750kHz 18V 2A FPWM Synchronous COT Step-Down Converter

Features

- Wide Input Voltage Range: 4.5V to 18V
- Output Voltage Range: 0.765V to 7V
- 140mΩ/70mΩ Low $R_{DS(ON)}$ internal FETs
- High Efficiency Synchronous-Mode Operation
- 750kHz Switch Frequency
- Up to 2A Output Current
- Advanced COT Control to Achieve Fast Transient Responses
- Force PWM Operation
- Integrated Internal Compensation
- Stable with Low ESR Ceramic Output Capacitors
- Over Current Protection with Hiccup Mode
- Thermal Shutdown
- Inrush Current Limit and Soft Start
- Build in Input Over Voltage Protection
- Available in SOT23-6 Package

Description

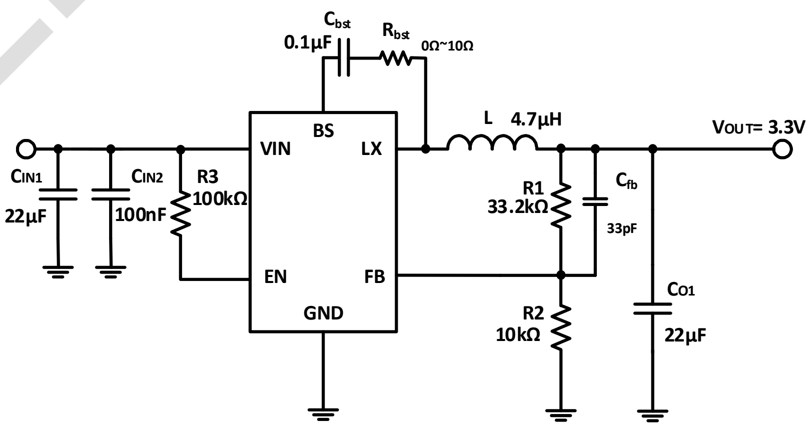
The TMI3252TFN is a high efficiency 750kHz, Advanced Constant-on-Time (COT) control mode synchronous step-down DC-DC converter capable of delivering up to 2A current with FPWM operation. TMI3252TFN integrates main switch and synchronous switch with very low $R_{DS(ON)}$ to minimize the conduction loss. Low output voltage ripple and small external inductor and capacitor size are achieved with 750kHz switching frequency. It adopts the COT architecture to achieve fast transient responses.

The TMI3252TFN requires a minimum number of readily available standard external components and is available in a 6-pin SOT23-6 ROHS compliant package.

Application

- Digital Set Top Boxes
- Flat Panel Television and Monitors
- Notebook Computer
- Wireless and DSL Modems

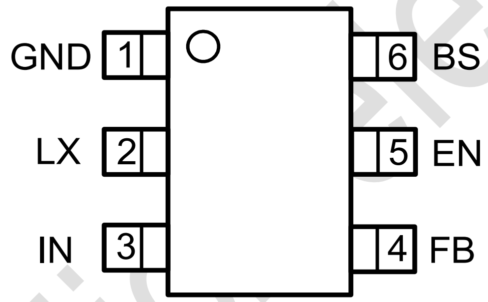
Typical Application



Absolute Maximum Ratings (Note 1)

Parameter	Min	Max	Unit
Input Supply Voltage, EN	-0.3	20	V
LX Voltages	-0.3	20	V
LX Voltages (<10ns transient)	-5.0	23	V
FB Voltage	-0.3	6	V
BS Voltage	-0.3	26	V
BS to LX Voltage	-0.3	6	V
Storage Temperature Range	-65	150	°C
Junction Temperature (Note2)	150		°C
Power Dissipation	1000		mW
Lead Temperature (Soldering, 10s)	260		°C

Package



SOT23-6
Top Marking: T2Uxxx
T2U: Device Code
xxx: Inside Code

Order Information

Part Number	Package	Top Marking	Quantity/Reel
TMI3252TFN	SOT23-6	T2Uxxx	3000

TMI3252TFN devices are Pb-free and RoHS compliant.

Pin Functions

Pin	Name	Function
1	GND	Ground pin.
2	LX	Switching pin.
3	IN	Power supply pin.
4	FB	Output Voltage feedback input pin. Connect FB to the center point of the external resistor divider.
5	EN	Enable pin. Drive this pin to a logic-high to enable the IC. Drive to a logic-low to disable the IC and enter micro-power shutdown mode. Don't floating EN.
6	BS	Bootstrap pin. A capacitor connected between LX and BS pin is required to form a floating supply across the high-side switch driver.

ESD Rating

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

JEDEC specification JS-001

Recommended Operating Conditions

Items	Description	Min	Max	Unit
V_{IN}	Input Voltage Range	4.5	18	V
T_J	Operating Junction Temperature	-40	125	°C

Thermal Resistance (Note3)

Items	Description	Value	Unit
θ_{JA}	Junction-to-ambient thermal resistance	125	°C/W
θ_{JC}	Junction-to-case(top) thermal resistance	60	°C/W
ψ_{JC}	Junction-to-case(top) characterization	2.5	°C/W

Electrical Characteristics

V_{IN}=12V, V_{OUT}=1.53V, T_A = 25°C, unless otherwise noted.

Parameter	Conditions	Min	Typ	Max	Unit
Input Voltage Range		4.5		18	V
Input OVP Rising Threshold			19.0		V
Input UVLO Rising Threshold			4.1	4.5	V
Input UVLO Hysteresis			0.35		V
Quiescent Current	V_{EN}=2V, V_{FB}=V_{REF} x 105%		360		μA
Standby Current	V_{IN}=12V, V_{EN}=2V, I_{OUT}=0A	2		15	mA
Shutdown Current	V_{IN}=12V, EN=0V		5	10	μA
Regulated Feedback Voltage	T_A=25°C, V_{IN}=12V	0.750	0.765	0.780	V
High-Side Switch On-Resistance			140		mΩ
Low-Side Switch On-Resistance			70		mΩ
High-Side Switch Leakage Current	V_{EN}=0V, V_{LX}=0V	1		10	μA
Low-side Switch Valley Current Limit		2.4	2.9	3.5	A
High-side Switch Peak Current Limit			3.5		A
Low-side Switch Negative Current Limit			-2		A
On-time	V_{IN}=12V, V_{OUT}=1.53V	120	170	220	ns
Switching Frequency	V_{IN}=12V, V_{OUT}=1.53V	600	750	900	kHz
Switching Frequency in Maximum Duty Cycle	V_{IN}=12V, V_{FB}=0.6V		130		kHz
Maximum Duty Cycle	V_{IN}=12V, V_{FB}=0.6V		97.5		%
Minimum On-Time			60		ns
Minimum Off-Time			190		ns
Output UV Falling Threshold	Reference to V_{FB}		54		%
Soft Start Time			1.2		ms
Hiccup on Time			3		ms
Hiccup Time Before Restart			42		ms
EN Rising Threshold		1.0	1.1	1.2	V
EN Hysteresis			110		mV
Thermal Shutdown Threshold (Note 4)			165		°C
Thermal Shutdown Hysteresis (Note 4)			30		°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: $T_J = T_A + P_D \times \theta_{JA}$. The maximum allowable continuous power dissipation at any ambient temperature is calculated by $P_{D\,(MAX)} = (T_{J(MAX)}-T_A)/\theta_{JA}$.

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

Note 4: Thermal shutdown threshold and hysteresis are guaranteed by design.

Block Diagram

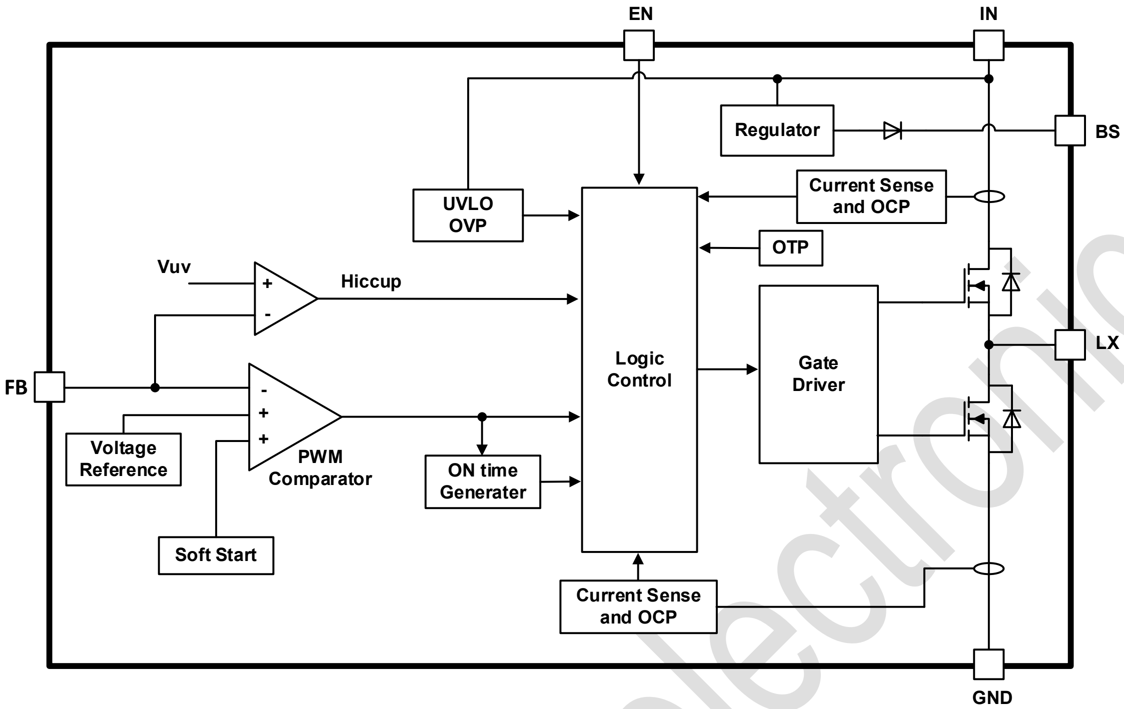


Figure 1. TMI3252TFN Block Diagram

Operation Description

Overview

The TMI3252TFN is an advanced constant on-time (COT) step down DC/DC converter with force PWM Operation mode that provides excellent transient response with no extra external compensation components. This device contains low resistance, high voltage high side and low side power MOSFETs, and operates at 750kHz operating frequency to ensure a compact, high efficiency design with excellent AC and DC performance.

Maximum Duty Cycle

TMI3252TFN is based on COT control mode and it has minimum off time. The maximum duty cycle is limited by minimum off time and maximum on time. TMI3252TFN has a mechanism to decrease the switching frequency by increasing on-time, when the input voltage of TMI3252TFN is close to output voltage and minimum off time is reached, the high side switch on time extends, and the frequency drops. With this function, the TMI3252TFN is able to 97.5% maximum duty cycle and 130kHz switching frequency typically.

Internal Soft-Start

The soft-start is implemented to prevent the converter output voltage from overshooting during startup. When the chip starts, the internal circuitry generates a soft-start voltage (SS) ramping up from 0V to 0.765V. When it is lower than the internal FB reference (V_{REF}), SS overrides REF so the error amplifier uses SS as the reference. When SS is higher than V_{REF}, V_{REF} regains control. The SS time is internally fixed to 1.2ms typically.

Over-Current-Protection and Short Circuits Protection

The TMI3252TFN has cycle-by-cycle current limit on both high-side MOSFET and low-side MOSFET. During every switching cycle and high side MOSFET is turned on, when the peak current of high-side MOSFET is larger than high-side MOSFET peak current limit the high-side MOSFET is turned off and low-side MOSFET is turned on immediately. When the low-side MOSFET valley current value is larger than the valley current limit during low side MOSFET on state, the device enters into valley over current protection mode and low side MOSFET keeps on state until inductor current drops down to the value equal or lower than the valley current limit, and then on time pulse could be generated and high side MOSFET could turn on again.

If the output is short to GND and the output voltage drop until feedback voltage V_{FB} is below the output under-voltage V_{UV} threshold which is typically 54% of V_{REF}, TMI3252TFN enters into hiccup mode to periodically disable and restart switching operation. The hiccup mode helps to reduce power dissipation and thermal rise during output short condition. The period of TMI3252TFN hiccup mode is typically 45ms.

Negative Current Limit

Low-side MOSFEET Negative Current Limit (NCL) is realized by monitoring the current following from LX to GND when Low-side MOSFET (LSFET) is turned on. When the current reaches negative current limit, the LSFET is turned off to limit the negative current.

TMI3252TFN work in FPWM mode. In order to prevent the Negative Current Limit is triggered on light load operation the inductor valley current should be designed to higher than I_{LIM_NEG}, when the output of TMI3252TFN have energy flowing backward from output side and drive feedback voltage start rise, its inductor current will increase negatively. TMI3252TFN first releases the output backward energy to the input under internal control loop adjustment, and slows down the output voltage rise range. In this process, the inductor current continues to increases negatively. After triggering the NCL, TMI3252TFN will turn off LSFET, and the HSFET is also controlled by internal control loop circuits. If the FB voltage is higher than the internal reference voltage, the HSFET is turned off by internal control loop circuits. The continuous output energy flowing backward will sustain feedback voltage higher than reference voltage, leading to the internal control loop of TMI3252TFN keeps HSFET and LSFET closing, once output voltage drops down to target voltage, the TMI3252TFN will return to normal switching operation immediately.

Startup and Shutdown

If both VIN and EN are higher than their appropriate thresholds, the chip starts switching operation. The reference block starts first, generating stable reference voltage and currents, and then the internal regulator is enabled. The regulator provides stable supply for the remaining circuitries. Three events can shut down the chip: EN low, VIN low and thermal shutdown. In the shutdown procedure, the signaling path is first blocked to avoid any fault triggering. The floating driver is not subject to this shutdown command.

Thermal Shutdown

The TMI3252TFN implements a thermal shutdown mechanism to protect the device from damage due to overheating. When the junction temperature rises to 165°C (typical), the device shuts down immediately. The TMI3252TFN releases thermal shutdown when the junction temperature of the device is reduced to 135°C typically.

Application Information

Setting the Output Voltage

The external resistor divider is used to set the output voltage (see Typical Application on page 1). Choose R1 to be around 39kΩ for optimal transient response. R1 is then given by:

Table 1: Selection for Common Output Voltages (V_{FB}=0.765V)

V_{OUT} (V)	R1 (kΩ)	R2 (kΩ)	C_{FB}(pF)	L (μH)
5	56.2	10	10~100	2.2~4.7
3.3	33.2	10	10~100	2.2~4.7
2.5	22.6	10	10~100	2.2~4.7
1.8	13.7	10	10~100	1.5~3.3
1.5	9.53	10	10~100	1.5~3.3
1.2	5.76	10	10~100	1.0~2.2
1	3.09	10	10~100	1.0~2.2

$$R_2 = \frac{R_1}{V_{out}/V_{FB} - 1}$$

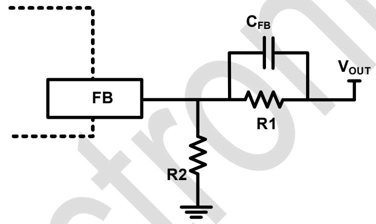


Figure 2. Feedback Network

A C_{FB} capacitor paralleling with high side divider resistor R1 can be used to improve load transient performance. It adds a zero in the frequency 1/2π·R1·C_{FB} to increase bandwidth of the system. 33pF C_{FB} is sufficient in most application. In fast transient load current condition, increasing C_{FB} capacitance helps to improve transient performance and reduce output ripple value. C_{FB} capacitor value could be regulated according to output capacitor value and loop stability margin.

Selecting the Inductor

A 1.0μH to 4.7μH inductor with a DC current rating of at least 25% percent higher than the maximum load current is recommended for most applications. For highest efficiency, the inductor DC resistance should be as small as possible. For most designs, the inductance 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 the inductor ripple current. Choose inductor ripple current to be approximately 30% if the maximum load current, 2A. The maximum inductor peak current is:

$$I_{L(MAX)} = I_{LOAD} + \frac{\Delta I_L}{2}$$

Selecting the Output Capacitor

The output capacitor (Co1) is required to maintain the DC output voltage. Ceramic, tantalum, or low ESR electrolytic capacitors are recommended. Low ESR capacitors are preferred to keep the output voltage ripple low. The output voltage ripple can be estimated by:

$$\Delta V_{OUT} = \frac{V_{OUT}}{f_S \times L} \times \left[1 - \frac{V_{OUT}}{V_{IN}}\right] \times \left[R_{ESR} + \frac{1}{8 \times f_S \times C_2}\right]$$

Where L is the inductor value and R_{ESR} is the equivalent series resistance (ESR) value of the output capacitor. In the case of ceramic capacitors, the impedance at the switching frequency is dominated by the capacitance. The output voltage ripple is mainly caused by the capacitance. For simplification, the output voltage ripple can be estimated by:

$$\Delta V_{OUT} = \frac{V_{OUT}}{8 \times f_S^{\,2} \times L \times C_2} \times \left[1 - \frac{V_{OUT}}{V_{IN}}\right]$$

In the case of tantalum or electrolytic capacitors, the ESR dominates the impedance at the switching frequency. For simplification, the output ripple can be approximated to:

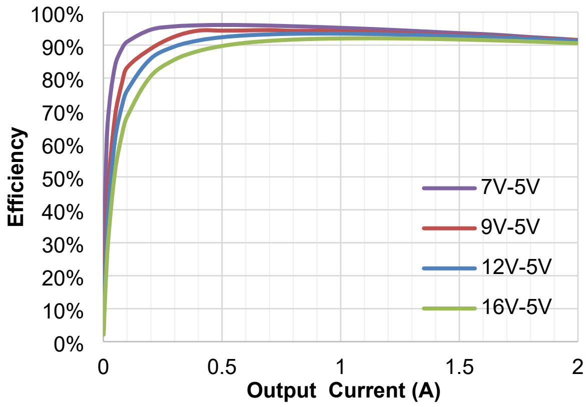
$$\Delta V_{OUT} = \frac{V_{OUT}}{f_S \times L} \times \left[1 - \frac{V_{OUT}}{V_{IN}}\right] \times R_{ESR}$$

The characteristics of the output capacitor also affect the stability of the regulation system. The TMI3252TFN can be optimized for a wide range of capacitance and ESR values. One or more 22μF ceramic output capacitors for most application are sufficient.

Typical Performance Characteristics

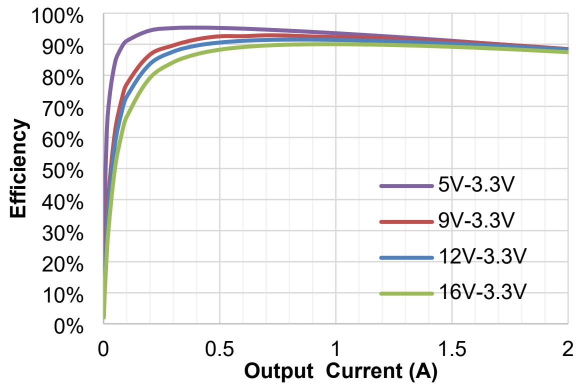
Efficiency

V_{OUT} =5V, L=4.7μH, DCR=30mΩ



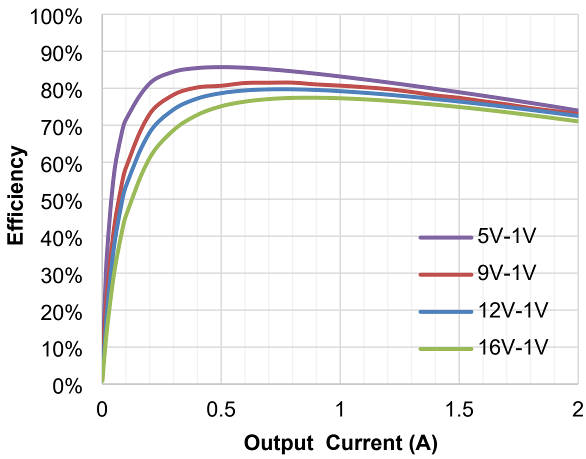
Efficiency

V_{OUT} =3.3V, L=4.7μH, DCR=30mΩ



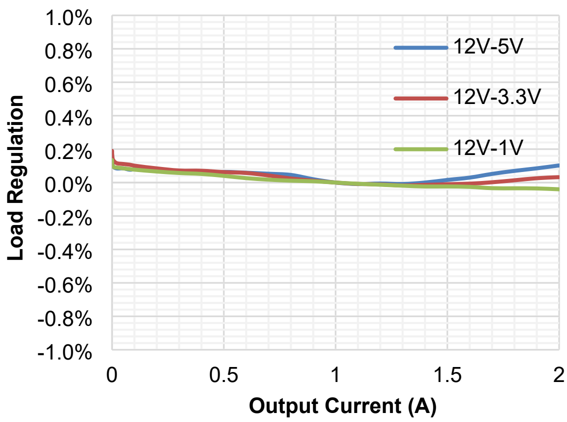
Efficiency

V_{OUT}=1.0V, L=2.2μH, DCR=20mΩ



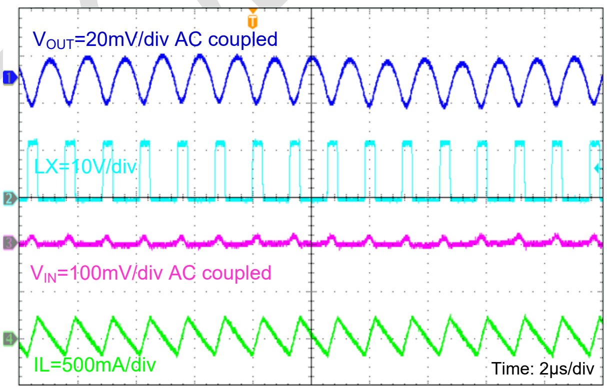
Line Regulation

V_{IN}=12V, T_A=25°C



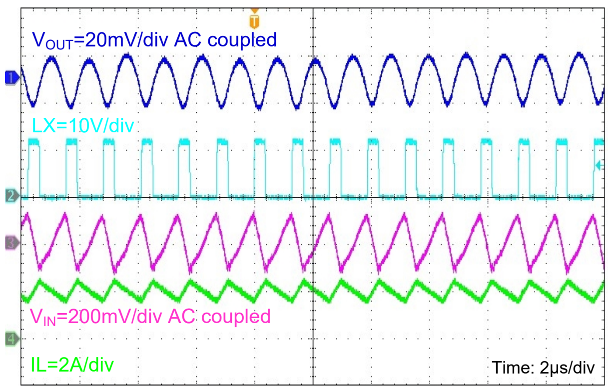
Steady State Operation

V_{IN} =12V, V_{OUT} =3.3V, No Load



Steady State Operation

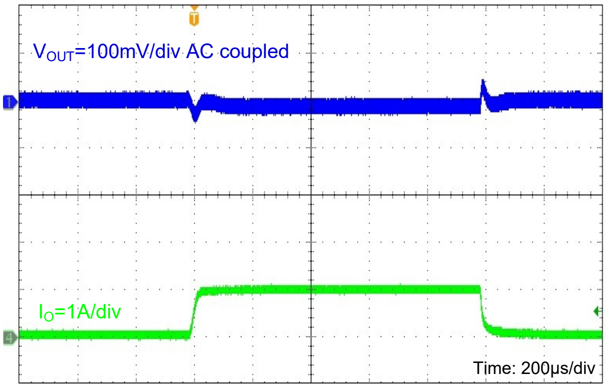
V_{IN} =12V, V_{OUT} =3.3V, I_o=Full Load



Typical Performance Characteristics(continued)

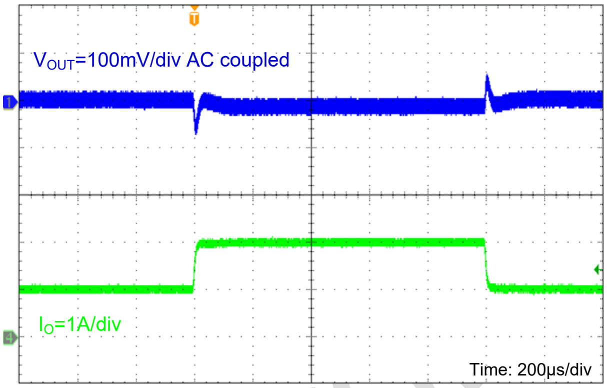
Load Transient

V_{IN} = 12V, V_{OUT} = 3.3V, I_o = 0A to 1A



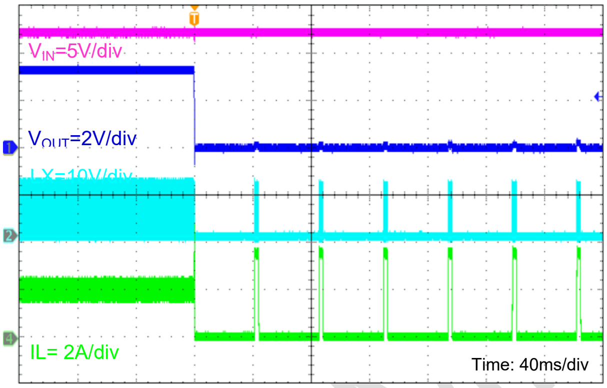
Load Transient

V_{IN} = 12V, V_{OUT} = 3.3V, I_o = 1A to 2A



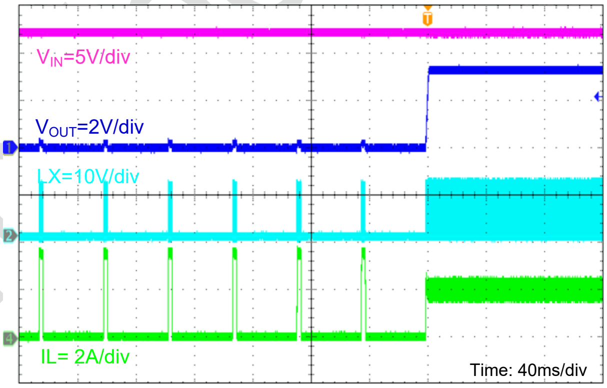
Output Short Entry

V_{IN} =12V, V_{OUT} = 3.3V, I_o = 2A



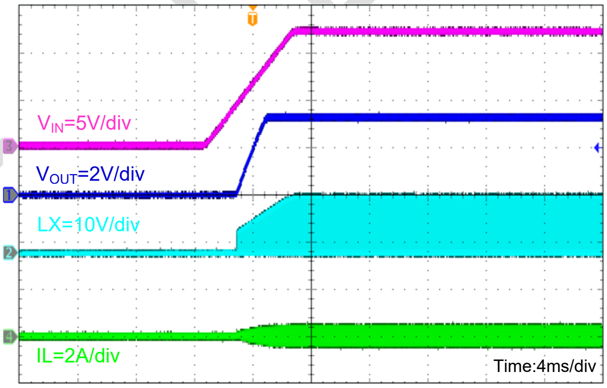
Output Short Recovery

V_{IN}=12V, V_{OUT} = 3.3V, I_o = 2A



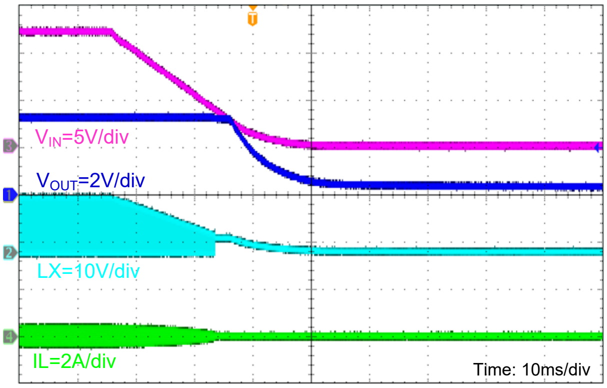
Input Power On

V_{IN} =12V, V_{OUT} = 3.3V, I_o = 0A



Input Power Down

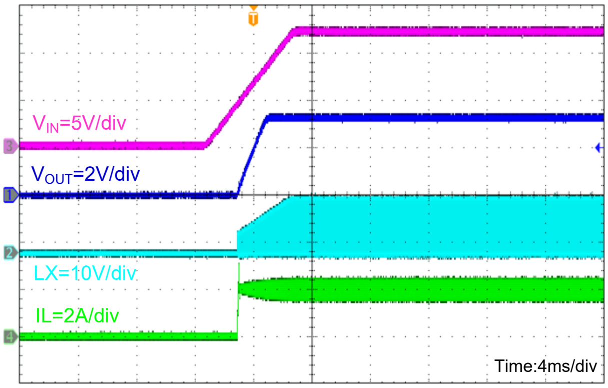
V_{IN} =12V, V_{OUT} = 3.3V, I_o = 0A



Typical Performance Characteristics(continued)

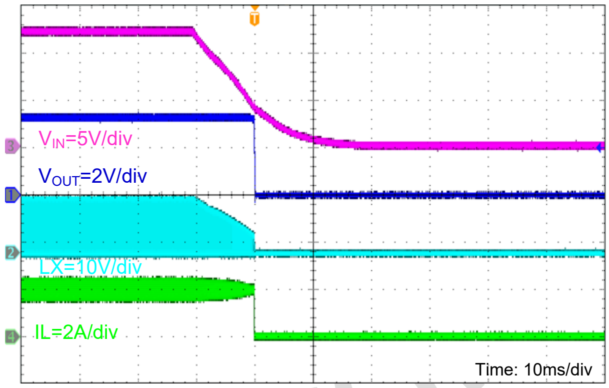
Input Power On

V_{IN} =12V, V_{OUT} = 3.3V, I_o = 2A



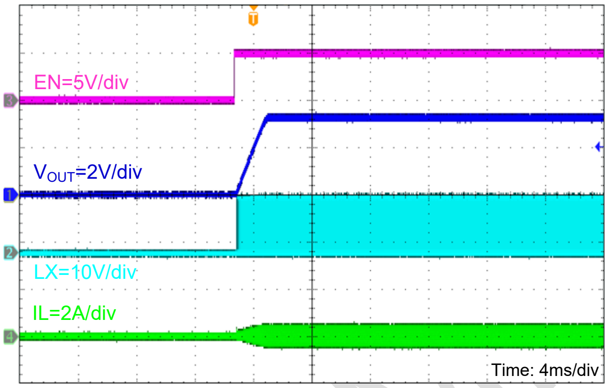
Input Power Down

V_{IN} =12V, V_{OUT} = 3.3V, I_o = 2A



EN Enable

V_{IN} =12V, V_{OUT} = 3.3V, I_o = 0A



EN Disable

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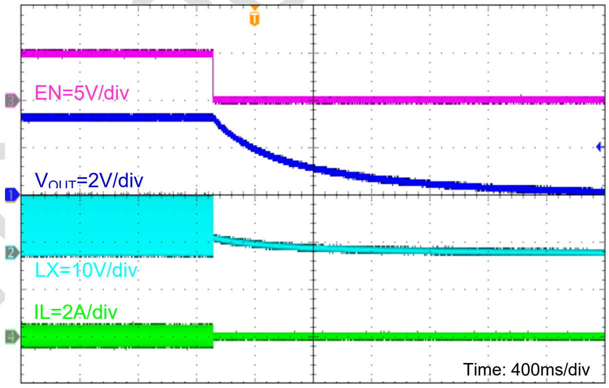
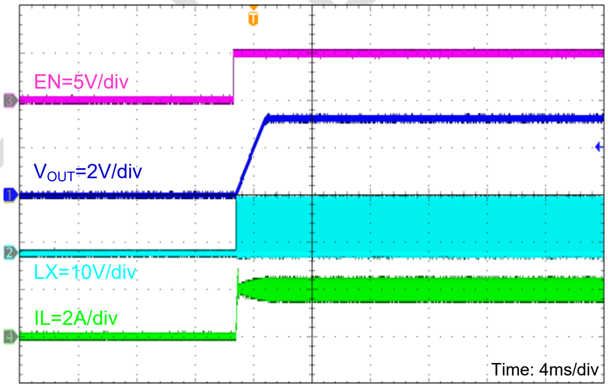


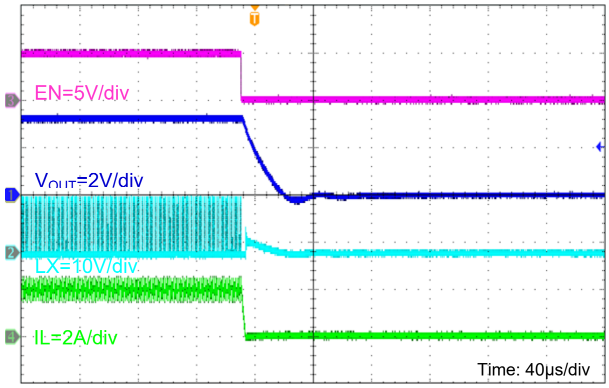
EN Enable

V_{IN} =12V, V_{OUT} = 3.3V, I_o = 2A



EN Disable

V_{IN} =12V, V_{OUT} = 3.3V, I_o = 2A



Typical Application Circuits

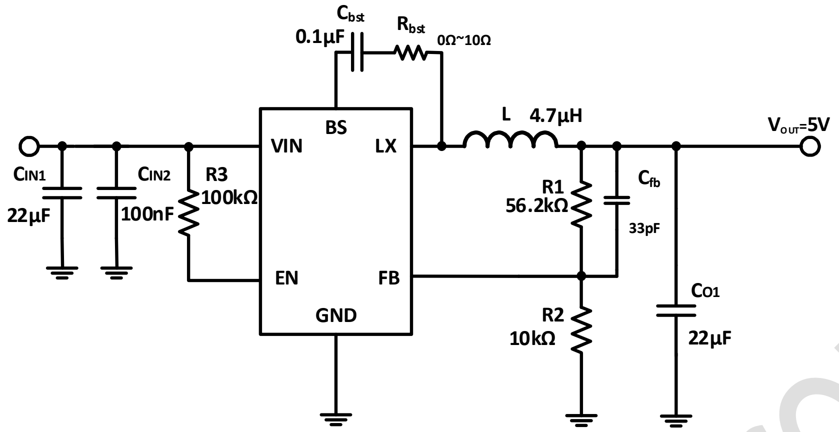


Figure 3. $12V_{IN}$, 5V Output

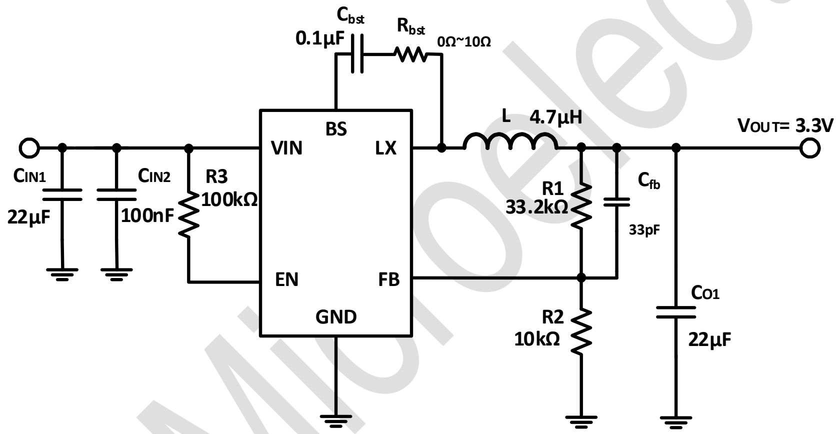


Figure 4. $12V_{IN}$, 3.3V Output

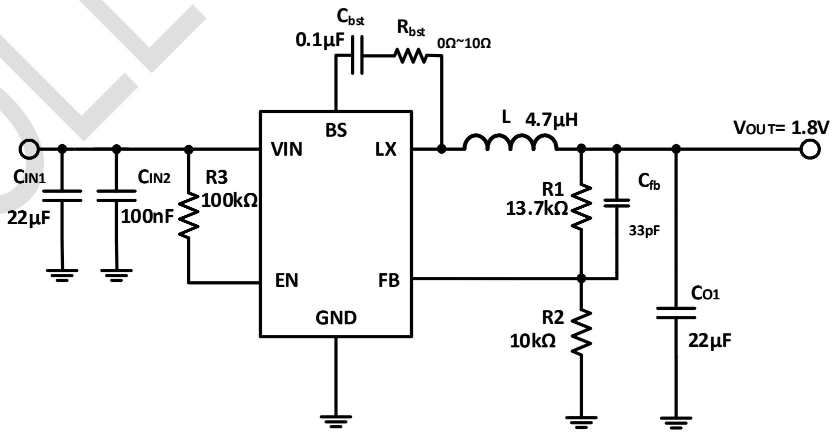


Figure 5. $12V_{IN}$, 1.8V Output

Typical Application Circuits (continued)

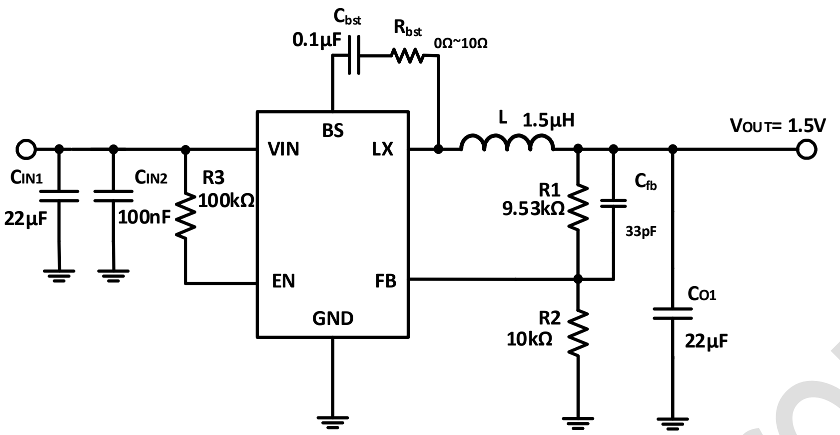


Figure 6. 12V$_{IN}$, 1.5V Output

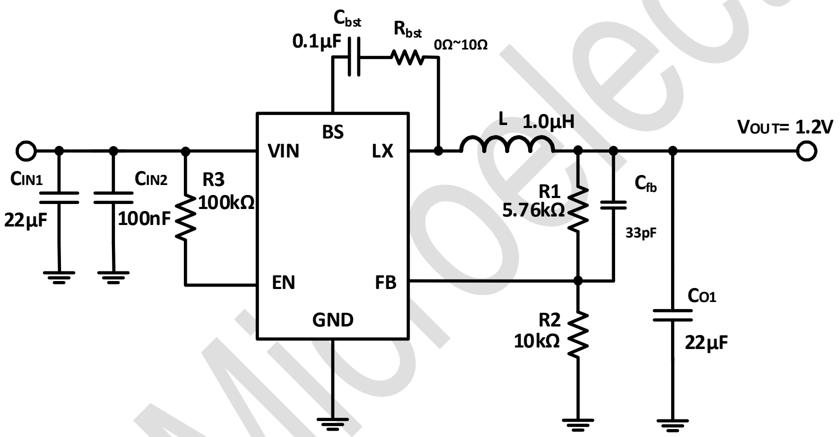


Figure 7. 12V$_{IN}$, 1.2V Output

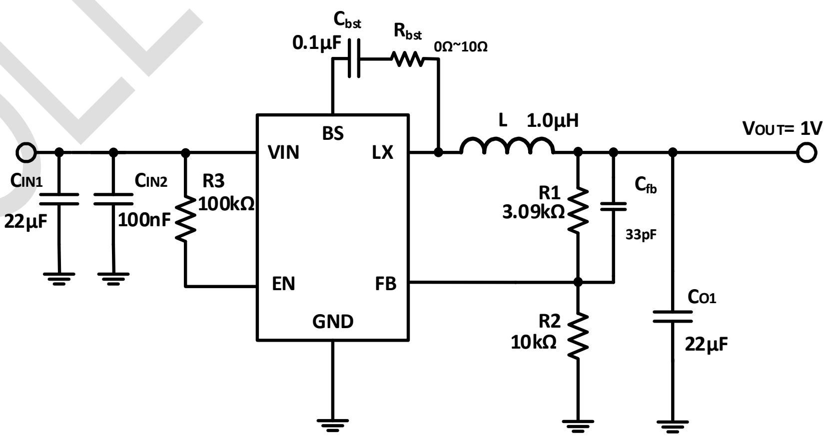


Figure 8. 12V$_{IN}$, 1V Output

PCB Layout Guide

PCB layout is very important to achieve stable operation. It is highly recommended to duplicate EVB layout for optimum performance. If change is necessary, please follow these guidelines and take Figure 9 for reference.

1) Keep the path of switching current short and minimize the loop area formed by Input capacitor, IN pin and GND.

2) Bypass ceramic capacitors are suggested to be put close to the IN Pin.

3) Ensure all feedback connections are short and direct. Place the feedback resistors as close to the chip as possible.

4) VOUT, LX away from sensitive analog areas such as FB.

5) Connect IN, LX, and especially GND respectively to a large copper area to cool the chip to improve thermal performance and long-term reliability.

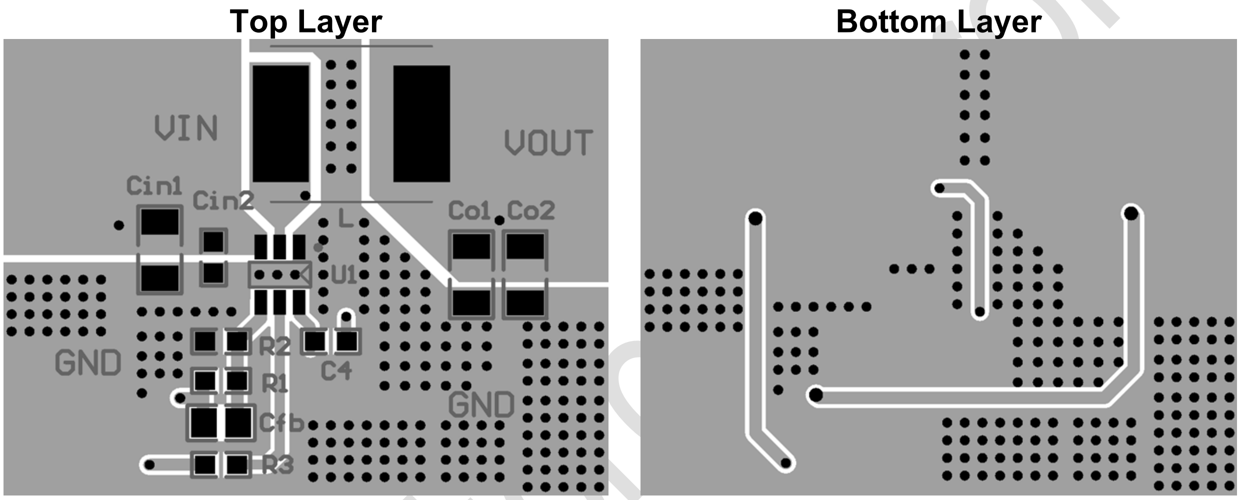
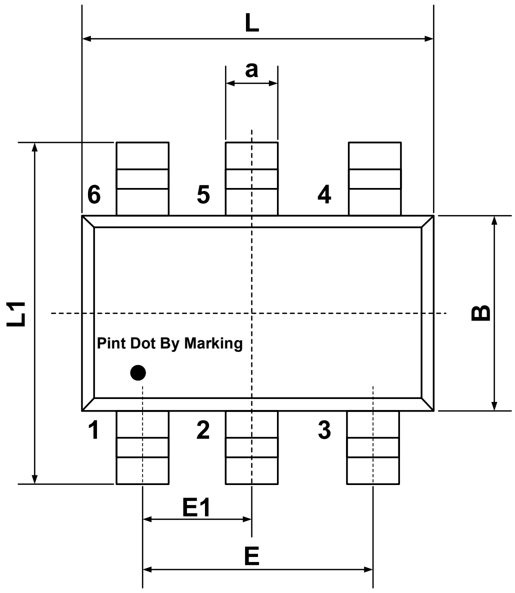


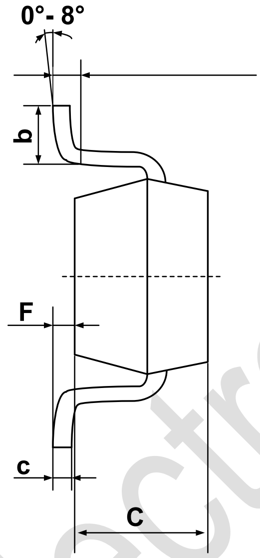
Figure 9. Sample of PCB Layout (TMI3252TFN)

Package Information

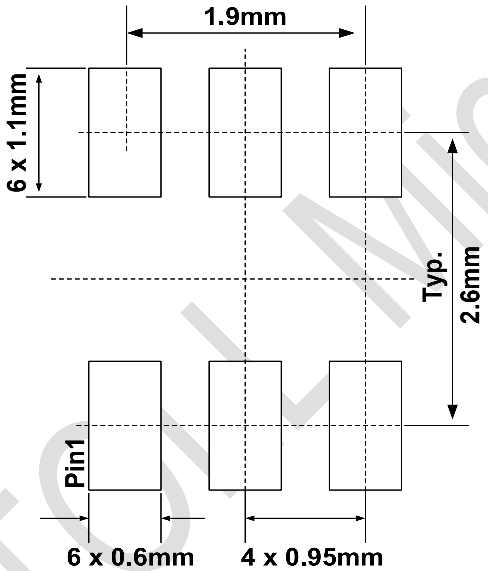
SOT23-6



TOP VIEW



SIDE VIEW



RECOMMENDED PAD LAYOUT

Unit: mm

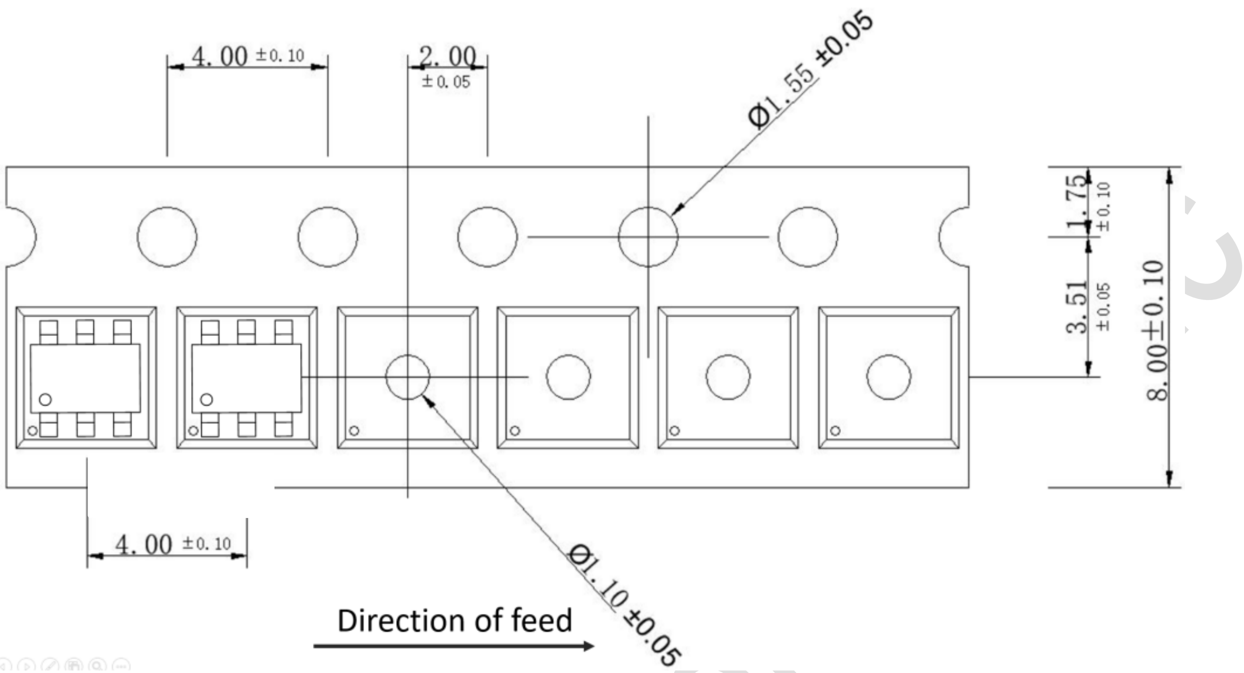
Symbol	Dimensions In Millimeters	
	Min	Max
L	2.82	3.02
B	1.50	1.70
C	0.90	1.30
L1	2.60	3.00
E	1.80	2.00
E1	0.85	1.05
a	0.35	0.50
c	0.10	0.20
b	0.35	0.55
F	0	0.15

Note:

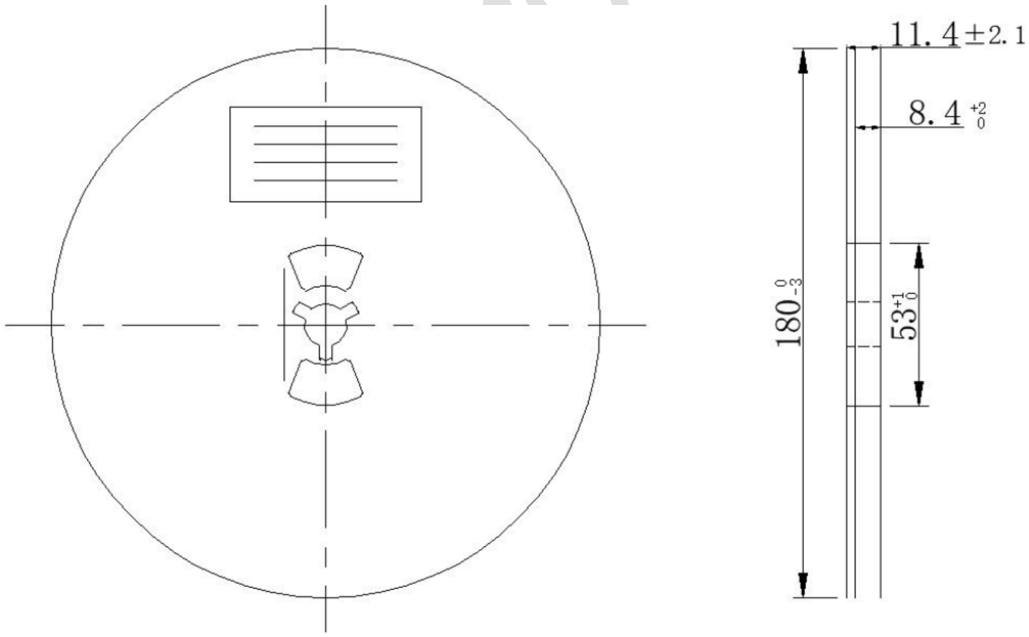
1) All dimensions are in millimeters.
2) Package length does not include mold flash, protrusion or gate burr.
3) Package width does not include inter lead flash or protrusion.
4) Lead popularity (bottom of leads after forming) shall be 0.10 millimeters max.
5) Pin 1 is lower left pin when reading top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

Important Notification

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