200 discharges also need to be done.
6. Air discharge will be performed at slots, apertures, and insulation surface.
 - 1)Points selected should be based on actual operating conditions.
 - 2)A minimum of 10 air discharges per test point.

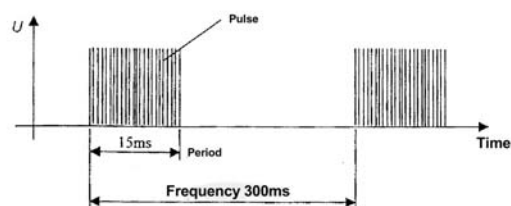
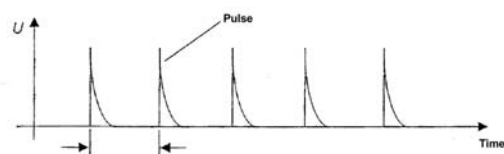
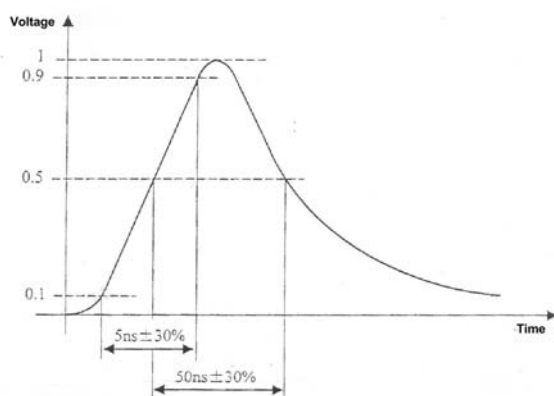
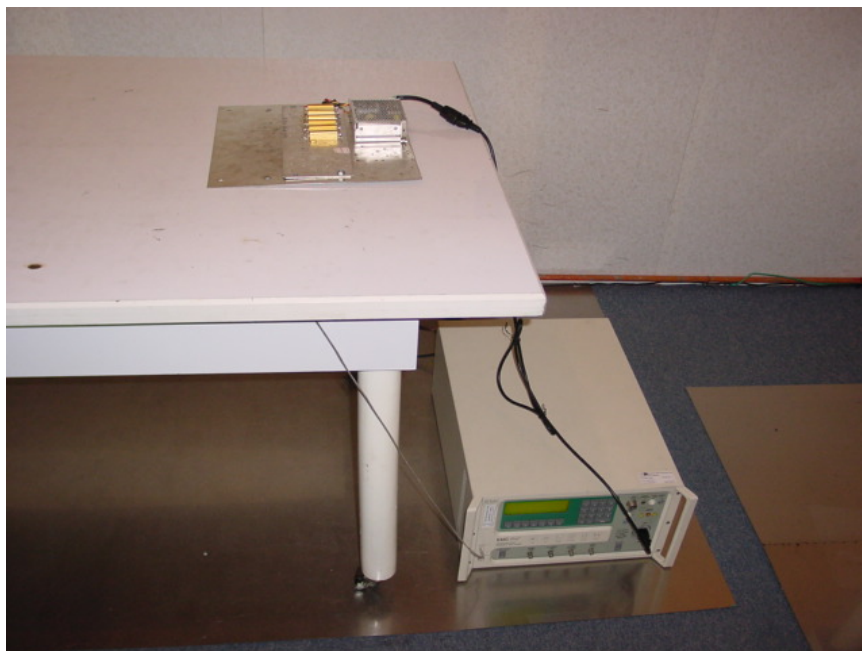
(5) RS (Radiated Susceptibility)**Setup**

1. Test shall be conducted in a special chamber lined with radiation absorbing plates.
2. Antenna is set at 1m above ground.
3. Antenna is placed at 3m from EUT.
4. EUT placed at 80cm above ground on a non-conducting surface.

Test procedure

1. A signal from the signal generator is sent through an amplifier to magnify it to the required level and then projected from the antenna. The EUT is subject to this radiated interference.
2. EUT is rotated either left or right to be tested on four faces.
3. The Antenna will be adjusted between horizontal and vertical directions.
4. The test frequency is between 80~1000MHz.

(6) EFT (Electrical Fast Transient)



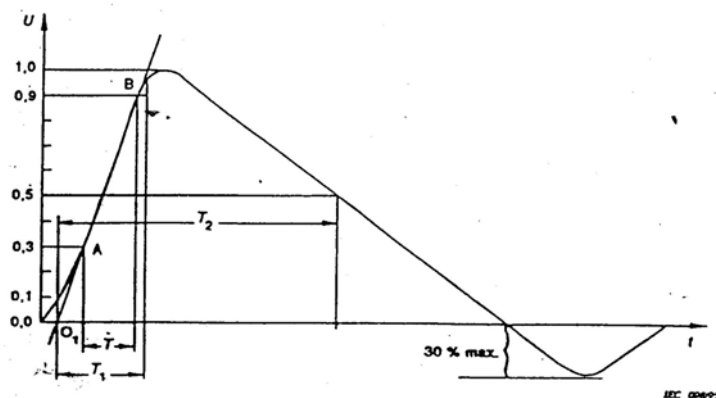
Setup

This test also needs to be executed on the reference ground plane and we only have to connect our sample to the equipment and select the test program.

Test procedure

The testing equipment will send out a 5 KHz continuous waveform for 15ms and we have to check whether it could cause a fault during power supply operation.

(7) Surge



Front time: $T_1 = 1,67 \times T = 1,2 \mu\text{s} \pm 30 \%$
 Time to half-value: $T_2 = 50 \mu\text{s} \pm 20 \%$.

Figure 2 – Waveform of open-circuit voltage (1,2/50 μs)
 (waveform definition according to IEC 60-1)

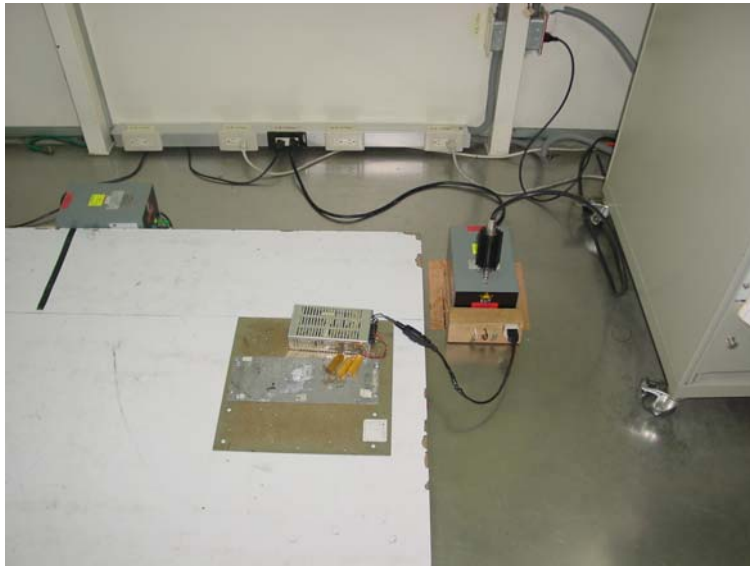
Setup

1. This test should be executed on the reference ground plane.
2. EUT should be place 80cm above ground on a non-conducting table.

Test procedure

1. The purpose of this test is to make sure that the power supply will not fail when a simulated surge is inserted through the AC source.
2. Connect AC source to the test sample and select the test program.

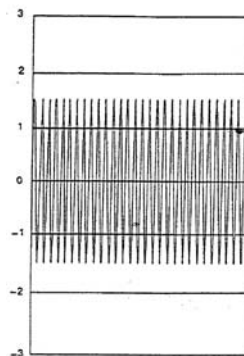
(8) CS (Conducted Susceptibility)



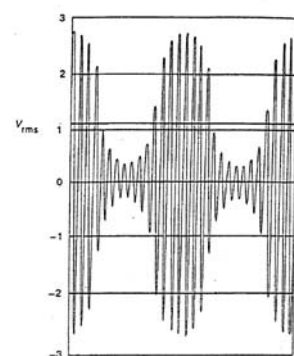
Test Level

Frerquency Range 150kHz ~ 80MHz		
Level	Voltage Level (e.m.f.)	
	U_o [dB(μ V)]	U_o [V]
1	120	1
2	130	3
3	140	10
x	Special	Special

x is an open level.



a) Not modulated
 $V_{pp} = 2.8V$
 $V_{rms} = 1.0V$



b) 80% AM modulated
 $V_{pp} = 5.1V$
 $V_{rms} = 1.12V$

Test signal send through AM modulator (1 kHz, 80%)

Setup

1. This test also should be executed on the reference ground plane and the power supply will be put on a non-conductive object which is 10cm away from the ground.
2. The power cord should be made a short as possible.

Test procedure

Signal generator will send out a signal to the power supply through CDN (Coupling Decoupling Network) and we have to check whether a fault condition occurs to the power supply.

(9) MF (Power-Frequency Magnetic Field)**Setup**

This test is executed on a reference ground plane and the power supply should be located 10cm above this plane.

Test procedure

1. Test equipment will send out a certain current flowing through the antenna surrounding the power supply. We have to check whether a fault condition occurs to the power supply due to the magnetic field induced by the current.
2. Place sample within the antenna and proceed with the test.
3. The antenna will be adjusted to the X, Y, and Z axis.

(10) DIP (Voltage Dip / Interruption)**Setup**

This test should be executed on a reference ground plane. We only have to connect the power supply to the test system and the pre-set program will automatically execute the test.

Test procedure

The purpose of this test is to change the power quality supplied to the sample unit and check whether it would fail under this interference.

1. Check influence of voltage dip/interruption on test sample.
2. Dip > 95% → 0.5 cycle (10ms)
Dip 30% → 25 cycles (500ms)
Interruption > 95% → 250 cycle (5000ms)

Chapter 5

Introduction To CE

5.1 Introduction to CE Marking

The European Union introduced the “CE mark” in an effort bring awareness to the need for health, safety, and environmental protection. Through CE marking, consumers will know which products are designed with their best interest in mind. Generally speaking, all products with safety concerns must have the CE mark in order to be exported to countries in the EU. Products bearing the CE mark can be traded freely in European member countries without being subjected to duplicate inspection process.

5.2 Related Directives of CE Marking

Presently, the European Union had put in effect around 20 directives in several different fields, such as low voltage, toy, industrial machinery, medical equipment, EMC, Restriction of Hazardous Substances Directive (RoHs) and Energy-related Products Directive (ErP)...etc.

- (1)Low Voltage Directive (LVD): L.V.D. was strictly enforced starting in 1997. It regulates electrical products within the voltage range of 50~1000 VAC / 75~1500 VDC. In terms of S.P.S., L.V.D. shares the same standards as other safety regulations. For instance, by meeting the ITE requirements of EN60950-1, you will also automatically fulfill LVD.
- (2)Electro-Magnetic Compatibility (EMC): EMC consists of EMI (Electro-Magnetic Interference) and EMS (Electro-Magnetic Susceptibility), it was strictly enforced starting in 1996. Products with transformers and electronic control circuits are all regulated by this directive.

(3)Restriction of Hazardous Substances Directive (RoHS) : RoHS took effect on 1 July 2006, and is required to be enforced and became a law in each member state of European union, in the purpose of restriction of the use of certain hazardous substances in electrical and electronic equipment. RoHS helps reduce damage to people and the environments in the developing countries where much of today's "high-tech waste" by eliminating the use of following ten substances, such as Lead (Pb), Mercury (Hg), Cadmium (Cd), Hexavalent chromium (Cr6+), Polybrominated biphenyls (PBB), Polybrominated diphenyl ether (PBDE), Bis(2-ethylhexyl) phthalate (DEHP), Butyl benzyl phthalate (BBP), Dibutyl phthalate (DBP), Diisobutyl phthalate (DIBP) where were added as part of DIRECTIVE (EU) 2015/863 which was published on 31 March 2015.

(4)Energy-related Products Directive (ErP) : In November 2009, the Eco-Design Directive EuP was replaced with the new energy-related products directive (ErP) 2009/125/EC. The old directive for energy using products only covered products that used energy, such as washing machines or computers. The new ErP-Directive covers products under the old EuP Directive as well as products that are energy-related and do not directly use energy such as water-saving taps and showerheads.

5.3 CE Compliance

The “CE Mark” is not issued by any particular regulatory agency. Manufacturers can declare conformity by fulfilling directives related to their field. For instance, the self declaration certificate of an electronics manufacturer will be composed of a list of directives that were satisfied. This is the only prerequisite for showing the CE mark. However, if a product was found non-confirming from random market inspection, the manufacturer may be asked to stop sales and recall previously sold units.

5.4 How Mean Well Test CE Related Regulations

For L.V.D., Mean Well products are certified by authorized third party/organization (such as UL, CSA, TUV, Nemko and Dekra). As for the EMC portion, an authorized laboratory will certify the product based on setup and test procedure specified by Mean Well. An EMC report will be provided by the lab showing which directives were met. Mean Well is ultimately responsible for issuing its own CE declaration of conformity.

SPS are components meant for powering complete systems. EMC performance is dependent on how the SPS is assembled in the system. It is recommended that the end user recheck EMC after installation. Majority of our customers use metal enclosures for their system. We try to simulate that type of setup by mounting both the power supply and load to a metal plate. If the enclosure of the system happens to be made out of plastic or the setup is significantly different from ours. There is a good chance that the EMC results will be completely different from what is found on our test report. Please refer to Figure 5.1 for EMC setup:

A conductive metal plate (galvanized steel) is used to simulated end user's enclosure. The standard dimension is 36 x 36 cm. A 23 x 23 cm plate may be used for low wattage units. As for high wattage units, a 72 x 32 cm plate may be used. The test setup will be mentioned clearly in the EMC Report.

EMC test method and setup:

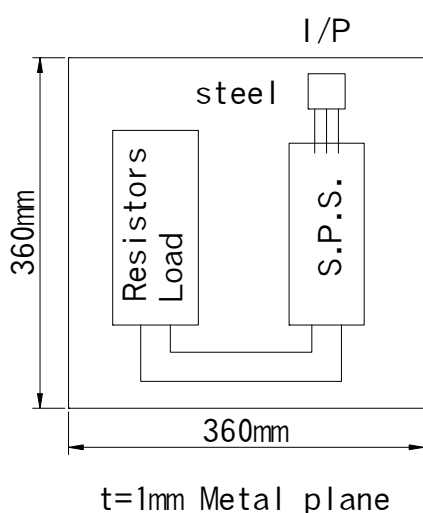


Figure 5.1: Standard setup for EMC test

The “CE marking” is a permit for products to enter the European market. Once our company signs the CE Declaration for a certain product, this means that the product meets the requirements of LVD and EMC directives.

Chapter 6 Reliability

6.1 Curve of Lifetime and Failure Rate

High reliability of switching power supply has been proved from its extensive use in household appliance and industrial equipment. The industrial sector holds SPS in high regards. Figure 6.1 is a typical curve of product lifetime and failure rate (Bath-Tub Curve).

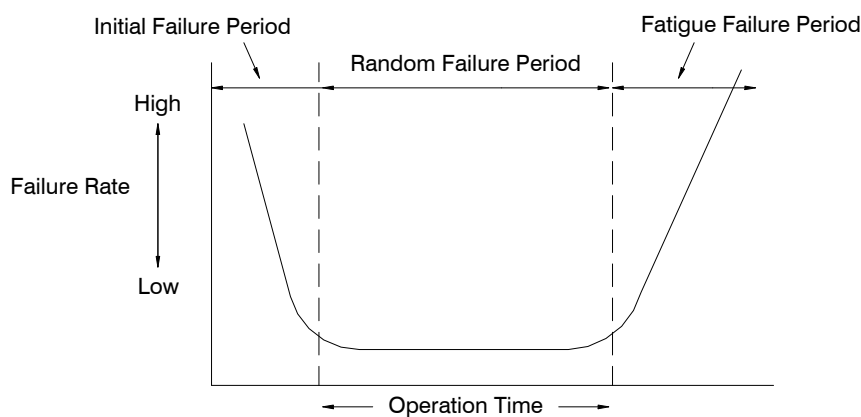


Figure 6.1: Bath-Tub Curve

(1) Initial Failure Period

To prevent “initial failure”, all manufacturers have sifted the defective components out by making burn-in tests. Normally when customers receive the S.P.S., it has already entered the “random failure period”.

(2) Random Failure Period

The stability of the S.P.S is related to its reliability (MTBF: Mean Time between Failure) and generally speaking, the failure rate is very low. But, the random failure rate has a lot to do with user's installation and operating conditions (ambient temperature, derating, ventilation, and vibration).

(3) Fatigue Failure Period

After the "random failure period", S.P.S is going to have higher failure rate and enters the "fatigue failure period". At this time most of the components have aged (such as fans, aluminum electrolytic capacitors) and hence induce failure.

6.2 Ambient Temperature and Components' Lifetime

- (1) High frequency and high efficiency switching technology, improvement of components, and integration with up to date technology can reduce the size of the S.P.S. But, components must also populate the PCB at higher density. The lifetime of components on a S.P.S. will vary significantly due to differences in ambient temperature. When an electrolytic capacitor is used for filtering, its internal chemical reaction will raise the surface temperature. Lifetime of the electrolytic capacitors is sensitive to ambient temperature.
- (2) In general, the lifetime of the electrolytic capacitors will be reduced by half for every 10°C increase in the ambient temperature. On the contrary, when temperature goes down 10°C, it's life time will be doubled. Figure 6.2 describes the relationship between lifetime of the power supply and ambient temperature. If the S.P.S. is continuously operated in high temperature environment, the electrolytic capacitors will enter the "fatigue failure period" earlier while in the mean time the other components are still at the "random failure period". To extend the lifetime of this S.P.S., we need to replace all the electrolytic capacitors.

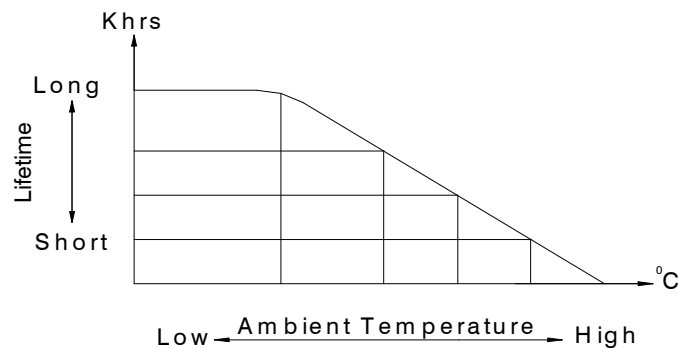


Figure 6.2: Lifetime of the power supply versus ambient temperature

(3) Estimation of Electrolytic Capacitor's Lifetime (Based on output capacitors).

1. The equation is provided by Rubycon

$$L = L_0 \times 2^{\left(\frac{T_{\max} - T_a}{10}\right)} \times 2^{\left(C - \frac{\Delta T_j}{10 - 0.25 \times \Delta T_j}\right)}$$

L : expected lifetime of the electrolytic capacitor.

L₀ : lifetime of the electrolytic capacitor working at maximum temperature and maximum ripple current.

T_{max} : accepted maximum ambient temperature of the electrolytic capacitor.

T_a : surrounding temperature of the electrolytic capacitor (through easurement).

C : Constant

$$\Delta T_j = \Delta T_{j0} \cdot \left(\frac{I_n}{I_m}\right)^2$$

I_m : Rated ripple current

I_n : Actual ripple current

F : Frequency coefficient

ΔT_{j0} : Internal temperature rise when maximum rated ripple current is applied

(4) In models with built-in fan, the lifetime of the fan is also related to operating temperature. Higher the ambient temperature leads to shorter lifetime. After a certain period of time, the fan should be cleaned or replaced because its bearing may wear out or dust may stick to the blades.

6.3 Ambient Temperature and Frequency of Return for Repair

Electronic technology has been developing at an astounding rate leading to more S.P.S. being used in all types of system. Although the lifetime of S.P.S. is pretty high, it will not last forever. So, regular maintenance is very important to guarantee the S.P.S.'s reliability. How often maintenance should be done depends on the operating condition and temperature. The operating temperature will affect the frequency of return for repair, which is shown as below:

Ambient Temperature	40°C ~ 45°C	Once per three years
Ambient Temperature	35°C ~ 40°C	Once per four years
Ambient Temperature	30°C ~ 35°C	Once per five years

The data above will vary depending on component grade used for the S.P.S.

Please contact your local supplier for more information about the maintenance and repair services.

6.4 Load Capacity and Ambient Temperature

Internal temperature of the S.P.S. will vary depending on output load condition and efficiency. Reducing the output load will decrease the internal temperature and extend the S.P.S.'s lifetime.

(1) Ambient Test Condition

- (a) Size of test chamber (internal volume): 45x45x50cm (WxDxH)
- (b) T_A : Internal temperature of ambient tester (simulate S.P.S.'s external temperature)
- (c) T_{A1} : The maximum internal temperature of the S.P.S. (simulate S.P.S.'s internal temperature)
- (d) T_{PC} : The highest temperature on the case of the S.P.S.
- (e) T_{CAP} : The maximum temperature on the electrolytic capacitor of the S.P.S.

Thermal coupler is installed at left or right and 15cm above the testing unit

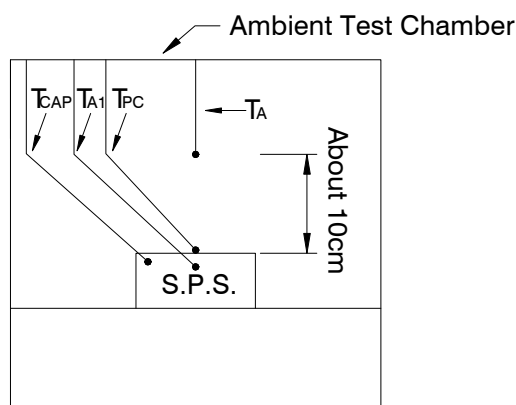


Figure 6.3: Set up diagram in the chamber



Figure 6.4 Picture of ambient tester (chamber)

(2) Free Air Convection Models (SP-100-24)

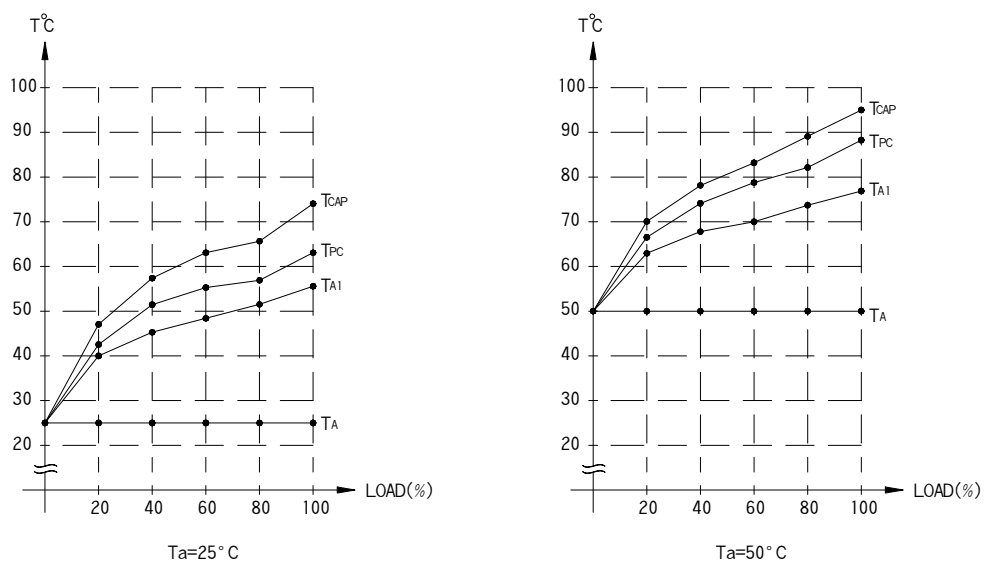


Figure 6.5: Relationship between load and temperature for free air convection models

(3) Forced Airflow Models (SP-200-24)

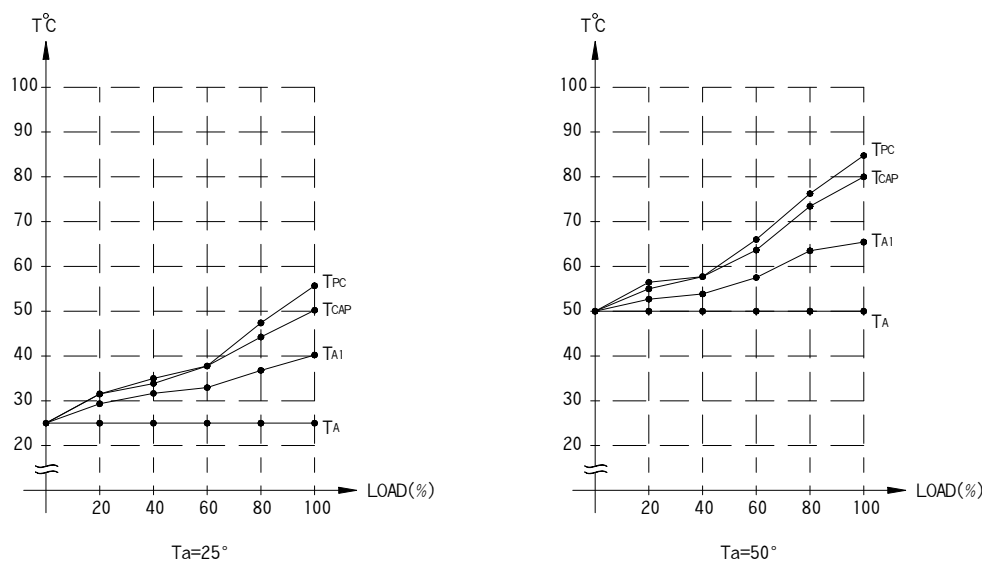


Figure 6.6: Relationship between load and temperature for forced airflow models

6.5 Reliability and Operating Environment

The operating environment of the S.P.S. will affect its reliability.

(1) Vapor, Moisture

If the S.P.S. is used in vaporous or moisture rich environment, there's the possibility that the S.P.S. may become out of order after a certain period of operation. Therefore don't use the S.P.S. in moisture rich environment. If it is necessary, please contact the supplier for more information about special treatment against the moisture.

(2) Dust

If the S.P.S. is used in a dusty environment, the dust may collect on the fan and PCB causing circuit failure because of decay in the insulation. Protective measure should be taken to reduce dust settlement (e.g. dust filter).

(3) Vibration and Impact

If the S.P.S. is used in a vibrating environment or subjected to impact, the power supply may become out of order.

(4) Electromagnetic Field

If S.P.S is used in an environment with high electrical field, magnetic field, or strong electromagnetic wave, the power supply may become out of order.

6.6 MTBF (Mean Time Between Failure)

Mean Time between Failure is the expected value for reliability prediction. Estimating the reliability of the products under development or in mass production can help decide whether customers' needs are satisfied.

MTBF is the mean operating time until the reliability of the product goes down to 36.8%. For instance, if the product's MTBF is 20,000 hours, it doesn't mean that this product can be used for 20,000 hours, but rather that after being used for 20,000 hours, the probability for proper operation is 36.8% ($e^{-1}=0.368$).

If it have been used for 2000 hours, the reliability at that moment is $e^{-\frac{1}{10}}=0.905$

If it have been used for 200 hours, the reliability at that moment is $e^{-\frac{1}{100}}=0.999$

$$MTBF = \frac{1}{\lambda}$$

$$R(t) = e^{-\lambda t}$$

R(t):Reliability
 λ :Failure Rate
 t: Working time
 e: 2.718

MTBF can be calculated by two different methods, which are "Part count" and "Stress Analysis". The regulations, MIL-HDBK-217F Notice 2(Stress Analysis) and TELCORDIA SR/TR-332(Bell Code) are commonly used to calculate MTBF. MIL-HDBK-217F is a United States military standard, and TELCORDIA SR/TR-332(Bell Code) is a commercial regulation. Currently, Meanwell adapts MIL-HDBK-217F Notice 2 as the main calculation model.

(1) Parts Count Method

Use MIL-HDBK-217F to get the failure rate for all components in the product and combining all the failure rates to get the reliability value.

(2) Stress Analysis Method

Operating a product at normal condition and within rated specification, a list of components' stress data can be gathered. Using the stress data in conjunction with the MIL-HDBK-217F standard, we can estimate reliability by the stress analysis method.

6.7 Reliability test procedure for MW product

Based on previous experiences, 70% of failures can be eliminated during the developing phase. Therefore, MW pays significant attention to any quality issues that may arise during development and production.

(1) D.R. (Design Review): executed by RD management

- (a) Circuit/ architecture: reviewing the stability of the applied technology and circuits. Furthermore, compare with similar circuit from other MW products.
- (b) New part selection and approval: review and verify the quality and specification of the selected new component. And also justifies the ability of the vendor to continuously supply the particular part in long term.
- (c) Cost Analysis: control the manufacturing cost of developing products to meet the marketing target
- (d) Ability to manufacture: review and adapt new equipment or manufacturing process in order to produce the new products.

(2) D.V.T. (Design Verification Test): executed by RD design verification department

- (a) ATE (Automatic Testing Equipment): Different testing procedures will be implemented to different products. such as voltage tolerance, ripple & noise etc...
- (b) Safety/EMC: base on the different safety requirement of the developing product, safety engineer will verify the design, and submit to safety agency for approval.
- (c) Component stress test: verify the electrical stresses on critical components. Those components have to be able to withstand the stresses during different operating conditions.

(3) D.Q.T. (Design Qualification Test): executed by QA department

- (a) Design Review:
 - ① verifies electrical functions in worst case operation.
 - ② BD/ high voltage resistor/ FAN quality/ life cycle of V_{cc} capacitor...
review the selection of these components.
- (b) Environmental and Accelerated Life in combination with different conditions of temperature/ humidity/ output load/ AC input, to verify the reliability and functionally of the product when operating in different environments.

- (c) Package-delivering Simulation: review the mechanical structure and material of the products by shaking and dropping the power supply as an individual unit or a set (carton).



Vibration testing conditions:

- (1)Waveform : Sine Wave
- (2)Frequency : 10 Hz ~ 500 Hz
- (3)Sweep Time : 10 min/sweep cycle
- (4)Acceleration : 2G ~ 5G
- (5)Orientation: X.Y.Z
- (6)Test Time: 1 hour in each axis
- (7)Sample Condition : Single unit /1 Carton
(Packed)



Drop Test:

Package Weight	Height
<21 lbs(<10kg)	29.9in (76cm)
21~41 lbs(10~19kg)	24in (61cm)
41~61 lbs(19~28kg)	18.1in (46cm)
61~100 lbs(28~45kg)	12.2in (31cm)

6.8 Salt Spray Test

6.8.1 Definition : Verify the structure and endurance of the internal components of the product according to the requirements of the US military standard specification MIL-STD-810

Capability of salt spray test environment

Content	Standard: MIL-STD-810G
PH of salt water solution	6.5~7.2
Chamber temperature	35±2℃
Falls-out rate	1~2ml/h/80cm ²
Concentration	5% Sodium chloride solution
Spray method	Continuous indirect spray

Test duration	Salt fog 24hr and ambient air drying 24hr, in total of 2 cycles. Ambient air drying condition: humidity <50% RH
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6.8.2 Spot test

Model	Stage	Quantity	Test condition	Warranty	Test Duration
Product with FAN	Trial run	1 pcs	Fan off test	≤ 3 years	Salt fog 24hr ; ambient air drying 24hr*2 cycles
				> 3 years	Salt fog 24hr ; ambient air drying 24hr*3 cycles
Product without FAN	Modification for conformal-coating	1 pcs	Fan on test	≤ 3 years	Salt fog 24hr ; ambient air drying 24hr*2 cycles (or define by customer)
				>3 years	Salt fog 24hr ; ambient air drying 24hr*3 cycles (or define by customer)

6.8.3 Testing procedures

(1) Testing condition:

- a. Standard models are stored and test under static state ◦
- b. For modification models, agreement of definition for testing procedures with customer is necessary before testing. Products are stored and test under static state ; FAN should be activated during the test by external power source.

(2) Testing requirement:

- a. Photo of Case and PCB from testing object should be taken before testing.
- b. Photo and functional check is need in between every cycle.

6.8.4 Explanation :

Assessment criterion:

a. Standard model:

- PASS : Product should function normally. Pictures of testing result should be recorded.
- Fail : NP or FAN fail. Pictures of testing result should be recorded. ◦

b. Modification for conformal-coating: (can be defined by customer)

- PASS : Product should function normally. Pictures of testing result should be recorded.
- FAIL : NP or FAN fail. Pictures of testing result should be recorded.

Chapter 7

Notes On Operation

7.1 Input Fuse

Each S.P.S. has a built-in fuse for protection. Once the fuse is blown, it means that something is wrong inside the power supply. If the power supply can not operate properly after replacing with a fuse of the same type and rating, please send back to the supplier for repair. If you want to add an external fuse, be sure that the rating of this fuse should be less than or equal to the internal fuse.

7.2 Safety

Inside the S.P.S., there is a dangerous high working voltage on the circuit. Therefore don't touch the components when the unit is powered ON or you may get shocked and endanger your life. When the S.P.S. is abnormal, please send it back to the supplier. **"Please Don't Try To Fix It By Yourself."**

7.3 Grounding

Use short and thick wiring when connecting the frame ground (FG) of the S.P.S. to earth ground on the case of the equipment to assure safety and prevent noise and leakage current.

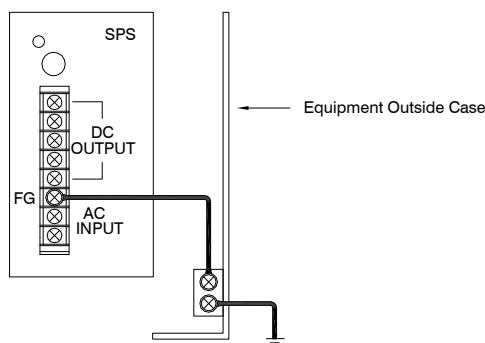


Figure 7.1: Proper way of grounding

7.4 Input and Output Wiring

- (1) Input and output should be wired in opposite directions to prevent input surge and output ripple noise from interfering with each other.
- (2) Output wiring should be short, thick, and meet the output current rating. Also, adding a small capacitor at the load can effectively reduce the noise. (Please refer to section 2.8)
- (3) Suitable terminal screws, wires, and tools should be used when connecting to the terminal block.
- (4) The FG (Frame Ground) of the AC input is different from the ground (-V / COM) of the DC output. There may be some isolation capacitors between them or it may be shorted together sometimes.

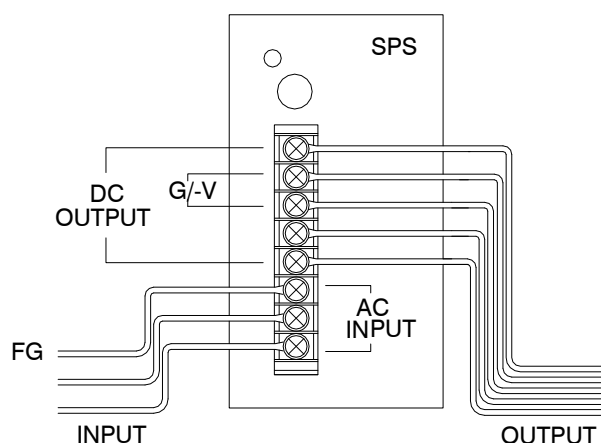


Figure 7.2 Wiring and connection

7.5 Heat Dissipation

The cooling methods of MEAN WELL products can be divided into the following types:

1. Free air cooling: The heat is dissipated by free air convection.
2. Forced air cooling: Uses fan to dissipate the heat.
3. Conduction cooling: Install the PSU on an aluminum plate with specified size, and dissipate heat through aluminum plate.
4. Water-cooling: Install the PSU on a water-cooling plate and conduct the heat to the water-cooling plate to dissipate heat. This water-cooled plate must be used together with a water-cooled PSU.

When installing the entire system, pay attention to the following requirements:

- (1) Each power supply should be installed in places with proper ventilation. (Example: installed in places with good ventilation, or inside enclosures with ventilation opening at the top)
- (2) Correct installation direction and location. (Example: ventilation holes face upward)
- (3) Each power supply should have proper heat sink. (Example: if the S.P.S. uses case as its heat sink, be sure to connect the case tightly and flush to the system's metal surface)
- (4) When more than one power supply is operated at the same time, be sure that there is enough space between each power supply. (Keep 5~15cm of space depending on the magnitude of the output power.)
- (5) Using forced airflow can effectively improve heat dispersion. (Example: add a fan and deploy it at the bottom of the system if using inhaling airflow. In contrast, deploy it at the top of the system if using exhaling airflow.)

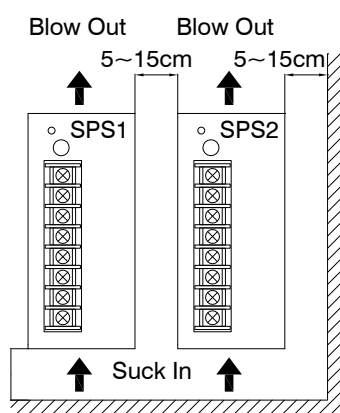


Figure 7.3: More than one power supply working at the same time, space for airflow should be taken into consideration

7.6 Output Derating (Please refer to the spec. of each machine)

- (1) Output Power to Temperature: We need to reduce the output power depending on the operating temperature and the direction that the S.P.S. is allocated.

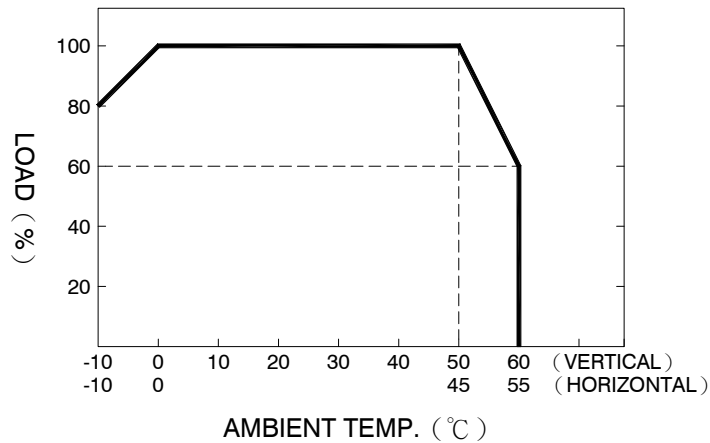


Figure 7.4 Relationship between output power and temperature (derating curve)

Example: If the S.P.S. is vertically installed, output power can be 100% between 0 ~50°C, and between 50 ~60°C the output power should be derated. At 60°C we need to reduce the output power to 60% of load. Above 60°C, we can not guarantee proper operation and lifetime of the unit.

- (2) Output Power to Input Voltage

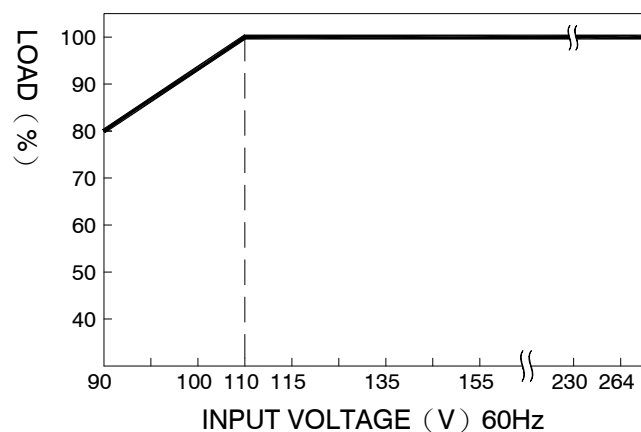


Figure 7.5 Relationship between output power and input voltage

When the input voltage is low, S.P.S. will have higher power loss because of the PFC circuit, therefore we need to reduce the output power. Refer to figure 7.5, between 110V ~ 264V the S.P.S. can output full load, but between 90V~110V we need to reduce the output power. At 90V, the output power will be derated to 80% of full load.

(3) Application in high altitude region

Generally, derating curve in the specification is a parameter below 2000m above sea level. When the altitude exceeds 2000m, the thin air will affect the cooling efficiency, so the ambient temperature must be reduced. For models with a fan, the operating ambient temperature should drop by 5 ° C for every 1000m increased altitude. For models without a fan, the operating ambient temperature should decrease by 3 ° C for every 1000m of increased altitude.

7.7 Remote ON/OFF Switch and Remote Sensing Wiring

- (1) Remote ON/OFF Switch: Using a TTL control signal connected to the +RC, -RC terminals of the S.P.S., we can control the output of the power supply. When +RC and -RC is short (0V), the S.P.S. will be ON; when it is open (the voltage between the two terminals > 4V), the S.P.S. is turned OFF. However, some models use different control logic.
- (2) Remote Sensing: We can compensate output line voltage drop by connecting +S and -S terminals to the load, but wires with enough diameter should still be used. In general this function can compensate for a voltage drop up to 0.3 ~ 0.5V. (About wire voltage drop/current, please refer to the appendix.)

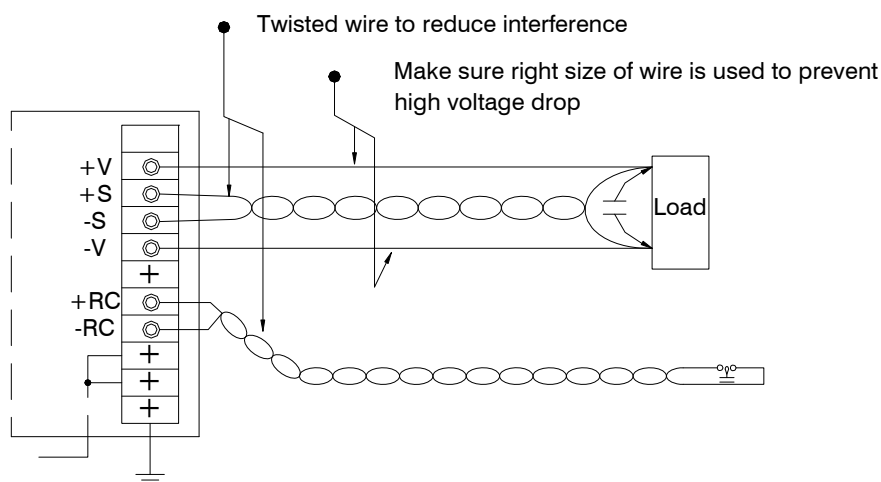


Figure 7.6 Remote ON/OFF and sensing wiring

7.8 Operation in Parallel

When power supplies are connected in parallel, we can increase the output current or use them for the redundant (back-up) function. Be sure that the tolerance of output voltage and wiring impedance are very small when connecting in parallel.

(1) S.P.S. With Built-in Parallel Function: Connecting “P” terminals together such as the PSP models (“G” terminal also need to be connected together). Input/output should be connected in parallel first and then connect to the AC source/load just as figure 7.7 (some S.P.S. need a minimum load after paralleling).

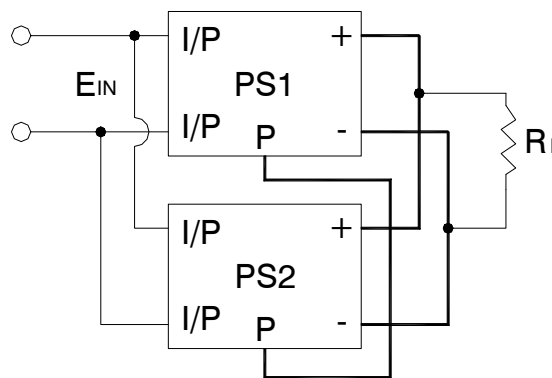


Figure 7.7: Wiring of S.P.S. with built-in parallel function

Notes on parallel operation:

1. Output voltage tolerance should be as small as possible (tolerance < 2%).
2. The power supplies should be paralleled using short and large diameter wiring and then connected to the load.
3. After paralleling, the available output power would be around 90% of the total power.
4. When power supplies are paralleled, if the total load is lower than 10% load of the individual unit, the indicator light and signal function (Power Good \ Pok \ Alarm Signal) may malfunction.
5. To make sure that the load current is effectively shared in parallel operation, in general we limit 4-6 power supplies to be paralleled at one time.
6. In some models, we also need to parallel the +S, -S terminals of the control connector to reduce unstable pulsation of output voltage.

(2) S.P.S. Without Built-in Parallel function (general models)

Add a diode at the positive-output of each power supply (as figure 7.8), the current rating of the diode should be larger than the maximum output current rating and attached to a suitable heat sink. This is only for redundant use (increase the reliability of the system) and users have to check suitability of the circuit by themselves.

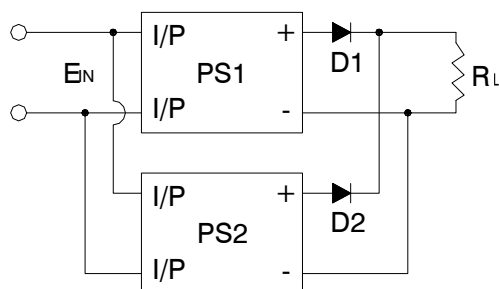


Figure 7.8: Paralleling by adding diodes in series connection

When using S.P.S. in parallel connection, the leakage current will increase at the same time. This could pose as a shock hazard for the user. Please contact the supplier if you have this kind of application.

7.9 Operation in Series

Power supplies can be operated in series. Here are the methods of doing it:

(1) Positive and negative terminals are connected as figure 7.10:

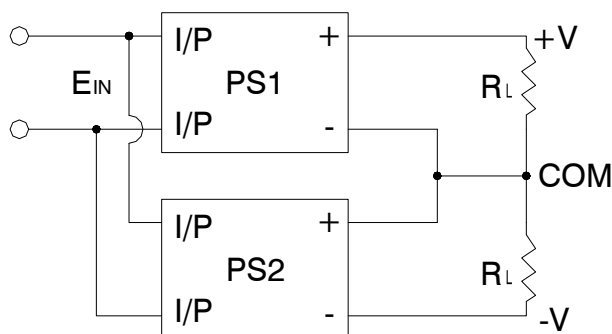


Figure 7.9: Positive and negative terminals connect in series

- (2) Increase the output voltage (current does not change). If there is no reverse blocking diode in the power supply, we should add an external blocking diode to prevent the damage of power supply while starting up. The voltage rating of the external diode should be larger than $V_1 + V_2$, and the rating of peak current should be greater than PSU rated output current. (shown in figure 7.10).

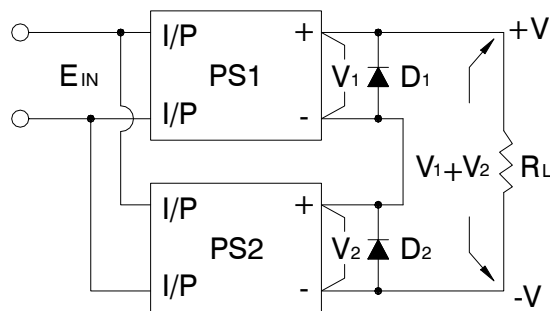


Figure 7.10: Series connection by adding external reverse blocking diodes

7.10 Output Wiring for Smaller Loads

When using one S.P.S. to power two different loads, a fuse should be added to the wiring of the smaller load for protection. If a short-circuit condition occur, this fuse can protect the wiring from being burned out.

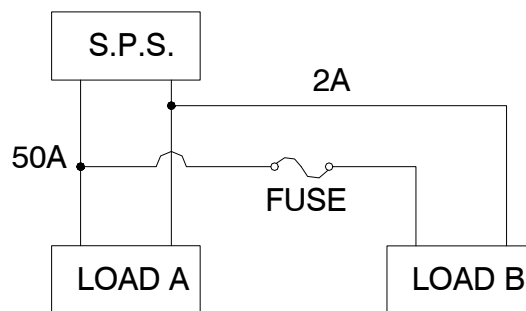


Figure 7.11 Output wiring

7.11 Minimum Load Requirement

To assure the regulation and stability of auxiliary outputs (CH2~CH4) on a multi-output S.P.S., we need to add a minimum load on the main channel (CH1). For example: Spec. of RD-120B is 5V/4.6A, 24V/4.6A. When the output is 5V/0A, 24V/4.6A, the 24V output voltage will be lower than the spec. In this situation, if we add a minimum load of 2A (by paralleling a 2.5Ω/30W resistor) at the 5V channel, then the output voltage of the 24V channel would increase to the tolerance range of the spec. Users also need to add a minimum load at the 24V channel to keep the output voltage within the spec. if only the 5V channel is used during certain modes of operation.

7.12 Operation in Low Temperature

If the S.P.S. uses a thermistor to suppress the inrush current; it could cause a failure to start up at low temperature (such as -10°C) due to temperature sensitivity. Following are some methods to solve this problem:

- (1) Keep the power supply at standby status (Keep AC source ON and then switch the output ON/OFF).
- (2) Use heater to increase the ambient temperature of S.P.S.
- (3) Reduce output load.

If the working temperature on the spec is $-10^{\circ}\text{C} \sim 50^{\circ}\text{C}$ and we want to operate it at -20°C , we should pay attention to the following issues:

- (1) Relative humidity should be low to prevent ice formation.
- (2) The output ripple will be larger.
- (3) Since we usually use the thermistor as the inrush current suppresser and the thermistor will increase its resistance when the temperature goes down. It is possible that the power supply may take a long time to start up or there could be failure to power up.
- (4) We can not guarantee the extent of reduction in functionality when the S.P.S. is working out of the specification range.

7.13 Working in High Temperature or In a Environment with extreme Temperature Difference

There are high voltage and high impedance circuits in the S.P.S. So before turning on the power supply, be sure that there is no water condensation in the unit. If the S.P.S. is working at low temperature and then stored at high temperature or outdoor environment with high moisture and temperature differences between day and night, water may condense in the power supply and damage it. If necessary, please contact the supplier about providing anti-moisture treatment.

7.14 Special Load

(1) Capacitive Load

If the S.P.S is connected to a large capacitive load such as large capacitors or lighting device, the set up time of the S.P.S. will increase or may even prevent the S.P.S. from starting up. Users should use power supplies with the constant current limiting function or ask the supplier for assistance.

(2) Inductive Load

If the S.P.S. is connected in parallel with coil loads, such as motors, solenoid valves etc., there will be a huge peak current or a reverse voltage when the load is activated. It is recommended to use suitable capacitors and add a blocking diode to protect the S.P.S. We also can use S.P.S. with the constant current limiting function to deal with it.

(3) Dynamic Load

If the S.P.S. is connected to a dynamic load such as LED monitor, the output current will change abruptly and cause high ripple current and audio noises. We can add suitable capacitors at the load end to improve these problems (but be careful about delay problem while turning ON).

7.15 Charger Operation (To assure charging efficiency and lifetime, please use models with charging function.)

When the S.P.S. is used as a charger, be sure to add a series blocking diode at the output terminal (with suitable heat sink). This arrangement is to prevent reverse voltage from the battery which may damage the SPS. Inappropriate operation can easily damage the S.P.S. or batteries, please contact the supplier if you have any questions about this type of application.

7.16 Inrush Current Suppressing Circuit

When using many S.P.S. at the same time, the huge inrush current may exceed the rating of external wiring. The following delay circuit can suppress the inrush current caused by multi-S.P.S. operation. Alternatively, ICL series can also be used.

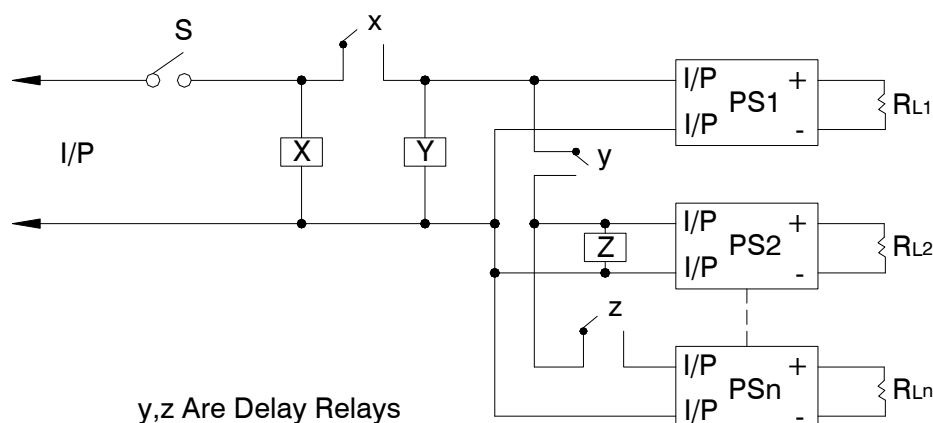


Figure 7.12: Delay circuit

7.17 Input Surge and Shock Suppression

- (1) Input Surge: The ON/OFF of heavy industrial machine will cause variance of nearby power line voltage. Sometimes the variance is so large that specification of the S.P.S. is exceeded and in turn may damage it, so there is a “surge absorber” between AC/L and AC/N in the S.P.S. to absorb this abrupt high voltage.
- (2) Shock Suppression: Lightning shock is a type of short-term high voltage and high energy pulse. To prevent damage from shock, we should add surge absorbers between AC/L - AC/N, AC/L - FG, and AC/N - FG, which are shown in figure 7.14.

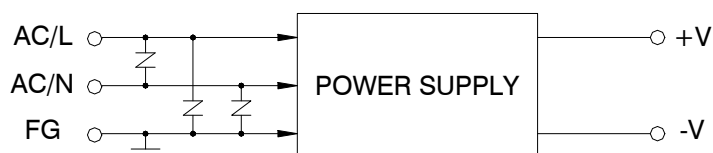


Figure 7.13: The connection of the Surge Absorber

7.18 Output Ripple Noise Suppression

- (1) Differential-Mode Noise Suppression

As in figure 7.14, adding C1~C4 can reduce this form of noise. C1 and C3 are electrolytic capacitors (reference value: 47 μ F~100 μ F), while C2 and C4 are high frequency capacitors (reference value: 0.01 μ F~0.1 μ F). In general, adding C3 and C4 is good enough to reduce this noise.

- (2) Common-Mode Noise Suppression

As in figure 7.14, adding L1, C5, and C6 can reduce the common mode noise. C5 and C6 are high frequency capacitors.

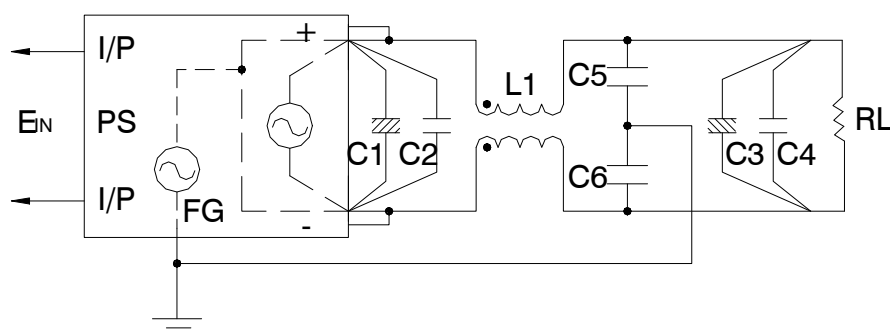


Figure 7.14: Ripple noise suppression

7.19 Trimming Output Voltage via External Resistor or Voltage

Some models can reach a desired output voltage by trimming through an external resistor or external voltage (Example: 1~5VDC).

(1) Trimming Output Voltage through External Resistor

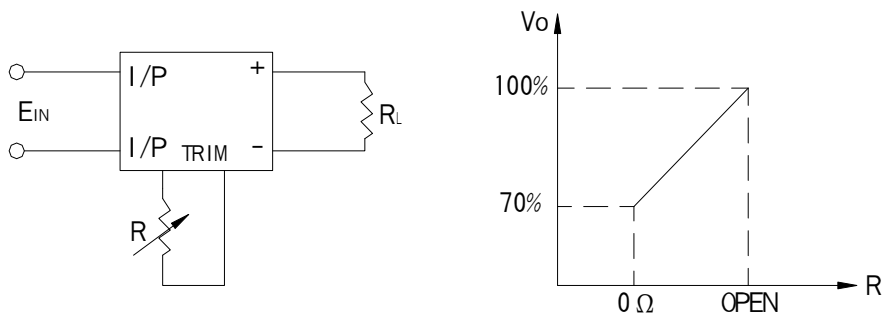


Figure 7.15: The diagram for using external resistor

Figure 7.16: Dependence of output voltage on value of external resistor

(2) Trimming Output Voltage through External Voltage

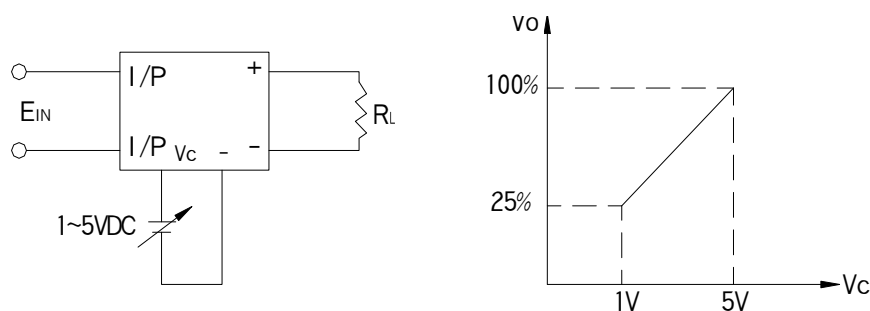


Figure 7.17: The diagram for using external voltage

Figure 7.18: Dependence of output voltage on value of external voltage

Notes:

1. The range of trimming voltage through external resistor or voltage control varies from model to model. Please refer to the specification before using it.
2. If you are not going to use the trim function (via voltage control), please connect its pins in short circuit. Otherwise, the power supply may malfunction. For more details, please consult the specification.

Chapter 8

Technical Support Q & A

This chapter consists of some of the most frequently asked questions. Due to limited number of pages available, further updates will only be done on the Mean Well website (www.meanwell.com). Please look to the FAQ section on the MW site for future updates.

8.1 Notes on choosing a switching power supply?

Ans: (1) To increase the reliability of the S.P.S., we suggest users choose a unit that has a rating of 30% more power than actual need. For example, if the system needs a 100W source, we suggest that users choose a S.P.S. with 130W of output power or more. By doing this, you can effectively boost the reliability of the S.P.S. in your system.

(2) We also need to consider about ambient temperature of the S.P.S. and whether there is additional device for dissipating the heat. If the S.P.S. is working in a high temperature environment, we need to make some derating to the output power. The derating curve of “ambient temperature” versus “output power” can be found on our spec sheets.

(3) Choosing functions based on your application:

A. Protection function: Over Voltage Protection (OVP), Over Temperature Protection (OVP), Over Load Protection (OLP), and etc.

B. Application function: Signaling Function (Power Good, Power Fail), Remote Control, Remote Sensing, and etc.

C. Special function: Power Factor Correction (PFC), Uninterruptible Power Supply (UPS) function.

(4) Make sure that the model qualifies for the safety standards and EMC regulations you need.

8.2 How do we choose a power supply to charge a battery?

Ans: MEAN WELL has ENC, HEP-600C, GC, PA, PB, RPB and RCB series for battery charger purpose (30~1600W). If these series does not meet customers' demands and they like to choose a power supply as a charger, we advice to pick up one which over load protection (OLP) mode is constant current limiting. The models in this mode provide constant current even when the protection circuit is triggered. In this model, when a battery is running low, the output current of the power supply will gently increase. The level of increase depends on battery's capacity and degree of exhaustion.

Hiccup or shut down model are not recommended because it will stop to generate current when OLP happens. The current can continuously provide to battery if the protection type is constant current limit. But this condition consider as over load usage, the OLP threshold need to be adjusted. Please contact MEAN WELL if any request.

8.3 Can MEAN WELL's power supply be used in the range of 45Hz ~ 440Hz? If YES, what will happen?

Ans: MEAN WELL's power supply can be used within this frequency range. But if the frequency is too low; the efficiency will also be lower. For example, when a SP-200-24 is operated under 230VAC and rated load, if the frequency of AC input is 60 Hz, the efficiency is around 84%; however, if the frequency of AC input reduces to 50 Hz, the efficiency will be around 83.8%. If the frequency is too high, the power factor of the S.P.S. with PFC (power factor correction) function will reduce and this also will cause higher leakage current. For example, when a SP-200-24 is operated under 230VAC and rated load, if the frequency of AC input is 60 Hz, the power factor is 0.93 and the leakage current is around 0.7mA; however, if the frequency of AC input increase to 440 Hz, the power factor will decrease to 0.75 and the leakage current will rise to around 4.3mA.

8.4 If we need a 24V output power supply, but MEANWELL does not have this model, can we use two 12V power supplies connecting in series instead of one 24V power supply?

Ans: YES, basically you can do this to get the right output voltage, but be careful that the rated output current of the series system should be the rating of the minimum one in these series connected power supplies. Furthermore, we like you to parallel a diode at the output of power supply to prevent possible damage of internal capacitors.

8.5 If we need a 1000W output, can we use two units of RSP-500 connected in parallel?

Ans: No, you can not do this connection because RSP-500 is not equipped with the parallel function. When two power supplies are connected in parallel, the one with higher output voltage will share more loading and deliver more (even “all”) power to the load and cause these two power supplies to be unbalanced. We suggest using PSP-600 because it is equipped with the current sharing function.

8.6 What is minimum load requirement and how can I read it from the spec?

Ans: There are some minimum-load requirements on MEAN WELL's multi-output power supplies. Please read the specification first before connecting to the load. In order to allow the power supply to work properly, a minimum load for each output is required, or else, the output voltage level will be unstable or outer tolerance range. Please refer to “Current range” in the specification as shown in the table below: Channel 1 requires a 2A minimum-load; channel 2 requires 0.5A; Channel 3 requires 0.1A; Channel 4 does not need any minimum-load.

OUTPUT NUMBER	CH1	CH2	CH3	CH4
DC VOLTAGE	5V	12V	-5V	-12V
RATED CURRENT	11A	4.5A	1A	0.5A
CURRENT RANGE	2~12A	0.5~4.5A	0.1~1A	0~1A

8.7 Why I can not turn on the power supply smoothly when the loads are motors, light bulbs or capacitive loads?

Ans: If you connect the S.P.S. to motors, light bulbs, or high capacitive loads, you will have a high output surge current when you turn on the S.P.S. and this high surge current will cause failure of start up. We suggest using S.P.S. with constant current limiting protection to deal with these loads.

8.8 Why did the power supply shuts down during operation and after turning it off, I can restart the power supply again?

Ans: In general there are two circumstances that will cause the power supply to shut down. The first one is the activation of the over-load-protection (OLP). To deal with this situation, we suggest increasing the rating of the output power or modifying the OLP point. The second one is the activation of over-temperature protection (OTP) when the internal temperature reaches the pre-set value. All of these conditions will let the S.P.S. enter protection mode and shut down. After these conditions are removed, the S.P.S. will be back to normal.

8.9 The output ground (GND) and frame ground (FG) is the same point in my system, can MEAN WELL's power supplies be used in such system?

Ans: Yes. Since our products are designed based on isolation concept, it will be no problem that the output ground (GND) and frame ground (FG) is the same point in your system. But, EMI may be affect by this connection.

8.10 During the operation of MEAN WELL power supply, there is some leakage current on the case. Is this normal? Will this leakage current hurt human body?

Ans: Due to the requirement of EMI, there will be some Y capacitors between line and neutral to the FG (case) to improve EMC. These Y capacitors will cause some leakage current flow from line or neutral to the case (normally case will be connected to earth ground). For example, safety requires that this current should be less than 5mAPK for Audio/video, information and communication technology equipment, so basically the leakage current you find on the case will not hurt human body. Proper connection to Earth ground will solve the leakage current problem.

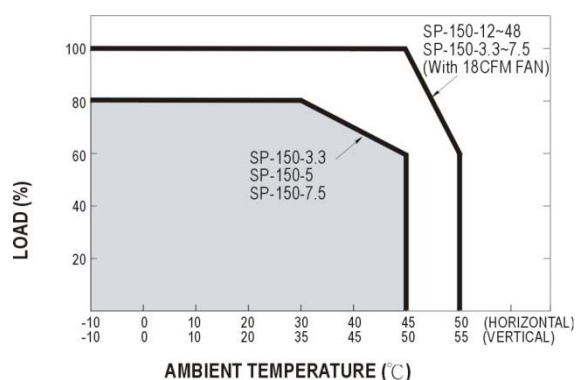
8.11 For certain need, is it possible to reduce the noise of fan?

Ans: Noise is directly related to the fan which is build into the power supply. Lowering the airflow of the fan means reducing the heat dissipation ability. It will also influence the reliability of the products. Furthermore, minimum airflow of fans is defined by Safety Organization and a safety appendage will be needed if using a new fan. Generally, when we choose a suitable power supply, fan is not necessary if wattage is under 150W. Between 150~500W, both fan and fan less products are available. Above 500W, a fan is needed.

8.12 What should be noticed when installing a power supply in vertical and horizontal directions?

Ans: Most small wattage and fan less power supplies are mainly installed in the horizontal position. If you have to install it vertically because of mechanical limitation, you should consider the output derating due to the heat concern. The temperature derating curve can be found on the spec sheet. Regarding the power supplies with built-in fan or the application has forced cooling system, vertical and horizontal installations have less difference.

Ex. In SP-150 derating curve, the ambient temperature difference in application is 5 Celsius from vertical to horizontal. The output wattage in forced cooling can be 20% higher than air cooling convection.



8.13 Why the fan is not running after turning on certain models?

Ans: Some models control the fan based on internal temperature to extend its life time.

For example, the Fan ON temperature for the RPG-300 series is $\geq 40^{\circ}\text{C}$ (RT1). If the internal temperature does not reach the preset value, the fan will remain still until receiving the start up signal.

8.14 What is “Inrush Current” ? What will we notice?

Ans: At input side, there will be (1/2 ~1 cycle, ex. 1/120 ~ 1/60 seconds for 60 Hz AC source) large pulse current (20~100A based on the design of S.P.S.) at the moment of power on and then back to normal rating. This “Inrush Current” will appear every time you turn on the power. Although it will not damage the power supply, we suggest not turning the power supply ON/OFF very quickly within a short time. Besides, if there are several power supplies turning on at the same time, the dispatching system of AC source may shut off and go into protection mode because of the huge inrush current. It is suggested that these power supplies start up one by one or use the remote control function of S.P.S. to turn them on/off.

8.15 What is PFC?

Ans: PFC stands for Power Factor Correction. The purpose of PFC is to improve the ratio of apparent power and real power. The power factor is only 0.4~0.6 in non-PFC models. In PFC models, the power factor can reach above 0.95. The calculation formulas are as below:

Apparent Power=Input Voltage x Input Current (VA)

Real Power= Input Voltage x Input Current x Power Factor (W)

From the environment friendly point, the electric power plant needs to generate a power which is higher than apparent power in order to steadily provide electricity to the market. The real usage of electricity should be defined by real power. Assuming the power factor is 0.5, the power plant needs to produce more than 2VA to satisfy 1W real power. On the contrary, if the power factor is 0.95, the power plant only needs to generate more than 1.06VA to provide 1W real power need. It will be more effective.

Active PFC topology can be divided into single stage PFC and two stage PFC, please refer to the chart below:

PFC Topology	Advantage	Disadvantage	Application limitations
Single stage PFC	<ul style="list-style-type: none"> • Low BOM cost • Simple circuitry design • High efficiency 	<ul style="list-style-type: none"> • Greater ripple difficult in optimizing feedback loop, PF will be easily affected. 	<ul style="list-style-type: none"> • No hold up time, leading output will be effected directly by the AC • higher Ripple current might affect the life time of LED lamp(direct driven) • Slow feedback respond, highly effected by load regulation.
Two stage PFC	<ul style="list-style-type: none"> • Suitable for high wattage application • Supreme PF performance • Easily adjustable for feedback compensation • Good performance in load regulation 	<ul style="list-style-type: none"> • Higher BOM cost • complex circuitry design 	<ul style="list-style-type: none"> • Can be applied in different environment, same as the usual PSU. No special restriction.

8.16 What is the difference between -V and COM which are marked on the output side?

Ans: COM (COMMON) means common ground. Please see below:

Single output: Positive pole (+V), Negative pole (-V)

Multiple output (Common ground): Positive pole (+V1, +V2...), Negative pole (COM)

8.17 In MEAN WELL's catalog, we see AC and DC at input, what is it all about?

Ans: Due to different circuit designs, MEAN WELL power supply inputs consists of three types as below: ($\sqrt{2}$ VAC \doteq VDC)

a. 85~264VAC; 120~370VDC

b. 176~264VAC; 250~370VDC

c. 85~132VAC/176~264VAC by Switch; 250~370VDC

(1) In a and b inputs models, power supply can work properly no matter under AC or DC input. Some models need correct connection of input poles, positive pole connects to AC/L; negative pole connects to AC/N. Others may require opposite connection, positive pole to AC/N; negative pole to AC/L. If customers make a wrong connection, the power supply will not be broken. You can just reverse the input poles and power supply will still work.

(2) In c input models, please make sure that you switch the 115/230V input correctly. If the switch is on the 115V side and the real input is 230V, the power supply will be damaged.

8.18 Why the input voltage marked on the spec. sheet is 88~264 VAC while the label on the power supply says that it is 100~240VAC?

Ans: During safety verification process, the agency will use a stricter standard -- $\pm 10\%$ (Audio/video, information and communication technology equipment uses +6%, -10%) of the input voltage range labeled on the power supply to conduct the test. So, operating at the wider input voltage range as specified on the spec. sheet should be fine. The narrower range of input voltage labeled on the power supply is to fulfill the test standard of safety regulation and make sure that users insert input voltage correctly.

8.19 Will MeanWell's products with CE marking meet the EMC requirements after assembling into my system?

Ans: We cannot guarantee 100% that the final system can still meet the EMC requirements. The location, wiring and grounding of the switching power supply in the system may influence its EMC characteristics. In different environment or applications, the same switching power supply may have different outcomes. Our test results are based on setup shown in the EMC report.

8.20 What is different between Audio/video, information and communication technology equipment (EN62368-1) and medical (EN60601-1) safety standard?

Ans: According to safety standard, the leakage current in EN62368-1 Class I cannot exceed 5mA_{PK} ; in EN60601-1 cannot exceed 0.3mA . Others criteria like safe distance and numbers of fuse are also different. Please consult the diagram in chapter 3 section 6.

8.21 What is MTBF? Is it distinct from Life Cycle? What is DMTBF?

Ans: MTBF and Life Cycle are both indicators of reliability. MEAN WELL uses MIL-HDBK-217F as the core of MTBF. An expected reliability is forecasted through the Stress Analysis (exclude fans). The exact meaning of MTBF is after continuously using of power supply in a certain time, the probability of operating properly is 36.8% ($e^{-1}=0.368$). If power supply is continuously used at double the MTBF time, the probability of operating properly becomes 13.5% ($e^{-2}=0.135$). Life Cycle is found through using the temperature rise of electrolytic capacitor to estimate the approximate life of power supply. For example, RSP-750-24 MTBF=109.1(25°C) hours; electrolytic capacitor C110 Life Cycle=213K hours ($T_a=50^{\circ}\text{C}$).

DMTBF (Demonstration Mean Time Between Failure) is a way to verify MTBF. Please refer to the following formula for calculation

$$\text{Total test duration} = \frac{\text{MTBF} * X^2}{2 * N * AF}$$

$$A = \exp \frac{Ae(\frac{1}{T1} - \frac{1}{T2})}{K}$$

In which,

MTBF : Mean Time Before Failure

X2 : The value can be obtained from Chi-Square Distribution table

N : Number of Sampling

AF : Accelerate Factor which can be calculated from AF formula

Ae=0.6

K (Boltzmann Constant) = 8.625×10^{-5} (eV/k)

T1 : The rated temperature of the specification, which should be calculated with Degree (K)

T2 : The temperature for accelerating the verification which should be calculated with Degree (K), and should not lead to any physical change to the product.

Chapter 9

Failure Correction Notes

When the S.P.S. cannot function properly, please refer to the following checklist and failure correction notes in table 9.1 and 9.2. If it still cannot be fixed after each item had been checked, some internal components might be broken. Please contact the supplier for repair service.

Table 9.1: No Output voltage

Cause		Check Points	Failure Correction	Notes
I/P Side	1. I/P wires not properly connected	External fuse blown?	Replace it with the same rating as the internal fuse	Make sure that the replacement fuse can withstand the inrush current
		Line or neutral wired to FG by mistake?	Rewire ACL/ACN to L and N terminals	
	2. Wrong I/P voltage	Is the AC switch in the right position (115/230V)	Switch it to the correct position	
O/P Side	3. Loose or wrong connection	Are the loads connected properly (i.e. polarity)?	Connect V+ & V- to the right loads.	
		Loose wiring or connectors?	Tighten the screws or make sure the connectors is making good contact	
		Wiring short circuit?	Make sure the wire still has good insulation	
	4. Over voltage Protection is activated	Output voltage is set too high exceeding the voltage adjustment range?	Turn off the AC source. Adjust VR to the center position and restart after 1 minute	The rotational axis of the VR is 240°
		Remote sense wire is loose?	Tighten the screws or reattached the wafer connector	
		Is the remote sense connected correctly?	Refer to the connecting instruction	

Cause		Check Points	Failure Correction	Notes
O/P Side	5. Over current protection is activated	Check whether the load has peak current requirement?	Make sure the SPS is sufficiently rated to power the load	
	6. Triggering Remote control	Is the right type of signal used?	Refer to the spec for remote control logic type	
	7. Series operation	Can this unit be wired in series?	Make sure the right setup is used	Refer to the technical manual
Others	8. Over temperature protection is activated	Is the ambient temperature over the working temperature of the unit?	Turn OFF the AC source and wait for 30 minutes. Then restart and maintain the working temperature within the specified range.	Use external forced air cooling to reduce the waiting period for restarting
		Has the fan stopped working or there is poor ventilation	Resolve factors for fan stoppage or poor ventilation and restart after 30 minutes	
	9. Water marks	Water splash or large temperature variation?	Move equipment away from that area or choose a place with stable ambient temperature	For outdoor applications such as moving sign. SPS can be treated with conformal coating to increase reliability

Table 9.2: Abnormal output (too high, too low, or unstable)

Cause		Check Points	Failure Correction	Notes
Output voltage is too high	1. Output voltage is too high	Output voltage is adjusted too high using the VR?	Adjust counterclockwise to reduce the voltage	
		Is the output connected in shunt with other voltage source	Remove source to prevent feedback into power supply	
		Connection of Remote sense is loose	Reconnect wires	
Output voltage is too low	2. Input voltage is too low	Is input voltage lower than the spec. value?	Check AC wiring and voltage level	Please also make sure the 115/230 selection switch is in the correct position
		Distortion of the input waveform?	Improvement can be made by using electronic AC source	

Cause	Check Points	Failure Correction	Notes	
Output voltage is too low	3. Output voltage is set too low	Is the output voltage set too low through VR adjustment?	Turn clockwise to adjust the voltage higher	
	3. Output voltage is set too low	For AC selection by switch model is the switch in the correct position (115/220V)	Switch to correct position	
		Measuring device properly calibrated & powered	Make sure the device is in working order	
	4. Output wiring is unsuitable	Is the output wiring too long and too thin (wire gauge)?	Using higher gauge and shorter wire	Measurement should be made at the output terminal (not the load). Also refer wire gauge table when making wire selection
		Are the terminals and connectors loose or defective	Inspect the connectors or tighten the screws of the terminals	
5. Over current protection is activated	Check whether the output current requirement is over the current rating	Use a current probe to check actual load usage.		
Output voltage is unstable	6. Oscillation due to remote sense connection	Is the wire for remote sense too long or not twisted?	Add capacitors on both the remote side and connector side. Use twisted wire for remote sense connection. Refer to Ch. 7 of the manual	
	7. Min. load is not met	Is the min. load on the main output satisfied (Multiple-out unit)?	Add external dummy load at the main output of the multi-output units Refer to the min. load specification.	
	8. Protection circuit is activated	Is the over current protection or over voltage protection activated?	Confirm that the output is not being overloaded or the load is not capable of causing over- voltage Connecting a battery with high voltage to the output may damage the OVP circuit Be careful about special loads such as motors, bulbs, and large capacitive loads	

	9.Oscillation due to wiring	No high frequency capacitors and electrolytic capacitors at the load end?	Add high frequency capacitors and electrolytic capacitors at the load end	
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9.1 Notes on Returning SPS for Repair

- (1) Please attach a small note along with the defective products that shortly describes the situation of failure. This will help us to make the failure analysis.
- (2) Please tighten the screws on terminal block. (You do not have to send back accessories and AC cord.)
- (3) Please return defective units in suitable packages to prevent damage during transportation, especially for the open frame models which have SMD components.
- (4) There will be a repair charges for products which warranties are one year overdue. The amount of repair charges depends on models' prices and defective situations.
- (5) It's strongly recommended to replace with a new unit if the unit is out of warranty for more than 2 years.
- (6) After receiving the defective products, we will finish the repair process within 7 working days and send it back within 5 working days.
- (7) As to the failure analysis, please refer to the tag hanging on the power supply.
- (8) If you need more details about your repair items, please contact your sales representative.

9.2 Recognizing the Serial Number

R	A 0	0	000001
1	2	3	4

- (a) The first part of number denotes
- C. Product Number (Made in Taiwan)
 - D. Product Number (Made in GuangZhou)
 - H. Product which complies with RoHS (Made in Guangzhou)
 - E. Product which complies with RoHS (Made in Suzhou)
 - R. Product which complies with RoHS (Made in Taiwan)
 - P. Semi-finished product number

(b) The second part of number denotes the year of manufacturing

Example: 98 means 1998; 99 means 1999

A0 means 2000; A5 means 2005

B0 means 2010; B5 means 2015

(c) The third part of number denotes the month of manufacturing. 1-0 means January to October. A means November. B means December.

(d) The fourth part of number denotes the exact order number when this model is being made. Example: 000001 means it is the first model made in this series.

9.3 Statistics for Repair

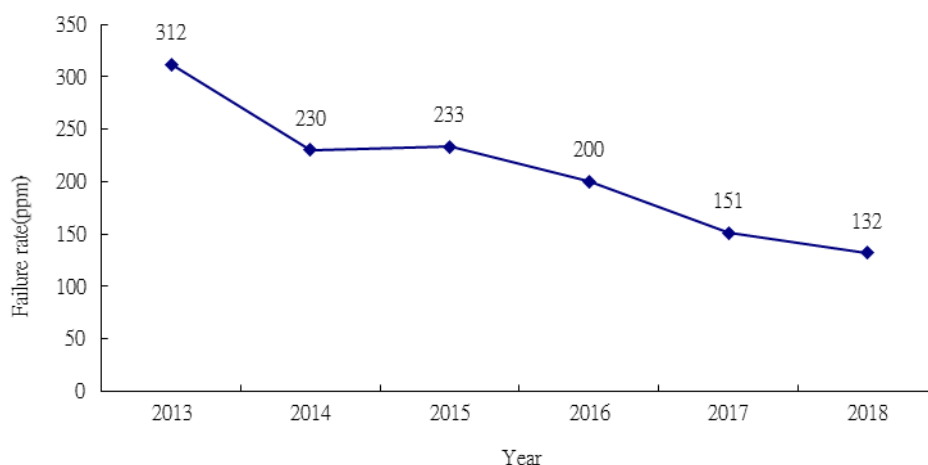
We set the target that the 2-year repair rate (the percentage that the products returned within 2 years after shipping out) should decrease 10% every year. Based on previous records, the rate was 200ppm in 2016, 151ppm in 2017 and 135.9ppm in 2018. The failure rate has steadily decreased each year.

Calculation Formula of Failure Rate under Warranty

$$= \frac{\text{Accumulation of the failure number annually}}{\text{Total sales number annually}}$$

Example: In 2018

$$\text{Failure Rate under Warranty} = \frac{9281}{70249392} = 132\text{ppm}$$



Abnormal Failure:

An artificially induced failure of a component, usually as a result of "abnormal" testing for regulatory agency safety compliance.

AC (Alternating Current):

A periodic current the average value of which over a period is zero. Unless distinctly specified otherwise, the term refers to a current which reverses at regularly recurring intervals of time and which has alternately positive and negative values.

AC Line:

The set of conductors that route ac voltage from one point to another.

AC Line Filter:

A circuit filter placed in the ac line to condition or smooth out variations that are higher in frequency than the line frequency.

Ambient Temperature:

The temperature of the environment, usually the still air in the immediate proximity of the power supply.

Ampere :

(A) Electron or current flow representing the flow of one coulomb per second past a given point in a circuit.

Amplifier:

A circuit or element that provides gain.

Anode:

The electrode from which the forward current flows within the cell.

ANSI:

American National Standards Institute.

Apparent Power:

A value of power for AC circuits that is calculated as the product of RMS current times RMS voltage, without taking the power factor into account.

Asymmetrical Waveform:

A current or voltage waveform that has unequal excursions above and below the horizontal axis.

ATE:

Automatic Tester Equipment.

Attenuation:

Decrease in amplitude or intensity of a signal.

Auxiliary Power:

A power source supplying power other than load power as required for proper functioning of a device.

Bandwidth:

A range of frequencies over which a certain phenomenon is to be considered.

Bead:

A small ferrite normally used as a high frequency inductor core.

Bifilar Winding:

Two conductors wound in parallel.

Bipolar Transistor:

A transistor which operates by the action of minority carriers across a P/N junction; and is a current controlled device as opposed to a voltage controlled device.

Bleeder Resistor:

A resistor added to a circuit for the purpose of providing a small current drain, usually to provide a load for improving output voltage stability, or to assure discharge of capacitors.

Bobbin:

A device upon which the windings of a transformer or inductor are wound, which provides a form for the coil and insulates the windings from the core.

Breakdown Voltage:

A voltage level at which dielectric insulation fails by excessive leakage current or arcing. In reference to power supplies the breakdown voltage is the maximum AC or DC voltage that can be applied from input to output and/or chassis.

Bridge Converter:

A DC to DC converter topology (configuration) employing four active switching components in a bridge configuration across a power transformer.

Bridge Rectifier:

A full wave rectifier circuit employing four rectifiers in a bridge configuration.

Brownout:

A reduction of the AC mains' distribution voltage, usually caused deliberately by the utility company to reduce power consumption when demand exceeds generation or distribution capacity.

Brownout Protection:

The ability of a power supply to continue operating within specification through the duration of a brownout.

Burn-In:

Operating a newly manufactured power supply, usually at rated load, for a period of time in order to force component infant mortality failures or other latent defects before the unit is delivered to a customer.

Capacitance:

Inherent property of an electric circuit or device that opposes change in voltage. Property of circuit whereby energy may be stored in an electrostatic field.

Capacitive Coupling:

Coupling of a signal between two circuits, due to discrete or parasitic capacitance between the circuits.

Cathode:

The electrode from which the forward current flows out the cell.

Center Tap:

An electrical connection made at the center of a transformer or inductor winding, usually so as to result in an equal number of turns on either side of the tap.

Chassis:

The structure supporting or enclosing the power supply.

Chassis Ground:

The voltage potential of the chassis.

Choke Coil:

An inductor.

Circular Mil:

Cross-sectional area of a conductor one mil in diameter.

Common Mode Noise:

Noise present equally on two conductors with respect to some reference point; often used specifically to refer to noise present on both the hot and neutral AC lines with respect to ground.

Compensation:

The addition of circuit elements to assist in stabilization of a control loop.

Constant Current Power Supply:

A power supply designed to regulate the output current for changes in line, load, ambient temperature, and drift resulting from time.

Constant Voltage Power Supply:

A power supply designed to regulate the output voltage for changes in line, load, ambient temperature, and drift resulting from time.

Control Circuit:

A circuit in a closed-loop system, typically containing an error amplifier, which controls the operation of the system to achieve regulation.

Convection:

The transfer of thermal energy in a gas or liquid by currents resulting from unequal temperatures.

Converter:

An electrical circuit which accepts a DC input and generates a DC output of a different voltage, usually achieved by high frequency switching action employing inductive and capacitive filter elements.

Cooling:

Removal of heat, which, in a power supply, is generated by transformation, rectification, regulation, and filtering. It can be accomplished using radiation, convection, forced air, or liquid means.

Cross Regulation :

The effect of a load change on one output to the regulation of another output.

Crowbar :

An over-voltage protection method which shorts the power supply output to ground in order to protect the load when an over-voltage fault is detected.

Current Limiting: An overload protection circuit that limits the maximum output; current of a power supply in order to protect the load and/or the power supply.

Current Mode :

A control method for switch-mode converters where the converter adjusts its regulating pulse width in response to measured output current and output voltage, using a dual loop control circuit. Since output current is measured, current mode control allows accurate sharing between power supplies.

DC-DC Converter:

A circuit or device that changes a dc input signal value to a different dc output signal value.

Derating:

A reduction in an operating specification to improve reliability. For power supplies it is usually a specified reduction in output power to facilitate operation at higher temperatures.

Design Life :

The expected lifetime of a power supply during which it will operate to its published specifications.

Differential Mode Noise :

Noise that is measured between two lines with respect to a common reference point excluding common-mode noise. The resultant measurement is the difference of the noise components of the two lines. The noise between the DC output and DC return is usually measured in power supplies.

Direct Current (DC):

Current that the polarity doesn't change with respect to time.

Drift :

The change in an output voltage, after a warm-up period, as a function of time when all other variables such a line, load, and operating temperature are held constant.

Dropout:

The lower limit of the AC input voltage where the power supply just begins to experience insufficient input to maintain regulation. The dropout voltage for linear supplies is quite load dependent. For most switching supplies it is largely design dependent, and to a smaller degree load dependent.

Duty Cycle :

The ratio of time on to time off in a recurring event.

Dynamic Load :

A load that rapidly changes from one level to another. To be properly specified, both the total change and the rate of change must be stated.

Efficiency :

The ratio of total output power to input power expressed as a percentage. Normally specified at full load and nominal input voltage.

Electronic Load :

An electronic device designed to provide a load to the outputs of a power supply, usually capable of dynamic loading, and frequently programmable or computer controlled.

EMI:

Abbreviation for Electromagnetic Interference, which is the generation of unwanted noise during the operation of a power supply or other electrical or electronic equipment.

ESR:

Equivalent Series Resistance. The value of resistance in series with an ideal capacitor which duplicates the performance characteristics of a real capacitor.

Fault Mode Input Current :

The input current to a power supply with a short circuit on the output.

FET:

Field Effect Transistor, a majority carrier voltage controlled transistor.

Filter :

A frequency-sensitive network that attenuates unwanted noise and ripple components of a rectified output.

Floating Output :

An output of a power supply that is not connected or referenced to any other output, usually denotes full galvanic isolation. They generally can be used as either positive or negative outputs. Non-floating outputs share a common return line, and are hence DC referenced to one another.

Flyback Converter :

The flyback converter is the simplest type of switcher. In most cases, it uses one switch and only needs one magnetic element - the transformer.

Foldback Current Limiting :

A type of protection circuit where the output current decreases as the overload increases. The output current reaches a minimum as the load approaches a short-circuit condition.

Forced Convection Cooling:

Using outer sources (such as fans) to help hot components disperse the heat.

Forward Converter :

Similar to flyback converter but the forward converter stores energy in the output inductor instead of the transformer.

Frequency :

Number of cycles per second measured in "Hertz".

Full Bridge Converter :

The full bridge is more complex than other switcher topologies. It has the capability for very high performance. It can product high power with four switchers and requires only two magnetic elements.

Fuse :

Safety protective device that permanently opens an electric circuit when overloaded.

Ground:

An electrical connection to earth or some other conductor that is connected to earth. Sometimes the term "ground" is used in place of "common," but such usage is not correct unless the connection is also connected to earth.

Ground Loop :

An unintentionally induced feedback loop caused by two or more circuits sharing a common electrical ground.

Half-Bridge Converter :

A switching power supply design in which two power switching devices are used to drive the transformer's primary side.

Heat Sink:

Device used to conduct away and disperse the heat generated by electronic components.

High Line:

Highest specified input operating voltage.

Hi-Pot:

Abbreviation for High Potential, and generally refers to the high voltages used to test dielectric withstand capability for regulatory agency electrical safety requirements.

Hold-Up Time:

The length of time a power supply can operate in regulation after failure of the AC input.

Input Line Filter:

An internally or externally mounted low-pass or band-reject filter at the power supply input which reduces the noise fed into the power supply.

Input Voltage Range:

The range of input voltage values for which a power supply or device operates within specified limits.

Inrush Current :

The peak current flowing into a power supply the instant AC power is applied. This peak is usually much higher than the steady state input current due to the charging of the input filter capacitors.

Inrush Current Limiting:

A circuit that limits the amount of inrush current when a power supply is turned on.

Insulation :

Non-conductive materials used to separate electric circuits.

Insulation Resistance :

The resistance offered, usually measured in mega-ohms, by an insulating material to the flow of current resulting from an impressed dc voltage.

Inverter :

A power supply that produces an AC output, usually from a DC input.

Isolation :

Two circuits that are completely electrically separated with respect to DC potentials, and almost always also AC potentials. In power supplies, it is defined as the electrical separation of the input and output via the transformer.

Isolation Transformer :

A component that isolates the primary and secondary side in the switching power supply.

Isolation Voltage :

The maximum AC or DC voltage which maybe continuously applied from input to output and/or chassis of a power supply.

Layer Winding :

A transformer winding technique where the primary and secondary windings are wound over each other and separated by an insulation layer.

Leakage Current :

A term relating to current flowing between the AC supply wires and earth ground. The term does not necessarily denote a fault condition. In power supplies, leakage current usually refers to the 60 Hertz current which flows through the EMI filter capacitors which are connected between the AC lines and ground (Y caps).

Line Regulation :

The change in output voltage when the AC input voltage is changed from minimum to maximum specified. It is usually a small value, and may be near zero with current mode control.

Linear Regulator:

A regulating technique where a dissipative active device such as a transistor is placed in series with a power supply output to regulate the output voltage.

Load Regulation :

The change in output voltage when the load on the output is changed.

Local Sensing :

Using the voltage output terminals of the power supply as sense points for voltage regulation.

Logic Enable :

The ability to turn a power supply on and off with a TTL signal. A logic-low generally turns the supply off while a logic-high turns it on.

Long Term Stability :

Power supply output voltage change due to time with all other factors held constant. This is expressed in percent and is a function of component aging.

Magnetic Amplifier :

Sometimes abbreviated "Mag Amp," a saturating inductor that is placed in series with a power supply output for regulation purposes.

Mains : The utility AC power distribution wires.

Margining:

Adjusting a power supply output voltage up or down from its minimal setting in order to verify system performance margin with respect to supply voltage. This is usually done electrically by a system-generated control signal.

Minimum Load :

The minimum load current/power that must be drawn from the power supply in order for the supply to meet its performance specifications. Less frequently, a minimum load is required to prevent the power from failing.

Modular :

A physically descriptive term used to describe a power supply made up of a number of separate subsections, such as an input module, power module, or filter module. Modular construction tends to lower the MTBF.

MTBF: Mean Time Between Failures.

Noise :

Noise is the aperiodic, random component of undesired deviations in output voltage. Usually specified in combination with ripple.

Normal Value :

A usual, average, normal, or expected operating condition. This stated value will probably not be equal to the value actually measured.

Off Line :

A power supply which receives its input power from the AC line, without using a 50/60 Hz power transformer prior to rectification and filtering, hence the term "off line" power supply.

Open Frame :

A power supply where there is no external metal chassis; the power supply is provided to the end user essentially as a printed circuit board which provides mechanical support as well as supporting the components and making electrical connections.

Optoisolator:

An electro-optical device which transmits a signal across a DC isolation boundary.

Output Good :

A power supply status signal which indicates that the output voltage is within a certain tolerance. An output which is either too high or too low will deactivate the Output Good signal.

Output Impedance :

The ratio of change in output voltage to change in load current.

Output Noise :

The AC component that may be present on the DC output of a power supply. Switch-mode power supply output noise has two components: a lower frequency component at the switching frequency of the converter and a high frequency component due to fast edges of the converter switching transitions. Noise should always be measured directly at the output terminals with a scope probe having an extremely short grounding lead.

Overload Protection :

A power supply protection circuit that limits the output current under overload conditions.

Overshoot :

A transient output voltage change which exceeds the high limit of the voltage accuracy specification and is caused by turning the power supply on or off, or abruptly changing line or load conditions.

Overtemp Warning :

A TTL compatible signal which indicates that an over-temperature condition exists in the power supply. Most commercial power supplies are designed to shut down if an over-temperature condition exists.

Over Voltage Protection :

A circuit which either shuts down the power supply or crowbars the output in the event of an over-voltage condition.

Parallel Operation :

Connecting the outputs of two or more power supplies with the same output voltage for the purpose of obtaining a higher output current. This requires power supplies specially designed for load sharing.

Peak Power :

The absolute maximum output power that a power supply can produce without immediate damage. Peak power capability is typically well beyond the continuous reliable output power capability and should only be used infrequently.

Power Factor :

The ratio of true power to apparent power in an AC circuit. In power conversion technology, power factor is used in conjunction with describing the AC input current to the power supply.

Power Fail :

A power supply interface signal which gives a warning that the input voltage will no longer sustain full power regulated output.

Preload :

A small amount of current drawn from a power supply to stabilize its operation. Preloads are usually provided by a bleeder resistor.

Primary :

The input section of an isolated power supply that is connected to the AC mains and hence has dangerous voltage levels present.

Pulse Width Modulation (PWM):

A switching power conversion technique where the on-line (or width) of a duty cycle is modulated to control power transfer for regulating power supply outputs.

Push -Pull Converter :

A switching-mode power supply topology which utilizes a center-tapped transformer and two power switches. The two switches are alternately driven on and off.

Quasi Regulated Output :

The regulation of an auxiliary output that is accomplished by regulation of the main output. A transformer turns ratio, commensurate with the desired auxiliary output voltage, is used in conjunction with the output around which the main control loop is closed. Quasi regulated outputs can be reasonably well regulated, but are significantly affected by second order effects in the converter.

Rated Output Current :

The maximum load current that a power supply can provide at a specified ambient temperature.

Reflected Ripple Current :

The RMS or peak-to-peak AC current present at the input of the power supply which is a result of the switching frequency of the converter.

Regulation :

The ability of a power supply to maintain an output voltage within a specified tolerance as referenced to changing conditions of input voltage and/or load.

Regulation Band :

The total error band allowable for an output voltage. This includes the effects of all of the types of regulation: line, load, and cross.

Remote Inhibit :

A power supply interface signal, usually TTL compatible, which commands the power supply to shut down one or all outputs.

Remote Sense :

Wires connected in parallel with power supply output cables such that the power supply can sense the actual voltage at the load to compensate for voltage drops in the output cables and/or isolation devices.

Return :

The designation of the common terminal for the power supply outputs. It carries the return current for the outputs.

Reverse Voltage Protection :

A protection circuit that prevents the power supply from being damaged in the event that a reverse voltage is applied at the input or output terminals.

RFI:

An abbreviation for Radio Frequency Interference, which is undesirable noise produced by a power supply or other electrical or electronic device during its operation. In power supply technology, RFI is usually taken to mean the same thing as EMI.

Ripple And Noise :

The amplitude of the AC component on the DC output of a power supply usually expressed in milli-volts peak-to-peak or RMS.

Safety Ground :

A conductive path to earth that is designed to protect persons from electrical shock by shunting away any dangerous currents that might occur due to malfunction or accident.

Secondary :

The output section of an isolated power supply which is isolated from the AC mains and specially designed for safety of personnel who might be working with power on the system.

SELV:

An abbreviation for Safety Extra Low Voltage, a term generally defined by the regulatory agencies as the highest voltage that can be contacted by a person and not cause injury. It is often specifically defined as 30 VAC or 42.4 VDC.

Soft Start:

A technique for gradually activating a power supply circuit when the power supply is first turned on. This technique is generally used to provide a gradual rise in output voltages and inrush current limiting.

Split Bobbin Winding :

A transformer winding technique where the primary and secondary are wound side-by-side on a bobbin with an insulation barrier between them.

Standby Current :

The input current drawn by a power supply when shut down by a control input (remote inhibit) or under no load.

Switching Frequency :

The rate at which the DC voltage is switched on and off during the pulse width modulation process in a switching power supply.

Temperature Coefficient :

The average output voltage change expressed as a percent per degree centigrade of ambient temperature change. This is usually specified for a pre-determined temperature range.

Temperature Derating :

Reducing the output power of a power supply with increasing temperature to maintain reliable operation.

Thermal Protection :

A power supply protection circuit which shuts the power supply down in the event of unacceptably high internal temperatures.

Topology:

The design type of a converter, indicative of the configuration of switching transistors, utilization of the transformer, and type of filtering. Examples of topologies are the Flyback, Forward, Half-Bridge, Full Bridge, and Resonant.

Tracking :

A characteristic in a multiple output power supply where any changes in the output voltage of one output caused by line, load, and/or temperature are proportional to similar changes in accompanying outputs.

Transient Recovery Time:

The time required for an output voltage to be within specified accuracy limits after a step change in line or load conditions.

True Power :

In an AC circuit, true power is the actual power consumed. It is distinguished from apparent power by eliminating the reactive power component that may be present.

Undershoot :

A transient output voltage change which does not meet the low limit of the voltage accuracy specification and is caused by turning the power supply on or off, or abruptly changing line or load conditions.

UPS (Uninterruptible Power Supply):

A power supply which continues to supply power during a loss of input power. Two types are the stand-alone UPS, which is located external to the equipment being powered, and the battery back-up power supply, which is embedded in the equipment being powered.

Voltage Balance :

The difference in magnitudes, in percent, of two output voltages that have equal nominal voltage magnitudes but opposite polarities.

Voltage Mode :

A method of closed loop control of a switching converter where the pulse width is varied in response to changes in the output voltage to regulate the output.

Warm-Up Drift :

The initial change in the output voltage of a power supply in the time period between turn-on and when the power supply reaches thermal equilibrium at 25 degrees Centigrade, full load and nominal line.

Warm -Up Time:

The time required after initial turn on for a power supply to achieve compliance to its performance specifications.

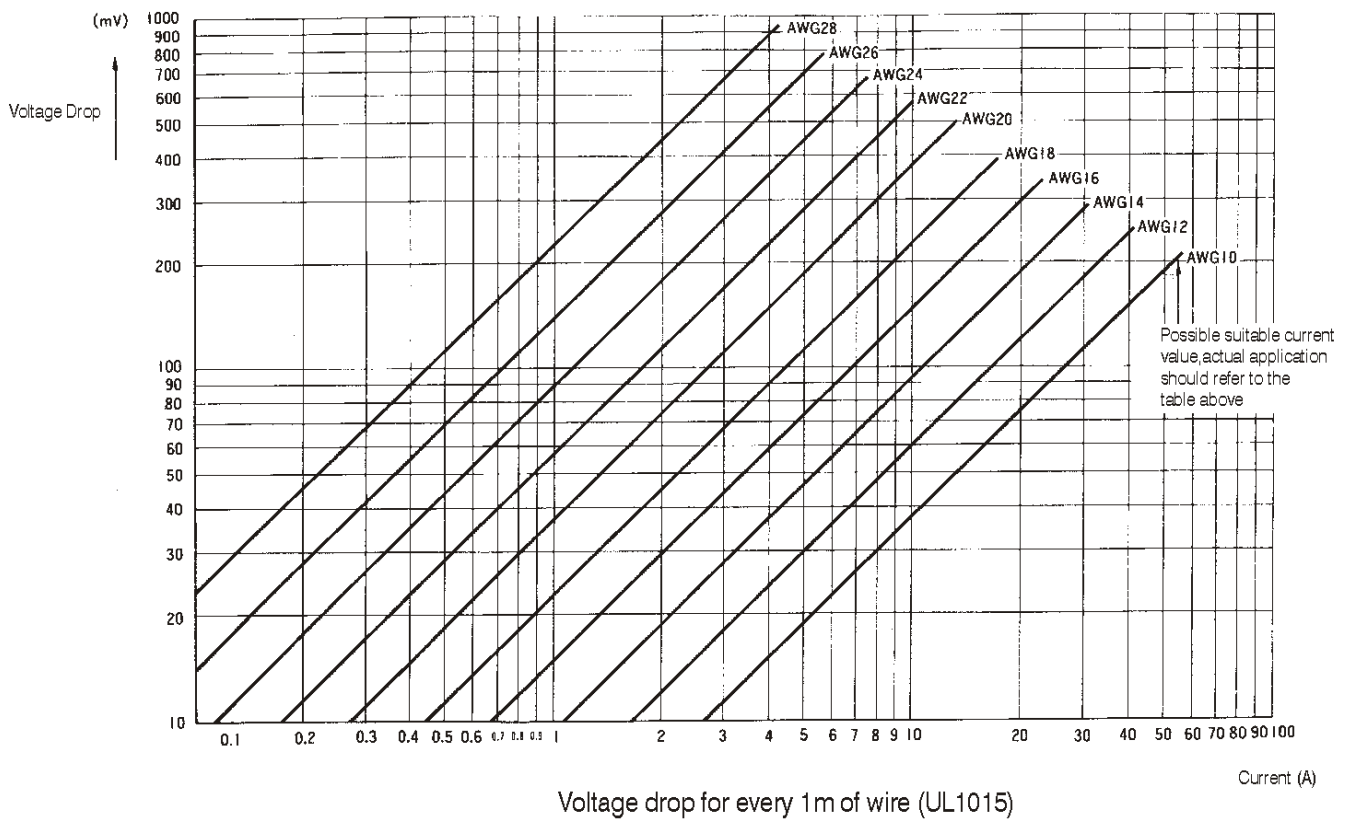


Appendix B. Voltage Drop Table For All Kinds Of Wiring

AWG No.	1A Voltage Drop (mV/m)	Composed Of (Strip/mm)	Suggested Maximum Current(A)		Cross-section on Area(mm ²)	Cross-section Area After twisting(Φ)
			UL 1007 (300V 80°C)	UL 1015 (600V 105°C)		
30	358	7/0.102	0.12	-----	0.051	
28	222	7/0.127	0.15	0.2	0.081	
26	140	7/0.16	0.35	0.5	0.129	
24	88.9	11/0.16	0.7	1.0	0.205	
22	57.5	17/0.16	1.4	2.0	0.326	0.8
20	37.6	26/0.16	2.8	4.0	0.517	1.0
18	22.8	43/0.16	4.2	6.0	0.823	1.3
16	14.9	54/0.18	5.6	8.0	1.309	1.6
14	9.5	41/0.26	-----	12.0	2.081	
12	6.0	65/0.26	-----	22.0	3.309	
10	3.8	104/0.26	-----	35.0	5.262	

Note: The suggested maximum current above only suit for 1~4 strips, 5 or more strips should use 80% of rating current

Voltage drop table for all kinds of wires



Voltage drop curves for all kinds of wires

Common Nouns And Units For Electrical Circuitry

Noun	Symbol	Unit	Symbol	Formula/Notes
Resistance	R	Ohm	Ω	V/A
Impedance	Z	Ohm	Ω	-----
Reactance	X	Ohm	Ω	$X_C = \frac{1}{2\pi fc}$ $X_L = 2\pi fL$
Capacitance	C	Farad	F	S*s
Inductance	L	Henry	H	Wb/A
Potential difference	V	Volt	V	Wb/s
Current	I	Ampere	A	V/ Ω
Power(Real)	P	Watt	W	VI cos θ
Power(Apparent)	S	Volt-Ampere	VA	V*A
Frequency	f	Hertz	Hz	Cycle/s
Energy	u	Joule	J	W*s
Temperature	T	Degrees Celsius	$^{\circ}\text{C}$	-----
Temperature(Absolute)	T	Kelvins	K	-----
Charge	Q	Coulombs	C	A*s
Gain	G	Decibel	dB	-----
Field Strength	H	Amperes per meter	A/m	-----
Field Strength(CGS)	H	Oerst	Oe	$4\pi 10^{-3}\text{A/M}$
Flux	Φ	Webers	Wb	V*s
Flux density	B	Teslas	T	Wb/m
Permeability	μ	Henries per meter	H/m	V*s/A*m

Common engineering units

Power	Factor	Metric Prefixes	Symbol
10^{-12}	0.000000000001	Pico	p
10^{-9}	0.000000001	Nano	n
10^{-6}	0.000001	Micro	u
10^{-3}	0.001	Milli	m
10^3	1000	Kilo	K
10^6	1000000	Mega	M
10^9	1000000000	Giga	G

Length convert

1 Foot=12 Inch
 1 Inch=2.54 cm
 1Yard=3ft=0.9144 m
 1 Mile=1.609344 km
 1 NM =1.852 km

Surface convert

1 Hectare =100 Ares
 1 Ares =100 Square meter
 1 Square feet=
 0.0929 Square meter

Volume convert

1 Gallon(US)=3.78541Liter
 1 Gallon(EN)=4.54609 Liter

Weigh convert

1Pound=16 Ounce
 1 Ounce =28.3495 g
 1ct=0.2 g
 1Pound=0.4535 kg
 1 Short ton =907.18474kg

Temperature convert

$^{\circ}\text{K} = ^{\circ}\text{C} + 273$
 $^{\circ}\text{F} = 9/5^{\circ}\text{C} + 32$

Power convert

1Hp=0.7457 kW

Thermal convert

1 Whr=0.860 K cal
 =3.412 BTU
 1 BTU=0.252 K cal
 1K cal=3.968 BTU

Global Voltage And Plug Comparison

Country	Hz	Voltage(V)	Plug Style	Country	Hz	Voltage(V)	Plug Style	Country	Hz	Voltage(V)	Plug Style	
ASIA				Fiji	50	240	C	USA	60	120	A E	A. Flat Shape Plug Flat Shape plug-4Φ Flat Shape Outlet 6A
Taiwan	60	110	A E	Tahiti	50	127	A E	Alaska	60	120/240	A E	
Hong Kong	50	200	B	EUROPE				Mexico	60	125	A E	
China	50	110/200	A B C D	Netherlands	50	220	B	Costa Rica	60	120	A D E	
Macau	50	115/127/220	B	Belgium	50	127/220	B	Nicaragua	60	120	A E	
Korea	60	100/220	A B C	Luxembourg	50	120/220	B	Venezuela	60	120	A E	B. Circle Shape Plug Circle Shape Plug - Flat Shape Outlet 6A
Japan	50/60	100	A E	West German	50	220	B	Bolivia	50	110/220	A B E	
Philippines	60	115/200	A B C E	East German	50	127/220	B	El Salvador	60	115	A E	
Vietnam	50	120/220/230	A B	France	50	127/220	B C	Colombia	60	110	A E	
Singapore	50	230	D	Denmark	50	220	B	Guatemala	60	120	A E	
Indonesia	50	127/230	B	Finland	50	220	B	Argentina	50	220	B D	C. Oblique-Flat Plug Oblique-Flat Plug - Flat Shape/4Φ Flat Shape Outlet
Malaysia	50	240	D	Norway	50	220/230	B	Uruguay	50	220	B D	
Brunei	50	240	B D	Sweden	50	220	B	Paraguay	50	220	B	
Thailand	50	220	A B D E	Switzerland	50	220	B	Brazil	60	127/220	A B E	
India	50	230	B	Hungary	50	220	B	Peru	60	220	A B E	
Nepal	50	220	B E	Austria	50	220	B	Chile	50	220	B	D. Three-Leg Plug Three-Leg Plug-Flat Shape/4Φ Flat Shape Output 13A
Bengali	50	230	B	Czechoslovakia	50	220	B	Panama	60	110/115/120	A E	
Pakistan	50	220/230	B	Poland	50	220	B	Belize	60	110/120	A D	
MIDDLE EAST				Russia	50	127/220	AB	Cuba	60	110	A B D E	
Jordan	50	220	B D	Romania	50	220	B	Dominica	60	110	A E	
Iran	50	220	B D	Bulgaria	50	220	B	AFRICA				
Iraq	50	220	B D	Yugoslavia	50	220	B	Egypt	50	220	B D	
Turkey	50	220	B	Greece	50	220	B	Kenya	50	240	B D	
Kuwait	50	240	B D	Italy	50	127/220	B	Zambia	50	230	D	
Saudi Arabia	50/60	127/220	A B D	Spain	50	127/220	AB	Morocco	50	115/127/220	B	E. Three-Leg Plug(North America)
United Arab Emirates	50	220/230/240	B D	Portugal	50	220	B	Nigeria	50	230	D	
OCEANIA				U.K.	50	240	C D	South Africa	50	220/230/250	B D	
Australia	50	240/250	C	AMERICA								
New Zealand	50	230	C	Canada	50	120	A D E					

Note: ①These plugs can't transform the voltage level.

②Although this table classifies the plugs and voltage levels for different countries, please still confirm it before using.