MEAN WELL ENTERPRISES CO., LTD.

LED POWER SUPPLY TECHNICAL MANUAL

ISO-9001Certificated Manufacturer

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Your Reliable Power Partner

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Chapter 1
LED Introduction

1.1 Explanation of LED fundamentals

LED is a light emitting semiconductor device with diode like characteristics. As forward current flows through the P-N junction of the semiconductor material, photons are released as a result of electrons moving across the diode and falling into the empty holes in the P type layer. Depending on the photon's frequency, it could either be invisible to the human eye (infrared portion) or be part of the visible spectrum. The lasted development in LED technology involves coating blue LED with phosphor to create white LED.

The V-I curve of LEDs are similar to diodes. Please refer to figure 1.1

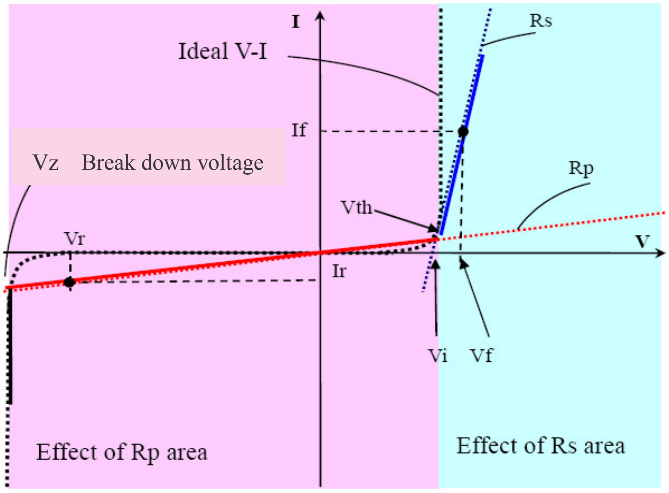


Figure 1.1: LED V versus I characteristic

White LEDs are generally used for lighting applications, the brightness of such device increases proportionally with the increase in forward conduction current. Due to the rise in demand for high power, high luminance white LED in the lighting industry, specifications are being standardized. Forward voltage is typically within the range of 3.0~3.5V with forward current of 350/700/1050mA resulting in power rating of 1/2/3W.

1.2 LED applications

Advantages of LEDs include low heat dissipation, diverse applications, miniaturization, high tolerance to shock/vibration, and ability to focus light beam. The use of white LED in the lighting industry is accelerated by the continuing improvement in luminous flux and efficiency. Typical applications include building architecture (wall lighting, wall decoration, garden lighting, spot lighting, stairway lighting, and patio lighting), outdoor use (street light, park light, and lamp post), commercial use (office lighting, sign board, display cabinet lighting), and home use (cabinet lighting, room lamination, desk lamp, and etc).

1.3 LED lifetime and reliability

Since LED is part of the solid state semiconductor device family, when properly designed-in, it has excellent lifetime and reliability figures. The lifetime of LED is typically between the range of 50,000~100,000 hrs. This exceeds the lifetime of traditional lighting device (1,000~10,000 hrs) by a large margin. Extra attention must be given to cooling of LED and design of LED driver or else you risk premature failure and accelerated decrease in luminance (refer to figure 1.2). The key to achieving energy conservation, high efficiency, and long lifetime is to select a suitable power source/drive method and provide proper cooling for the LEDs.

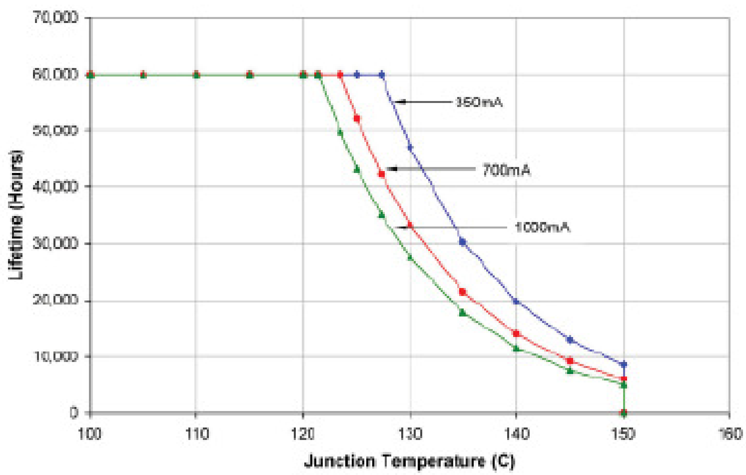


Figure 1.2: Lifetime and junction temp for Philips Power LEDs

1.4 LED drive methods

The main factor to driving a LED is the introduction of forward current. However due to it's nonlinear V-I characteristic, high Vf manufacturing tolerance, and Vf sensitivity to temperature change, the most common types of voltage source used are limited to either constant voltage or constant current. The drawback of using constant voltage source is that LEDs will not produce the same brightness, resulting in uneven reliability, decrease in luminance and lifetime. For these reasons, constant current voltage source are more preferable when it comes to driving high power LEDs. Just as named, the constant current source is not susceptible to the variations in forward voltage. Its current will remain at a constant level regardless of shift in LED Vf. Thus, constant brightness can be easily achieved. Constant current can also be attained by using a driver circuit with current sense resistive network so no adjustment of the power supply voltage is required.

1.5 Introduction to Constant Voltage (C.V.) Mode and Constant Current (C.C.) Mode of LED Power Supply

Most of the traditional switching power supplies provide a constant voltage (C.V.) to the load. For example, MEAN WELL's single output model RS-25-5 can provide 5V/0~5A to power all kinds of load. Its output voltage maintains at the constant value of 5V while its output current varies from 0~5A based on the load condition. When the loading is over 5A which is its rated current, the power supply unit will go into "overload protection" mode (generally speaking the activated range of overload protection is 105%~150% of rated output power). There are many different protection types that are often seen in the design of MEAN WELL power supply such as shutdown type (PSU will be shut off output), hiccup type (output voltage/current will be pulsing), and constant current type (output current will be fixed at a constant value between 105~150% of rated output current and the output voltage will go down to a low level). The power supply is under abnormal condition when the overload protection has been activated, so it is not suitable to let the power supply unit operate under this situation continuously. Equipped with "hiccup type" as their overload protection mode, the LPV, LPH-18 and LPL-18 series in MEAN WELL LED power supply family are considered to be "constant voltage power supply". For LED related applications, it can be used in system incorporated with LED constant current driver IC (Fig. 1.5) or series connected with a ballast resistor (Fig. 1.4).

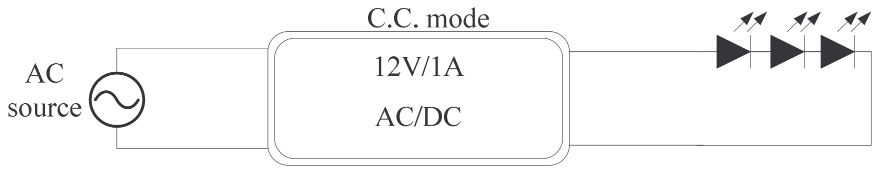


Figure 1.3

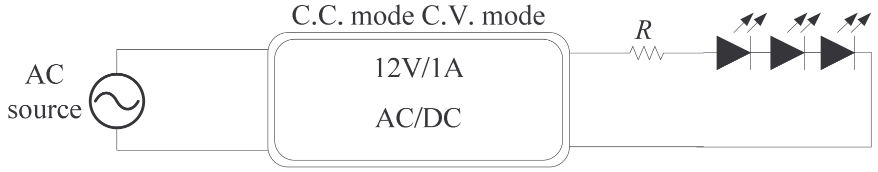


Figure 1.4

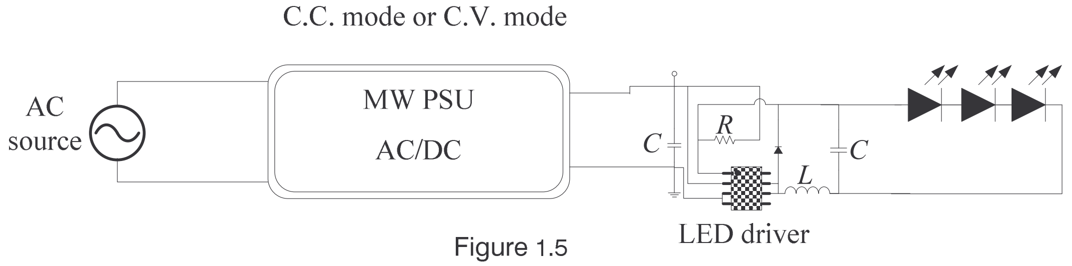


Figure 1.5

The so-called constant current (C.C.) LED power supply basically refers to the “constant current protection” concept and its output current is maintained at a fixed value by means of feedback control (this fixed current level will be close to its rated output current). The only difference is : Under constant current (C.C.) operation mode (or constant current protection mode), the C.C. LED power supply is still within the normal operating range and all the components have been chosen to continuously provide this constant current output. Generally speaking, the power supply unit will operate under constant current region only when the system design belongs to “LEDs drive by the power supply directly” (Fig. 1.3).

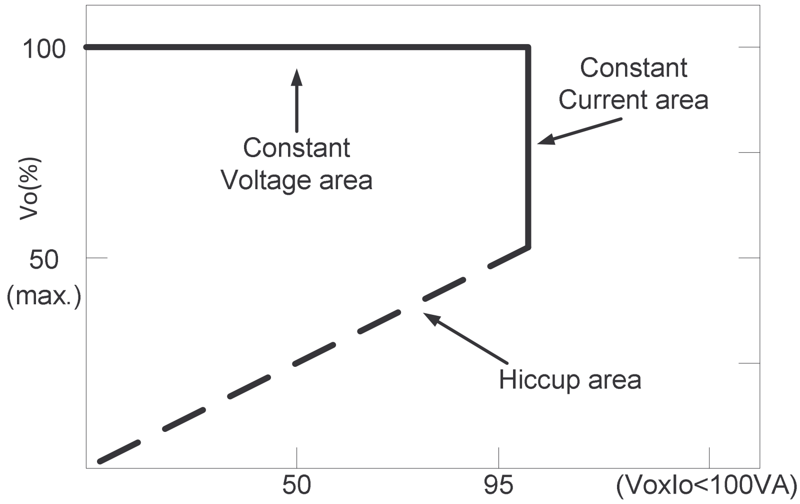


Figure 1.6: Typical LED power supply I-V curve

Fig. 1.6 is the I-V characteristic curve of a typical constant current LED power supply. The “constant current region” for each series of C.C. LED power supply may be different because of the different circuit design. As the figure shown above, the PSU will operate in the constant current region only when the output voltage is kept at 50% of rated output voltage or higher, so the sum of V_F of all series connected LEDs should be higher than this limitation. If the sum of V_F of all series connected LEDs can’t achieve 50% of rated output voltage, the power supply will go into the “hiccup region” and cannot drive the LEDs properly. Currently most of MEAN WELL’s LED power supplies can provide constant current output and the suitable operation region for directly connected LEDs is also specified in their SPECs (in the column of “Constant current range”). The constant current region can be 3V~100%V_O, 9V~100%V_O, or 70%~100%V_O in different product series because of the difference of circuit design (concerning Harmonic Class C compliance, the lower limit may reach 75% of rated output voltage for some models with PFC function). When using power supply to drive LEDs directly, designer of lighting fixture should make sure that the V_F sum of LEDs connected in series is high enough to operate the C.C. LED PSU in the correct region.

In fact, MEAN WELL’s constant current LED power supplies also possess the feature of “C.V. + C.C.”. That means before reaching the “constant current region”, they can be operated within the “constant voltage region” just like traditional power supplies. In this region, system design must incorporate suitable “LED drive IC” or “series connected with a ballast resistor”; after entering the “constant current region”, the PSU can provide constant current as the output and hence can drive the LEDs directly. We can find that the “C.V. + C.C.” characteristic can be used in many different LED installations and make the system design more flexible.

Below is the comparison chart of three different LED driving alternatives

Driving Method & PSU Selection	Feature	Advantage/Disadvantage
Direct driving Use C.C. mode power supply	Output voltage of PSU equals to the sum of V_F of all series connected LEDs and change of I_F will be greater due to changing temperature	◯ Lowest cost ◯ Highest efficiency X Unbalance current for each parallel branch X Uneven LED brightness for each parallel branch X Shorter lifetime for LEDs
Series connected with ballast resistor Use C.V. or C.C. mode power supply	Voltage difference between PSU output and sum of V_F of all series connected LEDs will be dropped on the ballast resistor; medium stability for I_F	◯ Low cost (only add on cost of the resistor) X Lowest efficiency (additional loss from the resistor)
Series connected with constant current LED driver IC Use C.V. or C.C. mode power supply	I_F of each branch connected in parallel will be adjusted by the IC automatically to the pre-set value; small tolerance for I_F	◯ Long lifetime for LEDs X Low efficiency X Highest cost

1.6 LED lamp driver structure

The most often seen LED lamp setup is the series configuration because this insures equal brightness to each of the LEDs. Even if the lamp consists of the same LED components from the same production lot there will still be slight differences in the forward voltage. As the working temperature increases, the LED forward voltage is bound to decrease leading to an increase in the forward current. This is why it will be necessary to add current limiting circuit to the LED setup. The most common driving structures are as below：

- **LED directly driven by a power supply Figure 1.7**

  This setup is the most cost effective and wirings are simple. The designer will only have to worry about LED characteristics. Once that is taken care off, all the designer has to do is select a stable power supply with constant current limiting.

However, there could still be issues with equal current sharing between each of the LED strings.

Matrix LED structure can be used to minimize extensive damage from the failure of just a few LED. If a MW constant current LED power supply is used to drive LEDs, direct connection is possible and current limiting resistors and LED driver ICs are not required to somewhat balance the current flow to each LED string. However the LED must be ranked in order to minimize large differences in the Figure 1.7 combined V_F of each of the LED strings which can lead to unbalance current flow to some of the strings and cause part of the LED structure to be damaged from high current flow.

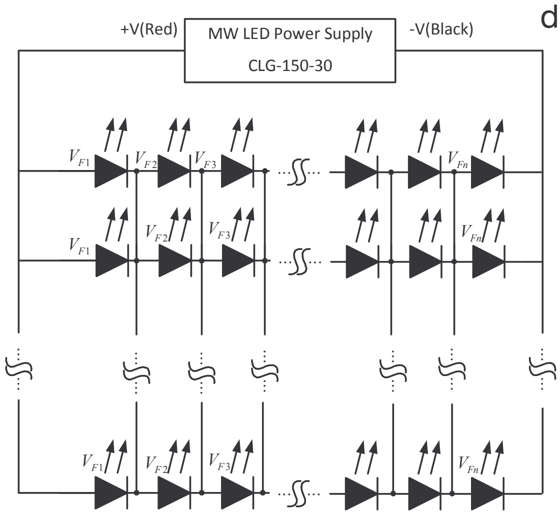
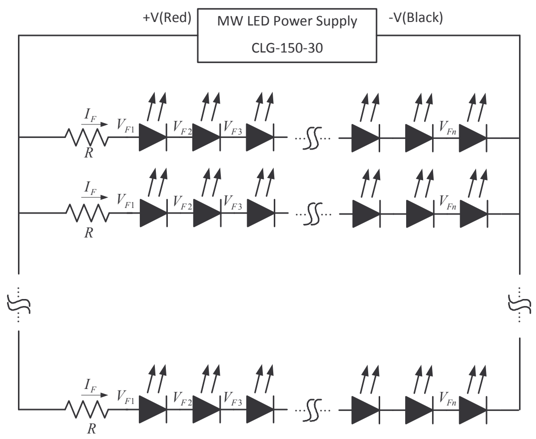


Figure 1.7 Constant current power supply drive LED load directly

- **Series connection of LED current limiting resistor, refer to Figure 1.8**

The advantage of this architecture is that it is inexpensive and rather easy to assemble. Better balance in output current as compared to the direct drive method. The disadvantages are high power dissipation of these resistors, If current varies with change in voltage, LED brightness may be uneven, can not control current precisely and lack for protection for the LEDs.



Example:
The use of CLG-150-30(30V/5A) to drive 8 LEDs in series and 8 strings in parallel

$$R = [V - (V_{F1} + V_{F2} + ... + V_{Fn})] / I_F$$

V : LED power supply rated output voltage

V_F : LED forward voltage (around 3.5V)

I_F : LED forward current (about 625mA)

$$R = [30 - (8 \times 3.5V)] / (5/8 string) = 3.2\Omega$$

Figure 1.8: Constant current or constant voltage power supply with LED driver resistor

- **Power supply in combination with linear driver IC, see figure 1.9**

The cost of this structure is moderate. Other advantages include long lifetime for both LED and the power supply, simplicity of circuit design. Disadvantages includes higher cost as compared to using driver resistor with just as much power dissipation, and unsuitable for use with high tolerance voltage source.

Linear constant current driver can not automatically adjust the current flow to the LED. It does not balance current as well as PWM constant current driver. Its basic IC structure composes of resistor + electronic switch. LED drive current is regulated through the control of the switch's conduction level.

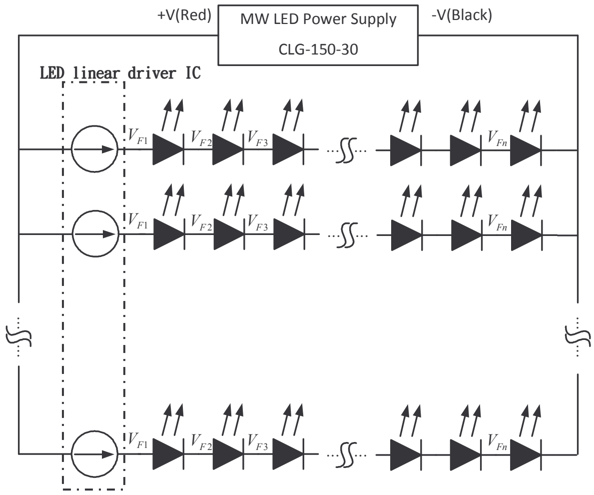
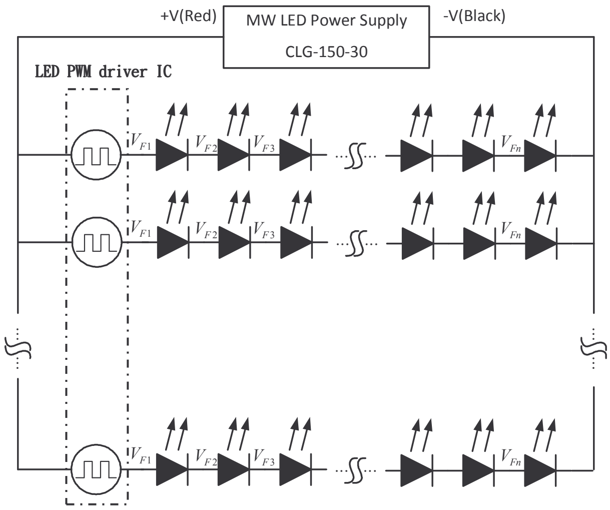


Figure 1.9: Constant current or constant voltage power supply with linear LED driver

- **Power supply in combination with PWM constant current driver IC, see figure 1.10**

This structure is the mainstream driving method preferred by most LED lighting manufacturer. The main reasons are steadiness of current control and even current sharing. Other advantages include long lifetime for both the LED and the power supply. Disadvantages include higher cost as compared to other driving methods, complicity in connection, the PWM driver can cause EMC interference and produce high frequency audio noise.



The PWM constant current driver will automatically adjust current flow to achieve balance in current for each LED string thus insure each branch has equal brightness. Main topologies include buck, boost, and buck-boost. Either pulse width or frequency is modulated to maintain constant current.

Figure 1.10: Constant current or constant voltage power supply with PWM constant current LED driver

Chapter 2
LED power supply specifications and regulations

2.1 Electrical specifications

Differences in operating environment dictates different power supply requirements. The following are some key features：

- Power factor ≥ 0.9 is required for lighting applications with the exception of decoration and commercial lighting.
- Constant voltage mode (CV): 50% minimum load for P.F≥0.9; constant current mode (CC): 75% minimum voltage for P.F≥0.9.
- Total harmonic distortion (THD): < 33%.
- Overload protection (OLP): <108% of the rated current (IEC62384 lighting regulation restricts maximum current at <110% of rated current).
- Required output currents are typically in multiples of 350/700/1050mA. Power supply selection depends on actual design.
- 277VAC input for North America region.
- Outdoor usage requires minimum ambient temperature -20^oC ~ 55^oC.
- Outdoor usage requires minimum IP65 (55) to protect from dust and moisture.
- Must withstand 4KV surge.
- Meet 5G vibration for street lights.

2.2 Safety and EMC standards

- UL1310 class 2 (output apparent power <100VA and output current≤5A)
- UL1012 (output power >100W)
- UL879 (Sign component manual- SAM list)
- EN61347-1 (lighting control gear "-1" is for lighting in general)
- EN61347-2-13 (AC-DC LED driver)
- CNS15233 (Taiwan LED street lights)
- EN61000-3-2 class C (harmonic current)
- EMI: EN55015
- EMS: EN61547; 4KV surge
- IP level / UL50/ NEMA (protect against dust and moisture level)

2.3 Main lighting regulations

- **IEC/EN61347-1/-2-13: European lamp control gear standards**

  The EN61347-1 safety standard is generally specified for lamp control gear used in Europe by IEC (International electro-technical Commission). It does not specifically standardize devices such as electronic ballasts, dimming controls or electronic inverters and converters. Moreover, test standards basically the same for different types of devices. In 2006, the EN61347-2-13 was written to standardize LED AC/DC power supplies. Currently most countries expect the U.S use this standard for LED AC/DC power supplies. Products can apply as Built-in, Independent or Integral. Independent is the most popular one. Thus, Mean Well LED power supply which can be externally connected applied for the Independent type.

  Below are the important requirements for the Independent type.

  - SELV is 25VDC. It is lower than the 60VDC of UL60950-1 and 50VDC of the EN60598-1 because children may be able to come into contact with the final products. However, theoretically this is not listed on the application. Once the SELV mark is printed on a power supply, the output voltage must be lesser than 25V so that it is touchable. If the output voltage is greater than 25V, an over voltage protection is needed.
  - Output current cannot be greater than 25A.
  - Withstand voltage is 3750VAC and secondary circuitry cannot be shorted with cases.

- **UL1310 Class 2：US power supply safety standard**
  UL1310 Class 2 is a standard that US uses to regulate low power source. More importantly, it limits the output apparent power to be lesser than 100VA, output current must be less than 5A and leakage current must be less than 0.5mA. Other requirements are not as strict or similar to ITE products. For input voltage, UL1310 regulates to 240VAC. If 277VAC input is used, the power supply must apply for UL1012 or other standards. Beside UL1310, some customers may also need UL879, which allows the power supply to be on the SAM List, so that lighting systems don't have to apply for any other safety standards.

- **UL subject 8750：LED lighting safety standard**
  UL subject 8750 is currently being drafted. In the future, UL will use it as the main safety standard for LED lighting products. Thus, LED power supply and final products must apply for this standard now in order to prevent delays in the future. Dry, damp and wet are the three main subjects for this standard. Testing and markings are also different. General power supplies standards such as UL1310, UL1012 or UL60950-1 may meet the requirements of this standard but it is better to certified with Class 2 or LPS (limited power source) because it will be easier for the product to comply to UL8750 in the future.

- **IEC/EN55015/2007：EU lighting EMI standards**
  This IEC/EN 55015 standard is written to regulate lighting system EMI. For conduction emission, it tests in between 9K~30MHz, which is not the same as the ITE EN55022 (150K~30MHz). For radiation emission, it tests at 9K~30MHz with a 2MX2M circular antenna and at 20M-300MHz at an open site location (2007 version). Currently, Mean Well LED power supplies are certified according to EN55015 with LED loads. However, we will keep updating the tests to comply with the 2007 version which becomes effective in 2010.

- **EN61000-3-2 Class C：**
  If a power supply output power is greater than 25W, it must meet Class C. Otherwise it can be test withed the class D standard. The order of strictness is Class C > Class D > Class A. For ITE less than 100W, power supply will pass Class A without PFC. In order to pass Class C and Class D, power supply must have PFC.

- **IEC/EN61547：EU lighting EMS standards：**
  IEC and EU use this standard to regulate lighting product EMS. This standard is similar to ITE EN55024 because they adapt it from EN61000-4 except for PM and DIP.

- **CNS15233：Taiwan LED street light safety standard**
  This standard was implemented to regulate LED street lights. The safety standard is adapted from the international street light regulation EN60598-1/-2-3. PF must >0.9 and THD<33%. Harmonic current must be in compliance with EN61000-3-2 Class C. EMC must meet EN55015 and EN61000-4-5, which includes 4KV surge. IP level must meet IP65. Mean Well CLG 60～240 does meet all the above standards.

2.4 Worldwide LED lighting safety standards

EU：LED lighting power supply (application/system) safety requirement mainly based on EN61347-1 + En61347-2-13. Other application marks include: MM (….), F mark (…) and IP level (protect against dust and moisture), and etc.

North America： In the future, LED power supply will be based on underwritten UL 8750 (UL1310, UL1012, and UL 60950-1). Final products with specified operating environment will follow standards such as UL48, UL65, UL588, UL1598 and UL879 (SAM list).

China：China currently does not have EMC standard for LED power supplies. Standards are mainly adapted from E.U EMC standards like GB7000.1 (EN60958-1), GB19510.1～GB19510.12 (EN61347-1; EN61347-2-*) and; EN61347-2-13 LED control gear)

Taiwan：Taiwan safety standards also adapted from IEC and EU standards but it doesn't have specific EMC standards for LED power supplies.

Other countries：Other country's lighting safety standards are under development such as Korea EK mark, Japan PSE mark, and Australia EMC standards. Basically, they all accept EN61347-11-2-13 which can be transferred from CB. However, each country will still add on their own test requirements.

LED safety regulations by country					
	Taiwan	China	EU	North America	Notes
LED power supply	CNS15174 C4499 IEC62384	GB19510.1	EN61347-1 EN61347-2-13	UL8750 UL1310 class 2 UL60950-1 (LPS) UL1012 (system concern)	Mainly EN61347-2-13 (USA bases mainly on UL1310 class2)
Lighting system	CNS15015 C4500 CNS14335	GB19510.1 GB19510.2~13 GB7000.1~18	EN61347-1 EN61347-2-2~12 EN60598-1 EN60598-2-2~24	UL1310 UL60950-1(LPS) UL1012 (system) UL48/UL65/UL588/ UL1598/UL879 (SAM List)	Mainly EN61347-1 & EN60598-1 (except USA)
Street light	CNS15233 CNS9118	GB7000.5	EN60598-2-3	UL8750 UL1598	Mainly EN60598-2-3
IP level	IP65 (power IP54)	IP55	IP55	UL50 NEMA 3×~4×	>IP55
Other requirements			MM Mark、F mark、SELV	SAM list	

2.5 LED lighting EMC standards

Lighting EMI standards is not the same as ITE. Testing requirements also are not the same. For EMS, it is only a bit different comparing with ITE.

EU: EMI based primarily on EN55015 (lighting regulation) + EN61000-3-2/3 and uses EN55024 (ITE regulation) as supplement. EMS based primarily on EN61347 (lighting regulation) and uses EN55024 (ITE regulation) as supplement.

North America: FCC part 18 (limit lines are different from EN55015 and EN55022, but compliance to EN55022 also means it can meet FCC part 18).

China: GB17743 (lighting regulation EN55015) + GB18595 (lighting regulation EN61547) + GB17625 (harmonic current regulation EN61000-3-2,3).

Taiwan: EMI CNS14115 (lighting regulation EN55015) + EMS CNS14676; LED street light CNS13438 (ITE regulation EN55022).

LED EMC standard by country						
		Taiwan	China	EU	North America	Note
Lighting standard	EMI	CNS14115 CNS13438	GB17743	EN55015	FCC Part 18	Mainly EN55015
	EMS	CNS14676	GB18595	EN61547		Mainly EN61547
Harmonic			GB17625.1	EN61000-3-2 Class C		Mainly EN61000-3-2

2.6 Introduction to IP level (IEC60529)

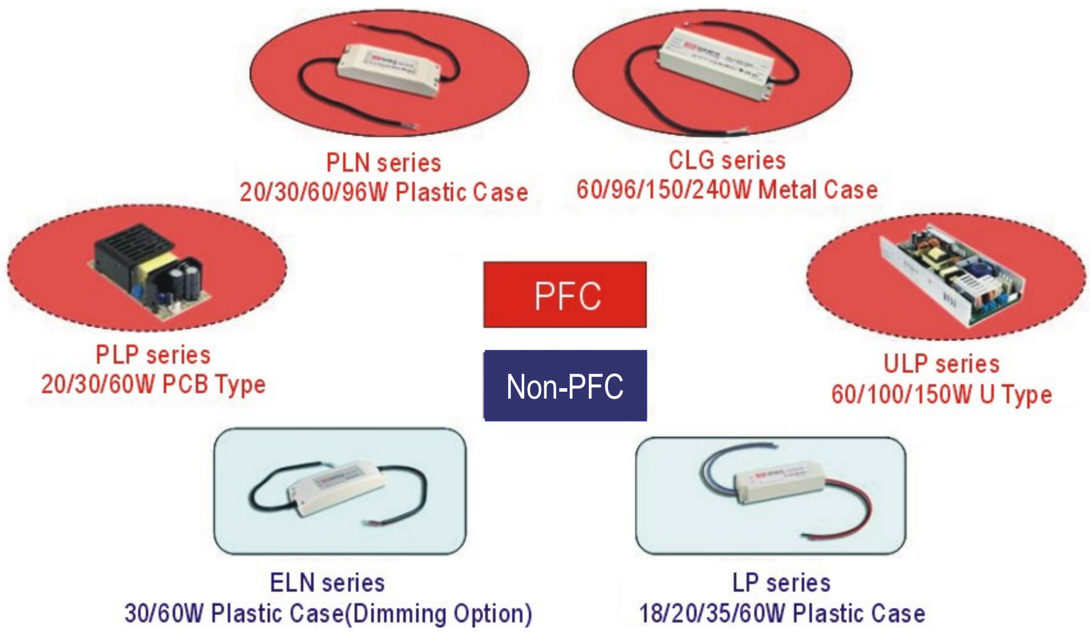
MW has incorporated dust proofing and water proofing into majority of its LED power supply design. Mainly based on the international standard IEC60529, detailed descriptions can be found in the following table：

(Note: IP64 or above suitable for use in high moisture indoor or outdoor environment)

IP xy protection level	
Degree of protection, foreign bodies (x)	Degree of protection, moisture(y)
0. Not protected 1. Solid foreign object (>50mm) 2. Solid foreign object (>12mm) 3. Solid foreign object (>2.5mm) 4. Solid foreign objects of 1,0 mm diameter and greater 5. Amount of dust that would interfere with normal operation 6. Dust tight	0. Not protected 1. Vertically falling water drop 2. Vertically falling water drop when enclosure is tilted up to 15 degrees 3. Water sprayed at an angle up to 60 ° on either side of the vertical 4. Water splashed against the component from any direction 5. Water projected in jets from any direction (12.5 liter/minute) 6. Water projected in powerful jets from any direction (100 liter/minute) 7. Temporary immersion in water (1 meter from the surface of the water for 30 minutes) 8. Continuous immersion in water, or as specified by the user

Chapter 3
How to choose MW LED power supply

3.1 MW LED power supply family



3.2 How to choose a suitable LED power supply

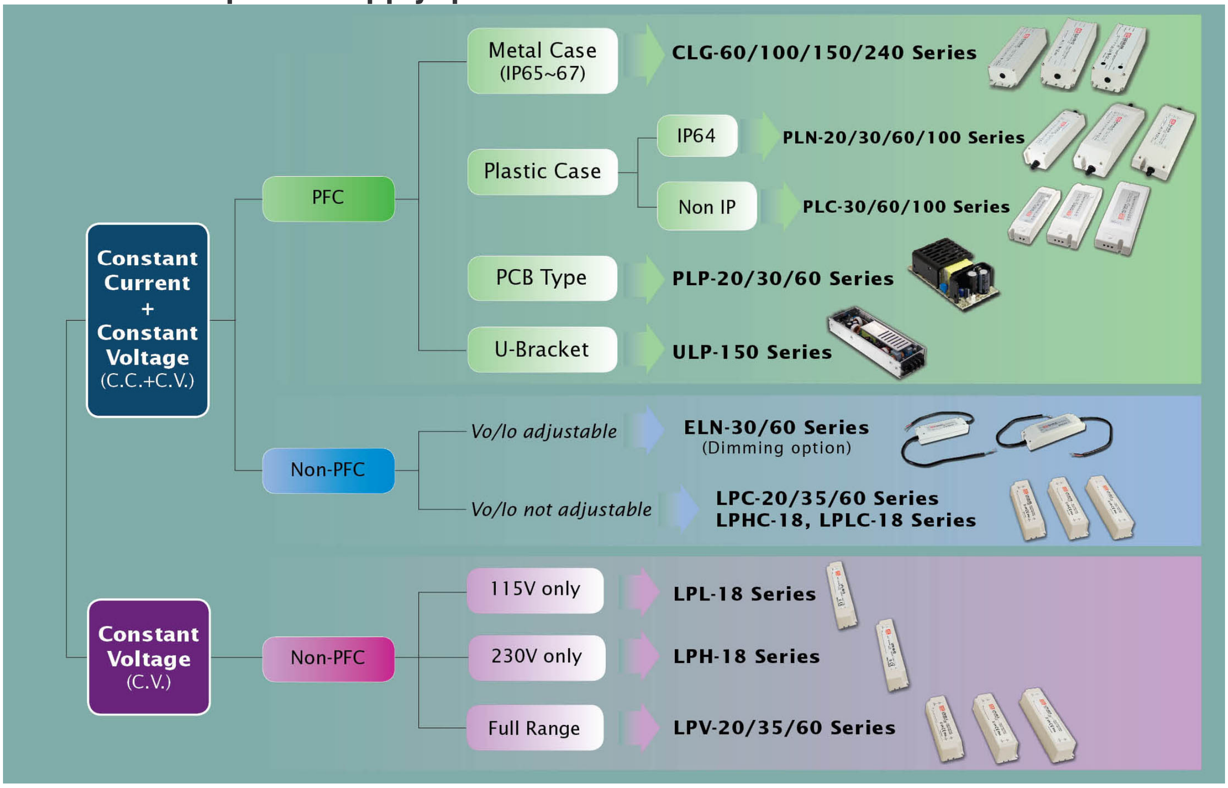
1. Power rating should be based on actual LED load requirement also include some tolerance in power.

2. Confirm LED drive method：
- Use MW power supply to drive LED lamp directly.
- Use MW power supply in combination in with constant current LED driver. IC to achieve precise constant current control.
3. Whether it is necessary to have power factor correction (PFC). Refer to the comparison chart below.
4. Confirm operating environment of the LED power supply in order to select suitable IP level and mechanical design (metallic enclosure, plastic enclosure, PCB type).
5. Confirm whether the application requires safety certifications.
6. If the power supply is going to drive the LED directly, model with adjustable voltage and current might be more preferable. Also, whether or not dimming function is needed ？

MW LED power supply comparison chart

Model	Case material		Potting	PFC	V/I Adjustment	IP	Hold-up Time	Ripple & Noise	Optional dimming	Application
	Metal	Plastic								
CLG-150/240 (not class 2)	v		v	v	v	65/67	Normal	Normal		General
CLG-100	v		v	v		67	Normal	Normal		General
CLG-60	v		v	v		67	None	High		LED
PLN-100		v		v	v	64	Normal	Normal		General
PLN-30/60		v		v	v	64	None	High		LED
PLN-20		v		v	Only I	64	None	High		LED
PLC-100		v		v	v	None	Normal	Normal		General
PLC-30/60		v		v	v	None	None	High		LED
ELN-60		v			v	64	Normal	Normal	v	General
ELN-30		v			v	64	Normal	Normal	v	General
LPH/LPL-18 LPHC/LPLC-18 LPV/LPC-20/35/60		v	v			67	Normal	Normal		General
PLP-20/30/60	PCB type			v	Only I	None	None	High		LED
ULP-150	U type			v	v	None	Normal	Normal		General

3.3 MW LED power supply quick selection table



3.4 MW LED power supply specification

Spec sheets includes information such as output electrical characteristics, input specifications, load conditions, protection functions, operating environment, safety and EMC compliance, and other importance notices. Please go to the MW website (www.meanwell.com) to download this information.

Chapter 4
Application on LED power supply

This chapter includes instructions on use of LED power supply, explanation of protection functions and dimming function, and issues on heat dissipation of LED. Suggested solutions for possible EMC problems in field applications will be also provided in this chapter.

4.1 Instructions on Assembly

- As step 1 shown in figure 9, connect LED luminaries to the output cable of Mean Well LED power supply.
- As step 2 shown in figure 9, connect the input cable of Mean Well LED power supply to AC mains.

! CAUTIONS: Step 1 should always come before step 2. If step 2 comes first, a high transient surge current will go into the LED luminaries and it can damage LEDs in an LED luminaries without LED driver IC.

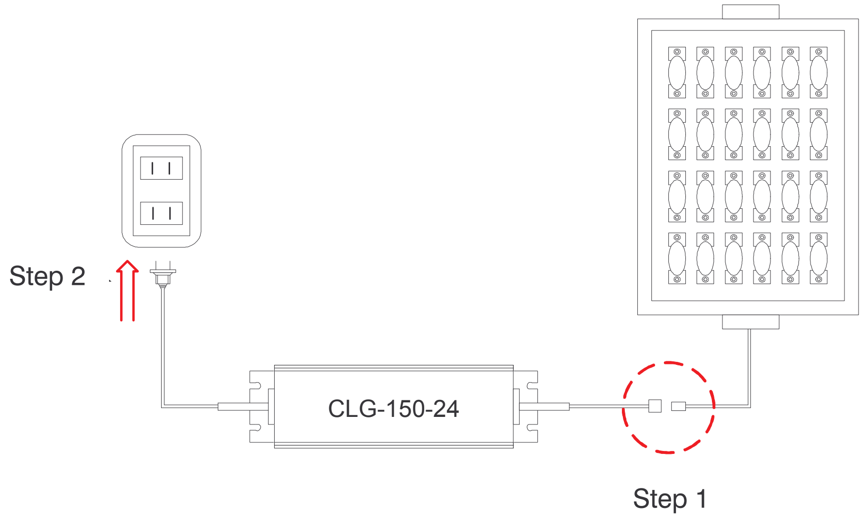


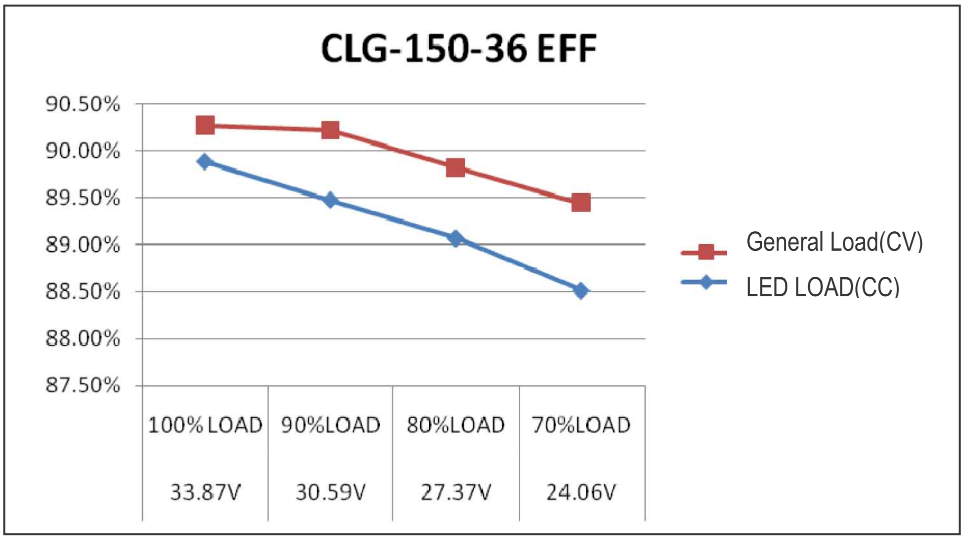
Fig.4.1: Assembly of LED power supply

4.2 Protection function

All of Mean Well's LED power supplies are designed with protection functions against inrush input current, peak input voltage, short-circuit at output, overload (OLP) at output and over voltage (OVP) at output. Some models also equip with over temperature protection (OTP). Please refer to Mean Well's switching power supply technical manual for detailed information.

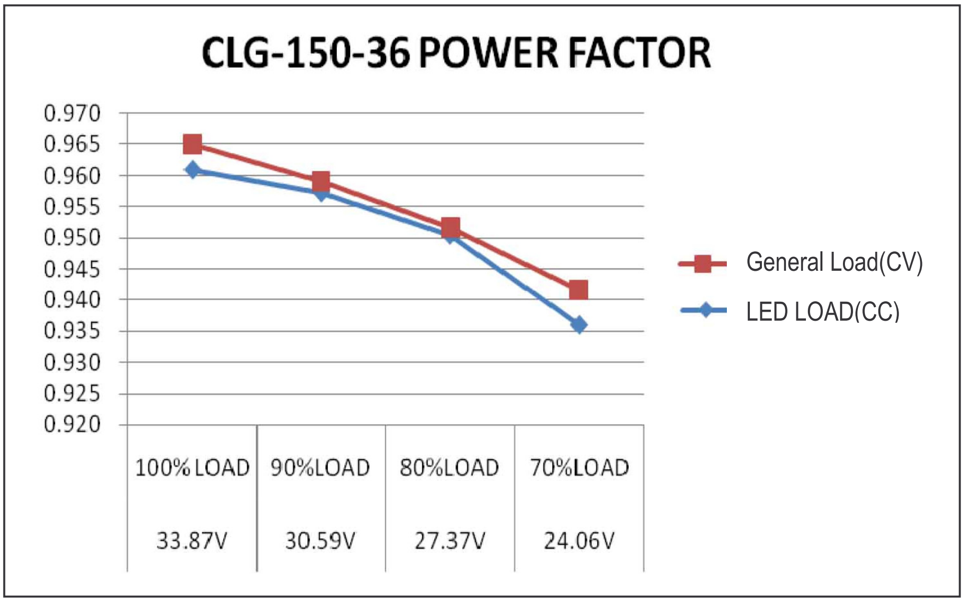
4.3 Effect of output load on efficiency

The types and levels of output load have significant effects on the efficiency of a power supply when operating at normal conditions. The chart below presents the change of the efficiency of CLG-150-36 operating at 70～100% LED load and 70～100% general load, and indicates that the efficiency will be lower as the total Vf (forward voltage) of LEDs in series is lower when LEDs are directly powered by LED power supply. Therefore, it is a better design to set the total Vf of LEDs in series at 85～95% of the rated voltage of the power supply.



4.4 Effect of output load on power factor (PF)

The effect of different types of load on power factor (PF) and harmonic current is as shown in the chart below. The power factor of Mean Well's LED power supply operating at LED load will be lower than at general load, and the total Vf level of LED in series will also affect power factor. Therefore, it is a better design to set the total Vf in LED luminaries close to the rated output voltage of the power supply.



4.5 Comparison of circuit topologies with power factor correction (PFC) function in LED power supply

Mean Well's LED power supplies equipping with power factor correction function mainly adopt the two kinds of circuit topologies below. A Comparison between circuit topologies with and without PFC function is shown as the table below.

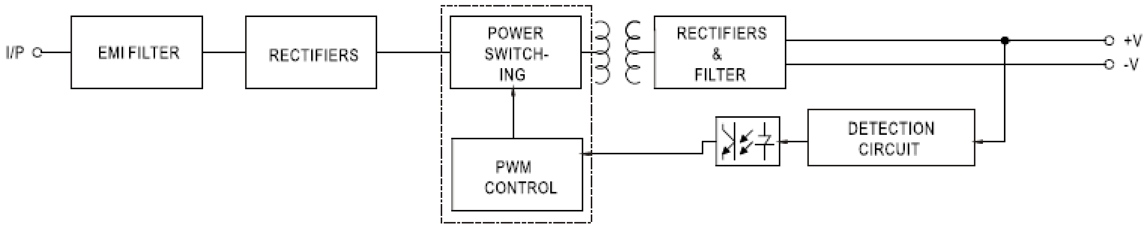


Fig.4.2: Block diagram of non-PFC circuit topology

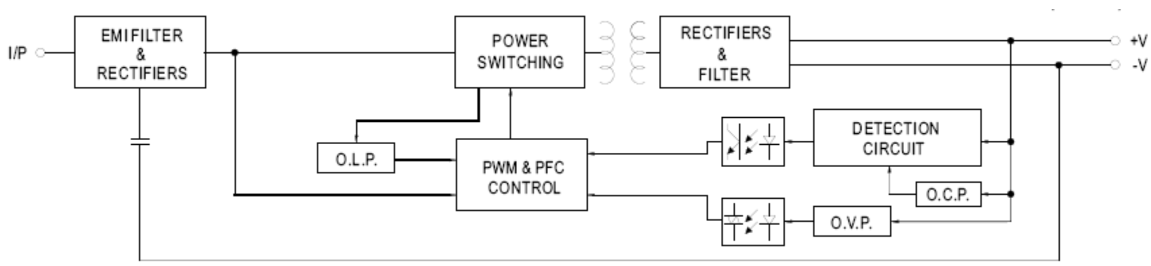


Fig.4.3: Block diagram of circuit topology with single stage PFC

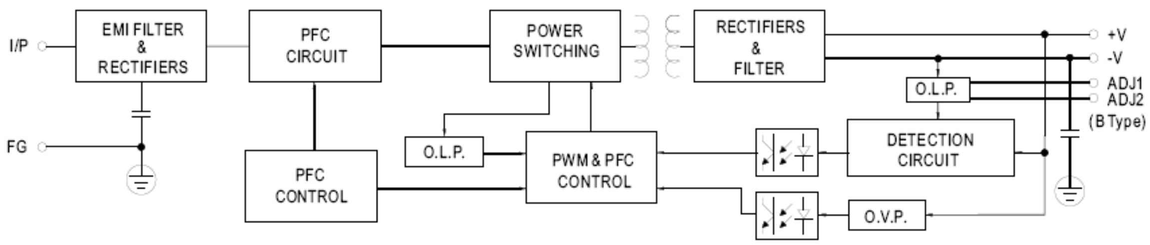


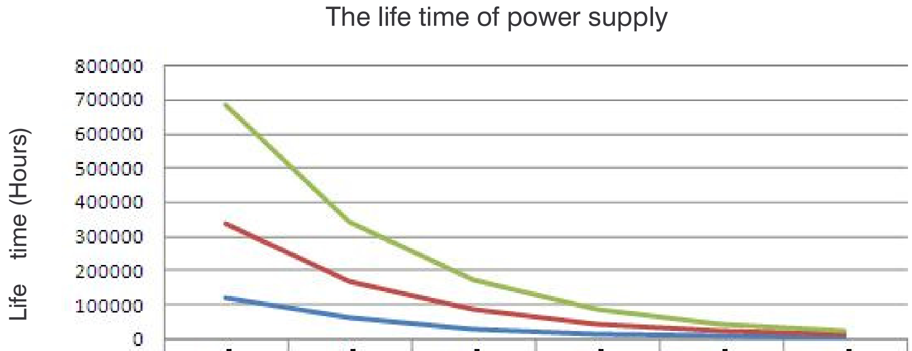
Fig.4.4: Block diagram of circuit topology with two-stage PFC

Circuit Topology	Representative Models	Advantage & Disadvantage	Limitations on Application
Non PFC (Fig.4.2)	ELN series LPV/C series LPL/H series	Advantage ・Low cost ・Simple circuit design with reliable electrical performance Disadvantage ・Not correspondent with PFC demand in energy saving ・Cannot meet major norms for LED luminaries	・Not for EU market & other major markets of LED luminaries ・Cannot meet energy saving requirement ・Same electrical characteristic as power supply for general purpose
Single stage PFC (Fig.4.3)	CLG/PLN-60 PLN-30 PLP-30/60	Advantage ・Low cost ・Simple circuit design ・High efficiency performance on small power rating design Disadvantage ・High output ripple voltage (15~20 times of two stage design) ・Difficult design of feedback circuit ・PF & THD easily affected by design of feedback circuit	・No holdup time worse immunity to fluctuation of AC mains ・High output ripple current – decrease life time of LED module directly powered by power supply ・Slow response time of feedback circuit, high effect of load characteristics
Two stage PFC+PWM (Fig.4.4)	CLG/PLN-100/150/240	Advantage ・Suitable for high power rating design ・Good PFC characteristics ・Easy design of feedback circuit ・Good load characteristic Disadvantage ・High cost ・Complicated circuit design	・Can be used for most of field applications

4.6 Heat dissipation of LED

LED is actually not with high luminous efficiency. Only 30% of supplied power is converted into visible light; the remaining of 70% is lost as heat. Due to this, thermal design plays an extremely important role in LED applications. According to the temperature characteristics of LED, luminous flux will attenuate by 3% and reliability will decrease by 10% for every temperature increment of 5℃ on LED. Therefore, temperature rise of LED is the major factor in life time and light loss.

- All of Mean Well's LED power supplies adopt thermal design of free air convection. Maximum operating temperature can reach 50℃~70℃. In addition, the metal enclosure of CLG series is able to release the heat through system case in where CLG series is installed, so as to improve system reliability.
- The life time of LED power supply is highly relevant to operating temperature. Take CLG-150 as example, for operations at the same load level, the lower the operating temperature, the longer its life time; for operations at the same operating temperature, the lighter the load, the longer its life time. When choosing a power supply, it is recommended to add a margin to the actual power usage to match the longer life time characteristic of LED. The relationship is as shown in Fig.4.5.



	20℃	30℃	40℃	50℃	60℃	70℃
50%Load	348612	174306	87153	43576.5	21788.25	10894.125
75%Load	215688	107844	53922	26961	13480.5	6740.25
100%Load	120384	60192	30096	15048	7524	3762

Fig.4.5: Relationship between output load, operating temperature and life time in LED power supply

- In Fig.4.6 (de-rating curve for CLG-150), in order to avoid high temperature rise and maintain the reliability of the power supply, the rated power capability needs to be de-rated when ambient temperature exceeds 55℃ for operation at 230Vac input. Due to the abovementioned, the management of operating temperature should be taken into consideration in system design.

It is suggested that the thermal design should be based on operating temperature, power usage, and other environmental conditions, etc., or the power supply can be installed in the place with relative low ambient temperature in the system.

- CLG-150 is designed with built-in thermistors for suppression of inrush current. As the resistance of thermistors will become higher as ambient temperature goes lower, CLG-150 can only be powered on at -10℃ at 110Vac input, but can at -30℃ at 230Vac input. For applications only requiring 110Vac input (230Vac input not required), decreasing the resistance of thermistors can improve startup problem at low ambient temperature.

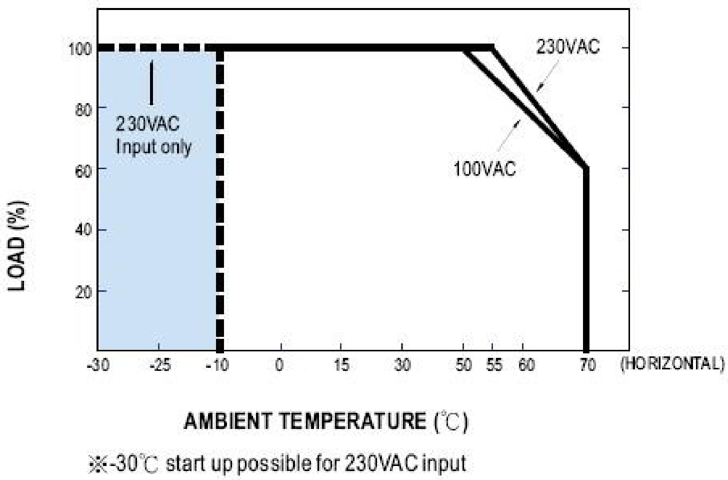


Fig.4.6: De-rating curve for output load against ambient temperature in LED power supply

4.7 Adjustment of output voltage and current

Some Mean Well's LED power supplies equip with functions of adjustable output voltage and current. Models with IP67 design (potted with heat transfer silicone) do not allow adjustment of output voltage and current, but CLG-150A/240A is with special design that allows external adjustment; for models with plastic enclosure, adjustment can only be made after taking apart the top cover. Adjustable voltage range will be +/-10% or +0/-15% of rated value and adjustable current range will be about 50～100% of rated value.

4.8 Dimming function

ELN-30/60 series is designed with optional dimming function (option when order). The dimming function accepts two kinds of input source. One is 1～10V DC voltage source (D type in Fig.4.7) and the other is PWM (Pulse Width Modulation) signal (P type in Fig.4.8). When using D type dimming function, 50% of light intensity of LED can be achieved by applying external 5V DC voltage to have the supply current for LED to be at 50% of rated value of ELN-30/60; when using P type dimming function, 50% of light intensity of LED can be achieved by applying a PWM signal with 50% duty cycle to have the supply current for LED to be at 50% of rated value of ELN-30/60. The output cable of ELN-30/60 models with dimming function has four wires. Red is for positive output, black for negative output, blue for positive input of dimming function (DIM+), and white for negative input of dimming function (DIM+).

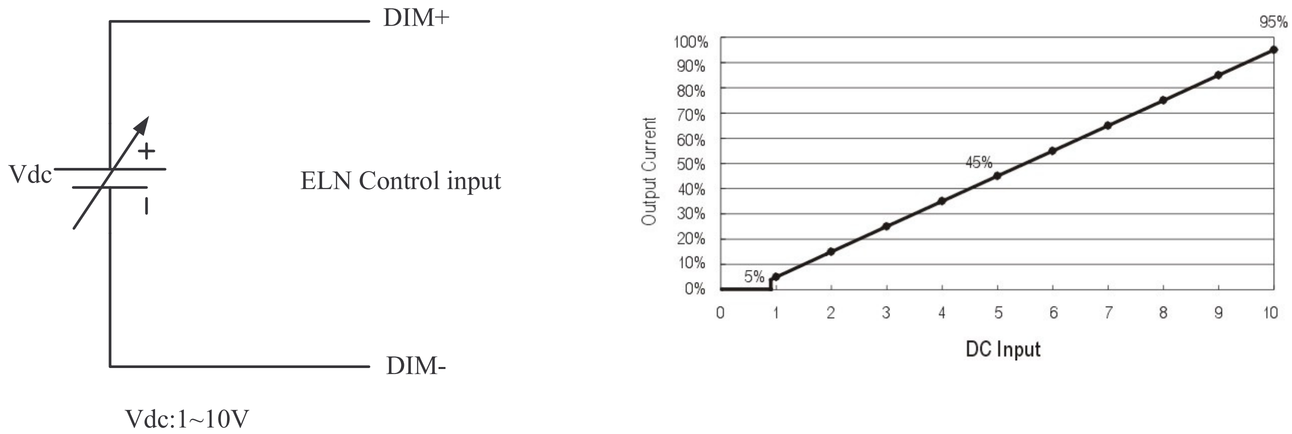


Figure 4.7: 1～10V DC voltage dimming control method (D-type)

Illumination grade white light LEDs are not suited for linear dimming control method. In order to avoid color cast of white light as a result of change of luminescence spectrum of LEDs, an appropriate dimming control method should be to change the light intensity by supplying current pulses of different width, and the pulses should be at fixed amplitude of forward current (If). Typical dimming functions mainly adopt the following control methods: PWM (Pulse Width Modulation), PFM (Pulse Frequency Modulation), and PAM (Pulse Amplitude Modulation).

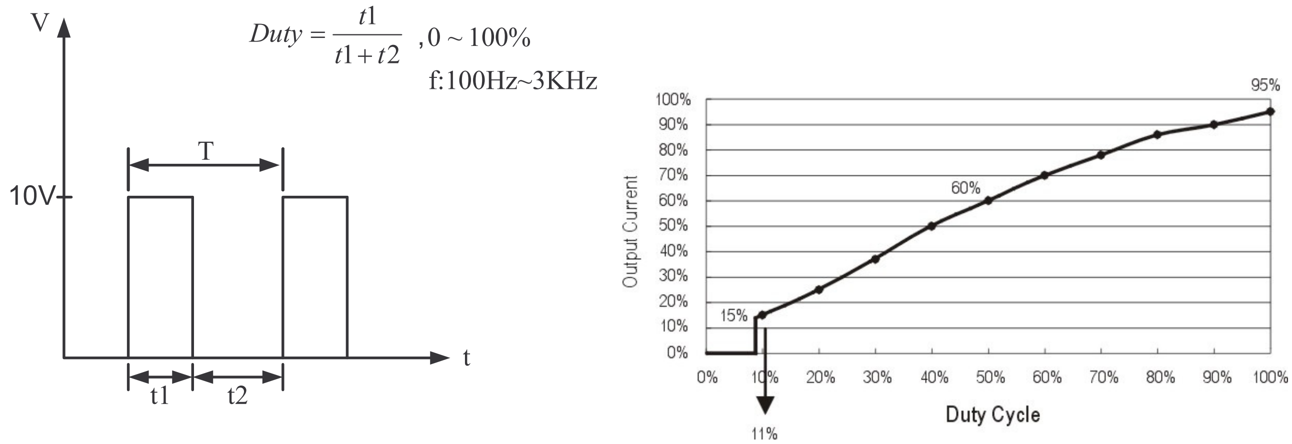


Figure 4.8: PWM dimming control method (P-type)

PWM technique is a traditional dimming control method. It supplies simple digital pulses to repeatedly turn on and off the LED driver. The light intensity of LEDs can be varied by using digital pulses of different width to change the supplied current. The advantages of PWM technique are to be able to provide high-quality white light, easy for applications and with high efficiency. But the fatal weakness is to easily generate electromagnetic interference. Sometimes it can even generate audible noise.

4.9 Suggested solutions for EMC of LED luminaries

- **Metal enclosure grounded to FG (Frame Ground)：**

  For applications with FG connection, it is suggested to bond the metal cases of LED power supply and LED module to FG to reduce EMI (Electromagnetic Interference) of the whole system.

- **Wiring：**

  Since the input and output cable length can be meters due to actual field applications, the common mode noise can be highly significant. To effectively reduce the noise, a clip-on common-mode core can be installed on the wiring close to LED module. This solution also applies if AC input cable is too long. Please refer to Fig.17 for illustration.

- **High surge level requirement：**

  In order to meet requirement of surge level for outdoor applications, the surge immunity of CLG-60/100/150/240 is designed to be up to 4KV. For surge immunity of higher level, varistors or gas tubes (500V rating) can be installed in the outside of the power supply. But the configuration should also comply with requirements in safety norms. Please refer to Fig.4.9 for illustration.

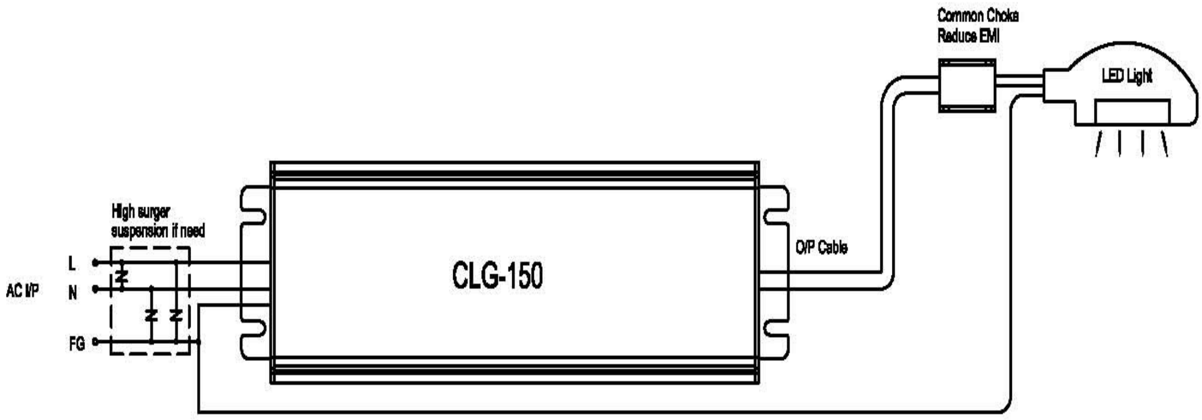


Fig.4.9: Illustration of suggested solutions for EMI and surge immunity

- **LED module with driver IC：**

  Since LED driver IC is a circuit topology employing high frequency switching (hundreds of KHz to several MHz), using it to deliver constant current to LED modules can complicate EMI debugging. Due to the EMI concerns, it is more than important to suppress the noise from driver IC. The PCB layout should focus on the size of driver IC's ground trace and configuration of In/out capacitors and inductors. It is suggested that common choke, differential choke and high-frequency X capacitor should be incorporated into the PCB layout between the output side of power supply and the circuit of LED driver IC. Please refer to Fig.4.10 for illustration.

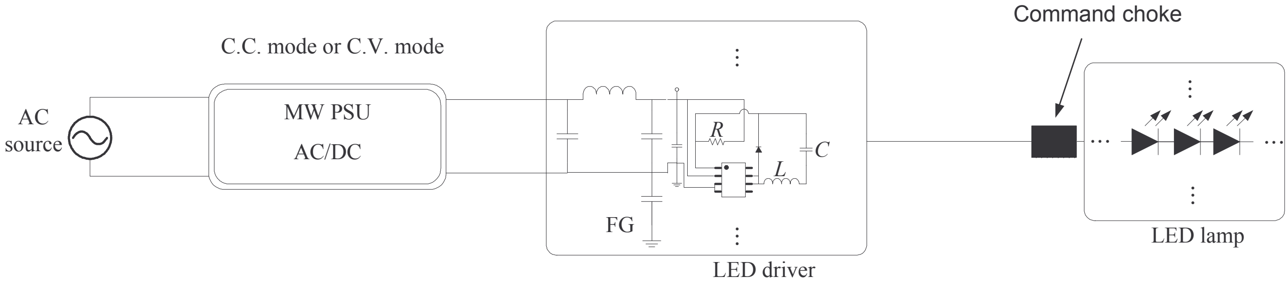


Fig.4.10 Illustration of suggested EMI solutions for LED driver IC

4.10 Use of waterproof connector：

Applications for outdoor use or indoor use of damp locations would require LED power supplies to be IP (Ingress Protection against dust and water by IEC60529) rated. Therefore, Mean Well's CLG and LP series are designed to be IP67 rated, and PLN and ELN are IP64 rated. However, although the design of the body of Mean Well's LED power supplies can meet the requirement of most of applications at outdoor or at indoor damp locations, the input and output cables are only with bare wires, which are not IP rated, for the convenience of field applications. Because the whole LED luminaries should be IP rated in field applications, input and output connections with waterproof connectors as follows (see Fig.4.11 & 4.12) should be used to meet the requirement of IP rating. Mean Well will provide 3 types of waterproof connectors (Fig 4.13). Please contact Mean Well's authorized local distributors or sales representatives for details.

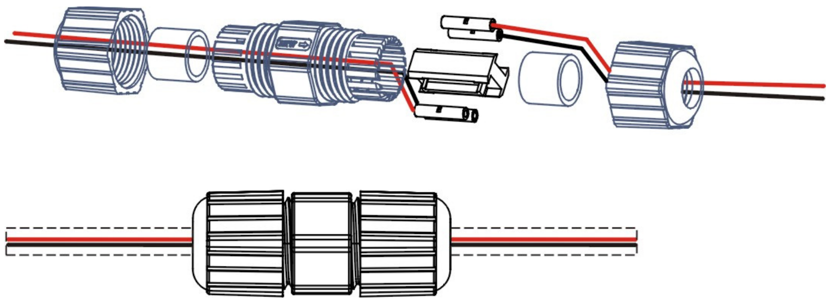


Fig.4.11 Exposed (break down) view of typical waterproof connector

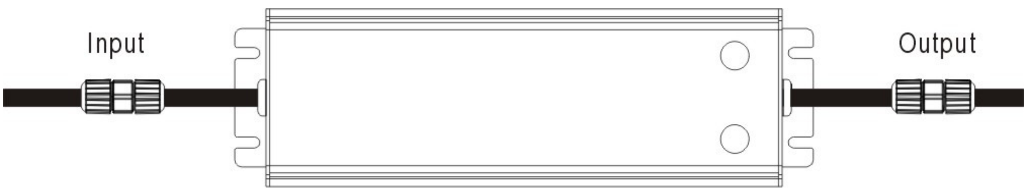
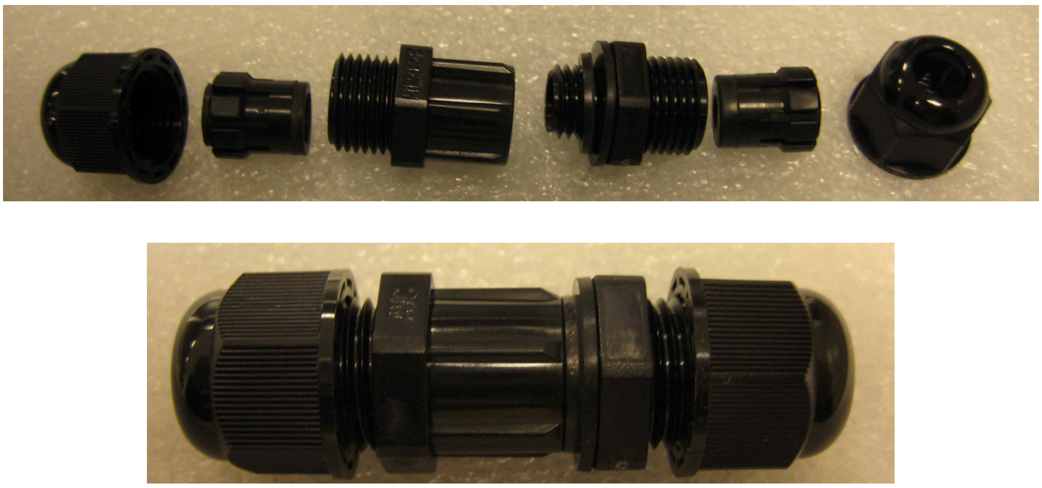
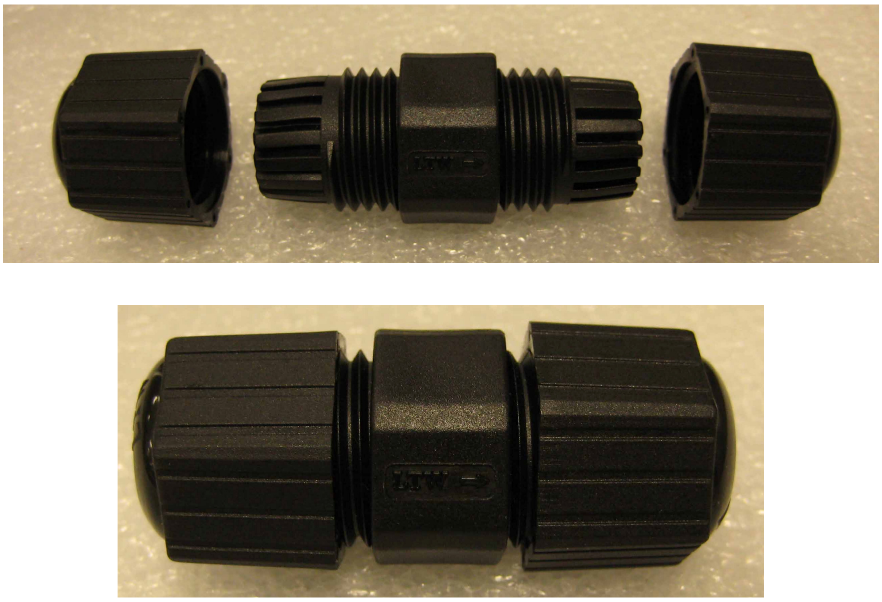


Fig.4.12 Setup diagram of LED power supply with waterproof connectors



（A）



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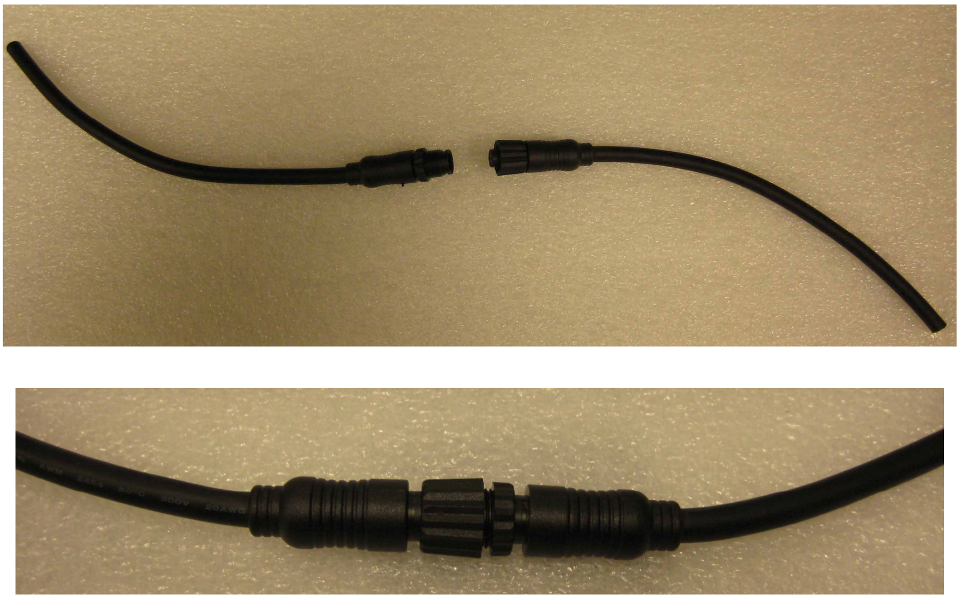

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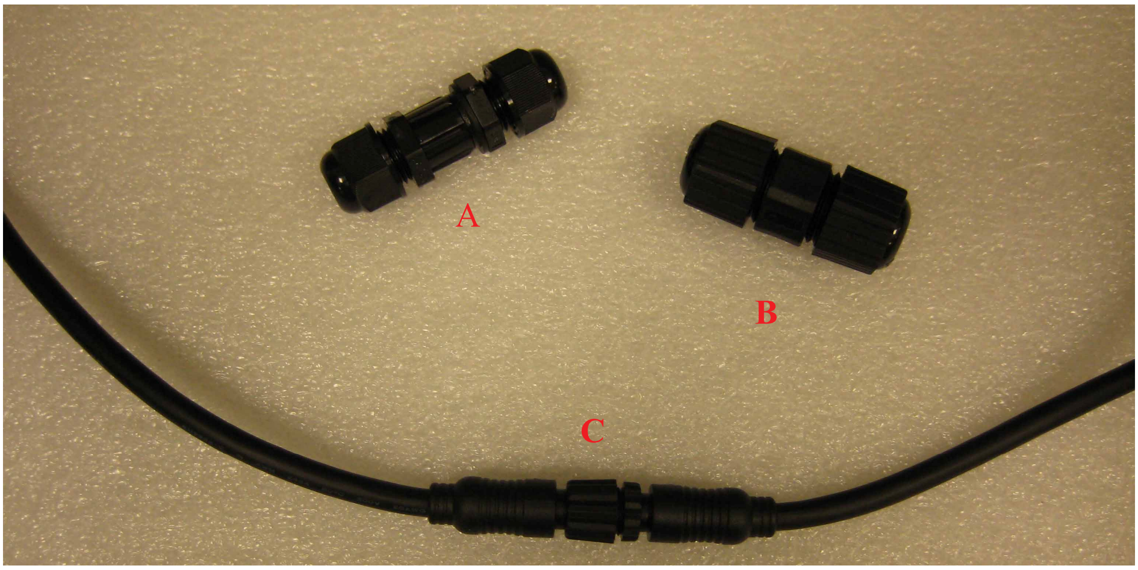

Fig.4.13 Optional waterproof connectors for MW LED power supply

Customized MW LED power supply can be offered with customer defined input and output cable length. Standardized optional cable length are 30cm,50cm,75cm,100cm,150cm, 200cm, 300cm and up to 500cm. If waterproof connector is also required, the recommended product code is as follows：

CLG-150-24A-I50A-050A

- CLG-150-24A: MW LED power supply
- I50A: Input cable length equals to 50cm with type A waterproof connector
- 050A: Output cable length equals to 50cm with type A waterproof connector

Chapter 5
LED driver design and comparison of actual results

5.1 LED driver IC circuit design

The main function of LED driver IC is to convert DC voltage into constant current source. At the same time take the voltage and current requirements of the LED device into consideration and meet these requirements. LED driver is similar in design to DC to DC converter. The following are some suggestions on design considerations. For detail information, you should still refer to the application notes provide by the LED driver manufacturer. The 2 main functions of the LED drivers are as follows：

1.Maintain constant current at all times, even when the power source voltage may vary as much as +/-15%, the current variation should still be limited to within +/-5%. The reasons being：

- Avoid exceeding the maximum rated current of the LED or else its reliability will be affected.
- Achieving the desired brightness and to ensure consistency of all LED brightness.

2.The drive circuit should maintain low power dissipation, so that the LED system as a whole can reach high efficiency demands. LED driver IC can be used with a suitable power supply to accurately control the supplied current.

5.2 Common LED driver structure

Buck converter, boost converter, and buck-boost converter can be picked based on the forward voltage level of the series connected LEDs.

Using buck converter as an example, the design consideration are as follows：

- The input voltage must be higher then the output voltage.
- The LED forward voltage will decrease as the temperature increases.
- It should be noted that input voltage level can not be higher than the rated input voltage of the LED driver IC.
- Input voltage equation： $V_{in} = n \times V_f + V_r$
  - V_{in} ：Input voltage provided by the power supply
  - n ：number of LEDs connected in series
  - V_f ：LED forward voltage
  - V_r ：Converter voltage drop, typically 2 ~ 3V

- **Driver IC should be selected based on actual load condition. Factors to be aware of：**
  - Driver IC's rated input voltage range.
  - What is its maximum current rating.
  - Layout for high frequency switching is very important.
  - If the load consists of many LEDs connected in series, the boost or buck-boost structure can be selected.

- **Selecting a suitable LED power supply**
  - Decision based on wattage requirement of the load.
  - Decision based on operation condition, whether IP rating is required.
  - Select rated voltage based on number of LEDs connected in series.
  - The need for dimming function.

The driver IC circuit should incorporate either soft start or buffer circuit as a means to minimize the possibility of LED driver latch from compatibility problem between the driver and the LED power supply.

In order to minimize heat generation and achieve constant brightness for a variety of voltage systems, the total maximum forward voltage must be close to, equal to or less than the supply voltage substrate by the working voltage of the LED driver. The maximum power dissipation found on the LED driver will occur when LED forward voltage is at its lowest and the input voltage from the power supply is at its highest.

5.3 Design notes

1. LED driver layout design notes

In terms of layout, critical components (OP capacitor, IP capacitor, diode) for the converter should be placed as close to IC as possible. This will avoid production of peak pulse caused by the inductive element of long PCB trace which may go into the IC causing IC failure. Such pulse may also cause electromagnetic interference and high output ripple. A decent layout design should be able to withstand this peak pulse interference. If the buck converter rectifier diode is place in an unsuitable location, a RC buffer can be added to patch the problem, however this RC circuit must be placed very close to the driver IC between the switch and the circuit ground.

2. PCB feedback layout design considerations

- Feedback trace should be kept short and away from sources of interference (such as switches, diodes, or inductors). But, it should not drastically alter the intended original layout design.
- Feedback trace must be placed orthogonal to the noise trace and not in parallel.

3. PCB ground layer design notes

- When using double side PCB, it is common practice to have one side consist of just the ground layer. It serves the dual purpose of heat dissipation and reducing EMI.
- Feedback trace should also be located at the bottom of the signal trace, thus eliminate field effect and line inductance.
- The capacitance effect created by the ground layer and the trace of the top layer can effectively reduce noise and electromagnetic interference.
- It is not necessary to change the location of key component for the sake of adding the grounding layer.
- In multiple layer PCB design, a ground layer should be placed in the inner layer with close proximity to tightly spaced components.

5.4 Example of LED driver design

Ex：Design a DEMO lighting system capable of testing 20~36V/30~240W LED POWER. LED specifications are VF=3.1~3.3V；IF=1A. How should the driver circuit be designed？

1. Decide what will be the number of LEDs connected in series, 6*3.1V=18.6V, 10*3.1V=31V, each string will consist of 6~10 LEDs connected in series.
2. Decide what the LED current should be. The optimum LED IF current is 2/3~3/4 of the rated current. 0.66A was chosen as the LED drive current.

This means each LED will dissipate about 2W. With a total of 72 LEDs, the total power dissipation will be 144W. Also incorporate a parallel resistor which can increase the IF current to 1A making per LED dissipation at 3W and total power dissipation 216W.

3. When the DEMO board is set at 9 in series and 8 in parallel, 9*3.1V=27.9V, 0.66A*8=5.28A, 27.9V*5.28A = 147.312W. According the above specification, we can select CLG-150-30 as the LED power supply (with rated current of 5A,it will be working in the CC mode)
4. If switch to the direct drive mode, the power supply voltage will be clamped down by the forward voltage of 27.9V. Current provided by the power supply will be at the constant current level of 105%. The constant current point can be adjusted by using the built-in VR.
5. While testing PLN-30-20(20V/1.5A), the LED configuration used will be 6 in series and 2 strings in parallel, 6*3.1V=18.6V, 2*0.66A=1.32A, 18.6V*1.32A=24.552W

Using the above cases as the base for design and taking LED driver characteristic into consideration, a suitable LED demo board was designed and built. Testing was done using both the direct drive method and the driver IC method. Comparison results can be found in section 5.5.

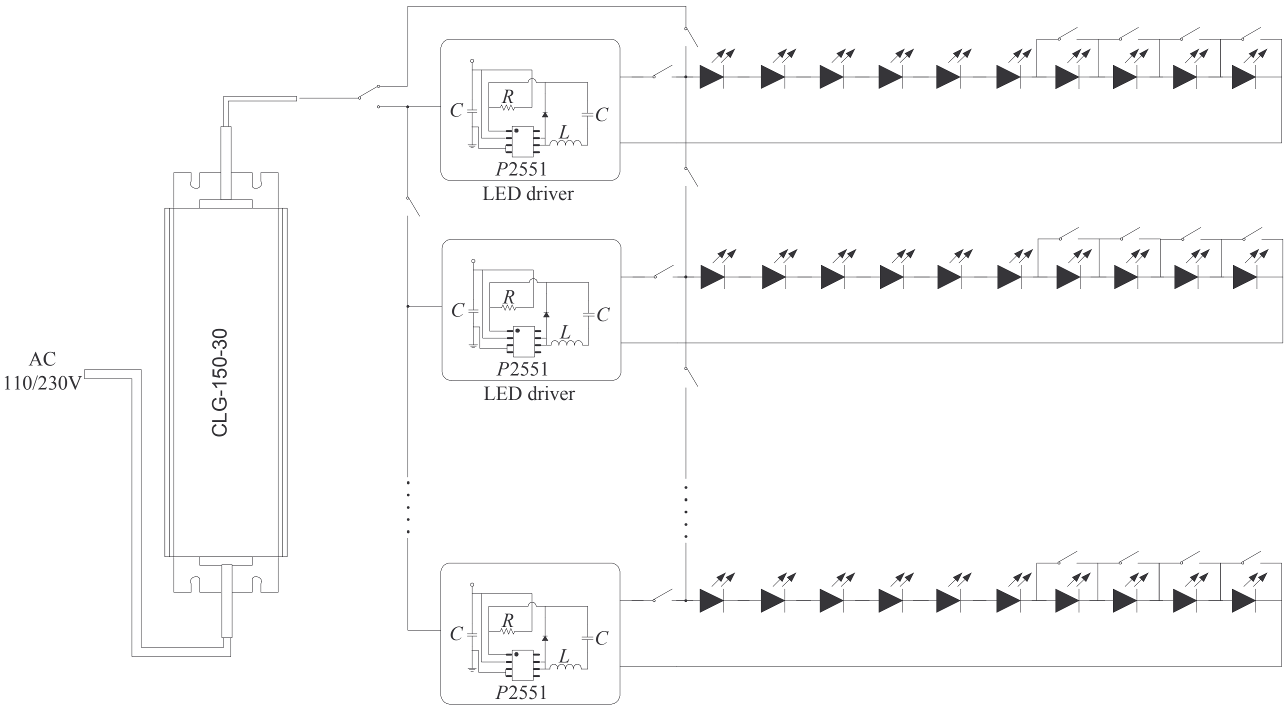

Figure 5.1: Example of LED lighting design

5.5 Comparison of LED drive method

The table below compares the efficiency of constant current driver IC and direct drive method. Since the efficiency of the LED driver itself is limited to 91~95%, when it is used in light systems, the overall system efficiency can only approach 81~86%. As for directly driven LED system, the efficiency the power supply itself basically constitutes the overall efficiency of the lighting system, thus higher efficiency can be achieved (about 90%).

In order to make high efficiency high reliability LED lamp fixture a reality, we must enhance the efficiency of the power supply to >90% and also bring up the efficiency of LED driver IC to >96%. Appropriate adjustment of the power supply voltage to match the LED lamp will also be critical to achieving high efficiency.

In the near future, high efficiency will definitely be ask of when it comes to designing lighting equipment such as street lamp.

CLG150-30A and driver IC (IC P2551)							
LED layout (S x P)	Input power (W)	Power supply voltage (V)	Power supply current (A)	P.S. eff. (%)	LED driver IC efficiency (%)	Demo board Eff. (%)	Power factor
8x8	150.3	30	4.5	90	95.3	86	0.997
8x7	131.5	30	3.9	89	94.7	84.3	0.997
8x6	110	30	3.3	90	93.1	84.3	0.994
7X8	132	30	4	90	92	83	0.996
6x8	118.6	30	3.5	88.5	91	81	0.996

CLG150-30A operates in constant current region							
LED layout (S x P)	Input power (W)	Power supply voltage (V)	Power supply current (A)	Output Power (W)	Loading percentage (%)	Demo board eff. (%)	Power factor
8x8	150	27	5	135	90	90	0.997
8x7	151.5	27.5	5	137.5	91.6	90.8	0.99
8x6	153.4	27.4	5	137	91.3	89.3	0.998
7x8	132	24	5	120	80	91	0.995
6x8	130.5	20.6	5	103	68.6	78.9	0.7

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