ACS1004

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

FEATURES

- AC Mains Direct LED Driver with Only Two External Components
- Wide AC Input Range : 90~280VAC
- Compact LED Driver Module Size due to Minimal Number of External Components
- Integrated 4 Ultra High Voltage Constant Current Sinks
- TRIAC Dimmable (Leading/Trailing Edge)
- Rheostat Dimmable
- 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 1.4 in normal LED configuration)
- LED Current Sinking Capability of up to $75mA_{rms}$
- Compact SOIC 8LD Package
- Flexible LED Forward Voltage Configuration
- Multiple LED Driver Configuration
- Over Temperature Protection

DESCRIPTION

The ACS1004 is an AC mains direct LED driver with a minimal number of external components. In 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 an internal shunt regulator. The ACS1004 can be used with different types of TRIAC dimmers. Since the ACS1004 drives all LED current sink outputs based on the AC line levels, whether the AC mains are controlled by a leading edge dimmer, a trailing edge dimmer or a AC level dimmer, the LED forward current closely follows the AC line and is perfectly in phase. It achieves the highest efficiency with high PF and low THD and makes the ACS1004 suitable for high-efficiency LED lighting systems. The ACS1004 can also be used with a rheostat dimmer switches which are suitable for desktop or indoor lamps.

Multiple ACS1004 drivers can be used together for over 10W LED lighting applications such as street lights, down lights, and etc.

APPLICATIONS

- General Solid State Lighting.
- LED Lamp for Decorative Lighting.
- LED Lamp for Low-Power Lighting – Candle light, and etc.

TYPICAL APPLICATION*

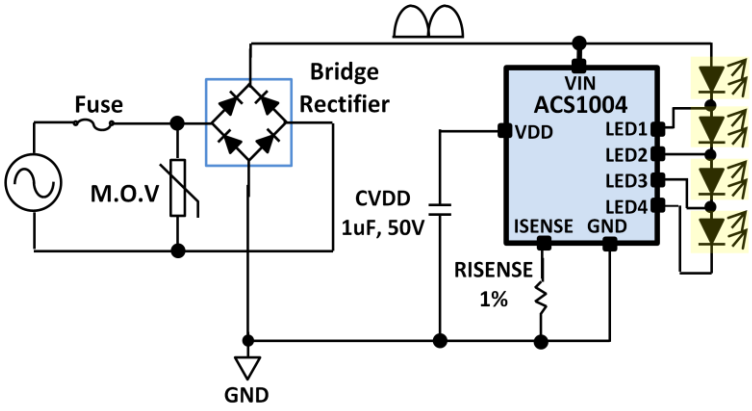


Figure 1. Typical Application

* Each forward voltage(VF) across each LED group is adjustable as needed.

ABSOLUTE MAXIMUM RATINGS

- VIN.....-0.3V to +500V
- LED1~3.....-0.3V to +500V
- LED4.....-0.3V to +200V
- ISENSE.....-0.3V to +6V
- Maximum Junction Temperature(T_{J-MAX}).....+150˚C
- LED1, LED2, LED3, LED4 Current.....60, 80, 100, 150mA

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, unless specified in conditions.
- LED forward current is based on LED forward voltage, VF=65V for each LED channel. Total LED forward voltage is 65V X 4 channels = 260V.

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
VIN SUPPLY					
VIN Quiescent Current	VIN = Max. 500V		0.75	1.20	mA
VDD OUTPUT					
VDD Voltage	VIN=20.0V	16	17	18	V
LED CURRENT					
ILED1	VIN=20.0V, VLED1=20.0V	20.7	23.0	25.3	mA

ILED2	VIN=20.0V, VLED2=20.0V	42.3	47.0	51.7	mA
ILED3	VIN=20.0V, VLED3=35.0V	77.4	86.0	94.6	mA
ILED4	VIN=20.0V, VLED4=20.0V	86.4	96.0	105.6	mA
LED RMS Current	Total VF=260V		71		mA
OVER TEMPERATURE PROTECTION					
OTP Temperature*			170		°C
THERMAL RESISTANCE					
θ_{JA} (EP-SOIC 8LD junction-to-air thermal resistance : PCB layer - 1S)**			91.78		°C/W
θ_{JA} (EP-SOIC 8LD junction-to-air thermal resistance : PCB layer - 2S2P)**			45.07		°C/W
LEAKAGE CURRENT					
LED1~4 Leakage Current	VLED1~3=500V, VLED4=200V, VIN=0V			1	uA

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
ACS1004S	SOIC-8LD	ACS1004S	2,500 Units, Tape and Reel

PIN CONFIGURATION (SOIC 8LD with EP)

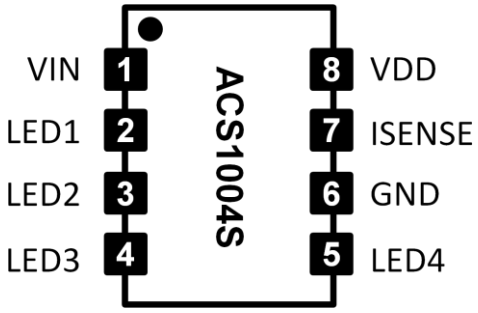


Figure 2. Pin configuration for SOIC 8LD

Pin Number	Pin Name	Description
1	VIN	Rectified AC Input Voltage
2,3,4,5	LED1~4	LED Current Tap Outputs
6	GND	Ground
7	ISENSE	LED Current Sense
8	VDD	Internal Shunt Regulator Output
0	EP	Exposed Thermal Pad

Table 2. Pin Description for SOIC 8LD with EP

PIN FUNCTIONS

VIN: **Rectified AC Input Voltage**. Connect this pin to rectified AC voltage after a bridge rectifier.
VDD: **Internal Shunt Regulator Output Voltage**. This pin supplies current to internal circuitry. A 17.0V shunt regulator is internally connected to this pin. A bypassing capacitor is recommended to be added to reduce noise from VIN.
ISENSE: **LED Current Sense**. Limits LED current depending on the sensing resistor voltage. The ISENSE pin is used to set the LED current regulation.

LED1-4: **LED Current Tap Outputs**. Connect the bottom cathodes of LED groups to these pins. Tie the pin(s) to GND if the corresponding string is not used.
GND: **Ground**. Tie this pin directly to local ground plane. This ground should not be tied to earth ground because it is non-isolated from AC mains.
EP: **Exposed Thermal Pad**. In package, EP is tied to GND inside IC.

BLOCK DIAGRAM

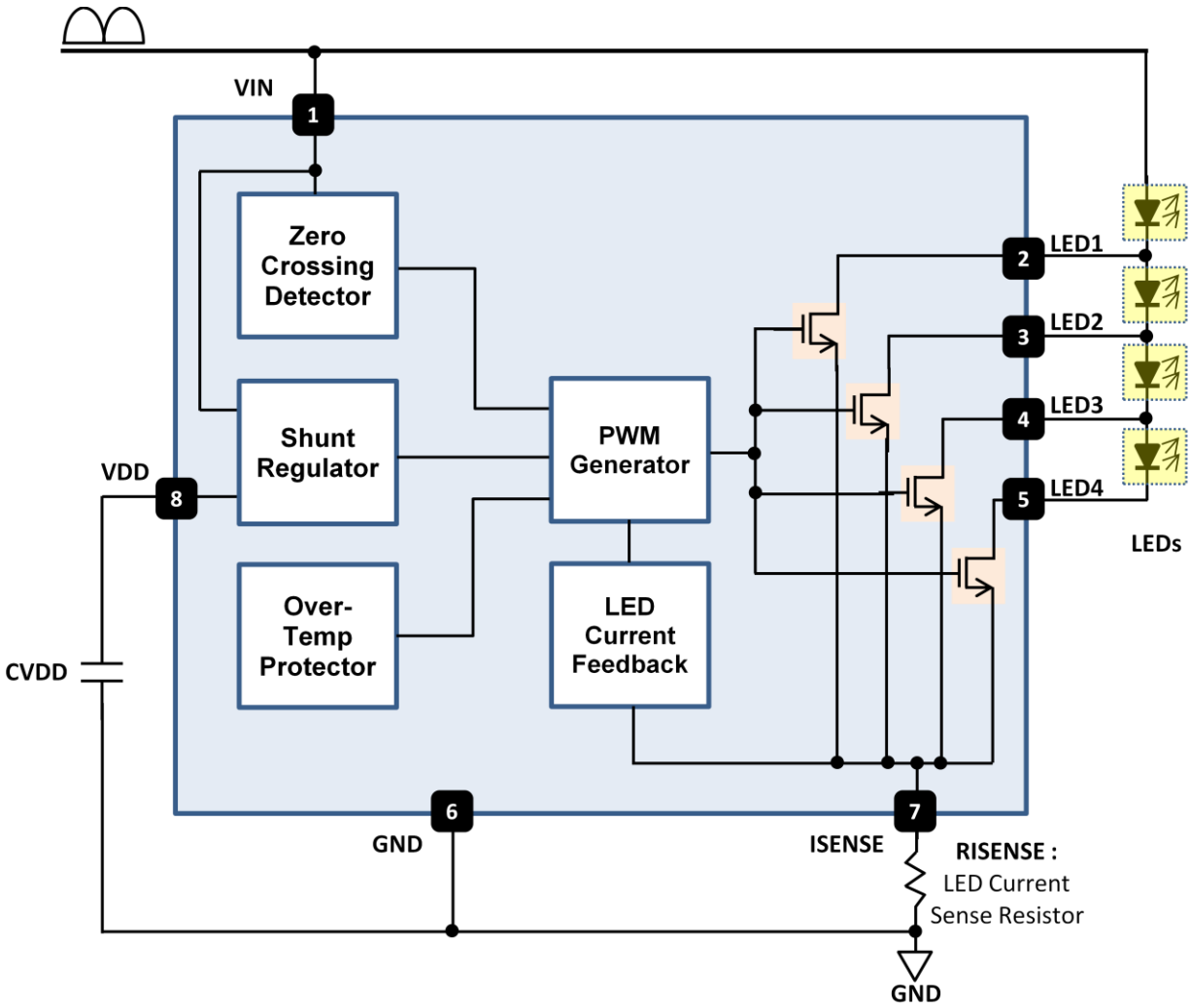


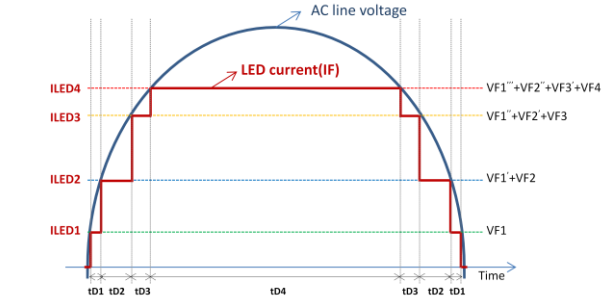
Figure 2. Block diagram of ACS1004

Functional Description

The ACS1004 can drive LED strings attached directly to the rectified AC mains using only two external components. With integrated high voltage current sinks, the ACS1004 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 3. ACS1004 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 ACS1004 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 and each LED channel current level depends on the RISENSE value. Each channel's current sink level is calculated as follows.

$$\text{ILED1} = \frac{0.23}{\text{RISENSE}} \quad \text{ILED2} = \frac{0.47}{\text{RISENSE}}$$
$$\text{ILED3} = \frac{0.86}{\text{RISENSE}} \quad \text{ILED4} = \frac{0.96}{\text{RISENSE}}$$

In ACS1004, the LED RMS current can be calculated using the peak regulated current, ILED4 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 Sine wave, $\sqrt{2}$=1.414. But the actual crest factor depends on the flattened time of the ILED4 and LED configuration. In ACS1004, the typical crest factor approximately is 1.35. The RISENSE resistor value can be calculated as follows.

$$\text{RISENSE} = \frac{\text{VACrms}}{1.35 \times \text{LEDPower}}$$

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

3. Internal Shunt Regulator Output, VDD

The ACS1004 doesn't use the rectification capacitor after the bridge diode. Basically, the VDD, which is

supply power for the ACS1004, has voltage ripple as well as the rectification voltage after the bridge as shown in Figure 4.

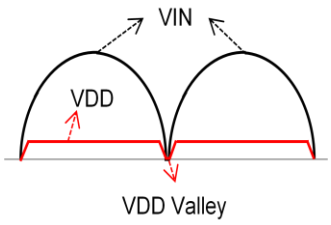


Figure 4. Internal VDD Function without CVDD

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 ACS1004 reset, but the ACS1004 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 1uF with 50V voltage rating.

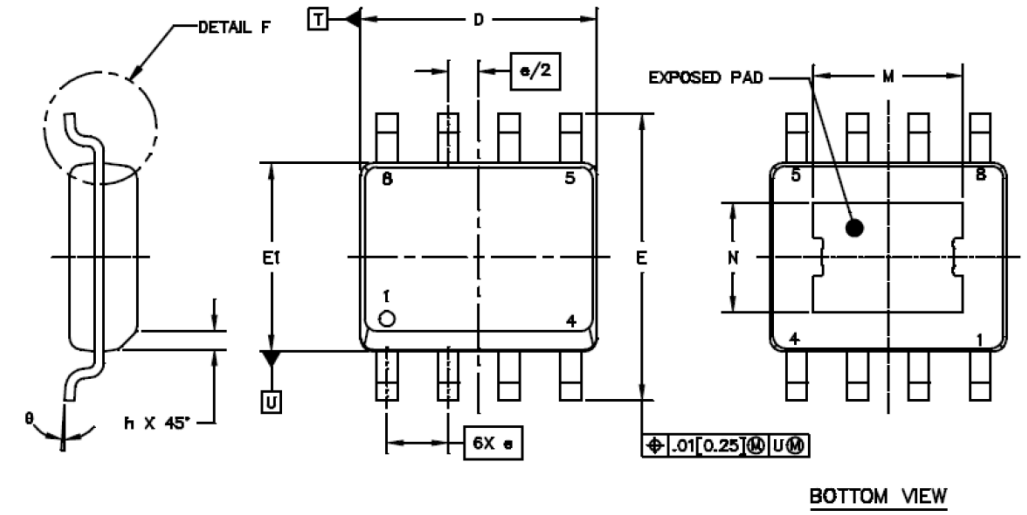
4. LED Configuration

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.

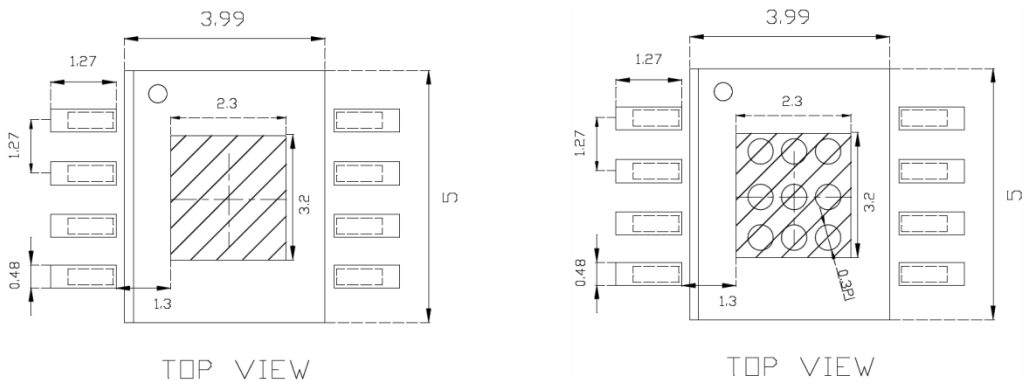
5. Over Temperature Protection

The ACS1004 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. If this protection is not necessary to be adopted, the over temperature protection can be disabled by an internal programming. But without this protection, the lifetime of the ACS1004 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 ACS1004.

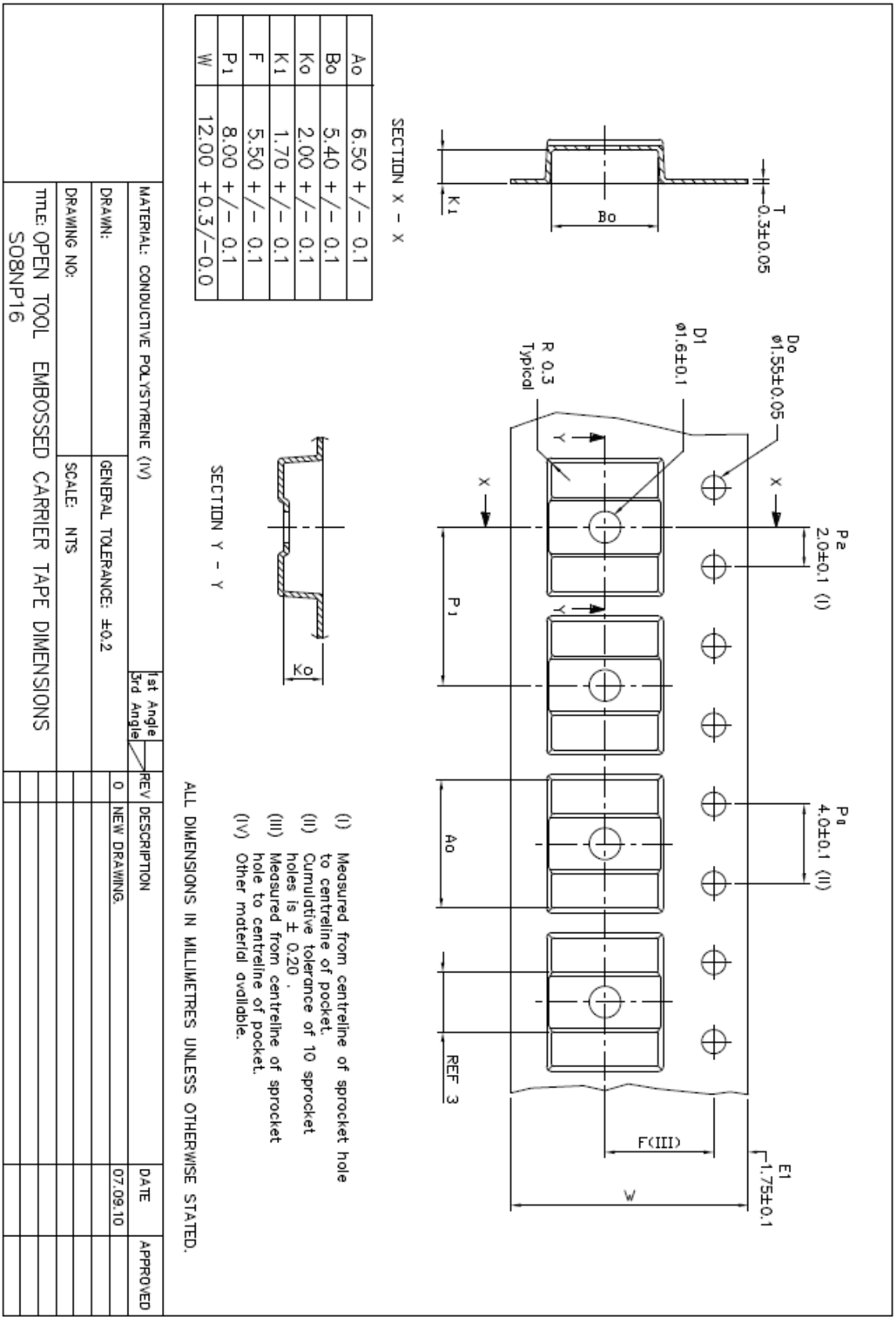
PACKAGE DESCRIPTION (SOIC 8LD with EP) / SOLDERING FOOTPRINT



	SYMBOL	MIN	NOM	MAX	MIN	NOM	MAX
TOTAL THICKNESS	A	.051		.067	1.30		1.70
STAND OFF	A1	.002		.006	0.05		0.15
LEAD WIDTH	b	.014		.019	0.36		0.48
L/F THICKNESS	c	.007		.010	0.18		0.25
BODY SIZE	D	.189		.197	4.80		5.00
	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	.118	.122	.126	3.00	3.10	3.20
	N	.086	.090	.094	2.18	2.29	2.39



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

GENERAL TOLERANCE: ±0.2

DRAWN:

SCALE: NTS

DRAWING NO:

TITLE: OPEN TOOL EMBOSSED CARRIER TAPE DIMENSIONS SO8NP16

REV	DESCRIPTION	DATE	APPROVED
0	NEW DRAWING.	07.09.10	

REVISION HISTORY

Revision number	Changes
1.0	1. Rev 1.0 Created
1.1	1. Changed regulated LED forward current with RISENSE value 2. Added Max. current for LED1~4 in Abs. Max. Rating
1.2	1. Added Max. sinking current capability in RMS value in feature section
2.0	1. Changed package dimension picture with higher quality 2. Footprint is added 3. VDD range is added in E.C. Table