

Dual 1.5A Flash LED Driver

Features

- 2.7V~5.5V Input Voltage
- Drive Up Total 1.5A or 0.75A per Channel
- Flash timeout: 660ms
- Up to 96% Efficiency
- Less than 1 μ A Shutdown Current
- 2MHz Step-Up Converter
- Independent Flash Mode Enable and Movie/Torch Mode Enable Pins
- Thermal Regulation Control
- Over-Temperature Protection
- LED Open or Short Protection
- Output Over-Voltage Protection
- Cycle-by-Cycle Inductor Current Limit
- 0.4mm Pitch, WBDFN 3mm \times 2mm \times 0.75mm -14L Package

Application

Smartphone Camera Flash

General Description

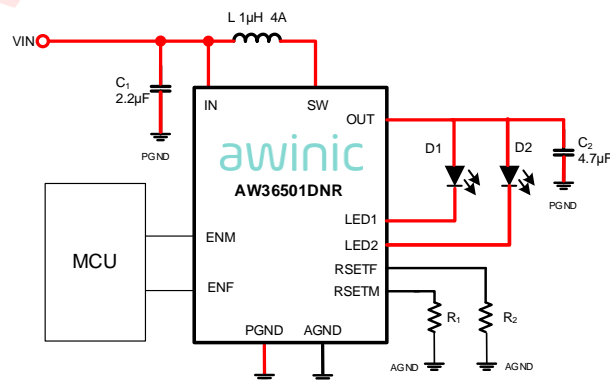
The AW36501 is a dual LED flash driver that provides a high level of adjustability within a small solution size. The AW36501 utilizes a 2MHz frequency synchronous boost converter to provide power to total 1.5A constant current LED sources. The chip support Flash mode and Movie/Torch mode, which can be configured with ENM and ENF enable pins. The maximum current of LED in Flash mode or Movie/Torch mode can be programmed by external resistors. The real LED current can be regulated through the PWM signal input from the ENM pin.

The AW36501 can improve single LED power by shorting two LED output sinks, up to 1.5A LED current for 660ms continuously. The integrated thermal regulation monitors the IC junction temperature and reduces the LED current in Flash mode to limit the IC's temperature.

Multiple protection functions are integrated into the chip, including LED open or short protection, output over-voltage protection, cycle-by-cycle current limit protection and over-temperature protection. The chip consume less than 1 μ A leakage current in shutdown. The AW36501 operates over -40 $^{\circ}$ C to 85 $^{\circ}$ C ambient temperature range.

The AW36501 is available in small 0.4mm pitch WBDFN 3mm \times 2mm \times 0.75mm -14L package.

Typical Application Circuit

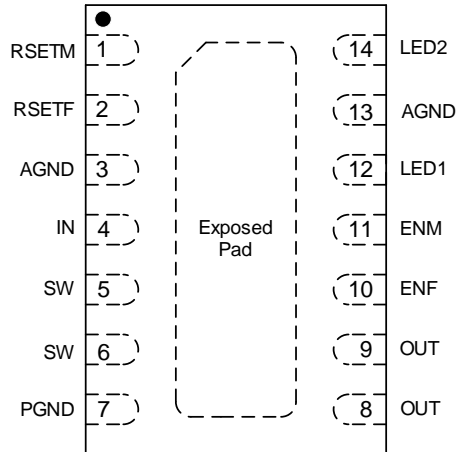


Typical Application Circuit of AW36501

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Pin Configuration And Top Mark

AW36501DNR
(Top View)



AW36501DNR Marking
(Top View)



TGNH - AW36501DNR

XXXX - Production Tracing Code

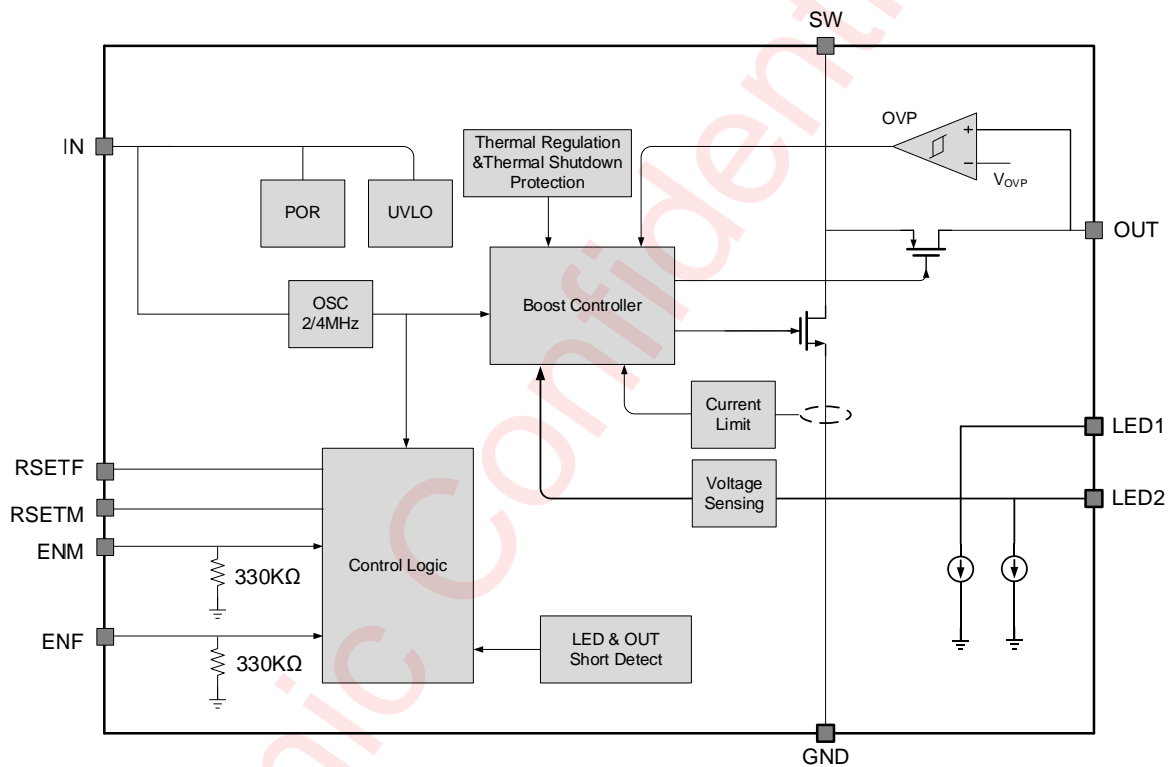
Pin Configuration and Top Mark

Pin Definition

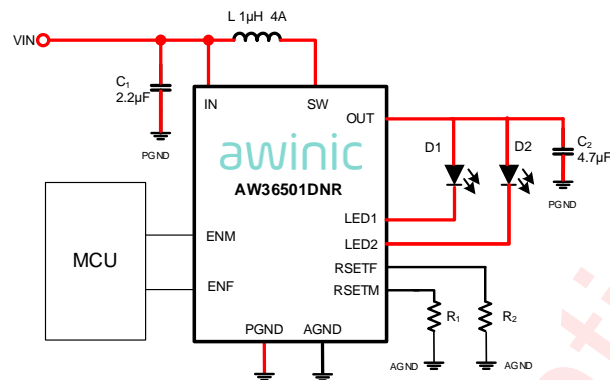
No.	NAME	DESCRIPTION
1	RSETM	Connect a resistor from this pin to GND. This pin sets the maximum current in Movie/Torch mode.
2	RSETF	Connect a resistor from this pin to GND. This pin sets the maximum current in Flash mode.
3, 13	AGND	Analog Ground.
4	IN	Input Voltage Connection. Connect IN to GND with a 2.2 μ F or larger ceramic capacitor.
5, 6	SW	Switching Node of the Step-up DC-DC Converter.
7	PGND	Power Ground.
8, 9	OUT	Step-up DC-DC Converter Output. Connect a 4.7 μ F ceramic capacitor between OUT and GND.
10	ENF	Logic input to enable Flash mode. Driver ENF high to turn on Flash mode, and the Flash ILED current equals $8625/R_{SETF} \times D_{PWM}$. D_{PWM} is the duty cycle of PWM signal at ENM pin, which frequency suggests to larger than 15kHz. Internal pull down resistor of 330k Ω between ENF and AGND.
11	ENM	Logic input to enable Movie/Torch mode and PWM Dimming input. Driver ENM high and the high time is not less than 5ms, then turn Movie/Torch mode will be turned on. The ILED current equals $7100/R_{SETM} \times D_{PWM}$. D_{PWM} is the duty cycle of PWM signal at ENM pin, which frequency suggests to larger than 15kHz. The PWM signal which the high time of the first pulse is more than 5ms. Then the chip will turn to shutdown mode when connects ENF and ENM to logic low and the low time of ENM is

		not less than 5ms. Internal pull down resistor of 330kΩ between ENF and AGND.
12	LED1	Low-side current sink output for D1.
14	LED2	Low-side current sink output for D2.
Exposed Pad	Exposed Pad	Exposed Pad must be connected to ground for good thermal dissipation. Exposed Pad is internally connected to AGND.

Functional Block Diagram



Typical Application Circuits



AW36501 Application Circuit

Notice for Typical Application Circuits:

- 1: Please place C_1 , C_2 , R_1 , R_2 as close to the chip as possible.
- 2: Connect the inductor on the top layer close to the SW pin.
- 3: For the sake of driving capability, the power lines, output lines, and the connection lines of L and LED should be short and wide as possible.
- 4: Traces carry high current are marked in red in the above figure.

Ordering Information

Part Number	Temperature	Package	Marking	Moisture Sensitivity Level	Environmental Information	Delivery Form
AW36501DNR	-40°C~85°C	WBDFN 3mm×2mm×0.75 mm -14L	TGNH	MSL1	ROHS+HF	3000 units/ Tape and Reel

Absolute Maximum Ratings^(NOTE1)

PARAMETERS		Range	Unit
IN, SW, OUT, LED1, LED2		-0.3 to 6	V
ENM, ENF, RSETM, RSETF		-0.3 to (VIN+0.3)	V
Continuous power dissipation		Internally limited	
Max Junction Temperature T_{JMAX} ^(NOTE2)		155	°C
Storage Temperature T_{STG}		-65 to 150	°C
Maximum lead temperature (soldering)		260	°C
Junction to Ambient Thermal Resistance θ_{JA}		67.3	°C /W
ESD, All Pins ^(NOTE3)	HBM	±2000	V
	CDM	±1500	V
Latch-Up (Test method: JEDEC Standard No.78F.01)		+IT: +200 -IT: -200	mA

NOTE1: Conditions out of those ranges listed in "absolute maximum ratings" may cause permanent damages to the device. In spite of the limits above, functional operation conditions of the device should within the ranges listed in "recommended operating conditions". Exposure to absolute-maximum-rated conditions for prolonged periods may affect device reliability.

NOTE2: Internal thermal shutdown function to avoid the device damage. Thermal shutdown is triggered at $T_j=155^{\circ}\text{C}$; Released at $T_j=135^{\circ}\text{C}$. Thermal shutdown is guaranteed by design.

NOTE3: The human body model is a 100pF capacitor discharged through a 1.5kΩ resistor into each pin. Test method: JS-001-2017. CDM test method: JS-002-2022.

Recommended Operating Conditions

Symbol	Parameter	Min.	Typ.	Max.	Unit
V_{IN}	Input voltage	2.7		5.5	V
C_{IN}	Input capacitance	2.2	2.2	22	μF
C_{OUT}	Output capacitance	4.7	4.7	22	μF
L_1	Converter Output Inductor	0.47	1	2.2	μH
T_A	Operating free-air temperature range	-40		85	°C

Electrical Characteristics

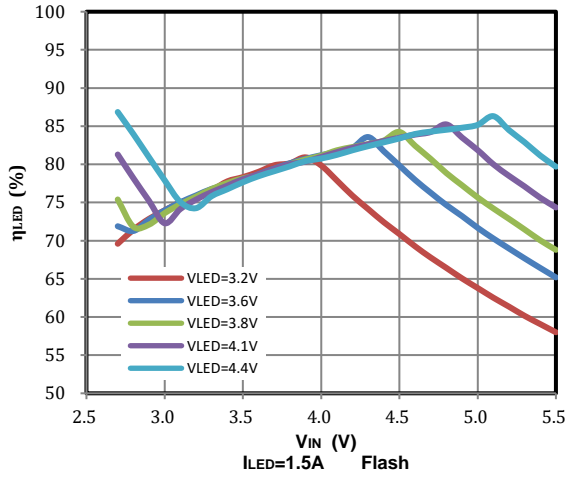
$V_{IN}=3.6V$, $T_A=25^{\circ}C$ for typical values. Unless otherwise specified.

PARAMETER		TEST CONDITION	MIN	TYP	MAX	UNIT
VIN SUPPLY						
V_{IN}	Input operating range		2.7		5.5	V
I_Q	Quiescent supply current	Device not switching, pass mode		175	300	μA
I_{SD}	Shutdown supply current	Device disabled, ENF=ENM=0V		0.1	1	μA
UVLO	Under voltage lockout threshold	Falling V_{IN}	2.38	2.5	2.62	V
		Hysteresis		0.1		V
CURRENT SINK						
I_{LED}	Current source accuracy	Flash mode, $R_{SETF}=11.5k\Omega$, $I_{LED1}+I_{LED2}=1.5A$	1.395	1.5	1.605	A
		Movie/torch mode, $R_{SETM}=71k\Omega$, $I_{LED1}+I_{LED2}=200mA$	180	200	220	mA
t_{TIME}	Flash timeout			660		ms
V_{LED_SHORT}	Short voltage protect threshold between V_{OUT} and V_{LED}		0.6	1	1.2	V
I_{SHORT}	LED short current limit			3		mA
BOOST CONVERTER						
R_{PMOS}	PMOS switch on-resistance			124		m Ω
R_{NMOS}	NMOS switch on-resistance			128		m Ω
I_{CL}	Switch current limit		2.14	2.52	2.9	A
F_{SW}	Switching frequency			2		MHz
V_{OVP}	V_{OUT} over-voltage protect threshold	ON threshold	5.2	5.3	5.4	V
		OFF threshold		100		mV
t_s	Flash mode soft-start time			1		ms
T_{SD}	Thermal shutdown threshold			155		$^{\circ}C$
	Thermal shutdown hysteresis			20		

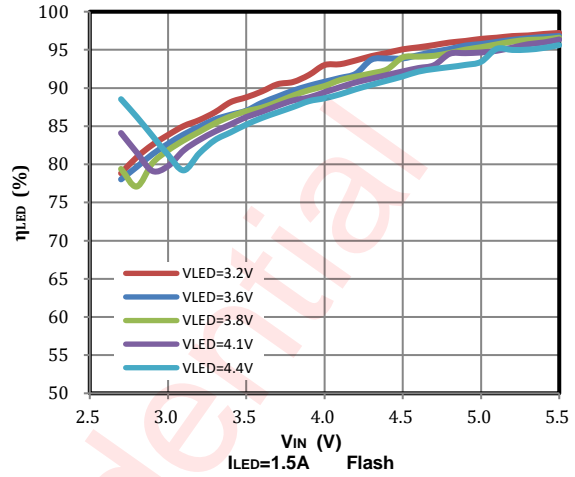
PARAMETER	TEST CONDITION	MIN	TYP	MAX	UNIT
ENM/ENF SPECIFICATIONS					
V _{IL}	Input logic low	0		0.36	V
V _{IH}	Input logic high	0.84		V _{IN}	V
R _{PD_ENM}	ENM Internal pull down resistors		330		kΩ
R _{PD_ENF}	ENF Internal pull down resistors		330		kΩ
START-UP AND SHUTDOWN TIMMING					
t _{ENMH}	High time of entering into Movie/Torch mode	5			ms
t _{ENML}	Low time for shutdown in Movie/Torch mode	5			ms
PWM DIMMING					
F _{PWM}	PWM Dimming Frequency	15		200	kHz
D _{PWM}	PWM Dimming Duty	5		100	%

Typical Characteristics

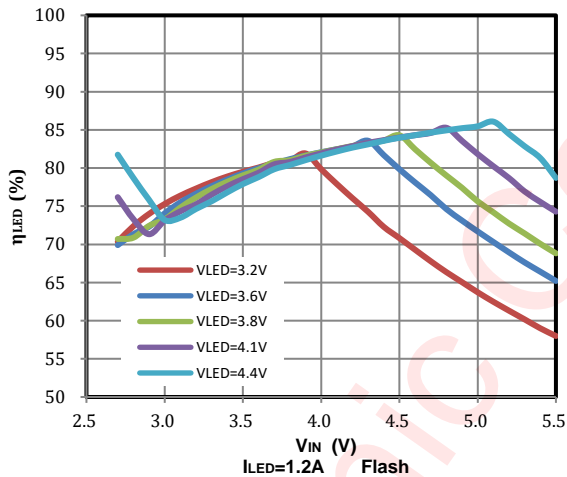
$V_{IN}=3.6V$, $T_A=25^\circ C$ for typical values. Unless otherwise specified.



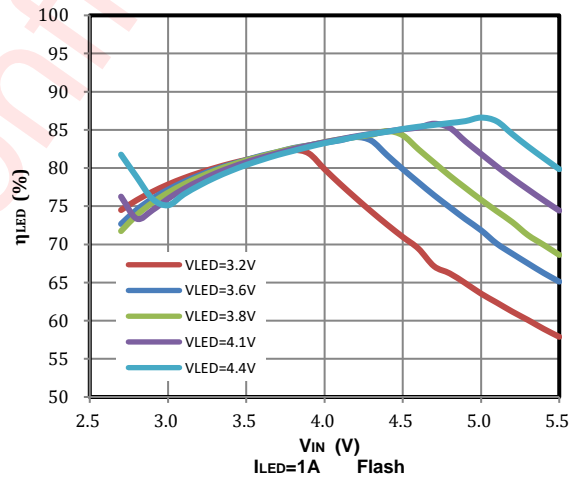
LED1&2 Efficiency vs Input Voltage



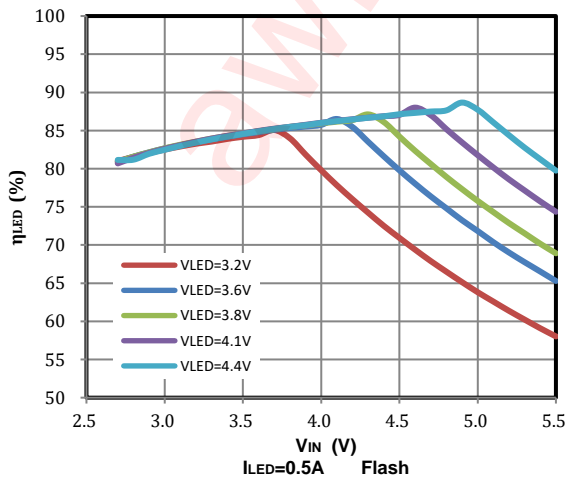
OUT Efficiency vs Input Voltage



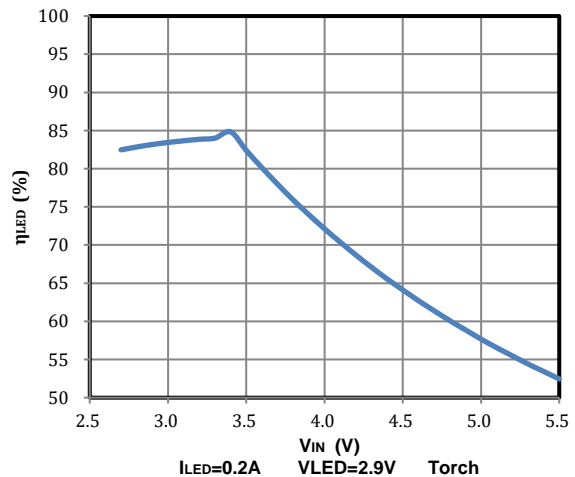
LED1&2 Efficiency vs Input Voltage



LED1&2 Efficiency vs Input Voltage

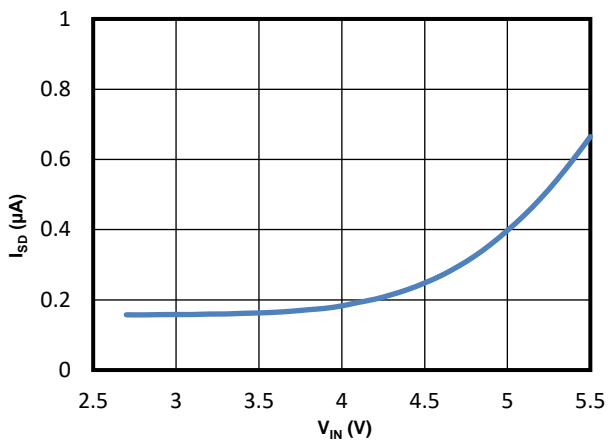


LED1&2 Efficiency vs Input Voltage

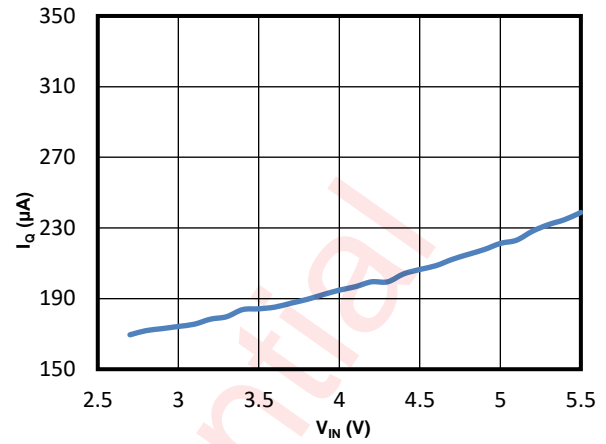


LED1&2 Efficiency vs Input Voltage

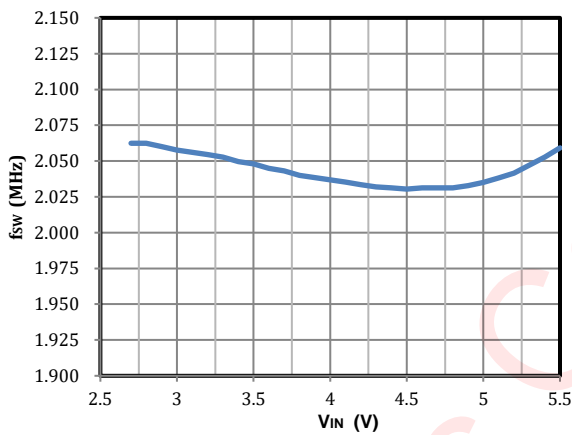
$V_{IN}=3.6V$, $T_A=25^\circ C$ for typical values. Unless otherwise specified.



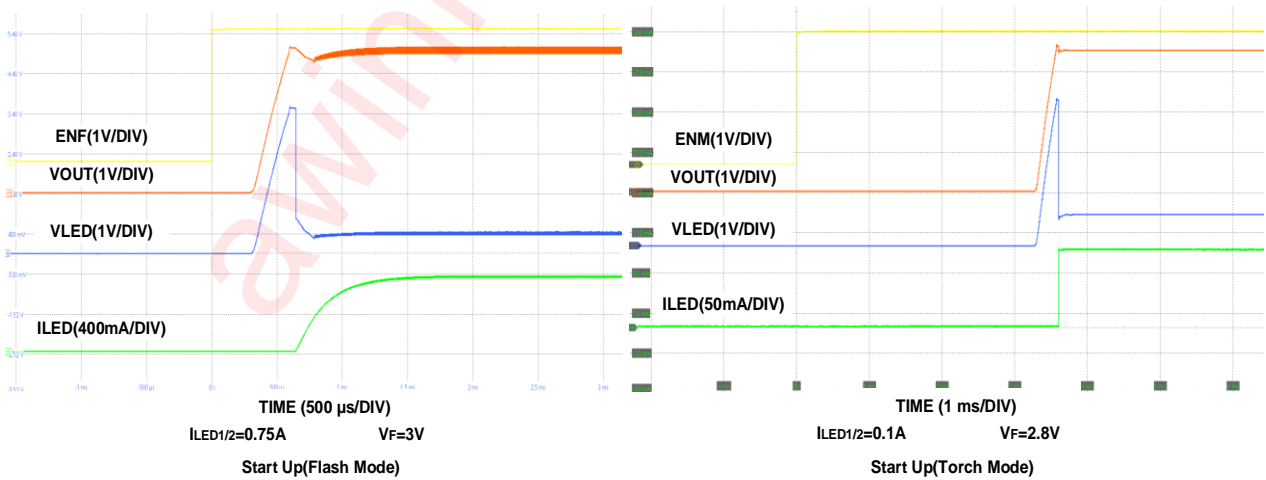
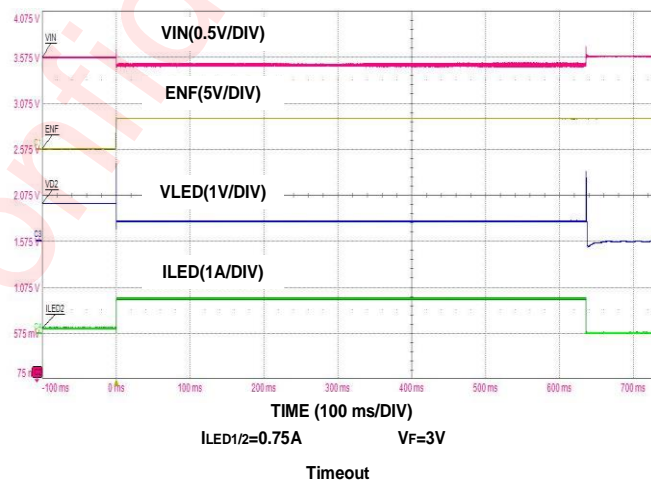
Shutdown Current vs Input Voltage



Quiescent Current vs Input Voltage



2-MHz Frequency vs Input Voltage



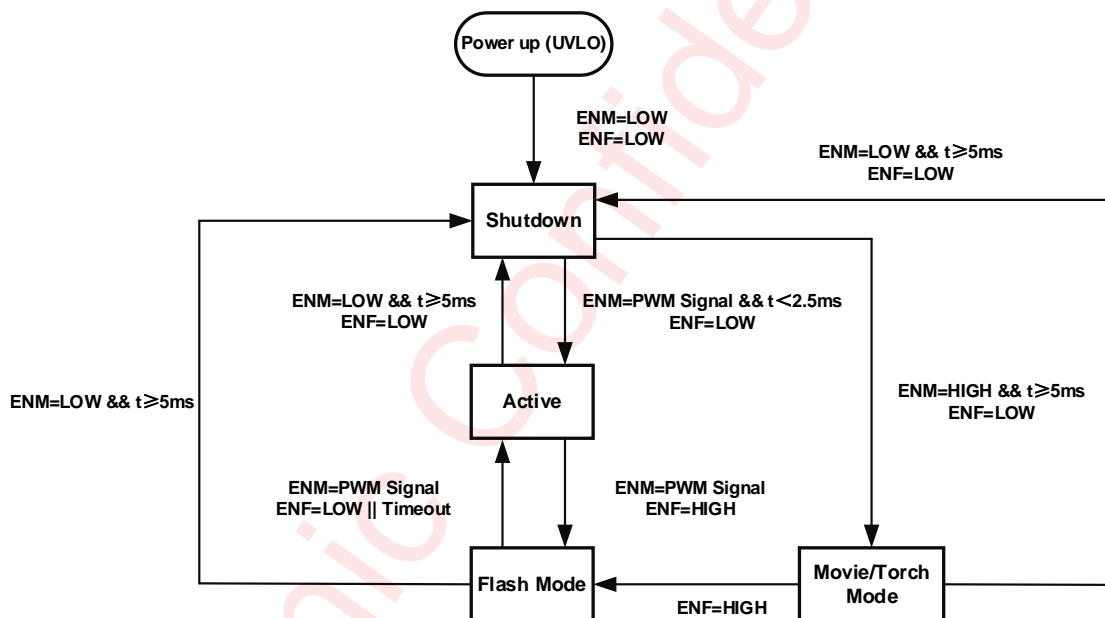
Detailed Functional Description

The AW36501 is a high-power flash LED driver that provides dual 1.5A LED current. The device incorporates a 2MHz frequency synchronous boost converter. Input voltage from 2.7V to 5.5V makes the AW36501 ideally suited for single Li-Lon battery powered applications.

The AW36501 turns on internal boost converter and boosts the voltage to maintain at least V_{HR} across the current sink. The minimum headroom voltage ensures that current sink can provide the maximum output capacity. When the input voltage above the enough voltage for LED and VHR, the device will enter into pass mode which the NMOS would not switch but turn the PMOS on continuously.

The AW36501 has two logic inputs can enable Flash mode or Movie/Torch mode. The maximum Flash LED current can be configure by external R_{SETF} resistors and the maximum Movie/Torch LED current can be set by R_{SETM} . The actual LED current can be regulated through the PWM signal input from the ENM pin.

State Diagram



Power On Reset

When the input voltage drops below the reset voltage threshold V_{POR} (2.2V typical), the device generates a reset signal and reset all circuits.

Soft Start-up

Turn on the AW36501 Movie/Torch and Flash modes can be done for the logic high-level through the ENM/ENF pin. On start-up, the device works on the liner charge stage when V_{OUT} is less than V_{IN} and the internal synchronous PMOS turns on as a current source and delivers 100mA (typical) to the output capacitor. During this time the current source (LED) is off. When the voltage across the output capacitor reaches V_{IN} the current source turns on.

Flash Mode

Flash Mode is activated by pulling the ENF pin HIGH. In Flash Mode, the current sink provides up to total 1.5A

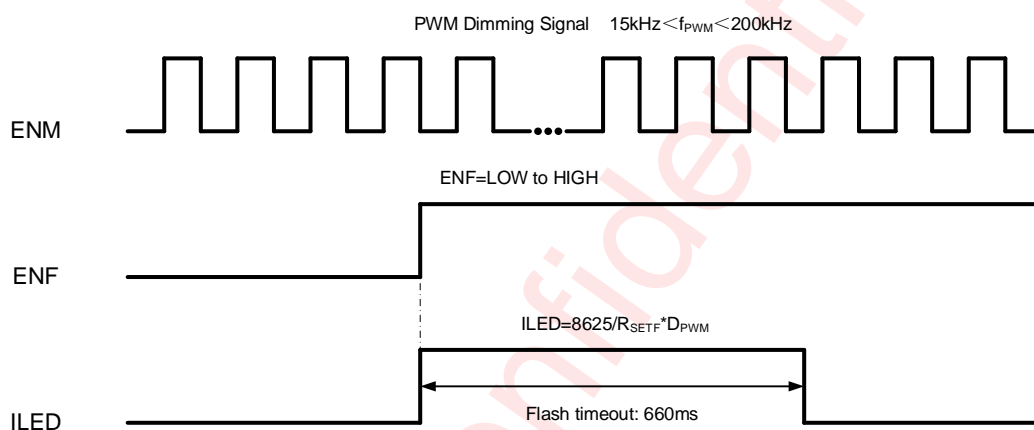
or 0.75A per channel. The maximum LED current in flash mode in each channel can be set by the external R_{SETF} resistor. The R_{SETF} resistor connected between the RSETF pin and ground. The LED current is regulated by the PWM signal at ENM pin, and the actual current in each output can be calculated by using:

$$I_{F(D1/D2)} = \frac{8625}{R_{SETF}} \times D_{PWM}$$

Where

- $R_{SETF}=11.5k\Omega$ (minimum)
- D_{PWM} is the duty cycle of ENM PWM signal

The AW36501 has the Flash timeout period which sets the maximum time of one flash event, and the Flash time is 660ms typically. The device will turn off the current sink after time is over or the logic of ENF is LOW.



Flash Mode Timing Sequence

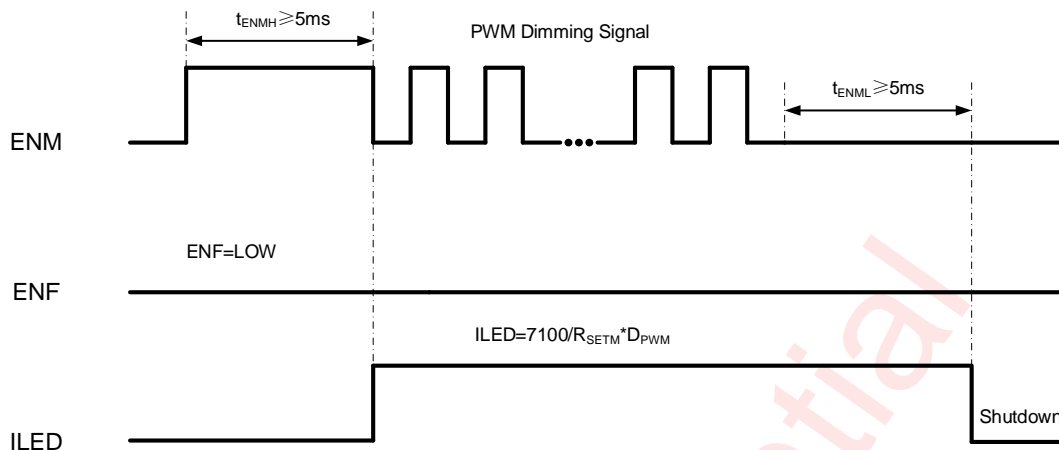
Movie/Torch Mode

When the high time of the ENM exceeds 5ms, the Movie/Torch Mode is active. The LED current in Movie/Torch Mode can be set by the external R_{SETM} resistor which is connected between the RSETM pin and ground. The current sink can provide to maximum total current of 400mA or 200mA per channel. The Movie/Torch mode also support PWM to analog dimming. And the real output current per channel can be calculated by using:

$$I_{M(D1/D2)} = \frac{7100}{R_{SETM}} \times D_{PWM}$$

Where

- $R_{SETM}=36k\Omega$ (minimum)
- D_{PWM} is the duty cycle of ENM PWM signal



Movie/Torch Mode Timing Sequence

Current Limit

The AW36501 features inductor current limit of 2.52A(typ.). When the inductor current limit is reached, the AW36501 terminates the charging phase of the switching cycle until the next switching period. If the over-current condition exists, the device operates continuously in current limit. The current limit is sampled during the NMOS switch period, so there is no mechanism to limit the current when the device operates in Pass Mode (current does not flow through the NMOS in pass mode).

Under Voltage Lockout (UVLO)

The AW36501 has an internal comparator that monitors the voltage at IN and turn off the output and current sink if the input voltage drops to 2.5V(typ.). If the input voltage rises above 2.6V(typ.), the normal operation can be resumed.

Over Voltage Protection (OVP)

When LED open event occurs, the AW36501 raises the output voltage in order to try and keep the LED at its target value. When VOUT reaches 5.3V(typ.) the overvoltage comparator trips and turn off the internal NMOS. When VOUT fall below 5.2V(typ.), the AW36501 begins switching again.

LED Short Protection

In case of LED short which the OUT pin short connect the LED pin, the AW36501 features sink current source limit of 3mA. This not only prevents the device from being damaged by high power, but also can not affect the normal operation of the other LED when there is a short circuit of LED in the dual-LED application. After the short circuit is released, the device will automatically recover the default current setting.

OUT Short Protection

VOUT short condition occurs if the voltage at OUT goes below 2.2V (typ.) while the device is in Torch or Flash mode. The AW36501 will return to liner charge stage when the out short is triggered. After the short circuit is released, the device will automatically recover the default current setting.

Thermal Regulation and Thermal Shutdown (TSD)

The AW36501 has an internal thermal regulation that sensing the die temperature and start reducing the LED current of two current sink automatically when the die temperature exceeds 100°C. The thermal regulation module will limit the LED current output to prevent the chip from easily triggering over temperature shutdown protection.

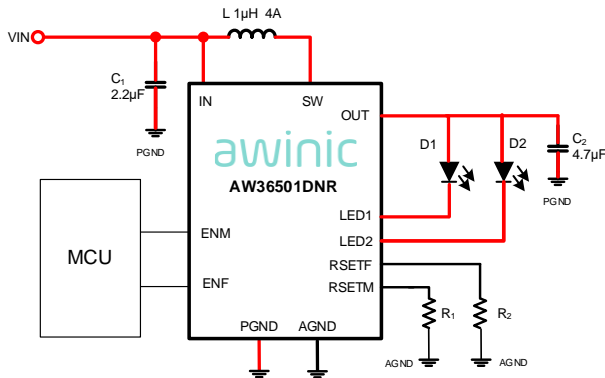
When the AW36501 die temperature reaches 155°C, the thermal shutdown detection circuit trips, forcing the AW36501 enter standby mode. The device will return to the normal operation after the die temperature below 135°C.

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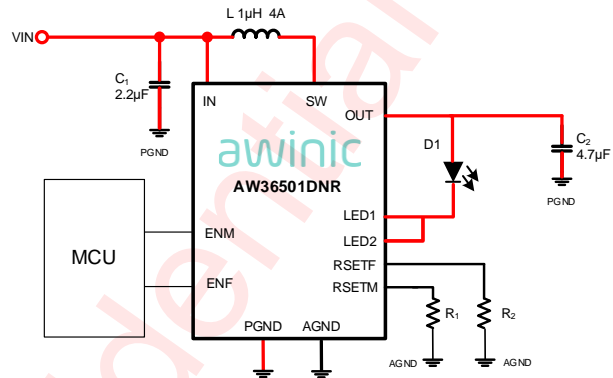
Application Information

Single/Dual LED Applications

Both LED lamp anodes are connected the OUT pin and the cathodes connected the LED1 and LED2 pin respectively for dual LED application. The AW36501 also can short connect the LED1 and LED2 to driver single LED and supply up to total 1.5A current. Each current can be set with the external resistor.



Dual LED Application Circuit



Single LED Application Circuit

Inductor Selection

The AW36501 is designed to use a 0.47µH to 2.2µH inductor. When the device works on Boost the inductor is typically the largest area of efficiency loss in the circuit. Therefore, choosing an inductor with the lowest possible series resistance is important. Additionally, the saturation rating of the inductor should be greater than the maximum operating peak current of the AW36501. This prevents excess efficiency loss that can occur with inductors that operate in saturation. For proper inductor operation and circuit performance, ensure that the inductor saturation and the peak current limit setting of the AW36501 are greater than I_{PEAK} in the following calculation:

$$I_{PEAK} = \frac{I_{LED} \times V_{OUT}}{\eta \times V_{IN}} + \frac{\Delta I_L}{2} \quad \text{where} \quad \Delta I_L = \frac{V_{IN} \times (V_{OUT} - V_{IN})}{f_{SW} \times L \times V_{OUT}}$$

To avoid the saturation of the inductor, the inductor should be rated at least for the maximum output current of the converter plus the inductor ripple current.

Input Capacitor Selection

Choosing the correct size and type of input capacitor helps minimize the voltage ripple caused by the switching of the AW36501 boost converter and reduce noise on the boost converter's input pin that can feed through and disrupt internal analog signals. In the typical application circuit a 2.2µF ceramic input capacitor works well. It is important to place the input capacitor as close as possible to the AW36501 input (IN) pin. This reduces the series resistance and inductance that can inject noise into the device due to the input switching currents.

Output Capacitor Selection

The AW36501 is designed to operate with a 4.7µF ceramic output capacitor. When the boost converter is running, the output capacitor supplies the load current during the boost converter on-time. When the NMOS switch turns off, the inductor energy is discharged through the internal PMOS switch, supplying power to the load and restoring charge to the output capacitor. This causes a sag in the output voltage during the on-time

and a rise in the output voltage during the off-time. The output capacitor is therefore chosen to limit the output ripple to an acceptable level depending on load current and input/output voltage differentials and also to ensure the converter remains stable.

Larger capacitors such as a 22 μ F capacitors in parallel can be used if lower output voltage ripple is desired. To estimate the output voltage ripple considering the ripple due to capacitor discharge (ΔV_Q) and the ripple due to the capacitors ESR (ΔV_{ESR}) use the following equations:

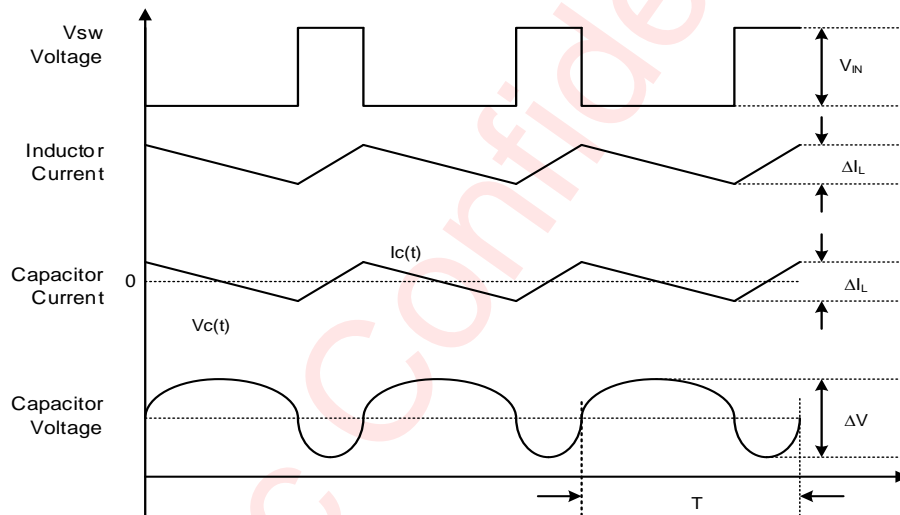
For continuous conduction mode, the output voltage ripple due to the capacitor discharge is:

$$\Delta V_Q = \frac{(V_{OUT} - V_{IN}) \times I_{LED}}{V_{OUT} \times f \times C_{OUT}}$$

The output voltage ripple due to the output capacitors ESR is found by:

$$\Delta V_{ESR} = R_{ESR} \times \left(\frac{V_{OUT} \times I_{LED}}{V_{IN}} + \frac{\Delta I_L}{2} \right) \quad \text{Where} \quad \Delta I_L = \frac{V_{IN} \times (V_{OUT} - V_{IN})}{f_{SW} \times L \times V_{OUT}}$$

In ceramic capacitors the ESR is very low so the assumption is that 80% of the output voltage ripple is due to capacitor discharge and 20% from ESR.



Output Ripple

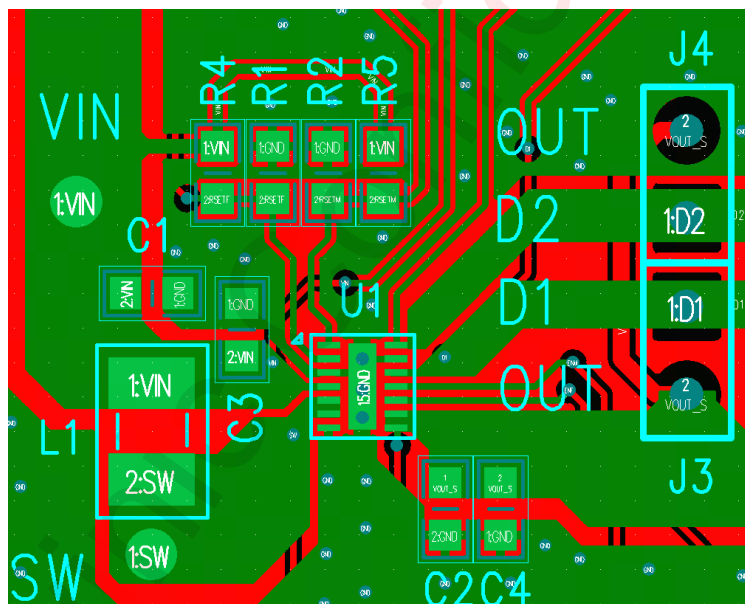
When choosing the input and output ceramic capacitors, choose the X5R or X7R dielectric formulations. These dielectrics have the best temperature and voltage characteristics of all the ceramics for a given value and size.

PCB Layout Consideration

Layout Guidelines

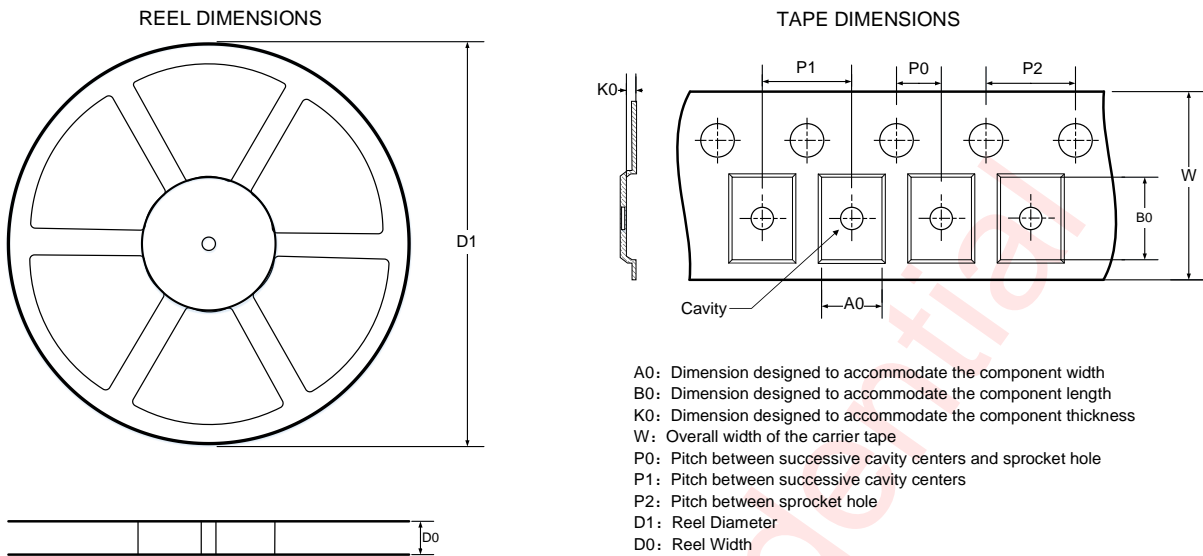
The high switching frequency and large switching currents of the AW36501 make the choice of layout important. The following steps should be used as a reference to ensure the device is stable and maintains proper LED current regulation across its intended operating voltage and current range.

1. Place the input capacitor (such as C3) on the top layer and as close to the AW36501 as possible. The traces which connect the input capacitors to both the VIN and GND pins should be short and wide to reduce parasitic inductance and resistance.
2. Place the output capacitor (such as C2) on the top layer and as close as possible to the OUT and GND pin. Connecting the C_{OUT} through short and wide traces can reduce the series inductance on the OUT and GND pins to avoid causing excessive noise in the device and surrounding circuitry.
3. Connect the inductor on the top layer close to the SW pin. Due to the large DC inductor current, short and wide traces are used to connect SW node to reduce series impedance and parasitic inductance interference from high-frequency switching signals to other signals.
4. Keep other signal lines away from SW nodes to avoid high-frequency interference.

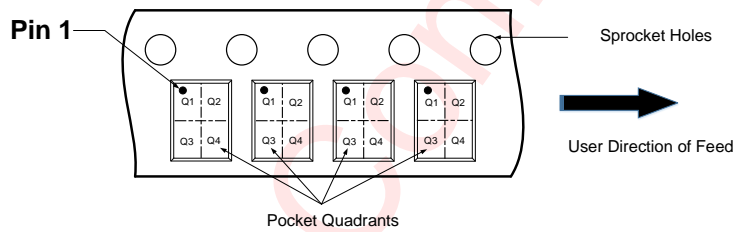


AW36501DNR Layout Example

Tape and Reel Information



QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE



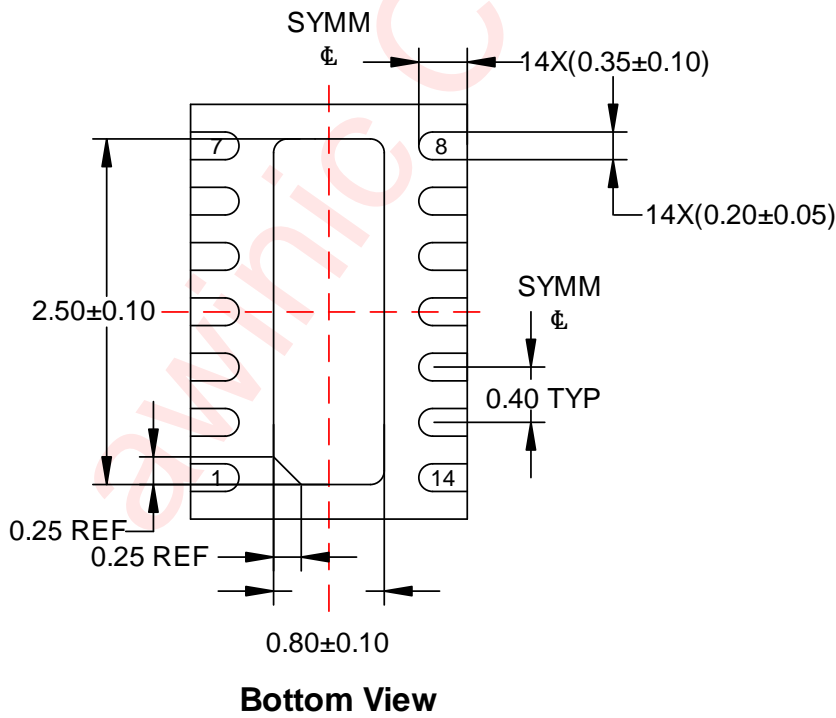
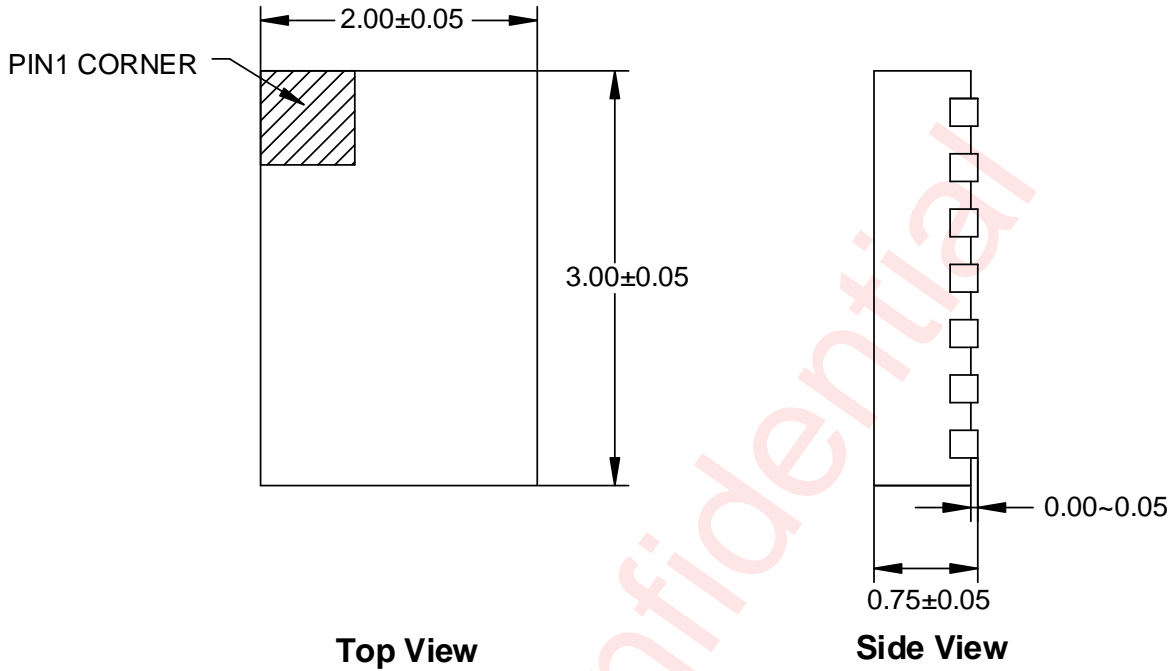
Note: The above picture is for reference only. Please refer to the value in the table below for the actual size

DIMENSIONS AND PIN1 ORIENTATION

D1 (mm)	D0 (mm)	A0 (mm)	B0 (mm)	K0 (mm)	P0 (mm)	P1 (mm)	P2 (mm)	W (mm)	Pin1 Quadrant
178.00	8.50	2.30	3.30	1.10	2.00	4.00	4.00	8.00	Q1

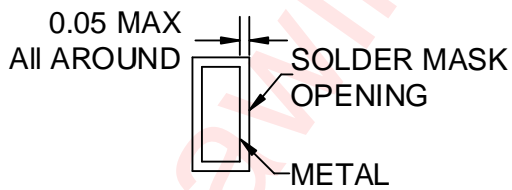
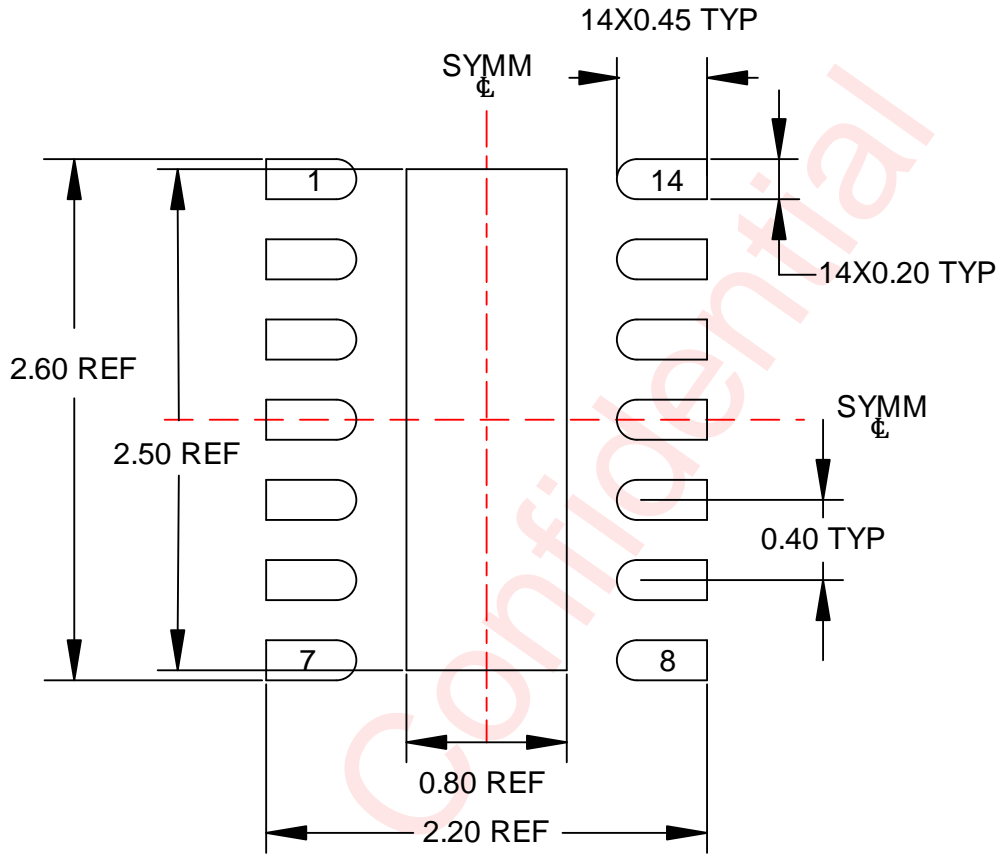
All dimensions are nominal

Package Description

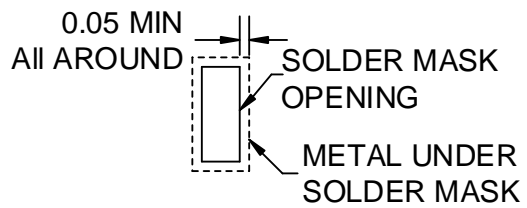


Unit: mm

Land Pattern Data



NON SOLDER MASK DEFINED



SOLDER MASK DEFINED

Unit: mm

Revision History

Version	Date	Change Record
V1.0	Nov 2023	Officially released

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