dynalite CD

technical guide • LED control

overview

Offering exceptional life, versatile control flexibility and unlimited colour mixing potential, LED sources are becoming increasingly prevalent in architectural lighting applications. The vast range of LED fittings and sources now available provides a multitude of creative illumination design possibilities. Harnessing this potential requires a sophisticated control system. Philips Dynalite has responded to this need and developed a comprehensive range of controllers, designed to directly connect and drive most popular conventions of LED fittings and sources. This guide outlines LED fitting circuit design concepts and provides instruction on selecting appropriate dimming control solutions.

LED fundamentals

Light Emitting Diodes (LEDs) are semi-conductor devices that emit photon energy (light) when an electrical current is passed through them. Detailed below is the electrical symbol that is commonly used to represent an LED.



Like any diode, LEDs pass current in one direction only, from Anode to Cathode and block current in the reverse direction. To produce light a voltage needs to be applied, which exceeds the LED's internal voltage drop (V_F) in order for current to flow. V_F is generally in the range of 0.7 - 4V and varies depending upon the material composition of the LED. The graph below plots the characteristic of a Lumileds Luxeon[®] LED in the light emitting range. If the applied voltage is less than V_F (about 3.2V) then current will not flow and the LED will not emit light.



dynalite 🚥

The light output level or brightness of an LED is generally directly proportional to the magnitude of forward current (I_F) . (See figure below)



LEDs are also designed to deliver optimum performance at their rated nominal current. Typical nominal current ratings for LEDs used in fittings generally range upward from 20mA through to 350mA. More recent technological developments on ultra-bright LEDs have also seen the release of products with nominal current ratings up to 1A.

The current through an LED should never exceed the device's nominal rating, otherwise permanent damage may result. For this reason, provision must be included with an LED fitting or the controller supplying the LED fitting, to regulate diode current to the correct level.

diode current regulation

The simplest method of driving an LED is to apply a DC voltage Vs to the LED with a resistor R in series. This will control the current and protect the LED. The forward current (I_F) can be controlled by selecting a suitable resistor.



For the Luxeon[®] LED above to run from a 12V supply at 350mA with a V_F of 3V, it would require a resistor value of:

 $R = (V_s - V_F)/I_F = (12 - 3)/0.35 = 25.7$ ohms

The nearest standard value resistor value is 27 ohms.

The power dissipated in this resistor would be:

 $P = V \times I = (V_{S} - V_{F}) \times I_{F}$ $= (12 - 3) \times 0.35$

= 3.15 W

The LED uses 0.35 X 3 = 1.05 W This circuit delivers an efficiency of 1.05/(1.05 + 3.15) = 25 %

Although series resistance can provide a convenient means of regulating current, there are often undesirable energy-efficiency implications as noted from the calculations above. There is also another major disadvantage to using this method; at the manufacturing stage, LEDs are sorted into ranges (or bins) of V_F which is measured at a constant current. Each bin is then supplied as a specific brightness; however there are variations in each range.

		Forward Voltage V _F		
Radiation			(\vee)	
Pattern	Color	Min.	Тур.	Max.
Batwing	White	2.79	3.42	3.99
	Warm White	2.79	3.42	3.99
	Green	2.79	3.42	3.99
	Cyan	2.79	3.42	3.99
	Blue	2.79	3.42	3.99
	Royal Blue	2.79	3.42	3.99
	Red (BD01)	2.31	2.85	3.27
	Red (BD03)	2.31	2.95	3.51
	Red-Orange	2.31	2.95	3.51
	Amber (BL01)	2.31	2.85	3.27
	Amber (BL03)	2.31	2.95	3.51

Electrical Characteristics at 350mA

The table above relates to the Lumileds Luxeon[®] LED that is designed to be driven at a constant current of 350mA. LED fittings commonly contain many LEDs that are connected in series and parallel arrays. If these LEDs were driven by a constant voltage supply the variation of up to 1.2V between $V_F(min)$ and $V_F(max)$ in two parallel branches, which is nearly 30% of $V_F(typ)$, would result in noticeably different brightness levels of LEDs across the array. It is possible to provide some compensation for this by including a current limiting resistor in each branch so that any variation in V_F has a less significant impact on branch current.

Another method of driving an LED is to include a constant current regulator, which eliminates any variations due to inconsistencies in V_F . To create a constant current regulator, a closed loop sensing circuit is required to monitor the current. This generally involves a sense resistor in series with the LEDs to determine the level of current. Discrete three terminal regulators such as the Motorola[®] LM317 are often used for this purpose as outlined in the diagram below.



The LM317 maintains 1.25V between V_{OUT} and V_{ADJ} , with I_{ADJ} negligible and constant.



Therefore the current though the LEDs is: I = 1.25/Rsense For a 350 mA LED Rsense would be 1.25/0.35 = 3.6 Ohms

When controlling multiple LEDs from a single constant current source, the LEDs should be connected in series to ensure the current in each LED is identical. If LEDs are connected in parallel the variation in V_F will again lead to different currents and therefore different brightness in each branch. As outlined previously, this can be improved by including a current limiting resistor in each branch so that any variation in V_F has a less significant impact on branch current. However in this case if an LED in one branch of a parallel array fails to an open circuit state, the current normally delivered to that branch will be driven through the other branches causing the LEDs to operate above their rated current and potentially fail.

LED dimming

It is possible to dim LEDs by simply reducing the current through the device. However, operating an LED below rated nominal current can result in a number of undesirable effects such as colour shift. An alternative to simple current regulation is Pulse Width Modulation (PWM). This technique dims the LED by supplying the nominal current at a variable duty cycle, which enables a much greater dimming range. 50% brightness is achieved with a 50% duty cycle. The frequency of the PWM is generally 100 Hz or greater, so that flicker is not discernable by the human eye. The following graphs illustrate PWM output for a range of dimming levels.



All Philips Dynalite controllers dim LED loads using pulse width modulation (PWM) ensuring that LEDs are always driven at the correct forward current.



LED circuit modes

The circuit configuration of LED fittings can be broadly classified in two basic types - current mode and voltage mode. Voltage mode LED fittings incorporate integral current regulation circuitry and are designed for connection to a nominal voltage supply. Following is the circuit diagram for a typical voltage mode LED fitting.



Current mode LED fittings have no internal current regulation and therefore must be connected to a constant current supply. Following is the circuit diagram for a typical current mode LED fitting.



The data sheet provided for an LED fitting will generally indicate whether it is a current or voltage mode device. Philips Dynalite produces fully dimmable controllers for both types of load.

common orientation

LED fittings often incorporate more than one branch circuit. This is quite prevalent with colour mix fittings that have a circuit for each primary colour (RGB). One end of each circuit is generally connected together to form a common. The orientation of the common will of course vary depending on which end of the circuits are connected together. The orientation of an LED controller and LED fitting must match to ensure correct operation. For this purpose LED fittings and LED controllers are broadly classified as either common anode or common cathode.

Common anode fittings as the name suggests, incorporate a common connected to the anode end of each LED circuit as illustrated below. Therefore the individual output channel polarity of common anode controllers must be negative with a positive common.

.



Conversely, common cathode fittings incorporate a common connected to the cathode end of each LED circuit. In this case the individual output channel polarity of common cathode controllers must be positive with a negative common.



In both cases the common is not necessarily at ground potential and should therefore never be connected to a supply ground at any point.

The orientation of proprietary LED fittings currently available is predominantly common anode. For this reason Dynalite LED controllers are designed to provide common anode output. Common cathode configuration is available as an option on certain Dynalite LED controllers. Please refer to product data sheet for specific option detail.

controller selection - voltage mode fittings

Selecting a suitable controller for voltage mode fittings is a straightforward process. First it is necessary to select a controller that can deliver the nominal fitting voltage. The data sheet for a typical constant voltage fitting will generally include values for the power consumed by the fitting and also the required nominal voltage V_F. Certain Philips Dynalite controllers which incorporate an integral power supply deliver a specific output voltage i.e. 24VDC, in line with popular nominal voltage conventions. Other Philips Dynalite controllers utilise external power supply. For multi-circuit fittings the common orientation should also be confirmed as compatible with the controller output. Finally, the controller channel output current capacity should be selected to exceed the connected load. The total load can be easily calculated by multiplying the total number of fittings per channel by the current per fitting. If only the power rating of the fitting is available the following expression can be used:



- $I_T = n \times P_F$
 - V_N
- I_T = Total current per channel
- P_F = Power rating of LED fitting
- V_N = Nominal voltage of fitting
- n = Number of LED fittings per channel

The controller selection process for voltage mode fittings can be summarised as follows:

- Select output voltage to match fitting nominal voltage.
- For multi-circuit LED fittings confirm common orientation aligns with controller.
- Select output current rating to exceed connected load.

The following table summarises the current range of Philips Dynalite voltage mode controllers.

Item Code	DDLEDC401	DDLEDC605
Controller Voltage	24VDC,	18-32VDC,
	12VDC (optional)	12-15VDC selectable
Common Orientation	Common anode	Common anode
	Common cathode (optional)	
Channels	4	6
Output current per channel	1A	5A
		Total controller load 20A
Power supply	Integral mains 240VAC	External safety extra low voltage
Housing	DIN Rail	DIN Rail

controller selection - current mode fittings

The considerations for selecting an appropriate controller for current mode fittings relate more to the controller's internal capacity to dissipate energy. This is because a constant current driver regulates the current flow through the LED circuit by effectively absorbing any excess voltage to maintain the nominal current level. In general, drive circuit internal power dissipation and thus heat generation is inversely proportional to the number of LEDs in series. Circuits with fewer LEDs in series will have greater heat generation in the drive circuit for a specific supply voltage. Therefore it is ideal to be aware of the power dissipation limits of the controller during the fitting design process.

The first step in selecting a suitable controller is to determine the appropriate supply voltage and confirm it falls within the maximum and minimum limits applicable for the controller. Following are calculations for determining these limits.

Maximum Supply Voltage

dynalite 🗘

 $V_s max = P_c + (n \times V_F)$ or $V_c max$, whichever is the lesser I_D

V_s max = Maximum supply voltage P_c = Max controller internal power dissipation per channel

I_D = Nominal LED current

n = Number of diodes in series per channel V_F = LED forward voltage V_c max = Maximum controller voltage

Minimum Supply Voltage $V_s min = 4 + (n \ge V_F)$ or 12VDC, whichever is the greater $V_s min =$ Minimum supply voltage n = Number of diodes in series per channel $V_F =$ LED forward voltage

Once again, for multi-circuit fittings the common orientation should be confirmed as compatible with the controller output. The final step is to calculate the controller internal power dissipation and ensure it is within the controller's limits. Following is the expression that should be used to determine this.

P_D = (V_S - (V_F x n)) x I_D P_D = Power dissipation per channel V_S = Supply voltage V_F = Diode forward voltage n = Number of diodes in series per channel I_D = Nominal diode current

It is sometimes necessary to increase the number of LEDs or introduce Zener diodes in series to increase the total V_F and therefore reduce the internal power dissipation.

The controller selection process for current mode fittings can be summarised as follows:

- Confirm required supply voltage is within acceptable limits for the controller.
- For multi circuit LED fittings confirm common orientation aligns with controller.
- Calculate and ensure internal power dissipation is within controller limits.



The following table summarizes the range of Philips Dynalite current mode controllers.

Item Code	DLEDC-48	DDLEDC60035
Controller Voltage	36VDC	18-32VDC,
		12-15VDC selectable
Common Orientation	Common anode	Common anode
Channels	48 (16xRGB)	6
Nominal Output Current	17-50mA software adjustable	350mA
Max internal power dissipation	0.4 Watts per individual channel	6 Watts combined total for consecutive pairs of
		channels (Ch 1&2, Ch 3&4, Ch 5&6). 4 Watts
		per individual channel.18 Watts box total
Power Supply	Integral mains 240VAC	External safety extra low voltage
Housing	Wall Mount	DIN Rail

current mode controller alternatives

Current mode fittings can be driven by a voltage mode controller if a current regulator such as the LM317 is included in the load circuit. The advantage of this is that the voltage mode controllers can deliver more power than constant current controllers and therefore more fittings can be driven from the one controller.

The following circuit diagrams demonstrate the capacity of each controller to drive multiple current mode LED arrays.



The DDLEDC605 can drive up to a total of 20A at 24V - A total of 480W including dissipated power.

.....



The DDLEDC401 can drive up to a total of 4A at 24V - A total of 96W including dissipated power.



The DDLEDC60035 can drive up to a total of 2.5A at 24V - A total of 60W including dissipated power.

© 2011 Dynalite Intelligent Light Pty Limited (ABN 97 095 929 829). All rights reserved. Not to be reproduced without permission. Dynalite, DyNet, DLight and associated logos are the registered trademarks of Dynalite Intelligent Light Pty Ltd. [®]Luxeon is the registered trademark of Lumileds Lighting U.S., LLC. [®]Motorola is the registered trademark of Motorola Inc.