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# FL77905

## Analog / PWM / Phase-cut Dimmable Compact LED Direct AC Driver

### Features

- The simplest Direct AC LED Driver with Only Two External RC Passive Components
- Wide AC Input Range : 90~305 V<sub>AC</sub>
- Three Integrated High-Voltage LED Constant Current Sinks of up to 75 mA (RMS) Capability
- TRIAC Dimmable (Leading/Trailing Edge)
- Rheostat Dimmable
- Analog/Digital PWM Dimming Function
- High Power Factor (above 0.98 in normal configuration)
- Adjustable LED Power with an External Current Sense Resistor
- Low Harmonic Content (THD under 20% in Normal Configuration)
- Compact SOIC 8-Lead Package
- Flexible LED Forward Voltage Configuration
- Power Scalability with Multiple Driver ICs
- Over-Temperature Protection (OTP)

### Description

The FL77905 is a direct AC line LED driver with minimal number of external RC passive components. In normal configuration, one resistor is to adjust LED power, and one capacitor is to provide a stable voltage to an internal biasing shunt regulator.

The FL77905 provides phase-cut dimming with wide dimming range, smooth dimming control and good dimmer compatibility. It achieves high efficiency with high PF and low THD which makes the FL77905 suitable for high-efficiency LED lighting systems. The FL77905 can also be used with a rheostat dimmer switches which are suitable for desktop or indoor lamps.

The FL77905 has a dedicated DIM pin which is designed to be used with analog or digital PWM dimming.

Operation of FL77905 admits driving higher-wattage systems, such as street lights and down lights, by simply parallel connecting the driver ICs.

### Applications

- General LED Driving Solution for Residential, Commercial and Industrial Lighting

### Ordering Information

Part Number	Operating Temperature Range	Package	Packing Method
FL77905MX	-40 to 125°C	8-Lead, Small Outline Integrated Circuit (SOIC) JEDEC MS012 150" Narrow Body, Exposed Pad	2,500 per Reel

## Typical Application

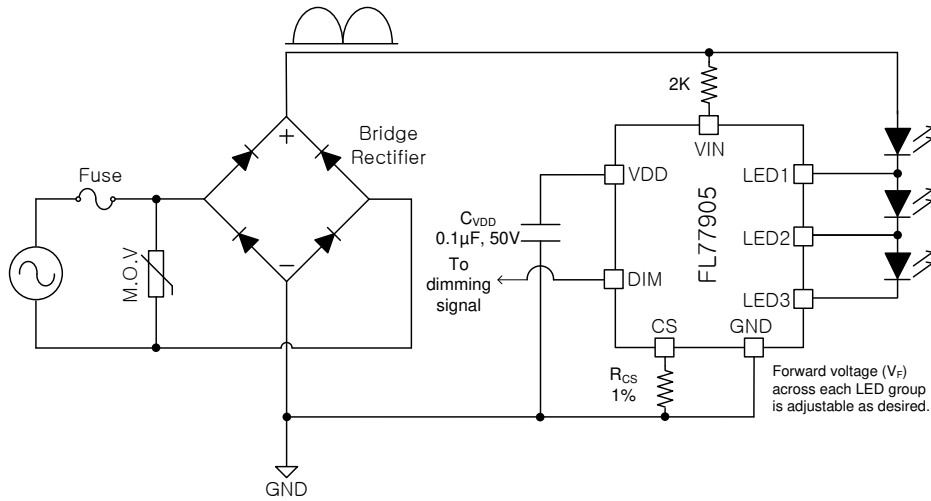


Figure 1. Typical Application Schematic

## Block Diagram

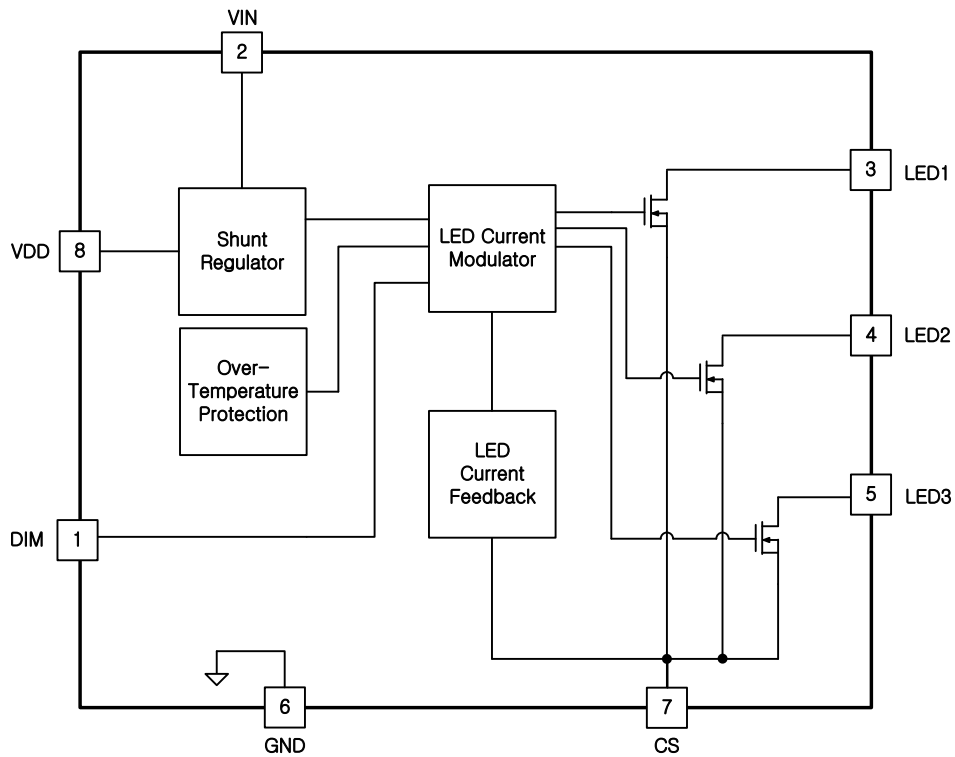


Figure 1. Simplified Block Diagram

## Pin Configuration

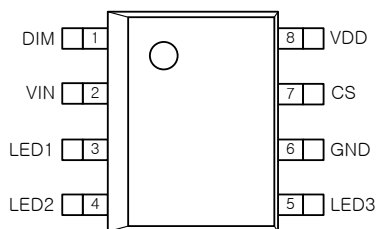


Figure 2. Pin Configuration (Top View)

## Thermal Characteristics <sup>(1)</sup> <sup>(2)</sup>

Component	Package	$\Theta_{JA}$ (1S PCB)	$\Theta_{JA}$ (2S2P PCB)	Unit
FL77905MX	8-Lead, Small Outline Integrated Circuit (SOIC) JEDEC MS012 150" Narrow Body, Exposed Pad	156	37	°C/W

### Notes:

- $\Theta_{JA}$ : Thermal resistance between junction and ambient, dependent on the PCB design, heat sinking, and airflow. The value given is for natural convection with no heatsink using the 1S and 2S2P boards, as specified in JEDEC standards JESD51-2, JESD51-5, and JESD51-7, as appropriate.
- Junction-to-air thermal resistance is highly dependent on application and PCB layout. In application where the device dissipates high levels of power during operation, special care of thermal dissipation issues in PCB design must be taken.

## Pin Definitions

Pin#	Name	Description
1	DIM	<b>Dimming Signal Input Pin.</b> This pin is used to further adjust LED current of a given $R_{CS}$ value. Apply 0 V to 5 V as the DIM signal. Both analog and digital PWM signal can be used.
2	VIN	<b>Rectified AC Input Voltage.</b> Connect this pin to rectified AC voltage after a bridge rectifier.
3	LED1	<b>LED String Cathodes.</b> Connect cathode(s) of each LED group to these pins.
4	LED2	
5	LED3	
6	GND	<b>Ground Reference Pin.</b> Tie this pin directly to local ground plane. This ground should not be tied to earth ground because it is not isolated from AC mains.
7	CS	<b>LED Current Sense Pin.</b> Limits the LED current depending on voltage across sensing resistor. The CS pin is used to set the LED current regulation target.
8	VDD	<b>Internal Biasing Shunt Regulator Output.</b> Voltage on this pin supplies internal circuitry of FL77905. A 17-V shunt regulator is internally connected to this pin. A bypassing capacitor is recommended to be added to reduce noise from VIN.
0	EP	<b>Exposed Thermal Pad.</b> EP is not tied to GND inside the IC. It is recommended to tie it to GND externally.

## Absolute Maximum Ratings

Stresses exceeding the absolute maximum ratings may damage the device. The device may not function or be operable above the recommended operating conditions and stressing the parts to these levels is not recommended. In addition, extended exposure to stresses above the recommended operating conditions may affect device reliability. The absolute maximum ratings are stress ratings only.

Symbol	Parameter	Min.	Max.	Unit
V <sub>IN</sub>	VIN Voltage	-0.3	500.0	V
V <sub>LED1</sub>	LED1 Pin Voltage	-0.3	500.0	V
V <sub>LED2</sub>	LED2 Pin Voltage	-0.3	500.0	V
V <sub>LED3</sub>	LED3 Pin Voltage	-0.3	200.0	V
V <sub>CS</sub>	CS Pin Voltage	-0.3	6.0	V
V <sub>DIM</sub>	DIM Pin Voltage	-0.3	6.0	V
T <sub>J</sub>	Junction Temperature	-55	+150	°C
T <sub>STG</sub>	Storage Temperature	-65	+150	°C
I <sub>LED1</sub>	LED1 Current		80	mA
I <sub>LED2</sub>	LED2 Current		100	mA
I <sub>LED3</sub>	LED3 Current		150	mA

### Notes:

- Stress beyond those listed under Absolute Maximum Ratings may cause permanent damage to the device.
- All voltage values, except differential voltages, are given with respect to the GND pin.
- Human Body Model, ANSI/ESDA/JEDEC JS-001-2012: 1.0 kV at Pins 2~4, 0.4 kV at Pin 5, 1.5 kV at Pins 1, 7~8.
- Charged Device Model, JESD22-C101: 1.0 kV at Pins 1~8.

## Recommended Operating Conditions

The Recommended Operating Conditions table defines the conditions for actual device operation. Recommended operating conditions are specified to ensure optimal performance to the datasheet specifications. Fairchild does not recommend exceeding them or designing to Absolute Maximum Ratings.

Symbol	Parameter	Min.	Max.	Unit
T <sub>J</sub>	Operating Junction Temperature	-40	+125	°C

## Electrical Characteristics

Unless otherwise noted,  $R_{CS} = 10 \Omega$ ,  $T_A = 25^\circ\text{C}$ . Currents are defined as positive into the device and negative out of the device.

Symbol	Parameter	Conditions	Min.	Typ.	Max.	Unit
<b>VIN Supply</b>						
$I_{\text{QUIES,VIN}}$	VIN Quiescent Current	$V_{\text{IN}} = 500 \text{ V Max.}$		0.75	1.20	mA
<b>VDD Output</b>						
$V_{\text{DD}}$	VDD Voltage	$V_{\text{IN}} = 20.0 \text{ V}$	16	17	18	V
<b>LED Current</b>						
$I_{\text{LED1}}$	LED1 Current	$V_{\text{IN}} = 20.0 \text{ V}, V_{\text{LED1}} = 20.0 \text{ V}$	40.4	47.0	53.6	mA
$I_{\text{LED2}}$	LED2 Current	$V_{\text{IN}} = 20.0 \text{ V}, V_{\text{LED2}} = 35.0 \text{ V}$	78.2	86.0	93.8	mA
$I_{\text{LED3}}$	LED3 Current	$V_{\text{IN}} = 20.0 \text{ V}, V_{\text{LED3}} = 20.0 \text{ V}$	87.8	96.0	104.2	mA
<b>Over-Temperature Protection</b>						
$T_{\text{OTP}}$	OTP Temperature <sup>(7)</sup>			170		$^\circ\text{C}$
<b>Leakage Current</b>						
$I_{\text{LED1-LK}}$	LED1 Leakage Current	$V_{\text{LED1}} = 500 \text{ V}, V_{\text{IN}} = 0 \text{ V}$			1	$\mu\text{A}$
$I_{\text{LED2-LK}}$	LED2 Leakage Current	$V_{\text{LED2}} = 500 \text{ V}, V_{\text{IN}} = 0 \text{ V}$			1	$\mu\text{A}$
$I_{\text{LED3-LK}}$	LED3 Leakage Current	$V_{\text{LED3}} = 200 \text{ V}, V_{\text{IN}} = 0 \text{ V}$			1	$\mu\text{A}$

**Note:**

- Not tested in production. Internal over-temperature protection circuitry protects the device from permanent damage. LEDs shut down at the junction temperature of  $T_J=170^\circ\text{C}$  (typical).

### Typical Performance Characteristics

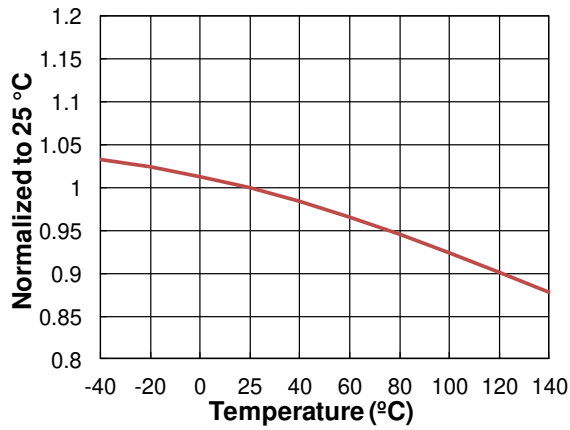


Figure 3.  $I_{QUES,VIN}$  vs. Temperature

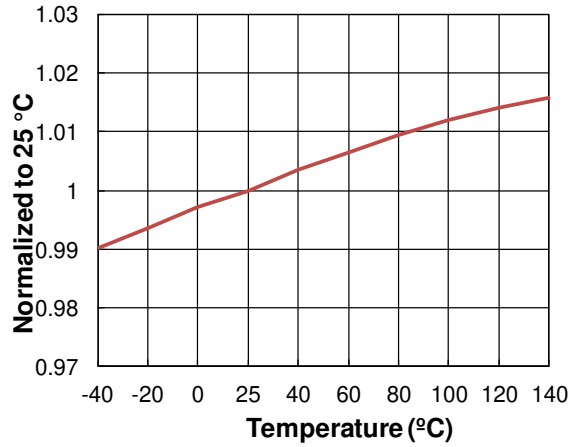


Figure 4.  $V_{DD}$  vs. Temperature

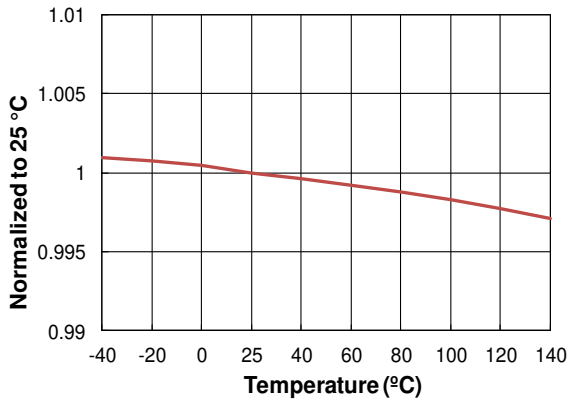


Figure 5.  $I_{LED1}$  vs. Temperature

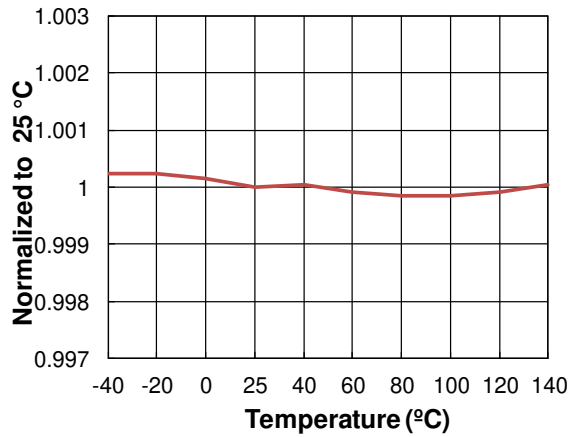


Figure 6.  $I_{LED2}$  vs. Temperature

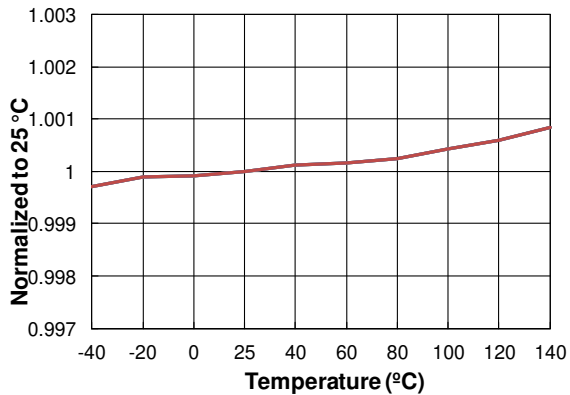


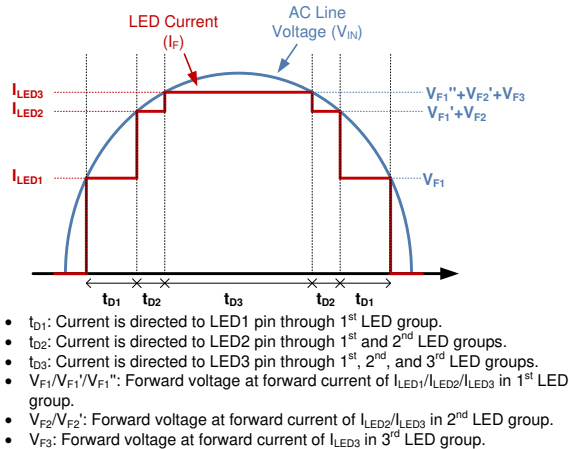
Figure 7.  $I_{LED3}$  vs. Temperature

## Functional Description

The FL77905 can drive LED strings attached directly to the rectified AC mains using only two external RC components ( $R_{CS}$  and  $C_{VDD}$ ). With three integrated high voltage current sink, LED current in each string is precisely controlled with system compactness. High PF and low THD are obtained by the optimized current sink levels. Phase-cut dimming is easily obtained with wide dimming range and good dimmer compatibility. Dedicated DIM pin is used to implement analog or digital dimming function. Flicker index in the direct AC drive topology can be improved by adopting proprietary self valley-fill solution.

## Operation

When the rectified AC line voltage,  $V_{IN}$ , is higher than the forward voltage of the consecutive LED groups, each LED group turns on automatically as the corresponding current sink has enough voltage headroom across it. Each current sink increases up to the predefined current level and maintains that level until the following channel's current sink gets enough voltage headroom across it.



**Figure 8. FL77905 Operation**

When  $V_{IN}$  reaches to the forward voltage across the 1<sup>st</sup> LED group ( $V_{F1}$ ) at forward current  $I_F = I_{LED1}$ , the current drawn from the  $V_{IN}$  is directed to the LED1 through the 1<sup>st</sup> LED group. In sequence, when  $V_{IN}$  reaches forward voltage across 1<sup>st</sup> and 2<sup>nd</sup> LED groups ( $V_{F1}'+V_{F2}'$ ) at  $I_F = I_{LED2}$ , the current is directed to LED2 across 1<sup>st</sup> and 2<sup>nd</sup> LED groups. Finally, when  $V_{IN}$  reaches  $V_{F1}''+V_{F2}'+V_{F3}$  at  $I_F = I_{LED3}$ , the LED current goes through 1<sup>st</sup>, 2<sup>nd</sup>, and 3<sup>rd</sup> LED groups and sinks to the LED3.

Whenever the active channel (one that is sinking LED current) is changed from one channel to the adjacent channel with respect to the change in the  $V_{IN}$ , the new active channel's current increases gradually while the existing active channel's current decreases at the same time. This smooth current transition reduces frequency harmonic contents and improves power factor as well as Electromagnetic Interference (EMI) characteristics.

By fully utilizing available headroom, the FL77905 offers maximum power, high efficiency, power factor and low harmonic distortion. Typically, power factor is higher

than 0.98 and THD is lower than 20%. The efficiency heavily depends on a LED configuration.

## LED Current and Power Setting

The LED current is managed by an external current sense resistor  $R_{CS}$ . Regulation target of each channel's current sink is calculated as follows:

$$I_{LED1} = \frac{0.47}{R_{CS}}, I_{LED2} = \frac{0.86}{R_{CS}}, \text{ and } I_{LED3} = \frac{0.96}{R_{CS}}. \quad (1)$$

Root-mean-square (RMS) value of the input current can be calculated using the peak regulated current,  $I_{LED3}$ , and crest factor. Since the LED current waveform is similar to the AC line voltage, the crest factor is close to the crest factor of a sine wave,  $\sqrt{2}=1.414$ . But the actual crest factor depends on the flattened time of the  $I_{LED3}$  and LED configuration. With FL77905, the typical crest factor is approximately 1.3. Thus, based on estimated input power,  $P_{IN}$ , the  $R_{CS}$  resistor value can be calculated as follows:

$$R_{CS} = \frac{0.96 \times V_{AC,RMS}}{1.3 \times P_{IN}} \quad (2)$$

The actual  $R_{CS}$  needs to be adjusted with respect to the LED configuration.

## LED Configuration

In the LED configuration, it is required to increase the total LED forward voltage,  $V_F$  to improve efficiency. For example, compared to using 3 LEDs with  $V_F$  of 80 V (total  $V_F = 80 \text{ V} \times 3 \text{ channels} = 240 \text{ V}$ ) for each LED group, using 3 LEDs with  $V_F$  of 90 V (total  $V_F = 90 \text{ V} \times 3 \text{ channels} = 270 \text{ V}$ ) will improve the efficiency simply due to the higher total  $V_F$ . Each LED channel can have different  $V_F$ . For example, if a design is implemented with 144 LEDs with  $V_F$  of 3 V for 2-foot fluorescent lamp replacement, the user can assign flexible number of LEDs for LED channels such as 28s2p-34s2p-20s1p ("s" stands for LEDs in series and "p" stands for LEDs in parallel) or 27s2p-27s2p-36s1p.

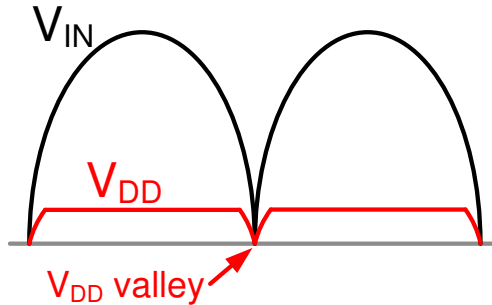
Which needs to be considered is that  $V_F$  of first LED group should be higher than  $V_{IN}$ -pin turn-on voltage, which is 20 V. If the  $V_F$  of the first LED group is configured to be lower than  $V_{IN}$ -pin turn-on voltage,  $I_{LED1}$  will not have the correct regulation level when input voltage,  $V_{IN}$ , is just exceeds the  $V_F$ .

A good starting point for choosing a LED configuration is to have about 260 V~280 V of the total  $V_F$  for 220 V<sub>AC</sub> mains and 130 V~140 V of the total  $V_F$  for 120 V<sub>AC</sub>.



### Internal Shunt Regulator Output, $V_{DD}$

The system implemented with FL77905 does not require a bulk capacitor after bridge-rectification diodes. As a result, the  $V_{DD}$ , which supplies biasing voltage for the FL77905, has voltage ripple like the rectification voltage after the bridge diodes as shown in Figure 9.



**Figure 9.  $V_{DD}$  Ripple without  $C_{VDD}$**

The  $V_{DD}$  ripple can be reduced by a bypassing capacitor,  $C_{VDD}$ . If the  $C_{VDD}$  is not used, or its value is small, the  $V_{DD}$  voltage fluctuates and goes even down to 0 V. It makes the FL77905 reset, but the FL77905 automatically restarts every cycle when the AC line voltage reaches a certain level. For a much stable operation, to implement  $C_{VDD}$  is preferred. The recommended  $C_{VDD}$  value is 1  $\mu$ F with 50 V of voltage rating.

### Over-Temperature Protection (OTP)

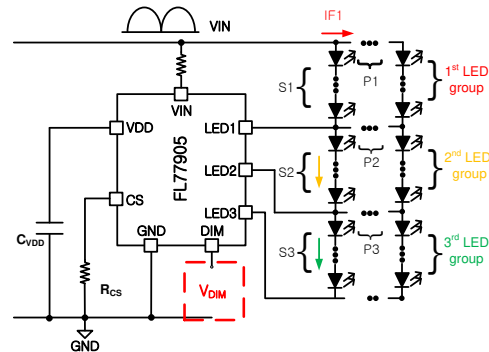
The FL77905 is with over temperature protection (OTP) inherently. When the driver's junction temperature exceeds a specified threshold temperature ( $T_J = 170^\circ\text{C}$ ), the driver will shut down automatically and then recover automatically once the temperature drops lower enough than the internal threshold temperature. Without this protection, the lifetime of the FL77905 can be reduced and irreparable damage can occur when it operates above its maximum junction temperature ( $150^\circ\text{C}$ ). Good thermal management is required to achieve best performance and long life span of the FL77905.

OTP also helps to screen out non-proper thermal management during design-phase of a lighting fixture.

### Analog/PWM Dimming Function

The FL77905 has its DIM pin always enabled. The DIM pin is used for analog, 0 V to 10 V, or pulse width modulation (PWM) dimming by applying a voltage signal between 0 to 5 V or PWM signals with 5-V peaks to the DIM pin.

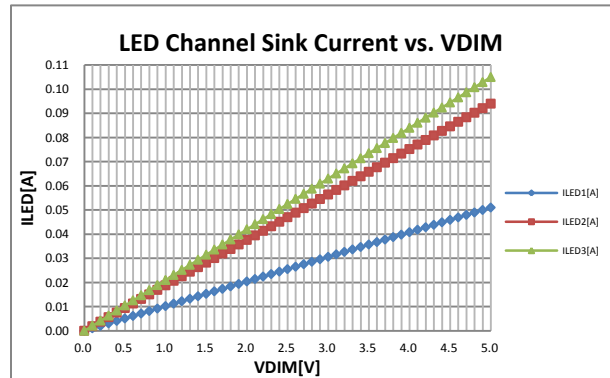
Note that, if DIM pin is floating, there will be no LED current, since DIM pin does not source voltage by itself. If DIM-pin function is not required, use external circuit to keep DIM-pin voltage at 5 V, or use the FL77904.



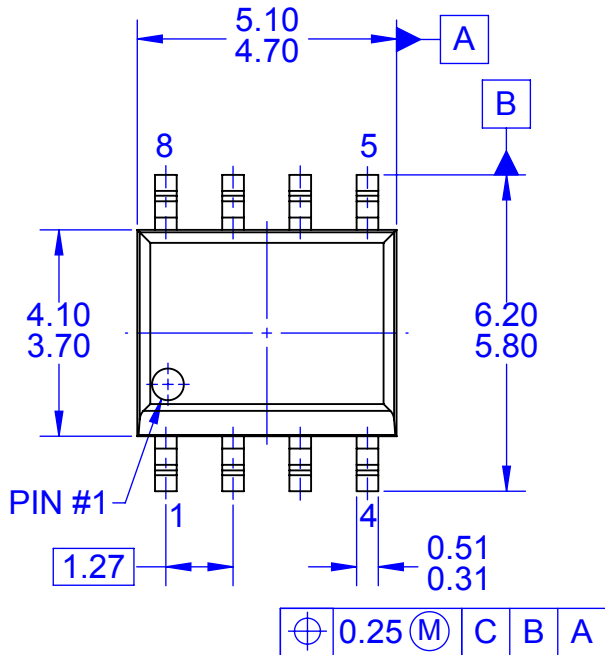
\* S1, S2, S3: Number of LEDs in series each LED group  
P1, P2, P3: Number of LEDs in parallel each LED group

**Figure 10. Analog or PWM Dimming Application**

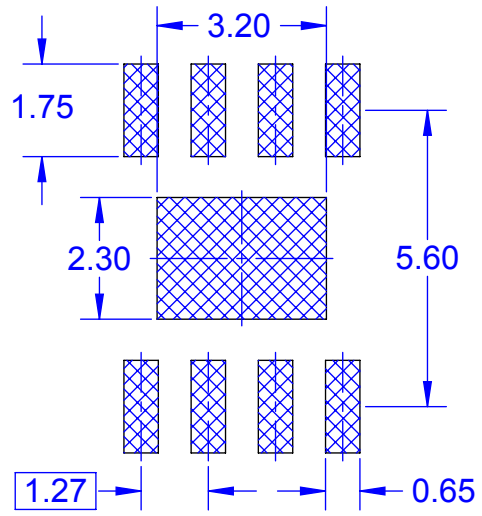
The LED channel sink and total RMS current through LEDs will be linearly adjusted with the  $V_{DIM}$  level as shown in Figure 11.



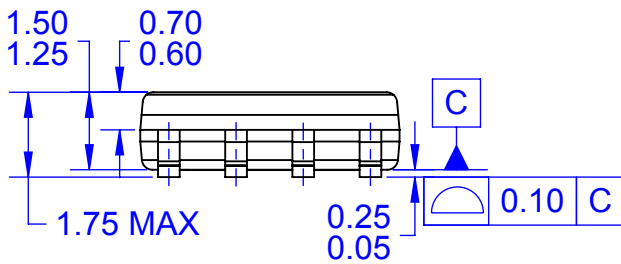
**Figure 11. LED Channel Sink Current vs.  $V_{DIM}$  ( $R_{CS} = 10 \Omega$ )**



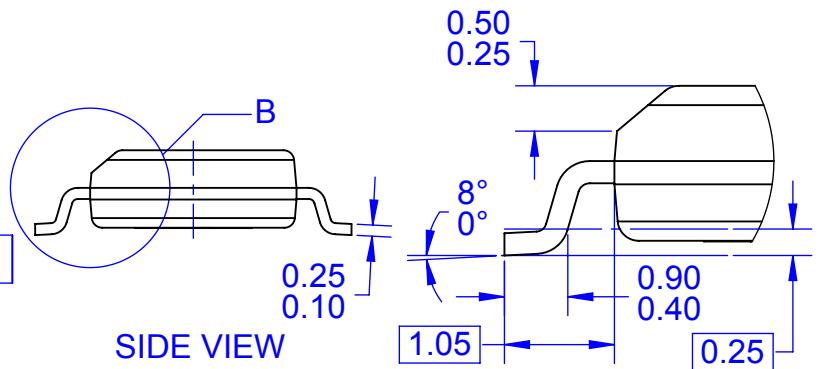
TOP VIEW



LAND PATTERN RECOMMENDATION

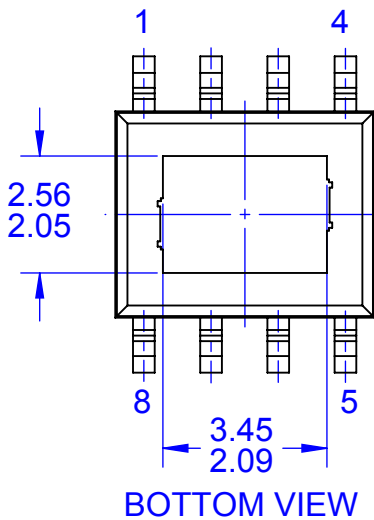


FRONT VIEW



SIDE VIEW

DETAIL B  
SCALE 2:1



BOTTOM VIEW

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