AW3606A Synchronous Step-up Converter with Ultra Low Quiescent Current

Features

- Ultra Low Quiescent Current:
- I_Q into VIN Pin: 200nA
- I_Q into VOUT Pin: 800nA
- Operating Input Voltage Range: 0.9V~5.2V
- Adjustable Output Voltage from 2.5V~5.2V
- ILoad⩾0.5A at VOUT=5V, VIN⩾3V
- Operation Mode: Boost Mode, Down Mode, Path Through Mode
- True Cutoff VIN to VOUT path During Shutdown
- Up to 93% Efficiency at 10mA~300mA Current Load
- Build-in OVP, OTP, UVLO Protection
- DFN 2mm x 2mm x 0.55mm-8L Package

Applications

Portable Products
Battery Powered Systems
Wearable Applications
Low Power Wireless Applications
Optical Heart Rate Monitor LED Bias

General Description

The AW3606A is a high efficiency synchronous step-up converter with ultra-low quiescent current down to 1μA, it is optimized for battery-powered applications, such as alkaline battery, coin-cell battery, Li-ion or Li-Polymer battery, that requires long battery life and tiny solution size.

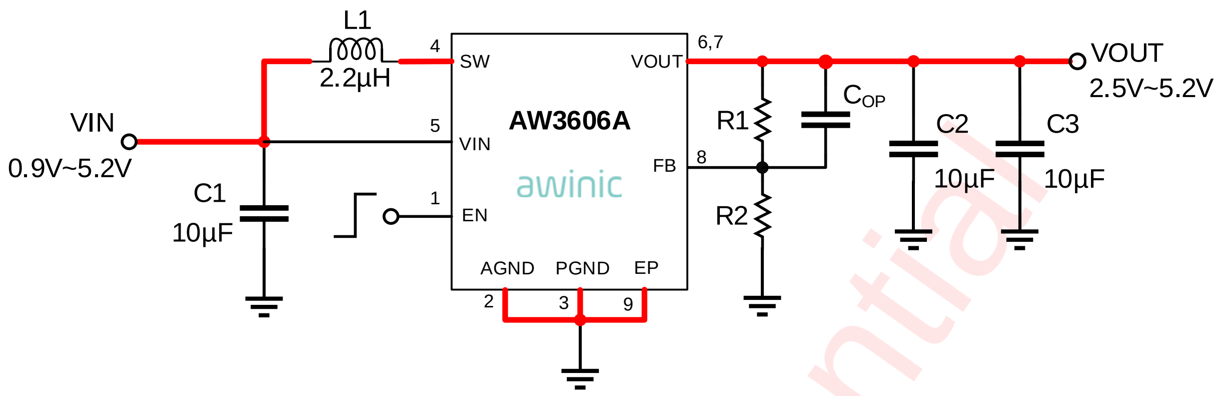
The AW3606A uses a hysteretic current mode control scheme with typical 1.4A peak switch current limit when VOUT voltage exceed 2.5V. It consumes 1μA quiescent current under light load condition. It supports up to 500mA output current when input voltage is above 3V, and achieve up to 93% efficiency at 200mA load.

The AW3606A operates in down mode and pass-through mode when input voltage is close to or higher than output voltage. In the down mode, the AW3606A will continue to regulate the output voltage even when the input voltage exceeds the output voltage. When VIN > VOUT + 0.37V, It enters pass-through mode and the device stops switching. The rectifying PMOS constantly turns on and low-side switch constantly turns off.

The AW3606A build-in true shutdown function when it is disabled, which isolates the load from the input to reduce the current consumption. Also, the AW3606A integrates OVP, OTP, UVLO protections.

The AW3606A offers adjustable output voltage version. It is available in a tiny DFN 8pin package.

Typical Application Circuit



Typical Application Circuit of AW3606A

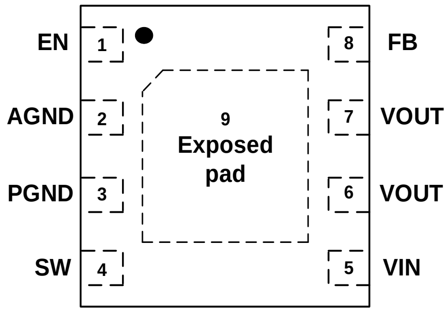
For best output and input voltage filtering, low ESR X5R or X7R ceramic capacitors are recommended.

The FB pin should be connected to the resistance divider, and the VOUT can be set to **VFB · (R1 + R2)/ R2**.

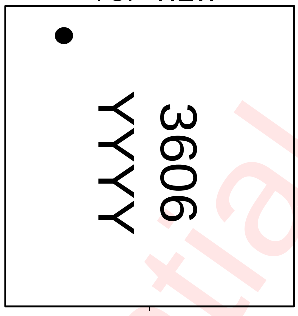
A C_{OP} is recommended between FB and OUT pin to optimize the load transient response performance.

Pin Configuration And Top Mark

AW3606ADNR
TOP VIEW



AW3606ADNR MARKING
TOP VIEW



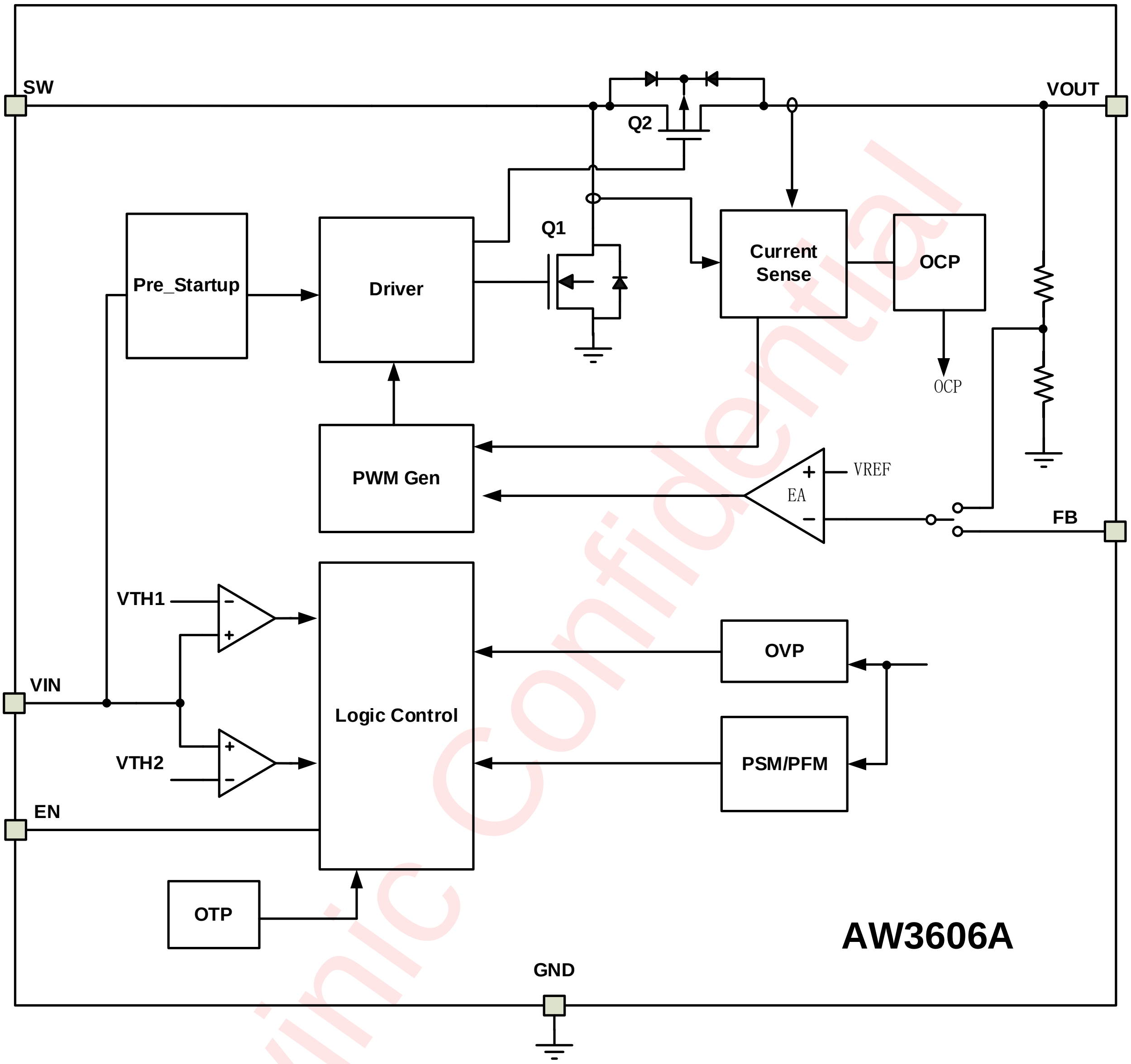
3606 - AW3606ADNR
YYYY - Production Tracing Code

Pin Configuration and Top Mark

Pin Definition

Pin No.	NAME	DESCRIPTION
1	EN	Enable Logic Input. Logic high voltage enables the device; logic low voltage disables the device. Do not leave it floating.
2	AGND	Analog Ground. Should be connected to PGND.
3	PGND	Power Ground. This is the power return terminal for the IC, C_{OUT} capacitor should be returned with the shortest path possible to this pin.
4	SW	Switch Pin of the Converter. It is connected to the inductor.
5	VIN	Power Supply Input.
6, 7	VOUT	Boost Converter Output.
8	FB	Voltage Feedback of Adjustable Output Voltage. Connect to the center tap of a resistor divider to program the output voltage.
9	Exposed Pad	Should be connected to AGND and PGND.

Functional Block Diagram



Functional Block Diagram

Ordering Information

Part Number	Temperature	Package	Marking	Moisture Sensitivity Level	Environmental Information	Delivery Form
AW3606A DNR	-40°C ~ 85°C	DFN 2mm x 2mm x 0.55mm-8L	3606	MSL1	RoHS+HF	3000 units/ Tape and Reel

Absolute Maximum Ratings(NOTE1)

PARAMETERS		RANGE
Input voltage range	VIN, FB, EN	-0.3V to 6V
Output voltage range	SW, VOUT	-0.3V to 6V
Operating free-air temperature range		-40°C to 85°C
Maximum operating junction temperature T_{JMAX}		150°C
Storage temperature T_{STG}		-65°C to 150°C
Lead temperature (soldering 10 seconds)		260°C
ESD(Including CDM HBM)(NOTE 2)		
HBM		±2kV
CDM		±1.5kV
Latch-Up		
Test condition: JESD78E		+IT：200mA -IT：-200mA

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: The human body model is a 100pF capacitor discharged through a 1.5kΩ resistor into each pin. Test method: ESDA/JEDEC JS-001

Thermal Information

PARAMETERS	DFN	UNIT
Junction-to-ambient thermal resistance $R_{\theta JA}$	71.36	°C/W
Junction-to-top characterization parameter Ψ_{JT}	2.91	°C/W
Junction-to-board characterization parameter Ψ_{JB}	31.25	°C/W

Recommended Operating Conditions

PARAMETERS	MIN	NORM	MAX	UNIT
Input Voltage Range V_{IN}	0.9		5.2	V
Output Voltage Range V_{OUT}	2.5		5.2	V
Inductor L	0.7	2.2	2.8	μH
Input Capacitor C_{IN}	1.0	10		μF
Output Capacitor C_{OUT}	10	20	100	μF

Electrical Characteristics

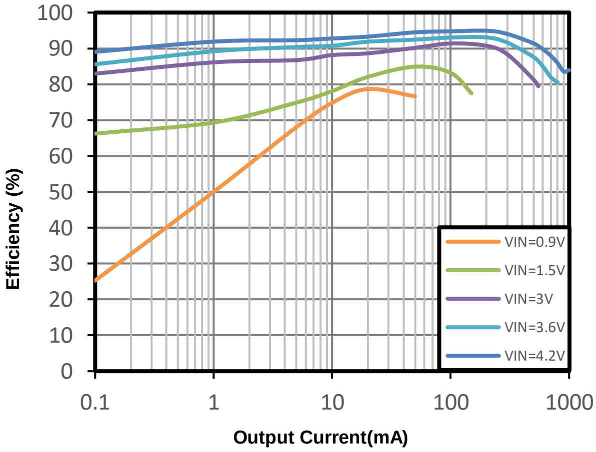
T_A = -40°C to 85°C and VIN = 0.9 V to 5.2 V. Typical values are at VIN = 3.7 V, T_A = 25°C, unless otherwise noted.

PARAMETER		TEST CONDITION	MIN	TYP	MAX	UNIT
POWER SUPPLY						
V_{IN}	UVLO threshold voltage	V_{IN} rising		0.7		V
	Hysteresis for UVLO			0.2		V
	Input Voltage Range		0.9		5.2	V
I_Q	Quiescent Current into VIN pin	EN=High, No load, no switching		0.35	0.6	μA
	Quiescent Current into VOUT pin	EN=High, No load, no switching		0.9	3	μA
I_{SD}	Shutdown Current into Vin pin	IC disabled, V_{IN} = 3.7 V, V_{OUT} = 0 V, T_A = -40 °C to 85 °C		0.2	1.8	μA
OUTPUT						
V_{OUT}	Output Voltage Range		2.5		5.2	V
V_{REF}	Feedback reference voltage	$V_{IN} < V_{OUT}$, PWM mode	0.98	1.00	1.02	V
		$V_{IN} < V_{OUT}$, PFM mode	0.99	1.02	1.05	
V_{OVP}	Output overvoltage protection threshold	V_{OUT} rising	5.6	5.8	6.0	V
	OVP hysteresis			100	200	mV
I_{FB_LKG}	Leakage current into FB pin			10	100	nA
POWER SWITCH						
$R_{DS(on)\_LS}$	Low side switch on resistance	V_{OUT}=5.0V		190		mΩ
		V_{OUT}=3.3V		240		
$R_{DS(on)\_HS}$	Rectifier on resistance	V_{OUT}=5.0V		280		mΩ
		V_{OUT}=3.3V		350		
ΔI_L	Inductor current ripple	V_{OUT}=5V, Guarantee by design		300		mA
I_{LIM}	Peak Current limit threshold	$V_{OUT} \geq 2.5$ V, boost operation		1.4		A
		$V_{OUT} < 2.5$ V, boost operation		0.75		
I_{SW_LKG}	Leakage current into SW pin (from SW pin to GND)	V_{SW} = 5.0 V, no switch			1	μA
CONTROL LOGIC						
V_{IL}	EN input low voltage threshold	$V_{IN} \leq 1.5$ V	$0.2 \times V_{IN}$			V
V_{IH}	EN input high voltage threshold	$V_{IN} \leq 1.5$ V			$0.8 \times V_{IN}$	

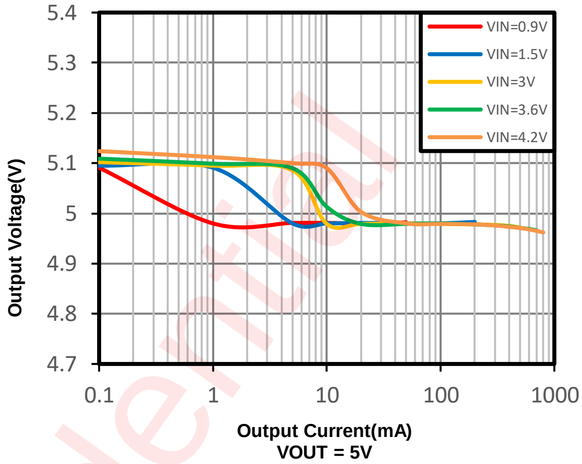
PARAMETER		TEST CONDITION	MIN	TYP	MAX	UNIT
V_{IL}	EN input low voltage threshold	V_{IN} > 1.5V	0.3			V
V_{IH}	EN input high voltage threshold	V_{IN} > 1.5V			0.9	
I_{EN_LKG}	Leakage current into EN pin	V_{EN} = 5.0 V			300	nA
Overtemperature protection				150		°C
Overtemperature hysteresis				25		

Typical Characteristics

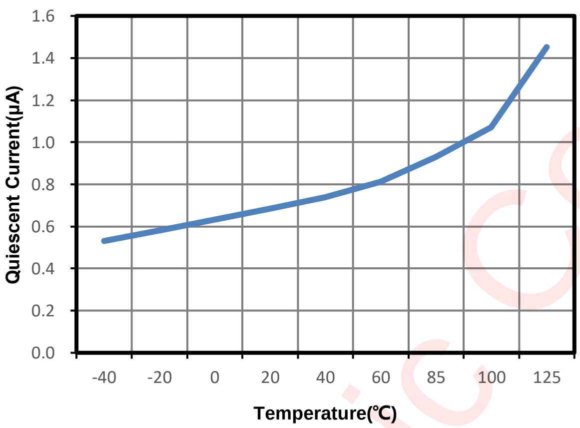
T_A=25°C, C_{IN} = 10μF, C_{OUT} = 20μF, V_{IN}=3.7V, unless otherwise noted.



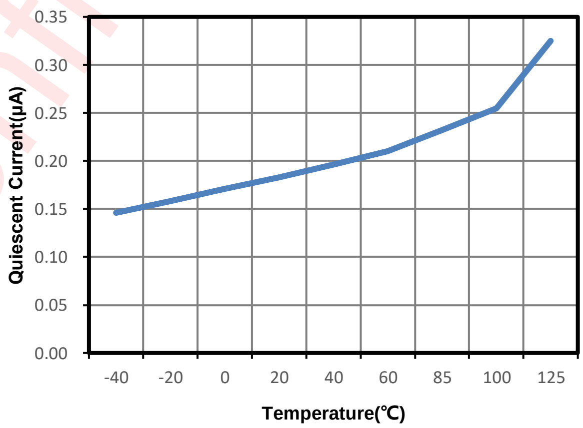
AW3606A VOUT = 5V
Load Efficiency with Different Inputs



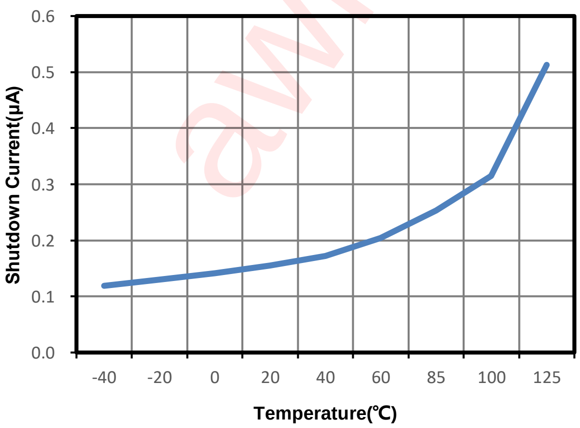
Load Regulation



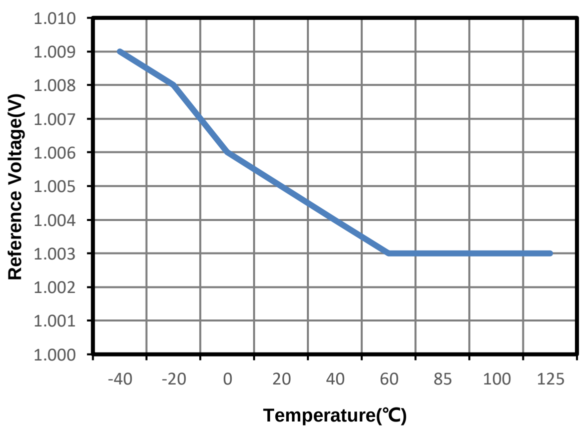
IQ_VOUT vs TEMP



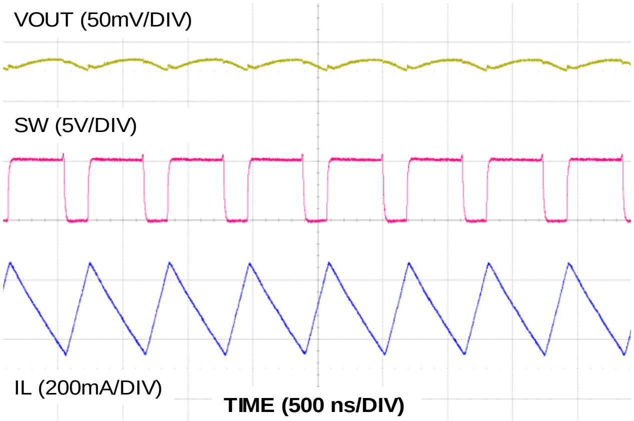
IQ_VIN vs TEMP



ISD vs TEMP

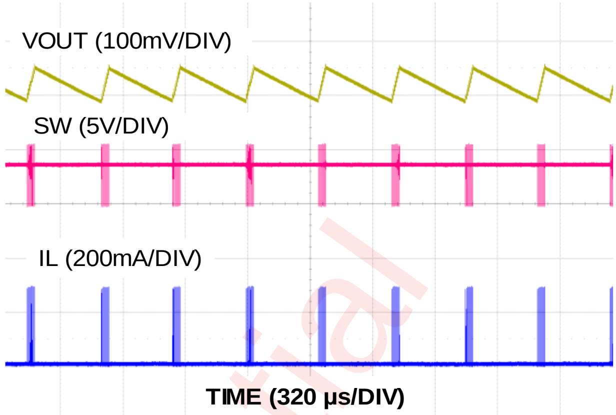


VREF vs TEMP



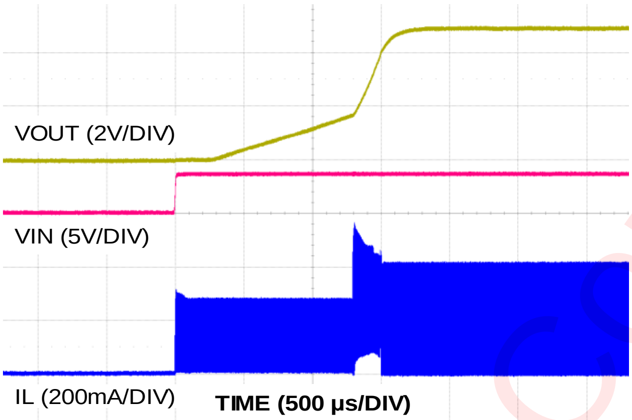
V_{IN} = 3.7V V_{OUT} = 5V I_{OUT} = 200 mA

Switching Waveform at Heavy Load



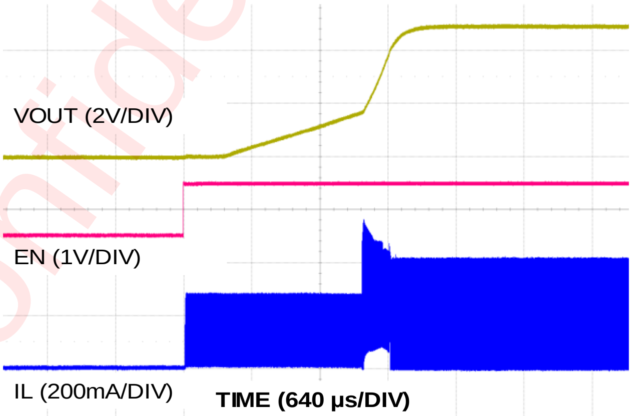
V_{IN} = 3.7V V_{OUT} = 5V I_{OUT} = 1mA

Switching Waveform at Light Load



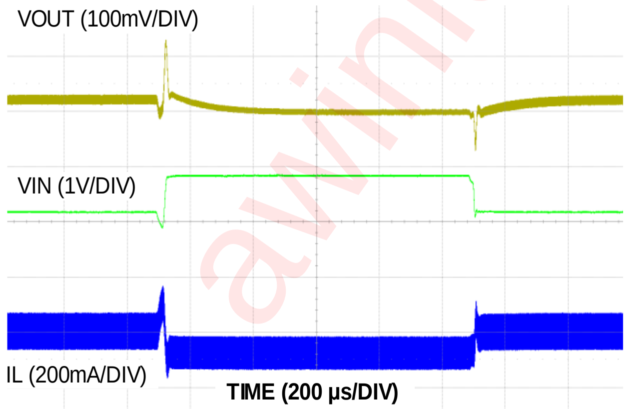
V_{IN} = 3.7V V_{OUT} = 5V I_{OUT} = 50mA

Startup by VIN



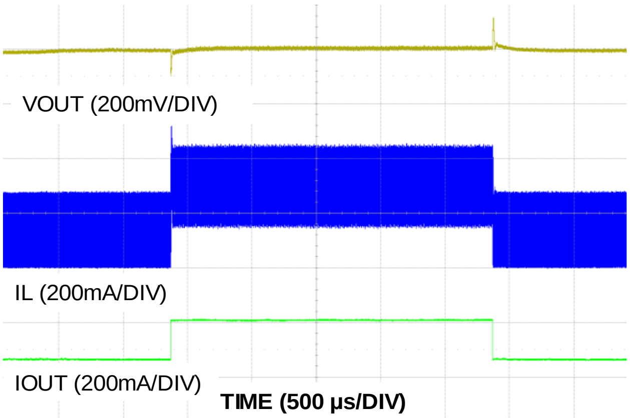
V_{IN} = 3.7V V_{OUT} = 5V I_{OUT} = 100mA

Startup by EN



V_{IN} = 2.4 V to 3.7 V V_{OUT} = 5 V I_{OUT} = 200 mA

Line Transient



V_{IN} = 3.7V V_{OUT} = 5V I_{OUT} = 50mA to 200mA

Load Transient

Detailed Functional Description

The AW3606A is a high efficiency synchronous step-up converter with ultra-low quiescent current down to 1μA, it is optimized for battery-powered applications, such as alkaline battery, coin-cell battery, Li-ion or Li-Polymer battery, that requires long battery life and tiny solution size. The AW3606A can work with an input voltage as low as 0.9V to provide an output voltage from 2.5V to 5.2V.

The AW3606A uses a hysteretic current mode control scheme with typical 1.4A peak switch current limit when the output voltage is above 2.5V. When the AW3606A shuts down, the output is completely isolated from the input voltage, allowing the output to draw less than 0.2μA in shutdown mode. The AW3606A works in Down Mode and Pass-Through operation when input voltage is close to or higher than the output voltage. By adding a resistor divider at FB pin, the device can be set to any voltage level for flexible applications.

Boost Controller Operation

The AW3606A boost converter is controlled by a hysteretic current mode controller. There are three modes of operation depending on the output load. If the required average input current is lower than the average inductor current defined by this constant ripple, the converter goes into discontinuous current operation. In this operation, it keeps the efficiency high under light load condition. If the load current is reduced further, the boost converter enters into Power save Mode(PSM). In PSM mode, the boost converter ramps up the output voltage with several switching cycles until the output voltage exceeding the setting threshold, the device stops switching and goes into a sleep status. In sleep status, the device consumes less quiescent current. If the load current increases and output voltage is below the setting threshold. It exits the PSM mode and enters into continuous current operation. In this mode, the controller keeps the inductor ripple current at almost 300mA. The input voltage, output voltage and inductor value affect the rising and falling slopes of inductor ripple current.

The output voltage VOUT is detected via an external feedback network which is connected to the voltage error amplifier. The voltage error amplifier compares this feedback voltage to the internal voltage reference and adjusts the output voltage at the target.

Under-Voltage Lockout

To avoid abnormal state of the device at low input voltage, under voltage lockout is implemented that shuts down the converter when input voltage lower than 0.5V.The device be enabled again until the input voltage goes up to 0.7V. A hysteresis of 200mV is added to shut down the converter when the input voltage is between 0.5V and 0.7V.

Enable and Disable

The AW3606A operates when the input voltage is above UVLO rising threshold and the EN is high. In shutdown mode with a low EN voltage, the device stops switching and the rectifying PMOS turns off as well. This isolates the load from the input, so that the output voltage can drop below the input voltage during shutdown. In shutdown mode, input current is less than 0.5μA.

Soft Start

The internal Enable signal is high when the input voltage is above UVLO rising threshold, the device begins to startup. There are three steps for start-up. Firstly, VOUT is below 1.6V, the device operates at the boundary of DCM(Discontinuous Conduction Mode) and CCM(Continuous Conduction Mode), and the inductor current is limited to about 200mA in this mode. When the output voltage rises to about 1.6V, the device switches to close-loop work mode with hysteretic current mode operation. The second stage, the inductor peak current is gradually increasing to 0.7*ILIM within 500μs.The soft start function reduces the inrush current during startup.

Finally, after VOUT reaches the target value, soft start stage ends and the peak current is determined by the output of an internal error amplifier which compares the feedback of the output voltage and the internal reference voltage.

The AW3606A is able to start up with 0.9V input voltage with larger than 3kΩ load. If the load is too heavy, the output voltage can't rise to above 1.6V. The AW3606A will stay in pre-soft start procedure until the output voltage is increased or the load current is reduced. The startup time depends on input voltage and load current.

Current Limit Operation

Current limit operation circuit senses the inductor current cycle-cycle. If the diagnostic circuit detects the inductor peak current exceeding the current limit threshold, the main switch turns off so as to stop further increase of the input current. In this condition the output voltage will decrease until the power balance between input and output is achieved. If the device goes into the down mode, the peak current is still limited by ILIM cycle-by-cycle. If the output drops below 1.6V, the AW3606A enters into startup process and limits the switch current to about 200mA. If the device goes into the pass-through operation, current limit function is not enabled.

Output Short-to-Ground Protection

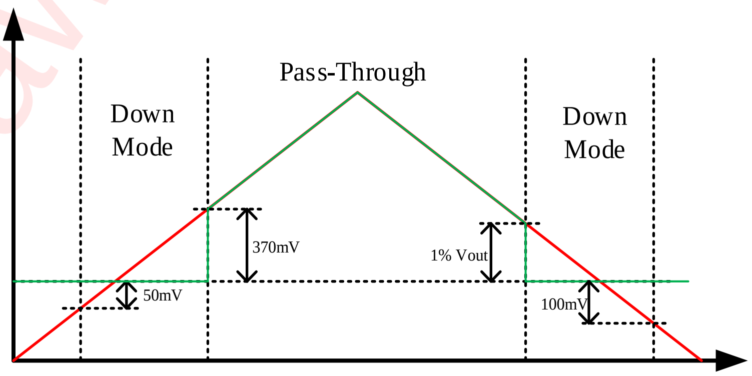
In the event of a short-to-ground, the device first turns off the MOS when the sensed current reaches the current limit, inductor peak current is limited at 200mA. Once the short circuit is released, the AW3606A begins to soft start and regulates the output voltage.

Over-Voltage Protection

AW3606A features over-voltage protection(OVP) for maximum safety. When the output voltage of the AW3606A exceeds the OVP threshold of 5.8V,the device stops switching .The device will start operating again until the output voltage falling to 5.7V.

Down Mode and Pass-Through Mode

The AW3606A works in down mode or pass-through mode when VIN is close to VOUT. With VIN raising, the AW3606A automatically switches from boost mode to down mode if VIN goes above the VOUT-50mV. It stays in down mode until VIN>VOUT+0.37V and then goes automatically into pass-through mode. During the pass-through mode, output voltage follows input voltage. The AW3606A switches from pass-through mode to down mode when VIN ramps down to 101% of the target output voltage. It exits down mode when VIN<VOUT-100mV, returning to boost operation.



Down Mode and Pass-Through Mode

In the down mode, the AW3606A will continue to regulate the output voltage even when the input voltage exceeds the output voltage. This is achieved by terminating the switching at the synchronous PMOS and applying a modulated voltage on its gate. Since the PMOS no longer acts as a low-impedance switch, a dropout voltage across the PMOS is introduced to increase the conduction loss which needs to be taken into account for thermal consideration.

In the pass-through operation, the device stops switching. The rectifying PMOS constantly turns on and low-side switch constantly turns off. The output voltage is the input voltage minus the voltage drop across the DC resistance (DCR) of the inductor and the on-resistance of the rectifying PMOS.

Thermal Shutdown

The AW3606A has an integrated thermal protection. The protection circuit senses the internal temperature of the chip and stop switching when temperature reaches 150°C. After the temperature returns to a safe value 25°C below the shutdown temperature, the system starts operating again.

Application Information

Programming the Output Voltage

There is the way to set the output voltage of the AW3606A.

The output voltage could be adjusted by connecting FB to the tap of an external voltage divider from VOUT to ground, as shown in Equation1,and the typical voltage at the FB pin is VREF of 1.0V.

$$V_{OUT} = V_{REF} \cdot \frac{R_1 + R_2}{R_2}$$

For the best accuracy and low quiescent current, R1 and R2 value usually are large. The current following through R2 should be 100 times larger than FB pin leakage current. Reducing the R2 value can improve the robustness against noise injection. Increasing the R2 value reduces the FB divider current for achieving the highest efficiency at low load current. For example, 1MΩ and 249kΩ resistors with 1% maximum tolerance are selected for R1 and R2.

Maximum Output Current

The maximum output current of the AW3606A can be estimated by Equation2.It determined by the input to output ratio and the current limit of the step-up converter.

$$I_{OUT(MAX)} = \frac{V_{IN} \cdot (I_{LIM} - \frac{\Delta I_L}{2}) \cdot \eta}{V_{OUT}}$$

Where η is the conversion efficiency, using 85% for estimation; ∆IL is the current ripple value and ILIM is the switch current limit.

Typically, the maximum output current of the typical application circuit with 5V adjustable output voltage is as follows in this table.

VIN	2.5V	3.3V	3.7V	4.4V
Maximum output current	0.4A	0.6A	0.7A	0.9A

Voltage across the DCR decreases the effective voltage across the inductor, which will affects the maximum output current. Especially at low input voltage, the voltage across the DCR and the low-side switch become large enough that could not be ignored for the effect on maximum output current.

Inductor Selection

Inductor is the most important component in power regulator design. In order to ensure proper operation of the steady state, transient behavior, and loop stability, inductor value, saturation current, and dc resistance (DCR) deserve careful consideration.

The device is optimized to with inductor values between 1μH and 2.2μH. For best stability consideration, a 2.2μH inductor is recommended for VOUT > 3.0V condition while choosing a 1μH inductor for applications under VOUT ≤ 3.0V condition. Inductors recommended for AW3606A device are as follows in this table.

VOUT (V)	Inductance (μH)	Saturation Current (A)	DC Resistance (mΩ)	Size (L×W×H)	Part number	Manufacturer
>3.0	2.2	2.4	116	2.0×1.6×1.2	DFE201612E-2R2M	muRata
	2.2	2.1	100	2.0×1.6×1.0	WPN201610U2R2MT	Sunlord
	2.2	1.95	80	2.5×2.0×1.2	74404024022	Würth
<3.0	1	2	80	2.0×1.6×0.9	LQM2MPN1R0MGH	muRata
	1	3.5	50	2.0×1.6×1.0	WPN201610U1R0MT	Sunlord
	1	2.6	37	2.5×2.0×1.2	74404024010	Würth

For the selected inductor, the operating frequency of the device in continuous current mode can be estimated by the following equation.

$$f = \frac{V_{IN} \cdot (V_{OUT} - V_{IN} \cdot \eta)}{L \cdot V_{OUT} \cdot \Delta I_L}$$

Where △IL is the inductor ripple current, η is the conversion efficiency.

Capacitor Selection

For best output and input voltage filtering, low ESR X5R or X7R ceramic capacitors are recommended.

Low ESR input capacitors reduce input noise and voltage ripple. An input capacitor value of 10μF is normally recommended to improve transient behavior of the regulator and EMI behavior of the total power supply circuit. The input capacitor should be placed close to the VIN and GND pins of the device.

For the output capacitor of VOUT pin, small ceramic capacitor and a large one are recommended. The small capacitor value of 1μF should be placed as close as possible to the VOUT and GND pins of the device.

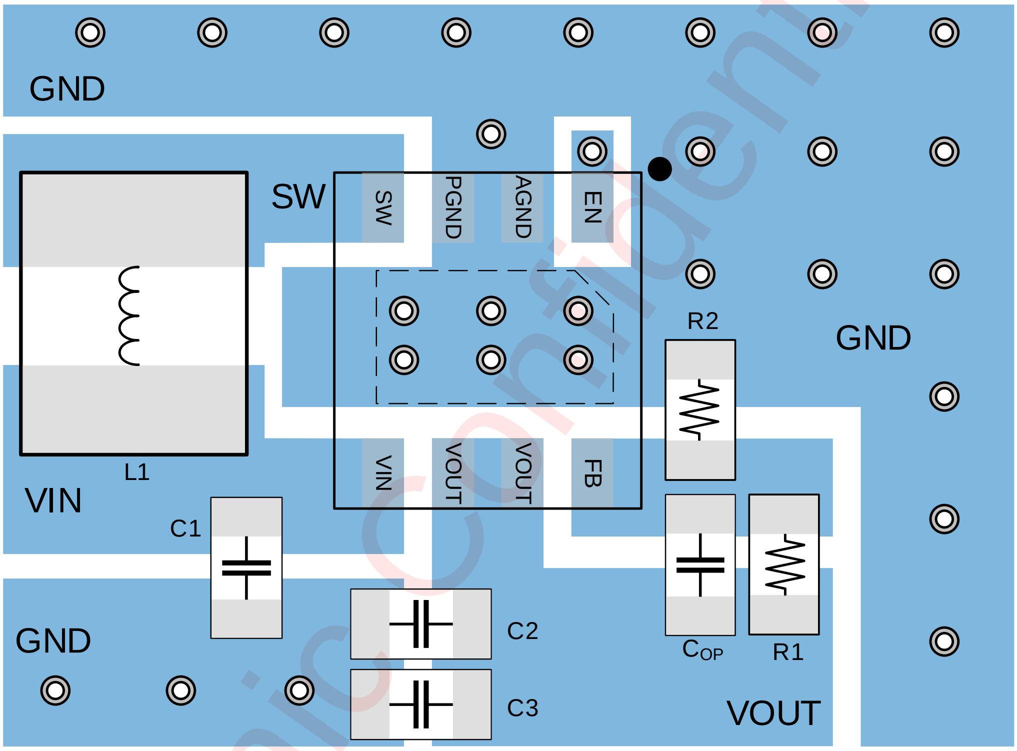
It's necessary to consider the ceramic capacitor's derating effect under bias carefully. Capacitors recommended for AW3606A device are as follows in this table.

Part Number	Capacitance (μF)	Rated Voltage (V)	Size Code (inch)	Temperature Characteristics	Manufacturer
GRM155R60J106ME05	10	6.3	0402	X5R	muRata
GRM155R61A106ME11	10	10	0402	X5R	muRata
GRM188R60J106ME47	10	6.3	0603	X5R	muRata
GRM188R61A106MAAL	10	10	0603	X5R	muRata
C1608X5R0J106K080AB	10	6.3	0603	X5R	TDK
C1608X5R1A106K080AC	10	10	0603	X5R	TDK
CC0402MRX5R5BB106	10	6.3	0402	X5R	YAGEO
CC0603KRX5R5BB106	10	6.3	0603	X5R	YAGEO

PCB Layout Consideration

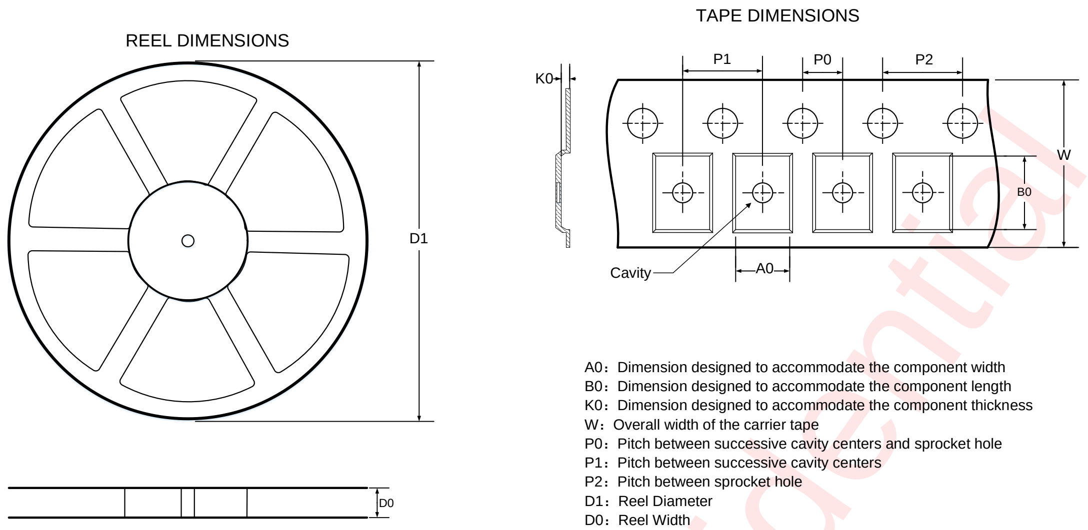
AW3606A is a boost convert, to obtain the optimal performance, PCB layout should be considered carefully. Here are some guidelines:

1. C1, C2, C3, and L1 should be placed as close to chip as possible;
2. Wide and short traces should be used for main current path and the power ground paths;
3. Considering the problem of high current temperature rise, it is necessary to enlarge the area of copper floor around the chip to dissipate heat;
4. A C_{OP} is recommended between FB and OUT pin. It can optimize the load transient response performance.



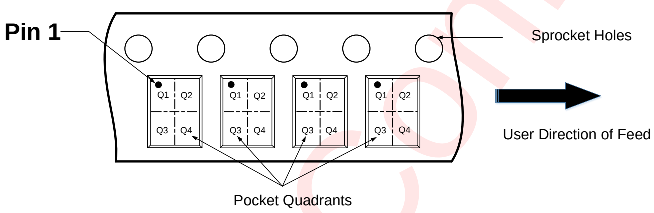
AW3606A Layout Recommendation

Tape And Reel Information



A0：Dimension designed to accommodate the component width
B0：Dimension designed to accommodate the component length
K0：Dimension designed to accommodate the component thickness
W：Overall width of the carrier tape
P0：Pitch between successive cavity centers and sprocket hole
P1：Pitch between successive cavity centers
P2：Pitch between sprocket hole
D1：Reel Diameter
D0：Reel Width

QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE

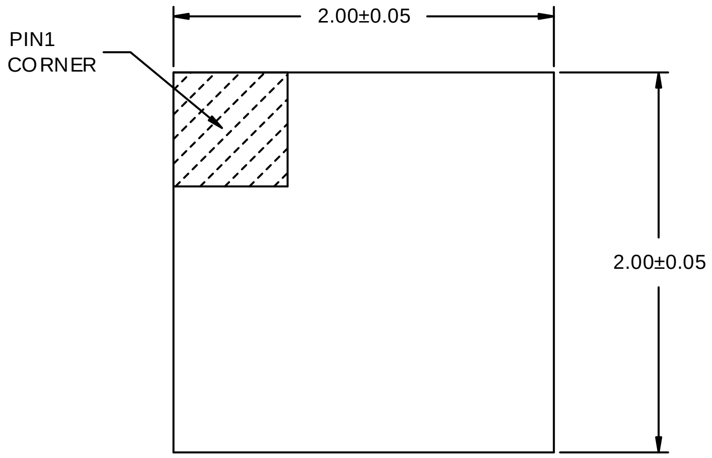


DIMENSIONS AND PIN1 ORIENTATION

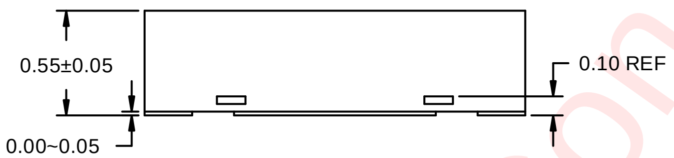
D1 (mm)	D0 (mm)	A0 (mm)	B0 (mm)	K0 (mm)	P0 (mm)	P1 (mm)	P2 (mm)	W (mm)	Pin1 Quadrant
178	8.4	2.25	2.25	0.75	2	4	4	8	Q1

All dimensions are nominal

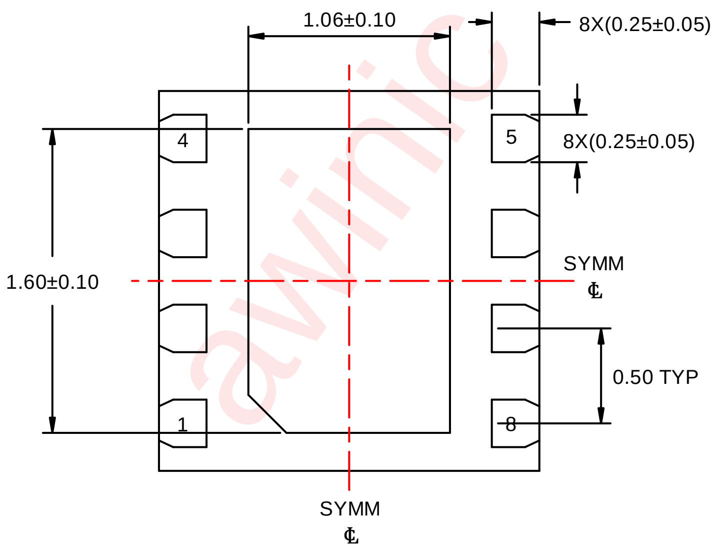
Package Description



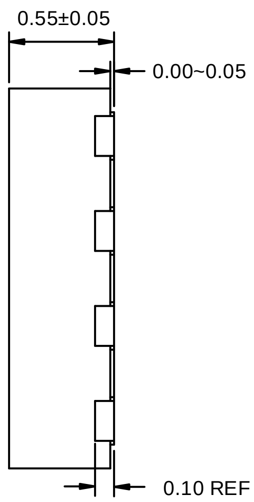
TOP VIEW



SIDE VIEW



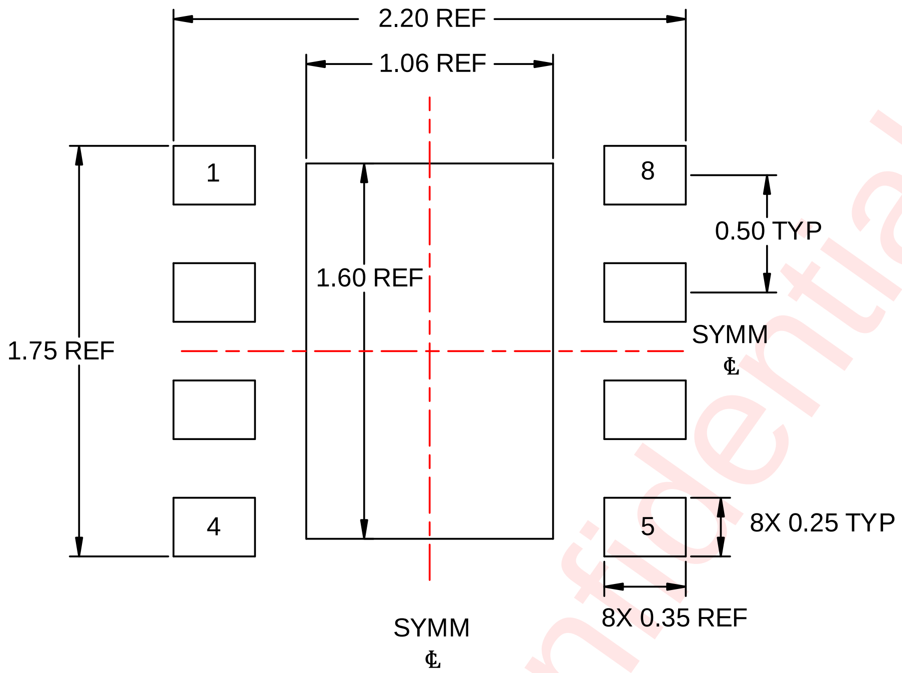
BOTTOM VIEW

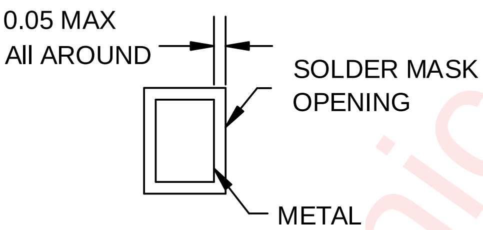


SIDE VIEW

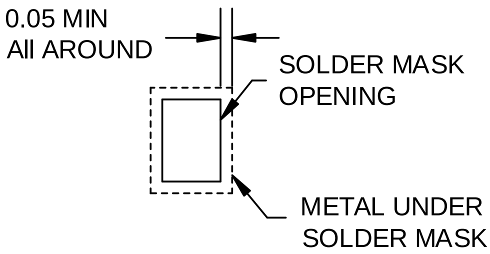
Unit：mm

Land Pattern Data





NON-SOLDER MASK DEFINED



SOLDER MASK DEFINED

Unit：mm

Revision History

Version	Date	Change Record
V1.0	Nov 2021	Officially released

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