3μA Ultra Low I_q, 6.5V, 1.2MHz, 0.8A Synchronous Buck Converter

FEATURES

- 2.5V to 6.5V Input Voltage Range
- High Efficiency: Up to 95% (@3.3VOUT)
- 1.2MHz Switching Frequency
- Ultra-low Quiescent Current: 3μA typical.
- Low Shutdown Current: <1μA
- PFM Mode for High Efficiency in Light Load
- Up to 0.8A Output Current
- Output Voltage as Low as 0.6V
- 100% Duty Cycle in Dropout Operation
- LX discharge function
- Short Circuit Protection
- Thermal Fault Protection
- Inrush Current Limit and Soft Start
- Input over voltage protection (OVP)
- Power Good Function in TMI3181
- <1μA Shutdown Current
- TMI3181：SOT23-6 Package
- TMI3181A：SOT23-5 Package

GENERAL DESCRIPTION

TMI3181 and TMI3181A are 1.2MHz switching frequency, 3μA ultra-low quiescent current, current mode buck converter with power good indication function. TMI3181 has a wide input voltage range from 2.5V to 6.5V. The device adopts peak current mode control, the output voltage can be adjusted from 0.6V to input voltage. It has fast load transient response. The 1.2MHz high switching frequency minimizes the size of external components while keeping switching losses low. It has two operating modes, PWM control and PFM mode switching control in different load condition, and allowing high efficiency over a larger load range.

APPLICATIONS

- Battery-Powered Application
- IoT Modules
- Wearable Device
- Intelligent Lock

TYPICAL APPILCATION

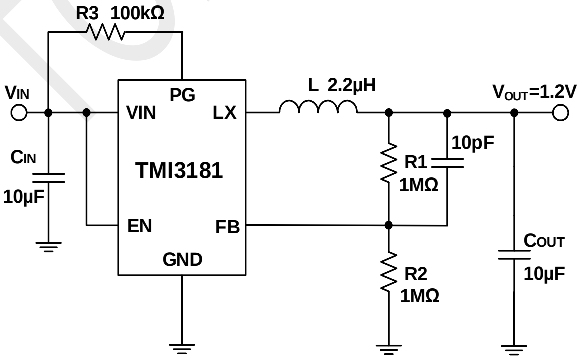
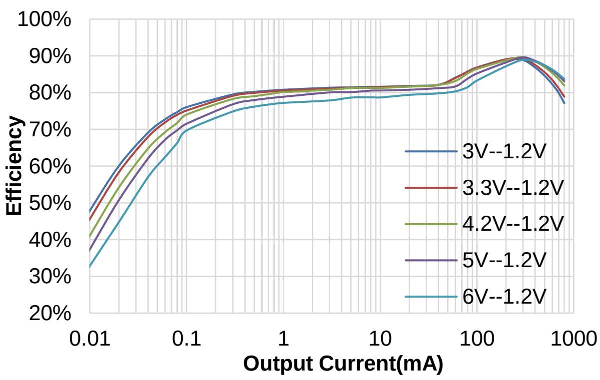


Figure 1. Basic Application Circuit

Efficiency

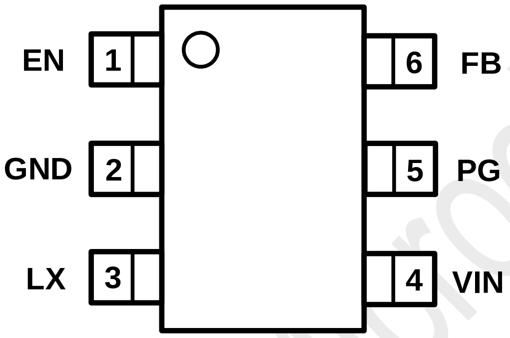
V_{OUT}=1.2V, L=2.2μH, T_A=25°C, I_O=10μA to 0.8A



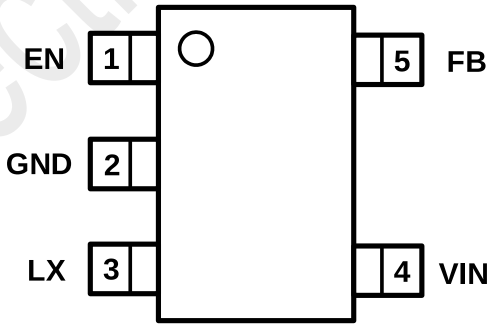
ABSOLUTE MAXIMUM RATINGS (Note 1)

Parameter	Min	Max	Unit
Input Supply Voltages	-0.3	7	V
EN, LX Voltages	-0.3	7	V
LX Voltage (<10ns transient)	-3	7.5	V
LX Voltage (<5ns transient)	-4	8	V
PG, FB Voltage	-0.3	6	V
Storage Temperature Range	-65	150	°C
Junction Temperature (Note 2)	-40	150	°C
Power Dissipation	-	600	mW
Lead Temperature Soldering,10sec	-	260	°C

PIN CONFIGURATION



SOT23-6
TMI3181



SOT23-5
TMI3181A

Top Mark: T7AXXX (T7A: Device Code, XXX: Inside Code) for TMI3181
Top Mark: T7IXXX (T7I: Device Code, XXX: Inside Code) for TMI3181A

Part Number	Package	Top mark	Quantity/ Reel
TMI3181	SOT23-6	T7AXXX	3000
TMI3181A	SOT23-5	T7IXXX	3000

TMI3181 and TMI3181A devices are Pb-free and RoHS compliant.

PIN FUNCTIONS

Pin		Name	Function
TMI3181	TMI3181A		
1	1	EN	Chip Enable Pin. Drive EN above EN high threshold to turn on the part. Drive EN below EN low threshold to turn it off. Do not leave EN floating.
2	2	GND	Ground Pin
3	3	LX	Power Switch Output. It is the switch node connection to Inductor.
4	4	VIN	Power Supply Input. Must be closely decoupled to GND with a 10μF or greater ceramic capacitor.
5	-	PG	Power Good Open Drain Output Pin.
6	5	FB	Output Voltage Feedback Pin.

ESD RATING

Items	Description	Value	Unit
V_{ESD_HBM}	Human Body Model for all pins	±2000	V
V_{ESD_CDM}	Charge Device Model for all pins	±1000	V

JEDEC specification JS-001

RECOMMENDED OPERATING CONDITIONS

Items	Description	Min	Max	Unit
Voltage Range	VIN	2.5	6.5	V
T_J	Operating Junction Temperature Range	-40	125	°C

THERMAL RESISITANCE (Note 3)

Items	Description	Value	Unit
θ_{JA}	Junction-to-ambient thermal resistance	200	°C/W
θ_{JC}	Junction-to-case thermal resistance	65	°C/W

ELECTRICAL CHARACTERISTICS

(V_{IN}=5V, V_{OUT}=1.2V, T_A = 25°C, unless otherwise noted.)

Parameter	Test Conditions	Min	Typ	Max	Unit
Input Voltage Range		2.5		6.5	V
OVP Threshold			7		V
OVP Hysteresis			0.24		V
UVLO Threshold			2.38		V
UVLO Hysteresis			0.28		V
Quiescent Current	V_{EN}=2.0V, V_{FB}=V_{REF}x105%		3	8	µA
Shutdown Current	V_{EN}=0V		0.01	0.1	µA
Regulated Feedback Voltage	T_A = 25°C	0.588	0.600	0.612	V
Oscillation Frequency	V_{FB}=100% x V_{REF}		1.2		MHz
	V_{FB}=0V		400		kHz
On Resistance of PMOS	I_{LX}=100mA		0.3		Ω
On Resistance of NMOS	I_{LX}=-100mA		0.15		Ω
Peak Current Limit in normal operation		1.25	1.5		A
Peak Current Limit in Hiccup mode		1	1.2		
EN Rising Threshold Voltage		0.6	0.9	1.2	V
EN Hysteresis			0.12		V
EN Leakage Current			0.01	0.5	µA
Power Good Threshold for V_{FB} Rising	Reference to V_{REF} voltage		90%		
Power Good Threshold for V_{FB} falling	Reference to V_{REF} voltage		85%		
Power Good Sink Current	V_{FB} < 90% x V_{REF}			4	mA
LX Leakage Current	V_{EN}=0V, V_{IN}=V_{LX}=5V		0.01	1.0	µA
Soft Start Time	10% V_{OUT} to 90% V_{OUT}		270		µs
Discharge Resistance on LX pin	V_{EN}=0V, V_{LX}=0.1V		200		Ω
Thermal Shutdown Threshold (Note 4)			160		°C
Thermal Shutdown Hysteresis (Note 4)			25		°C

Note 1: Absolute Maximum Ratings are those values beyond which the life of a device may be impaired.

Note 2: T_J is calculated from the ambient temperature T_A and power dissipation P_D according to the following formula: $T_J = T_A + (P_D) \times \theta_{JA}$.

Note 3: Measured on JESD51-7, 4-layer PCB.

Note 4: Guaranteed by design.

FUNCTION DESCRIPTION

TMI3181 and TMI3181A are ultra-low quiescent current synchronous step-down DC-DC converter. The device operates at 1.2MHz switching frequency and adopts peak current mode control structure. The input voltage range of TMI3181 is 2.5V to 6.5V. With 6.5V input voltage, the output current can be up to 0.8A. TMI3181 and TMI3181A operate in PFM mode under light and no-load conditions to save power consumption. In PFM mode, the device increases the output voltage through several LX switching pulses, while the error amplifier output voltage, V_{COMP}, drops. When the V_{COMP} voltage drops the internal threshold, the device stops switching, so the FB voltage in PFM mode is slightly higher than the normal 0.6V reference voltage in PWM operation.

Adjustable output voltage can be programmed with external feedback dividers, ranging from 0.6V to close to the input voltage. It uses an internal MOSFET for high efficiency and can generate low output voltages using an internal reference of 0.6V. During drop operation, the converter duty cycle is increased to 100% and the output voltage tracks the input voltage minus the low $R_{DS(ON)}$ drop of the P-channel high side MOSFET and the inductive DCR. Internal error amplifiers and compensation provide excellent transient response to load and line regulation. Internal soft start eliminates any output voltage overshoot when the device is enabled or the input voltage is applied.

Input Over Voltage Protection

TMI3181 and TMI3181A have input side over voltage protection function. When input voltage is higher than input OVP threshold 7V typical, TMI3181 and TMI3181A stops switching operation to protect device works with high input voltage. When input voltage is recovered from OVP and drops down input OVP threshold with OVP hysteresis typical 240mV, the device starts to switch as normal operation automatically. This function protects device from switching in abnormal high input voltage and input surge condition.

Input Under Voltage Lockout

TMI3181 and TMI3181A implements input under voltage lockout function to avoid mis-operation at low input voltages. When the input voltage is lower than input UVLO threshold with UVLO hysteresis, the device is shut down. The typical 280mV input UVLO hysteresis value of TMI3181 is useful to prevent device from abnormal switching caused by input voltage oscillation around UVLO threshold during input voltage power-up and power-down with high load condition.

Soft Start

TMI3181 and TMI3181A have built-in soft-start circuits to control output voltage rise rate to avoids excessive inrush current during IC start up. The typical soft-start time from 10% V_{OUT} to 90% V_{OUT} is 270μs typically.

Enable Control and Output Discharge Function

The device provides automatic output voltage discharge when EN is pulled low, and UVLO, and OVP, and OTP is triggered. The output of the buck converter is discharged through LX. Therefore, once the device is enabled again, the output voltage will rise from zero. This is very helpful for accurate start-up sequencing.

Over Current Limit and Output Short Protection

TMI3181 and TMI3181A have high side switching current limit function and prevents the device from high load current condition. The typical high side peak current limit value is 1.5A. When output load current increases and inductor current peak value reaches peak current limit value, high side MOSFET is turned off immediately and the output voltage drops down according to load condition. If output voltage keeps falling down, once the VFB voltage is lower than 300mV typical, the device enters into output short hiccup protection condition in order to reduce power consumption and device thermal rise in the condition of output short to GND. In the state of short output hiccup mode protection, the typical peak current of device hiccup is 1.2A. The typical hiccup cycle is 5ms, the switching operation time in hiccup mode is 0.8ms, and the switching frequency in hiccup mode is 400kHz typically.

Thermal Shutdown

TMI3181 and TMI3181A enter thermal shutdown once the junction temperature exceeds thermal shutdown threshold 160°C typically. Once the device junction temperature falls below the threshold with hysteresis, TMI3181 and TMI3181A return to normal operation automatically.

Power Good

TMI3181 also has power good open drain output to indicate output voltage status. When input voltage is higher than UVLO and EN is enabled, PG status is determined by output voltage. The PG pin goes high impedance when the output is above 90% of regulated nominal voltage and PG pin is pulled low once output voltage falls below the threshold that is 85% of regulated nominal voltage. When the device is shut down by EN pulling low, the PG is pulled low as well. When PG is pulled low, the sink current limit is 4mA.

FUNCTIONAL BLOCK DIAGRAM

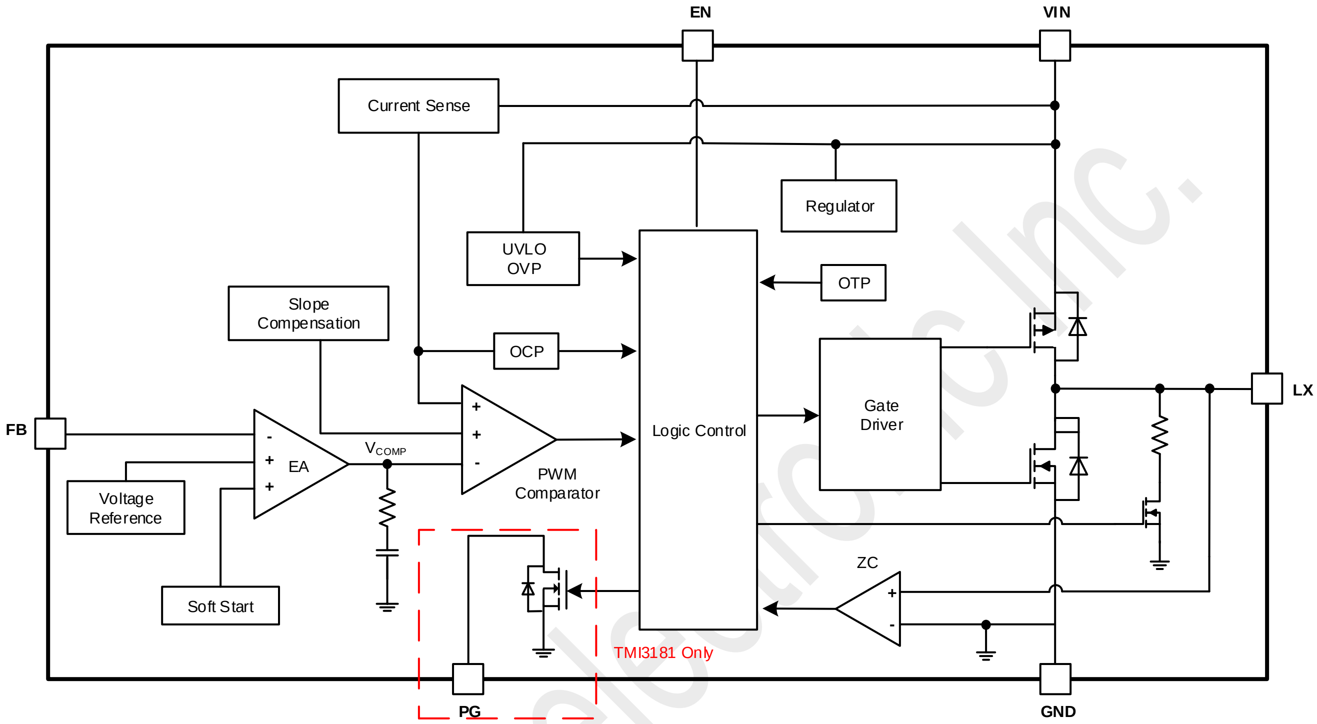


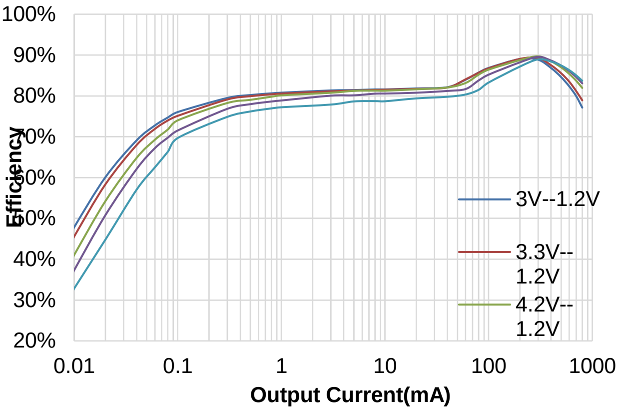
Figure 2. TMI3181 and TMI3181A Block Diagram

TYPICAL PERFORMANCE CHARACTERISTICS°C

Test condition: V_{IN}=6.5V, V_{OUT}=1.2V, L=2.2μH, Cfb=10pF,T_A=25°C, unless other noted.

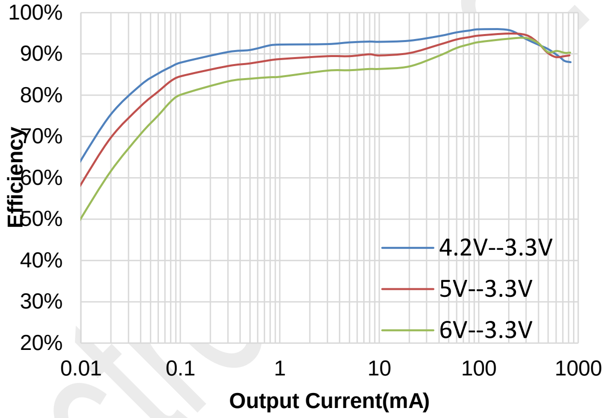
Efficiency at V_{OUT} = 1.2V

V_{OUT} =1.2V, L=2.2μH, T_A=25°C, I_O=10μA to 0.8A



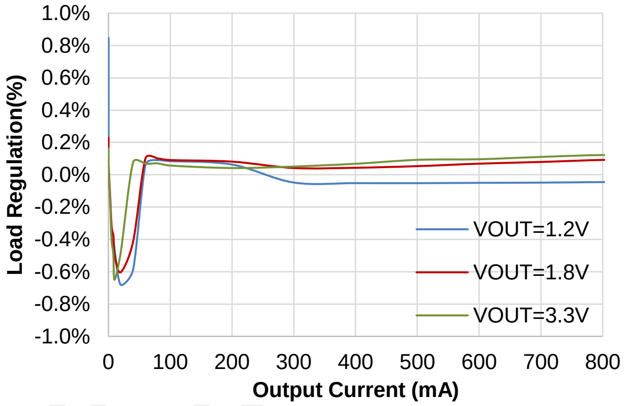
Efficiency at V_{OUT} = 3.3V

V_{OUT} =3.3V, L=2.2μH, T_A=25°C, I_O=10μA to 0.8A



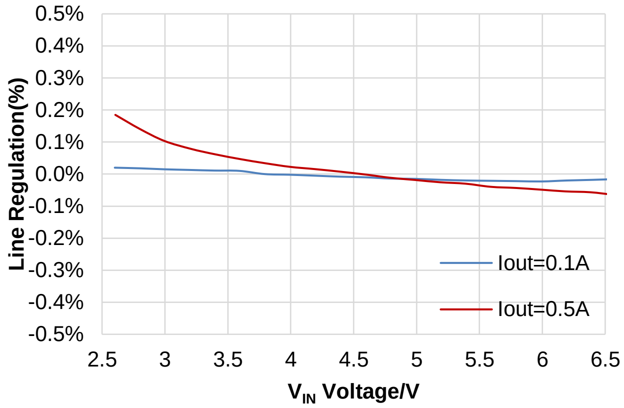
Load Regulation at V_{IN}=5V

V_{OUT} =3.3V, L=2.2μH, T_A=25°C, I_O=0A to 1A



Line Regulation at V_{OUT}=1.2V

V_{OUT} =3.3V, L=2.2μH, T_A=25°C

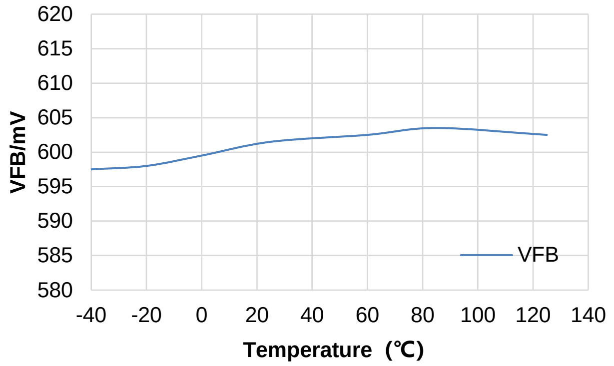


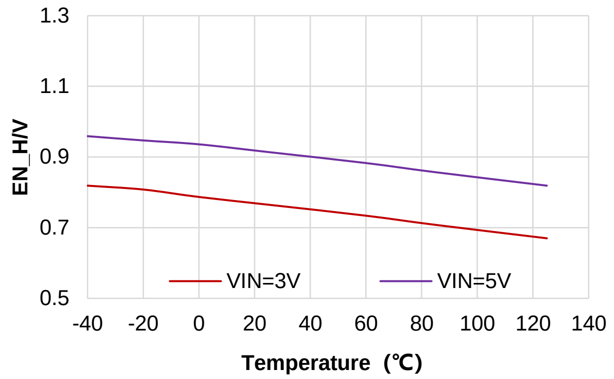
Regulated Feedback Voltage

VIN=5V, L=2.2μH, -40°C ≤ TA ≤ 125°C

EN Input High Level

VOUT =1.2V, L=2.2μH, -40°C ≤ TA ≤ 125°C

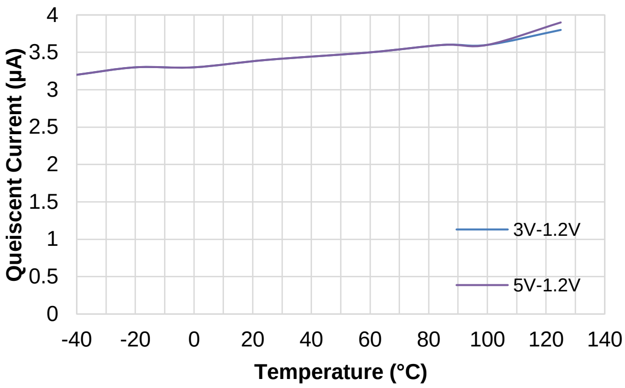




TYPICAL PERFORMANCE CHARACTERISTICS (continued)

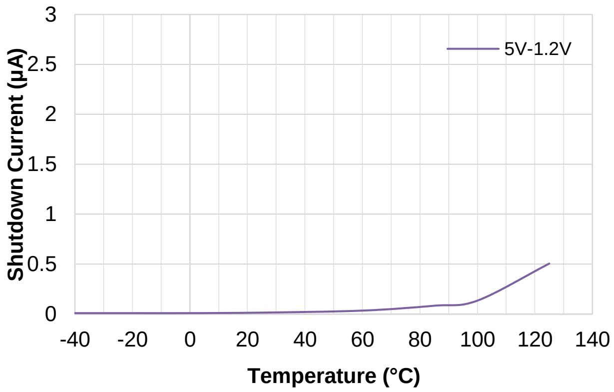
Input Quiescent Current

V_{OUT} =1.2V, L=2.2μH, Cfb=10pF, Switching



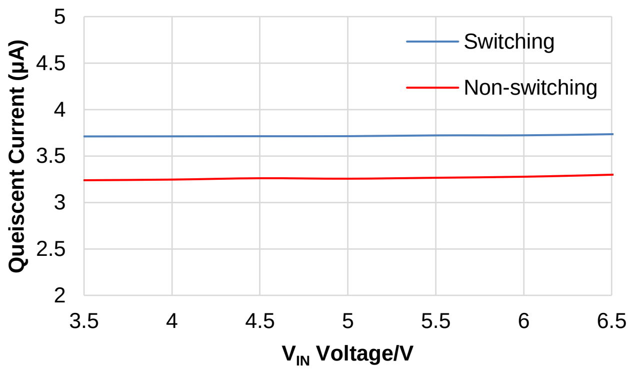
Shutdown Current

V_{OUT} =1.2V, L=2.2μH, EN=0V



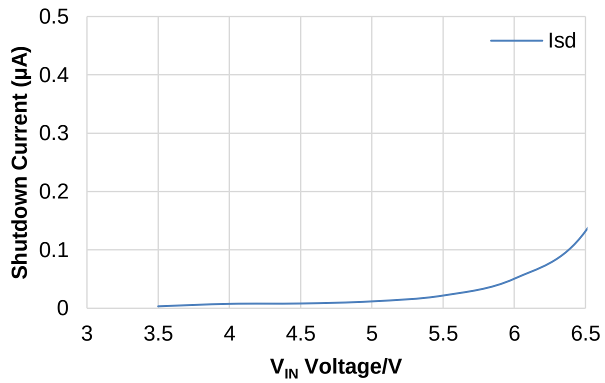
Input Quiescent Current

V_{OUT} =3.3V, L=2.2μH, Cfb=10pF



Shutdown Current

V_{OUT} =3.3V, L=2.2μH, EN=0V

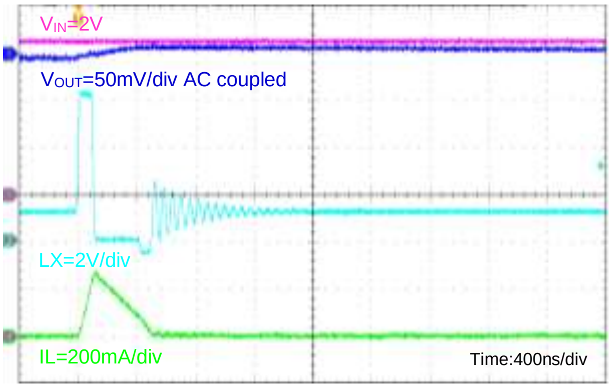


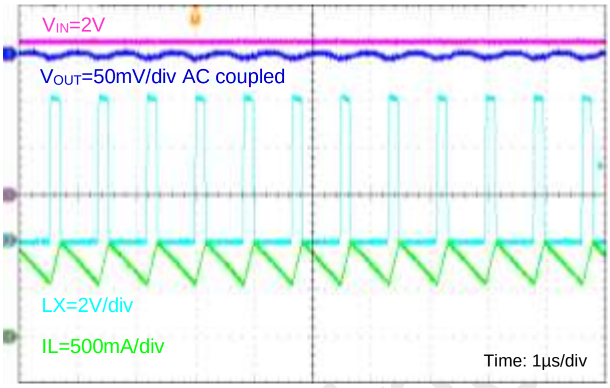
Steady State Operation

V_{IN} =6.5V, V_{OUT} =1.2V, No Load

Steady State Operation

V_{IN} =6.5V, V_{OUT} =1.2V, I_o=0.8A

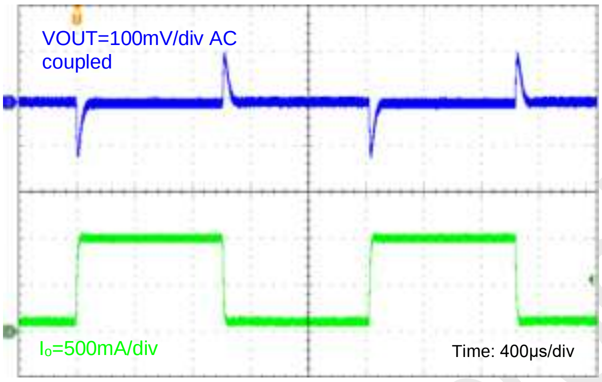




TYPICAL PERFORMANCE CHARACTERISTICS (continued)

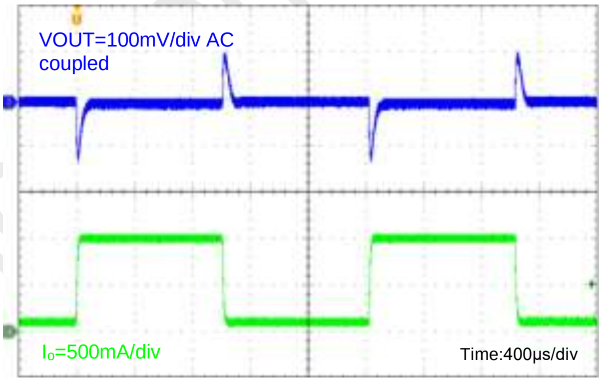
Load Transient

V_{IN} =5V, V_{OUT} =1.2V, I_o = 0.1A to 0.8A



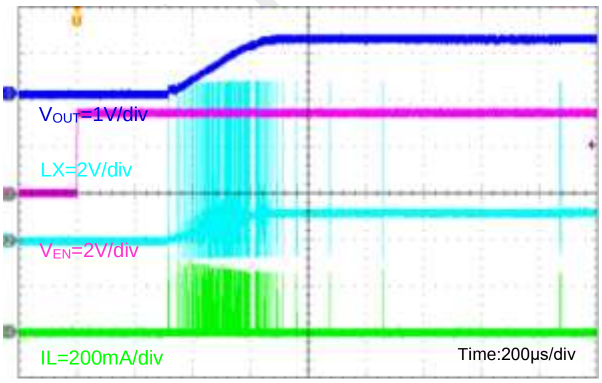
Load Transient

V_{IN} =6.5V, V_{OUT} =1.2V, I_o = 0.1A to 0.8A



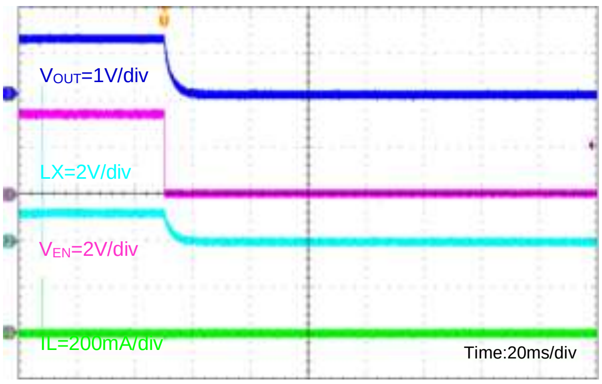
EN Enable Power On

V_{IN} =6.5V, EN=3.6V, V_{OUT} =1.2V, No Load



EN Disable Power down

V_{IN} =6.5V, EN=3.6V, V_{OUT} =1.2V, No Load

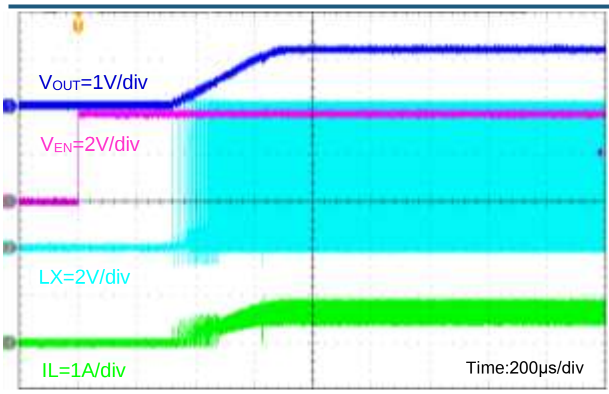


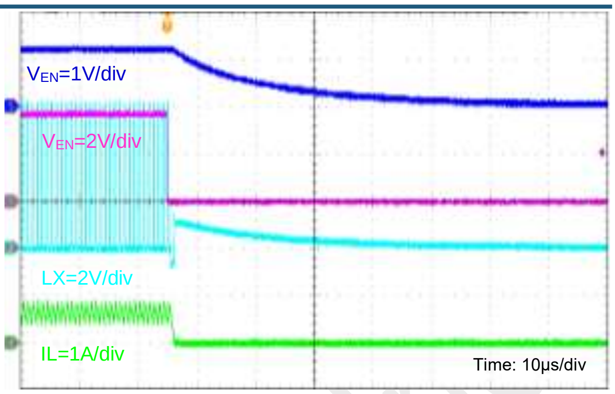
EN Enable Power On

V_{IN} =6.5V, EN=3.6V, V_{OUT} =1.2V, I_o =0.8A

EN Disable Power down

V_{IN} =6.5V,EN=3.6V, V_{OUT} =1.2V, I_o =0.8A

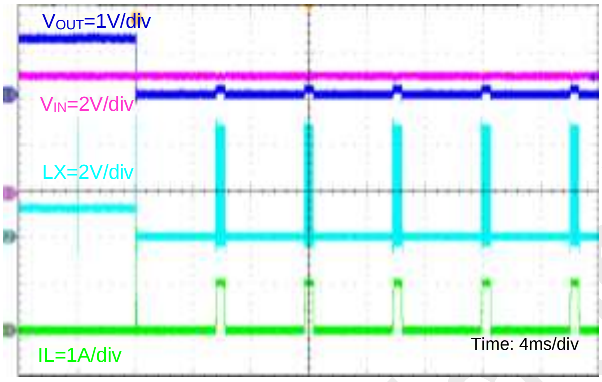




TYPICAL PERFORMANCE CHARACTERISTICS (continued)

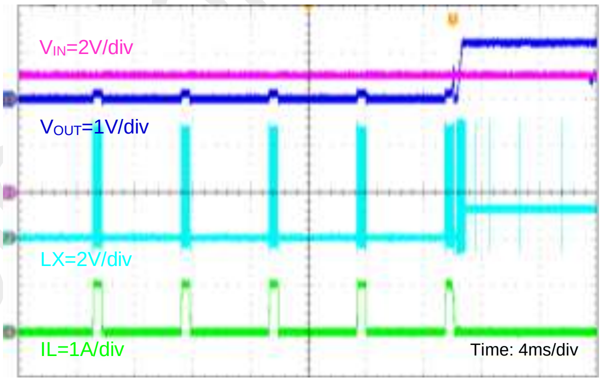
Output Short Entry

V_{IN} =5V, V_{OUT} =1.2V, No Load



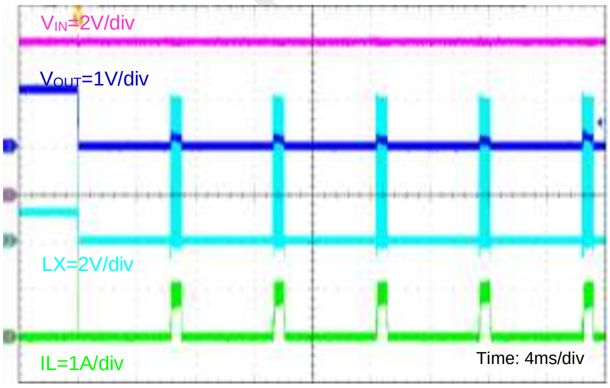
Output Short Recovery

V_{IN} =5V, V_{OUT} =1.2V, No Load



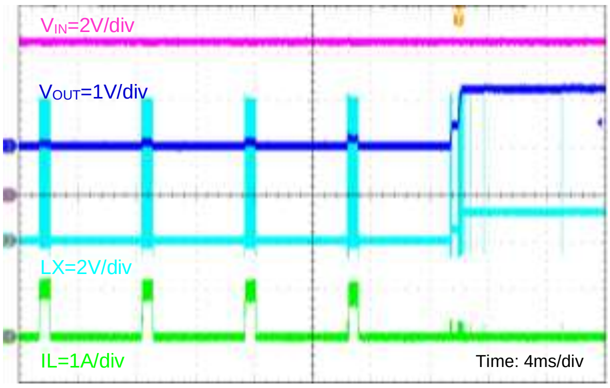
Output Short Entry

V_{IN} =6.5V, V_{OUT} =1.2V, No Load



Output Short Recovery

V_{IN} =6.5V, V_{OUT} =1.2V, No Load

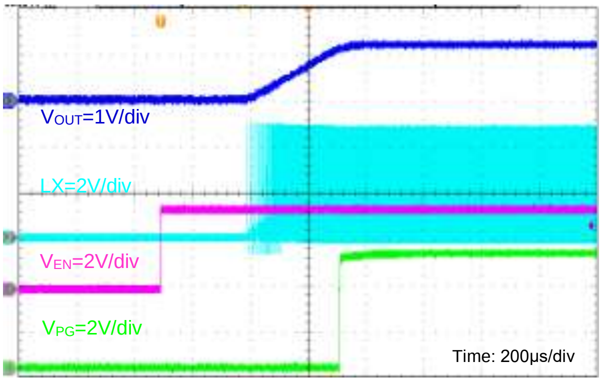


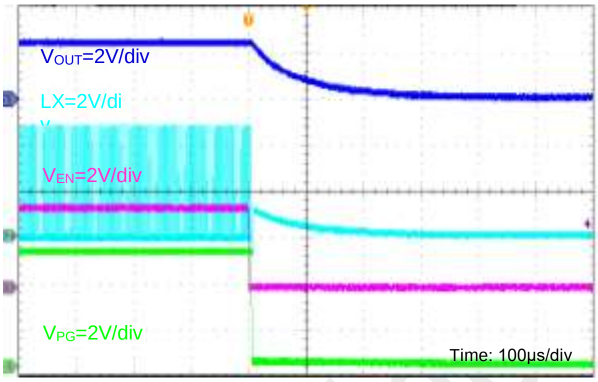
PG when EN Enable

V_{IN} =5V, V_{OUT} =1.2V, I_o =0.8A

PG when EN Disable

V_{IN} =5V, V_{OUT} =1.2V, I_o =0.8A


VOUT=1V/div
LX=2V/div
VEN=2V/div
VPG=2V/div
Time: 200μs/div


VOUT=2V/div
LX=2V/di
VEN=2V/div
VPG=2V/div
Time: 100μs/div

APPLICATION INFORMATION

Setting the Output Voltage

Figure 1 shows the basic application circuit for the TMI3181. TMI3181 and TMI3181A can be externally programmed. Resistors R1 and R2 in Figure 1 program the output to regulate at a voltage higher than 0.6V. The external resistor sets the output voltage according to the following equation:

$$V_{OUT} = 0.6 \times (1 + \frac{R_1}{R_2})$$

$$R_1 = (V_{OUT} / 0.6 - 1) \times R_2$$

The value of output divider resistors introduces same system consumption, so larger value output divider resistors should be used in ultra-low power consumption system. TMI3181 and TMI3181A can support output divider resistors around 1MΩ to 2MΩ to reduce system power consumption. A feedforward capacitor paralleled with high side feedback resistor could be used to provide more stability margin of the system. In no load condition, feedforward capacitor helps to reduce switching pulse number in PFM operation mode and keep low operation quiescent current in switching condition. In application, it is highly recommended to use 10pF feedforward capacitance for TMI3181 and 10pF to 68pF feedforward capacitance for TMI3181A.

Inductor Selection

For most designs, 2.2μH inductance can satisfy most application conditions. Inductance value is related to inductor ripple current value, input voltage, output voltage setting and switching frequency. The inductor value can be derived from the following equation:

$$L = \frac{V_{OUT} \times (V_{IN} - V_{OUT})}{V_{IN} \times \Delta I_L \times f_{OSC}}$$

Where ΔI_L is inductor ripple current. Large value inductors result in lower ripple current and small value inductors result in high ripple current, so inductor value has effect on output voltage ripple value.

Input Capacitor Selection

The input capacitor reduces the surge current drawn from the input and switching noise from the device. The input capacitor impedance at the switching frequency should be less than input source impedance to prevent high frequency switching current passing to the input.

A low ESR input capacitor sized for maximum RMS current must be used. Ceramic capacitors with X5R or X7R dielectrics are highly recommended because of their low ESR and small temperature coefficients. A 10μF ceramic capacitor for most applications is sufficient. A large value may be used for improved input voltage filtering.

Output Capacitor Selection

The output capacitor is required to keep the output voltage ripple small and to ensure regulation loop stability. The output capacitor must have low impedance at the switching frequency. Ceramic capacitors with X5R or X7R dielectrics are recommended due to their low ESR and high ripple current ratings. The output ripple V_{OUT} is determined by:

$$\Delta V_{OUT} \le \frac{V_{OUT} \times (V_{IN} - V_{OUT})}{V_{IN} \times f_{OSC} \times L} \times \left(ESR + \frac{1}{8 \times f_{osc} \times C3} \right)$$

An effective 10μF ceramic can satisfy most applications.

Output capacitance is less than 50uF, or output ripple is not less than 5mV. When the output capacitance increases by more than 50uF, the output frequency hopping will occur frequently, the interval of wave generation will become smaller, and the static current will increase.

Layout Consideration

When laying out the printed circuit board, the Following checking should be used to ensure proper operation of the TMI3181 Check the following in your layout:

1. The power traces, consisting of the GND trace, the LX trace and the IN trace should be kept short, straight and wide.

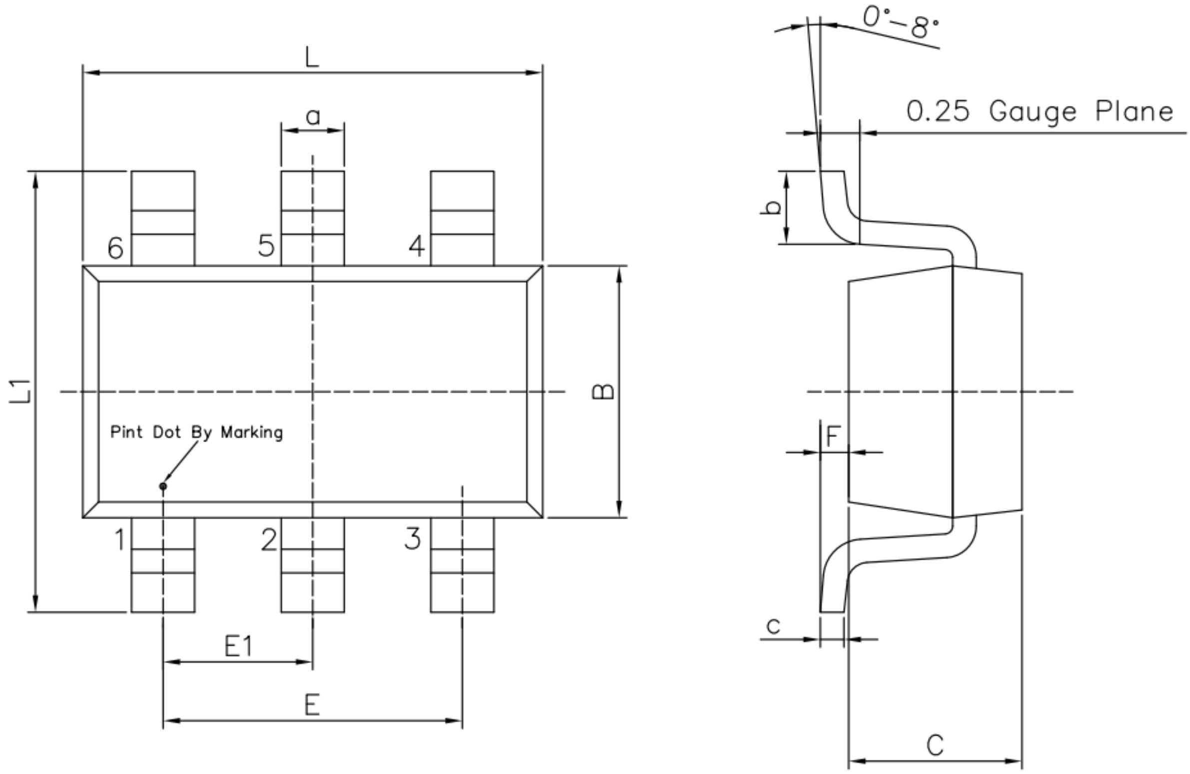
2. Does the (+) plates of C_{in} connect to IN as closely as possible. This capacitor provides the AC current to the internal power MOSFETs.

3. Keep the switching node, LX, away from the sensitive VOUT node.

4. Keep the (-) plates of C_{in} and C_{out} as close as possible

PACKAGE INFORMATION

SOT23-6



Unit: mm

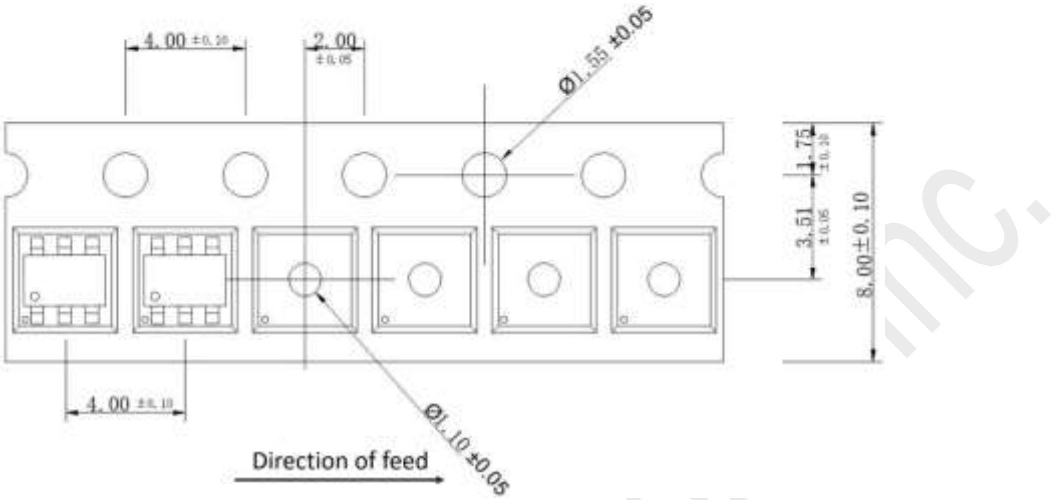
Symbol	Dimensions In Millimeters		Symbol	Dimensions In Millimeters	
	Min	Max		Min	Max
L	2.82	3.02	E1	0.85	1.05
B	1.50	1.70	a	0.35	0.50
C	0.90	1.30	c	0.10	0.20
L1	2.60	3.00	b	0.35	0.55
E	1.80	2.00	F	0	0.15

Note:

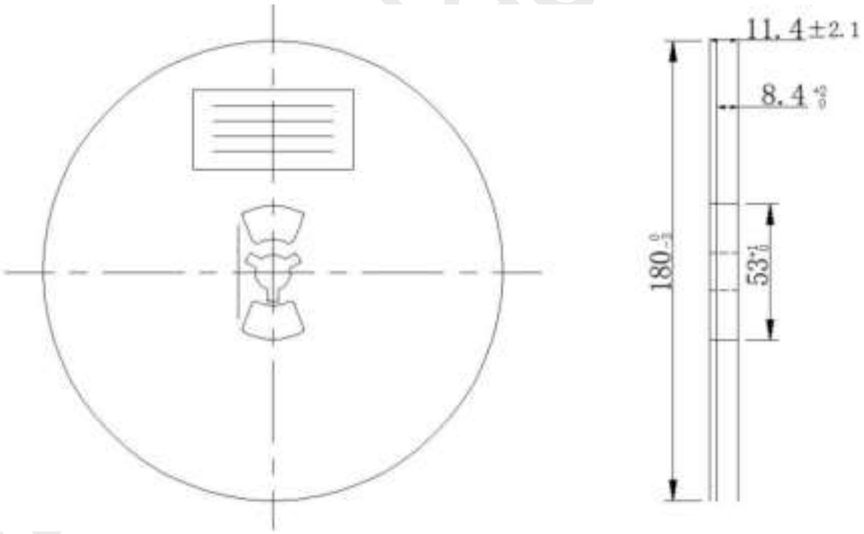
1) All dimensions are in millimeters.
2) Package length does not include mold flash, protrusion or gate burr.
3) Package width does not include inter lead flash or protrusion.
4) Lead popularity (bottom of leads after forming) shall be 0.10 millimeters max.
5) Pin 1 is lower left pin when reading top mark from left to right.

TAPE AND REEL INFORMATION

TAPE DIMENSIONS: SOT23-6



REEL DIMENSIONS: SOT23-6

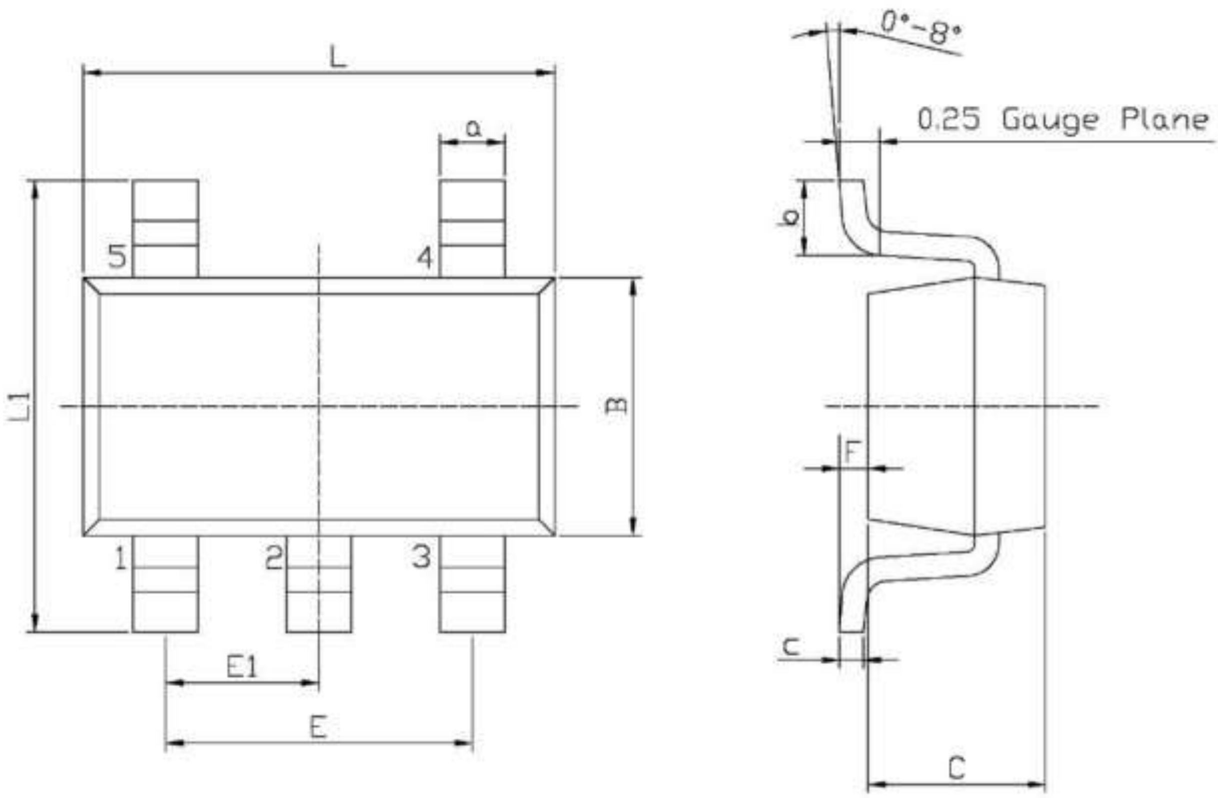


Note:

1) All Dimensions are in Millimeter
2) Quantity of Units per Reel is 3000
3) MSL level is level 3.

PACKAGE INFORMATION

SOT23-5



Unit: mm

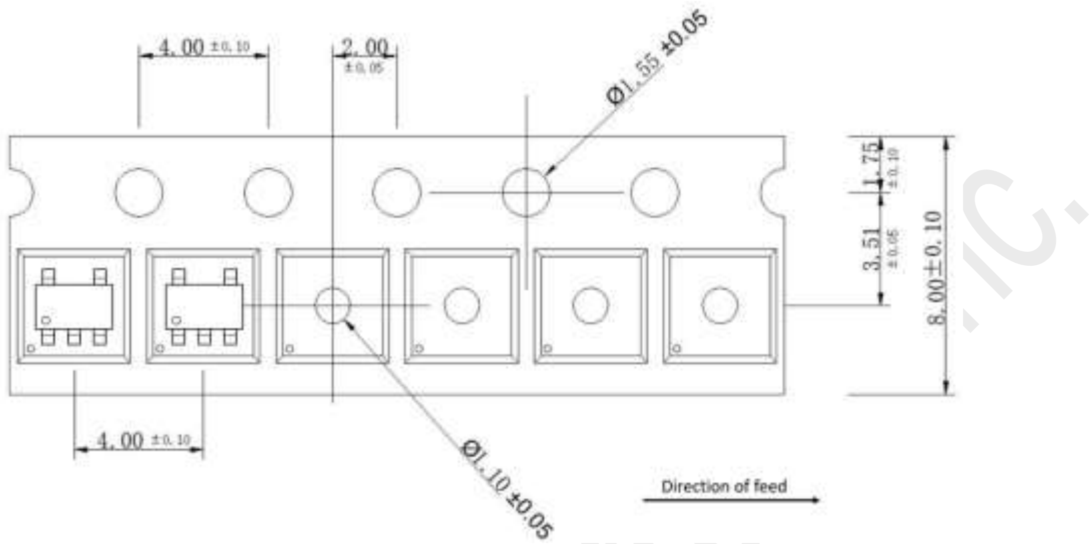
Symbol	Dimensions In Millimeters		Symbol	Dimensions In Millimeters	
	Min	Max		Min	Max
L	2.82	3.02	E1	0.85	1.05
B	1.50	1.70	a	0.35	0.50
C	0.90	1.30	c	0.10	0.20
L1	2.60	3.00	b	0.35	0.55
E	1.80	2.00	F	0	0.15

Note:

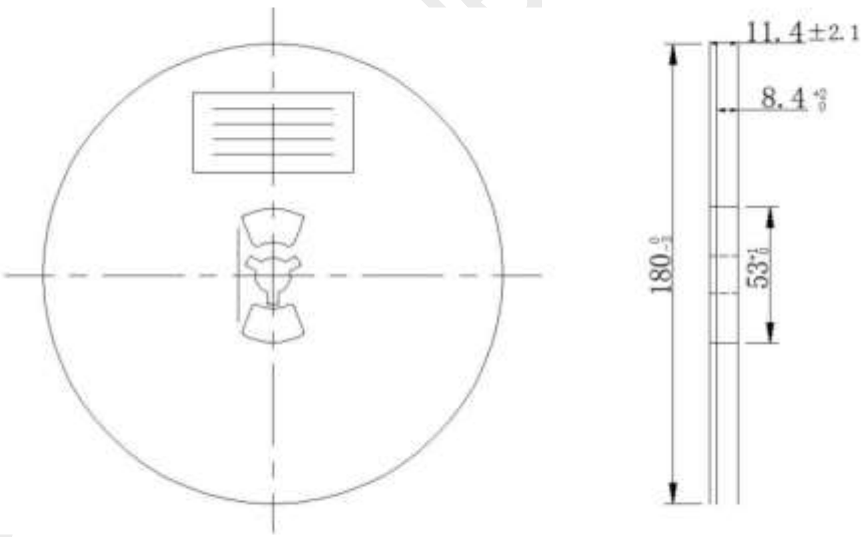
1) All dimensions are in millimeters.
2) Package length does not include mold flash, protrusion or gate burr.
3) Package width does not include inter lead flash or protrusion.
4) Lead popularity (bottom of leads after forming) shall be 0.10 millimeters max.
5) Pin 1 is lower left pin when reading top mark from left to right.

TAPE AND REEL INFORMATION

TAPE DIMENSIONS:



REEL DIMENSIONS:



Note:

4) All Dimensions are in Millimeter
5) Quantity of Units per Reel is 3000
6) MSL level is level 3.

Important Notification

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