ACS1404

Compact Direct AC Line LED Driver with high PF and low THD using Only Two External Components

FEATURES

- Direct AC Line LED Driver with Only Two External Components over Wide VAC Range (90V to 280V)
- Compact LED Driver Module Size due to Minimal Number of External Components
- Integrated 4 Ultra High Voltage Constant Current Sinks
- Automatic Detection of AC Line Frequency (50Hz/60Hz/70Hz)
- TRIAC Dimmable (Leading/Trailing Edge)
- Rheostat Dimmable
- Analog/digital PWM Dimming Function
- High Power Factor (above 0.99 in normal configuration)
- High Efficiency Greater than 90% in Optimized LED Configuration
- Adjustable LED Power with an External Current Sense Resistor
- Low Harmonic Content (THD under 15% in normal configuration)
- Low Crest Factor (under 1.7 in normal LED configuration)
- LED Current Sinking Capability of up to 150mA$_{rms}$
- SOP16 EP / 7x7 QFN 48L
- Flexible LED Forward Voltage Configuration
- Multiple LED Driver Configuration
- Over Temperature Protection

DESCRIPTION

The ACS1404 is a direct AC line LED driver with a minimal number of external components. In a normal configuration, only two components are used. One resistor is to provide adjustable LED power and one capacitor is to provide a stable voltage to the internal shunt regulator.

The ACS1404 can be used with different types of TRIAC dimming control switches. Since the ACS1404 drives all LED current sinks based on AC line level, whether AC mains are controlled by a leading edge dimmer, a trailing edge dimmer or a AC level dimmer, the LED current closely follows the AC line which achieves the high efficiency, high PF and low THD, which makes the ACS1404 suitable for high-efficiency LED lighting system. The 1404 has dedicated PWM pin with which it can be used with analog dimming or digital PWM. The ACS1404 can also be used with a rheostat dimmer switch which is suitable for desktop or inside lamps.

If desired, multiple ACS1404 can be used together to drive high power LED applications such as street lamp, down lights, et cetera.

TYPICAL APPLICATION

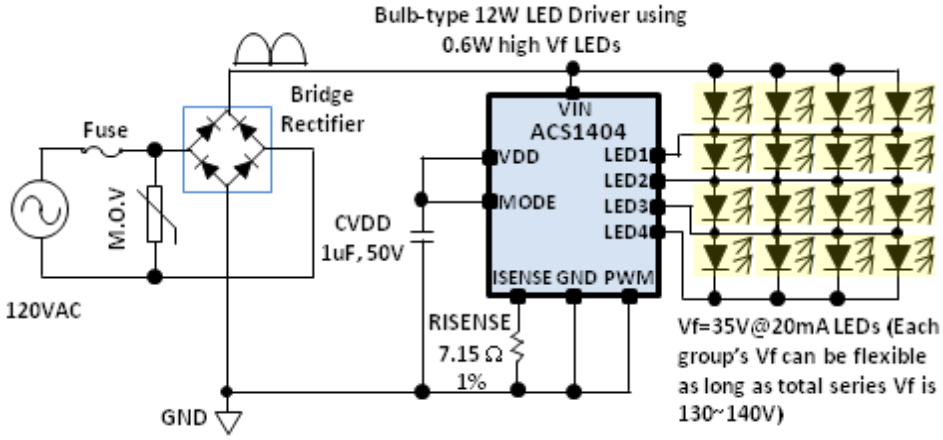


Figure 1. 12W @120VAC LED bulb-type application

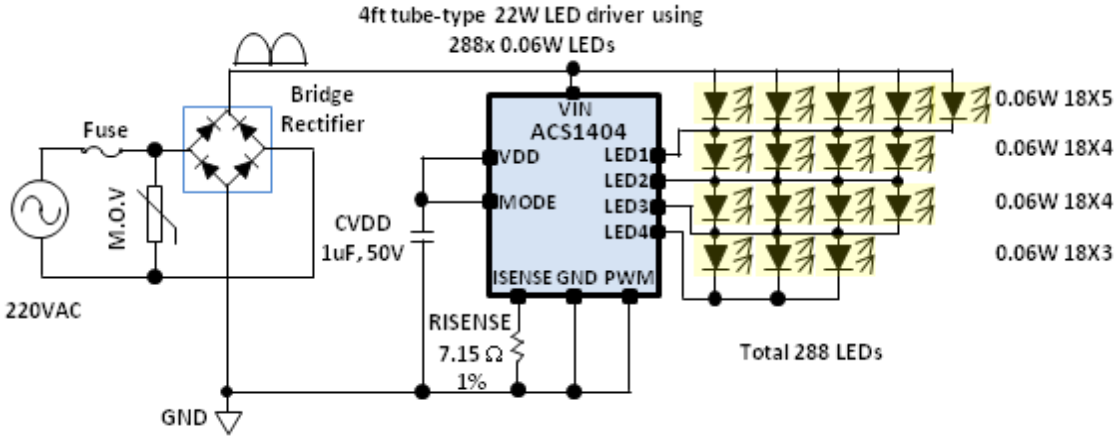


Figure 2. 22W @220VAC LED tube-type application

ABSOLUTE MAXIMUM RATINGS

- VIN, LED1~3.....-0.3V to +500V
- LED4.....-0.3V to +200V
- VDD, MODE.....-0.3V to +20V
- ISENSE, PWM.....-0.3V to +6V
- Maximum Junction Temperature($T_{J\text{-}MAX}$).....+150˚C
- LED1, LED2, LED3, LED4 Current.....80, 160, 160, 240mA

OPERATING CONDITION

- Junction Temperature(T_J).....-40˚C to +125˚C

ELECTRICAL CHARACTERISTICS

- Specifications are at T = 25°C unless specified in conditions. VIN = 220VAC, RISENSE = 10Ω (1%), unless specified in conditions.
- RMS LED forward current is based on LED forward voltage, Vf=65V for each LED group and crest factor of 1.4. Total LED forward voltage is 65V X 4 channels = 260V. Actual RMS LED current depends on Vf used for each LED group and crest factor.

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
VIN SUPPLY					
VIN Quiescent Current	VIN = 20 ~ 500V		1.20	1.50	mA
VDD OUTPUT					
VDD Voltage	VIN=20.0V	16	17	18	V
LED CURRENT					
ILED1	VIN=20.0V, VLED1=20.0V	16.5	18.3	20.1	mA
ILED2	VIN=20.0V, VLED2=20.0V	33.0	36.6	40.2	mA
ILED3	VIN=20.0V, VLED3=35.0V	74.1	82.3	90.5	mA
ILED4	VIN=20.0V, VLED4=20.0V	82.4	91.5	100.6	mA
LED RMS Current	Total VF=260V		63		mA
OVER TEMPERATURE PROTECTION					
OTP Temperature*			170		°C
THERMAL RESISTANCE					
θ_{JA} (EP-SOIC 16LD junction-to-air thermal resistance : PCB layer - 2S2P)**			35		°C/W
θ_{JA} (EP-QFN junction-to-air thermal resistance : PCB layer - 2S2P)**			26		°C/W

Table 1. Electrical Characteristics

* Internal over-temperature protection circuitry protects the device from permanent damage. LEDs shut down at the junction temperature, T_J=170°C(typ.).
** 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.

ODERING INFORMATION

Order Number	Package Type	Top Mark	Supplied As
ACS1404S	SOIC-16LD	ACS1404S	2,500 Units, Tape and Reel
ACS1404Q	QFN-48L	ACS1404Q	416 Units, Tray

PIN CONFIGURATION (SOIC 16LD with EP)

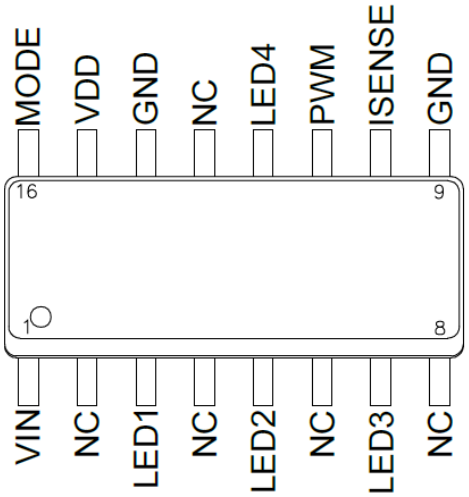


Figure 3. Pin configuration for SOIC 16LD

Pin Number	Pin Name	Description
1	VIN	Rectified AC Input Voltage
3,5,7,12	LED1~4	LED String Cathode
9, 14	GND	Ground Pin
10	ISENSE	LED Current Sensing Pin
11	PWM	Apply 0V to 5V as PWM signal
15	VDD	Shunt Regulator for Internal Circuitry
16	MODE	Tie to VDD for normal mode and GND for PWM MODE
0	EP	Exposed Thermal Pad

Table 2. Pin Description for SOIC 16LD with EP

PIN CONFIGURATION (QFN48 7X7)

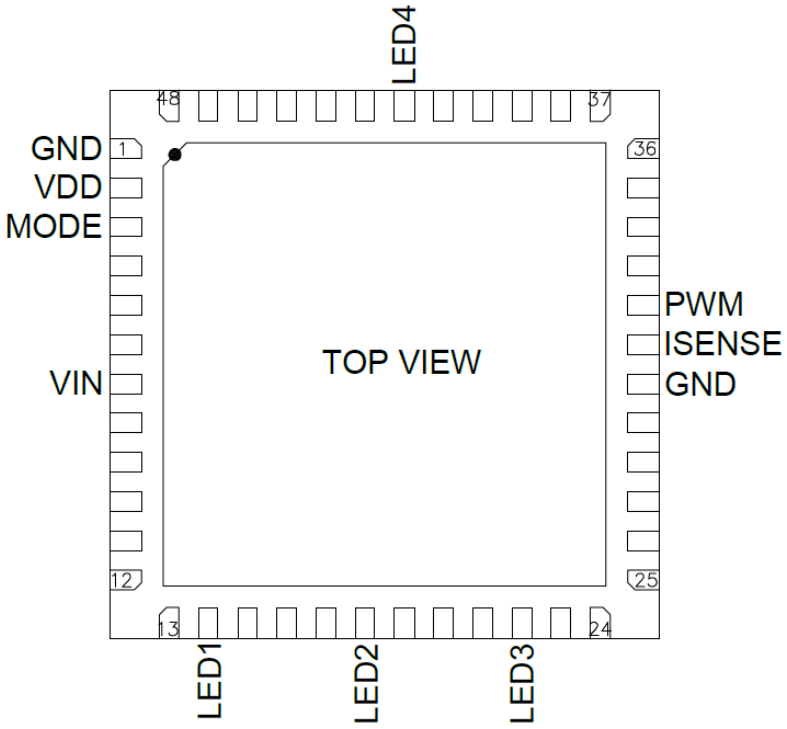


Figure 4. Pin configuration for QFN 7X7 48L with EP

Pin Number	Pin Name	Description
7	VIN	Rectified AC Input Voltage
14, 18, 22, 42	LED1~4	LED String Cathode
1, 30	GND	Ground Pin
31	ISENSE	LED Current Sensing Pin
32	PWM	Apply 0V to 5V as PWM signal
2	VDD	Shunt Regulator for Internal Circuitry
3	MODE	Tie to VDD for normal mode and GND for PWM MODE
0	EP	Exposed Thermal Pad

Table 3. Pin Description for QFN 7X7 48L with EP

PIN FUNCTIONS

VIN: Rectified AC Input Voltage. Connect this pin to rectified AC voltage after bridge rectifier.
VDD: Input Voltage. This pin supplies current to the internal circuitry. A 17.5V shunt regulator is internally connected to this pin. A bypassing capacitor is recommended to be added to reduce noise from VIN.
ISENSE: Sense LED current for each LED group. Refer to resistor setting equation to decide proper resistor value.
MODE: Connect this pin to VDD in normal mode. Connect this pin to GND to use PWM pin. Apply 0V to 5V as PWM signal.
PWM: When MODE pin is tied to GND, this pin is used to control LED current with given RISENSE. Both analog or digital PWM signal can be applied.
LED1-4: LED Channel Output. Connect the bottom cathode(s) of each LED group to these pins. Tie the pin(s) to GND if the corresponding LED group is not used. LED1~3 is 500V rated and LED4 is 200V rated.
GND: Ground. Tie both pins directly to local ground plane. This ground should not be tied to earth ground since it is non-isolated from AC mains.
EP: Exposed thermal pad. In QFN package, EP is tied to GND inside IC. In SOP16 package, EP is not tied to GND inside IC and it is advised to tie it to GND.

BLOCK DIAGRAM

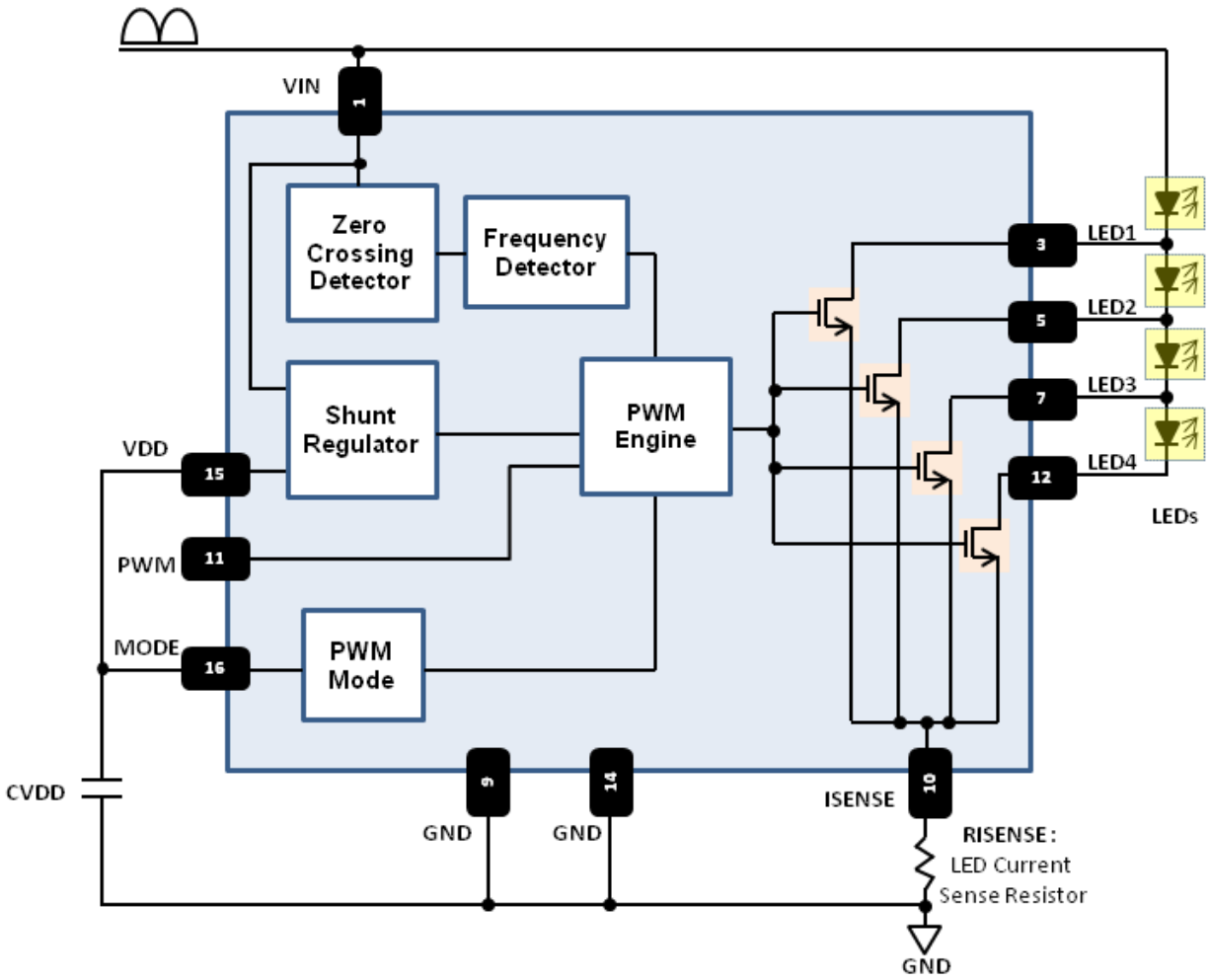


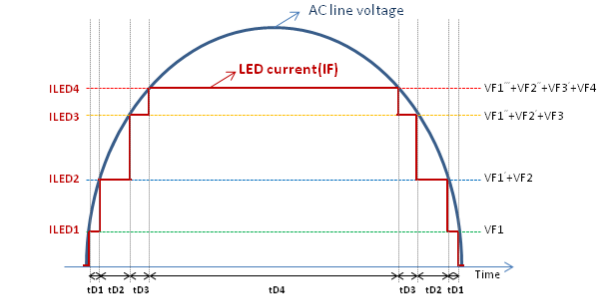
Figure 5. Block diagram of ACS1404S

Functional Description

The ACS1404 can drive LED strings attached directly to the rectified AC mains using only two external components. With integrated high voltage current sinks, the ACS1404 provides compact LED lighting solution without requiring bulky and unreliable external components. The two required components are a resistor(RISENSE) for the LED power setting and capacitor(CVDD) for the internal regulator.

1. Operation

When the rectified AC line voltage, VIN, is higher than the internal reference level, each LED group turns on automatically when the corresponding current sink has its headroom. Each LED channel current sink increases up to the predefined current level for each current sink and maintains its level until the following channel's current sink reaches to its headroom.



•tD1 : Current is directed to LED1 through the 1st LED group.
•tD2 : Current is directed to LED2 through the 1st and 2nd LED groups.
•tD3 : Current is directed to LED3 through the 1st, 2nd, and 3rd LED groups.
•tD4 : Current is directed to LED4 through the 1st, 2nd, 3rd, and 4th LED groups.
•VF1/VF1'/VF1'' /VF1''' : Forward voltage at forward current of ILED1/ILED2/ILED3/ILED4 in the 1st LED group.
•VF2/VF2'/VF2'' : Forward voltage at forward current of ILED2/ILED3/ILED4 in the 2nd LED group.
•VF3/VF3' : Forward voltage at forward current of ILED3/ILED4 in the 3rd LED group.
•VF4 : Forward voltage at forward current of ILED4 in the 4th LED group.

Figure 6. ACS1404 Operation

When the VIN reaches to the forward voltage across the 1st LED group(VF1) at forward current(IF)=ILED1, the current drawn from the VIN is directed to the LED1 through the 1st LED group(T1). In sequence, when the VIN reaches to the forward voltage across the 1st and 2nd LED groups(VF1'+VF2) at IF=ILED2, the current is directed to the LED2 across the 1st and 2nd LED groups(T2). Then, when the VIN reaches to VF1''+VF2'+VF3 at IF=ILED3, the LED current across the 1st, 2nd, and 3rd LED groups sinks to the LED3. Finally, when the VIN reaches to VF1'''+VF2''+VF3'+VF4 at IF=ILED4, the current through all 4 LED groups is directed to the LED4. 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 VIN, the new active channel's current increases gradually while the existing active channel's current decreases gradually.

This smooth current transition reduces frequency harmonic contents and improves power factor as well as EMI characteristics. By fully utilizing available headroom, the ACS1404 offers maximum power, high efficiency, power factor and low harmonic distortion. Typically, power factor is higher than 0.99 and THD is lower than 15%. The efficiency heavily depends on a LED configuration.

2. LED Current and Power Setting

The RMS LED current is managed by an external LED current sense resistor (RISENSE) and each LED channel current level depends on the RISENSE value.

Since the LED current waveform is similar to the AC line voltage, the crest factor is close to the crest factor of Sine wave, $\sqrt{2}$=1.414. But the actual crest factor depends on the flattened time of the ILED4 and LED configuration. In the ACS1404, the typical crest factor approximately is 1.4. The RISENSE resistor value can be calculated as follows.

$$\mathrm{RISENSE} = \frac{0.92 \times \mathrm{VACrms}}{1.4 \times \mathrm{LEDPower}}$$

The actual RISENSE needs to be adjusted with respect to the LED configuration.

3. Internal Shunt Regulator Output, VDD

The ACS1404 doesn't use the rectification capacitor after the bridge diode. Basically, the VDD, which is internal supply power for the ACS1404, has voltage ripple as well as the rectification voltage after the bridge supply power for the ACS1404, has voltage ripple as well as the rectification voltage after the bridge as shown in Figure 7.

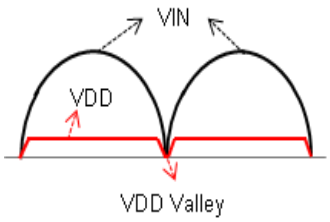


Figure 7. Internal VDD Function without CVDD

If the CVDD is not used, or its value is small, then the VDD voltage fluctuates and even goes down to 0V. It makes the ACS1404 reset, but the ACS1404 automatically restarts every cycle when the AC line voltage reaches to a certain level. For more stable operation, the CVDD can be used. The recommended capacitor value is 0.1uF with 50V voltage rating.

4. LED Configuration

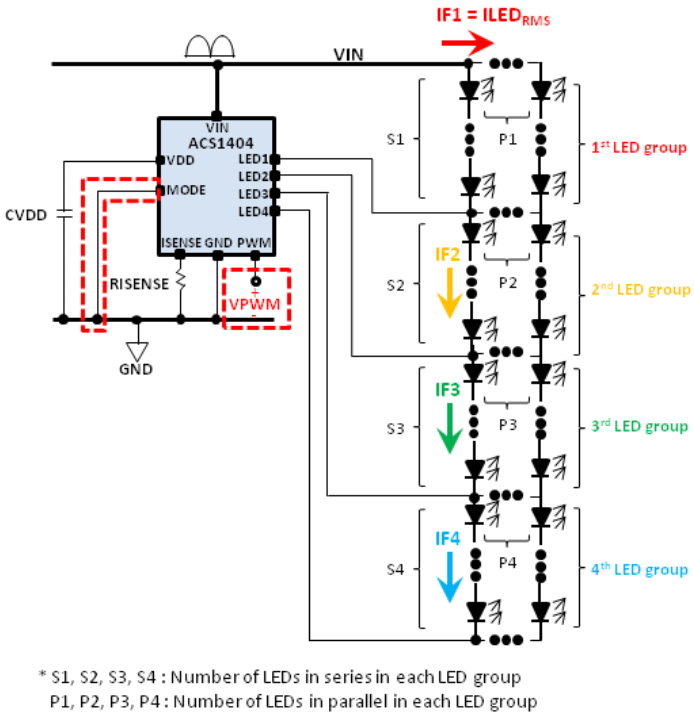
In the LED configuration, it is required to increase the total LED forward voltage, VF to improve efficiency. For example, compared to using 4 LEDs with VF of 60V(total VF = 60V X 4 channels=240V) for each LED channel, using 4 LEDs with VF of 65V(total VF = 65V X 4 channels = 260V) will improve the efficiency simply due to the higher total VF. Each LED channel can have different VF. For example, if a user uses 144 LEDs with VF of 3V for 2ft fluorescent lamp replacement, the user can assign flexible number of LEDs for LED channels such as 25s2p-32s2p-6s2p-18s1p ("s" stands for LEDs in series and "p" stands for LEDs in parallel) or 18s2p-18s2p-18s2p-36s1p. One needs to consider having VF of LED1 channel higher than VIN turn-on voltage, which is 20V. If the VF of the LED1 channel is configured to be lower than VIN turn-on voltage, LED1 will not have the correct regulation level. A good starting point for choosing a LED configuration is to have about 260V~280V of the total VF for 220VAC mains and 130V~140V of the total VF for 120VAC.

5. Over Temperature Protection

The ACS1404 includes over temperature protection by default. When the driver's junction temperature exceeds a specified thermal threshold(T_J=170°C), LEDs will shut down automatically and then recover automatically once the temperature drops below the thermal threshold. Without this protection, the lifetime of the ACS1404 can be reduced and irreparable damage can occur when it operates above its maximum junction temperature range($T_{J\text{-}MAX}$=150°C). Good thermal management is required to achieve maximum performance and long life span of the ACS1404.

6. Analog/PWM Dimming Function

The ACS1404 uses the PWM pin for analog, 0V to 10V, or pulse width modulation(PWM) dimming by applying a certain voltage which is 5V and under or PWM signals with 5V peaks to the PWM pin.



* S1, S2, S3, S4 : Number of LEDs in series in each LED group
P1, P2, P3, P4 : Number of LEDs in parallel in each LED group

Figure 8. Analog or PWM dimming application

To enter the analog dimming mode, the mode pin should be tied to GND. The LED channel sink and total RMS current through LEDs will be linearly changed with the VPWM level, as shown in figures below.

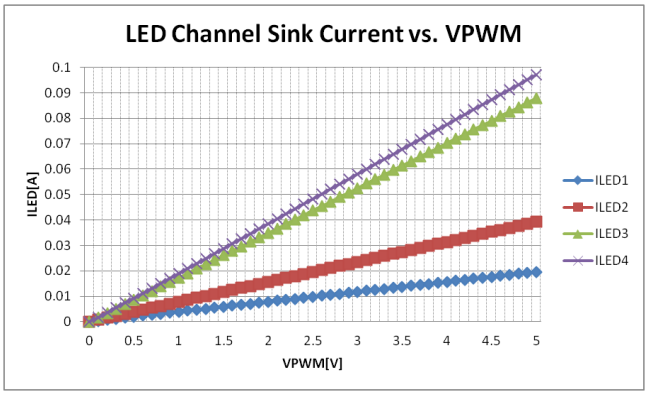


Figure 9. Measured LED channel sink current vs. VPWM (RISENSE=10Ω)

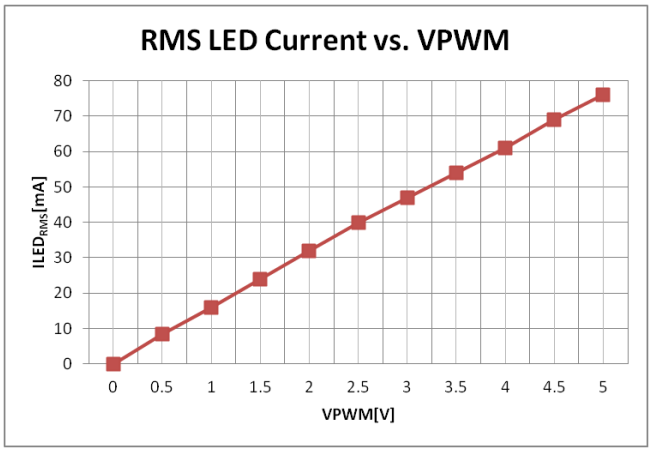
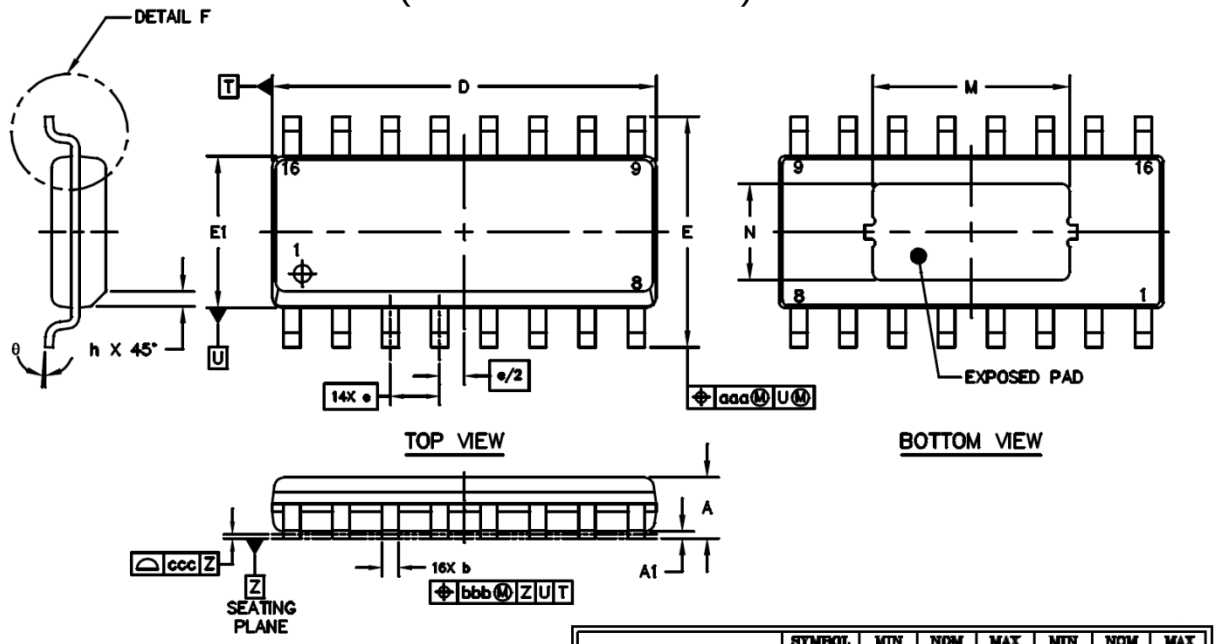
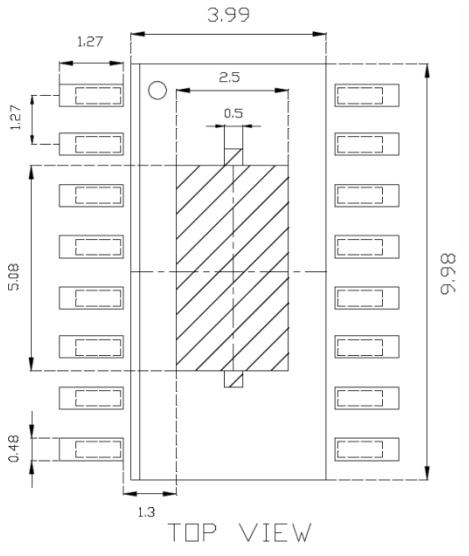


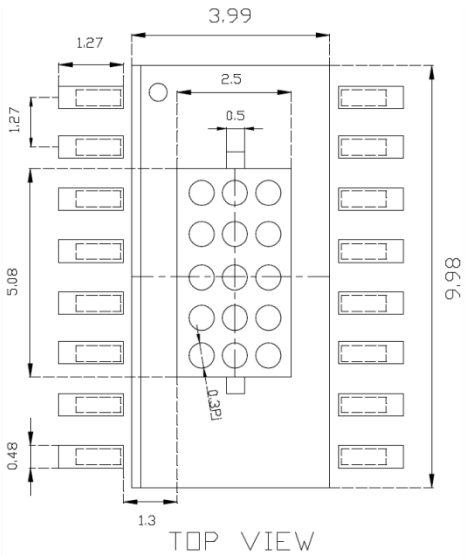
Figure 10. LED current vs. VPWM (Simulation results : RISENSE=10Ω / VAC=120V)

PACKAGE DESCRIPTION (SOIC 16LD with EP) / SOLDERING FOOTPRINT

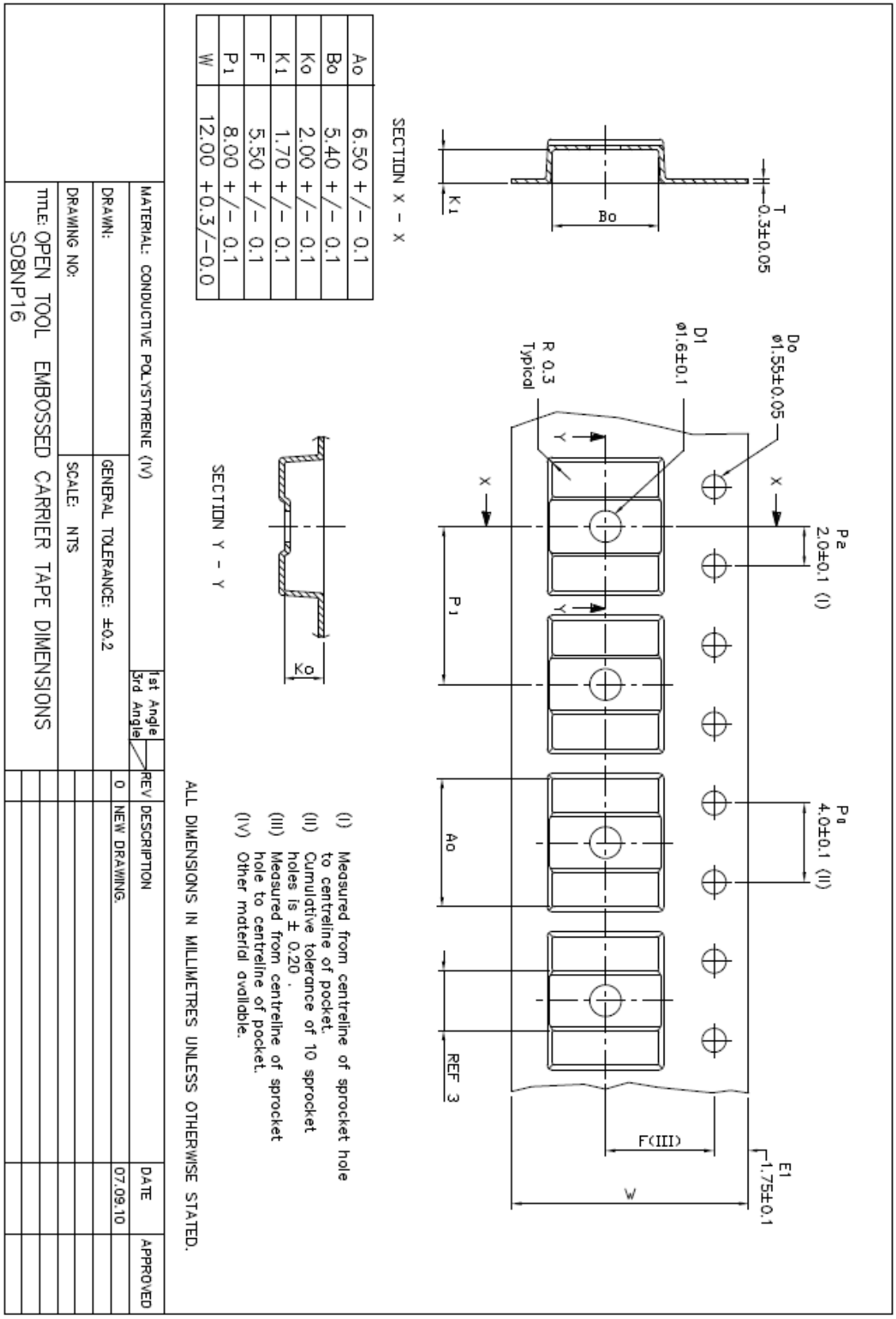


	SYMBOL	MIN	NOM	MAX	MIN	NOM	MAX
TOTAL THICKNESS	A	.053	----	.069	1.35	----	1.75
STAND OFF	A1	.004	----	.010	0.10	----	0.25
LEAD WIDTH	b	.014	----	.019	0.36	----	0.48
L/F THICKNESS	c	.007	----	.010	0.18	----	0.25
BODY SIZE	D	.386	----	.393	9.80	----	9.98
	E1	.150	----	.157	3.81	----	3.99
	E	.228	----	.244	5.79	----	6.20
LEAD PITCH	e	.050 BSC			1.27 BSC		
	L	.016	----	.050	0.41	----	1.27
	h	.010	----	.020	0.25	----	0.51
	θ	0°	----	8°	0°	----	8°
EP SIZE	M	.196	.200	.204	4.978	5.08	5.182
	N	.094	.098	.102	2.388	2.489	2.591
LEAD EDGE OFFSET	aaa	.010			0.25		
LEAD OFFSET	bbb	.010			0.25		
COPLANARITY	ccc	.004			0.10		





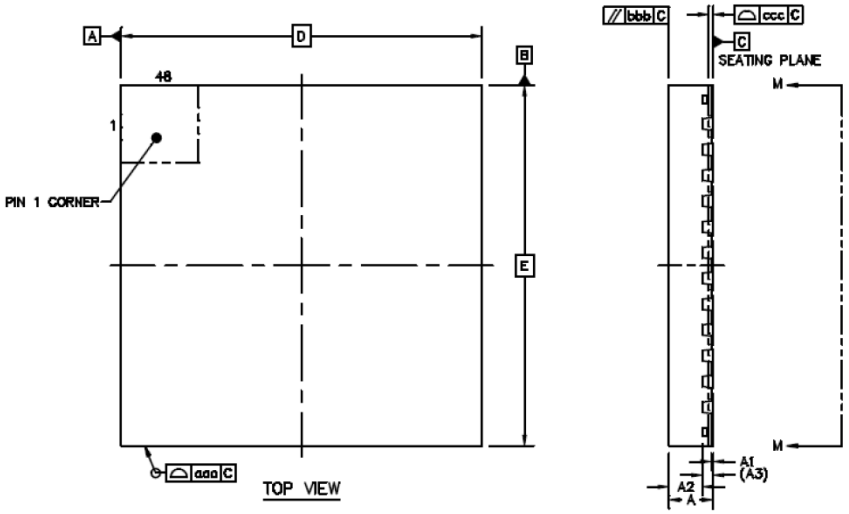
TAPING DIMENSION

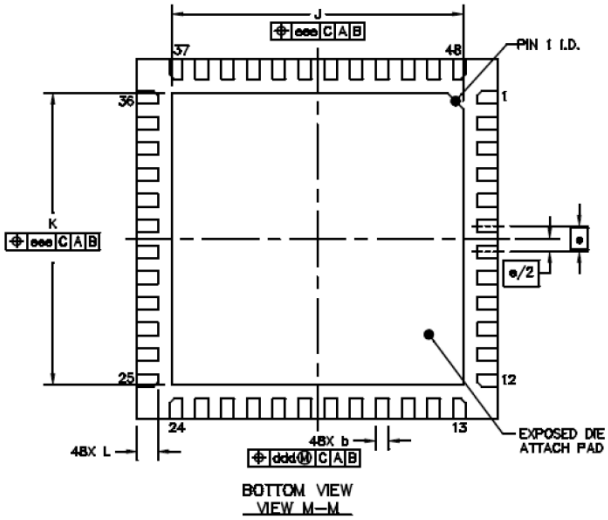


Ao	6.50 +/− 0.1
Bo	5.40 +/− 0.1
Ko	2.00 +/− 0.1
K1	1.70 +/− 0.1
F	5.50 +/− 0.1
P1	8.00 +/− 0.1
W	12.00 +0.3/−0.0

MATERIAL: CONDUCTIVE POLYSTYRENE (IV)		1st Angle / 3rd Angle		
DRAWN:	GENERAL TOLERANCE: ±0.2	REV	DESCRIPTION	DATE	APPROVED
		0	NEW DRAWING.	07.09.10	
DRAWING NO:	SCALE: NTS				
TITLE: OPEN TOOL EMBOSSED CARRIER TAPE DIMENSIONS SO8NP16					

PACKAGE DESCRIPTION (QFN 7X7 48L with EP)





		SYMBOL	MIN	NOM	MAX
TOTAL THICKNESS		A	0.8	0.85	0.9
STAND OFF		A1	0	0.035	0.05
MOLD THICKNESS		A2	---	0.65	0.67
L/F THICKNESS		A3		0.203 REF	
LEAD WIDTH		b	0.2	0.25	0.3
BODY SIZE	X	D		7 BSC	
	Y	E		7 BSC	
LEAD PITCH		e		0.5 BSC	
EP SIZE	X	J	5.55	5.65	5.75
	Y	K	5.55	5.65	5.75
LEAD LENGTH		L	0.35	0.4	0.45
PACKAGE EDGE TOLERANCE		aaa		0.1	
MOLD FLATNESS		bbb		0.1	
COPLANARITY		ccc		0.08	
LEAD OFFSET		ddd		0.1	
EXPOSED PAD OFFSET		eee		0.1	

REVISION HISTORY

Revision number	Changes
1.0	1. Rev 1.0 Created.
1.1	1. PIN 9 of SOC 16 is changed from ISENSE to GND. 2. Recommended VDD capacitor is reduced from 1uF to 0.1uF.
1.2	1. Sinking capability is increased from 120Arms to 150Arms. 2. Abs. Max rating for each current sink is added.
1.3	1. Analog/PWM dimming function is added.
2.0	1. Document format is changed 2. LED current for each tap is added in EC table 3. VDD range is changed 4. Minimum of VDD Iq is removed 5. Package dimension is changed with clearer drawing 6. Soldering footprint is added 7. RISENSE equation is updated 8. LED RMS current is changed in EC table