600kHz,18V, 5A FPWM Synchronous COT Step-Down Converter

Features

- 40mΩ/20mΩ Low $R_{DS(ON)}$ internal FETs
- Force PWM Operation Mode
- Wide Input Range: 4.5V to 18V
- Feedback Voltage Accuracy 0.76V±1.5%
- 600kHz Switch Frequency
- Up to 5A Output Current
- COT control to achieve fast transient responses
- 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

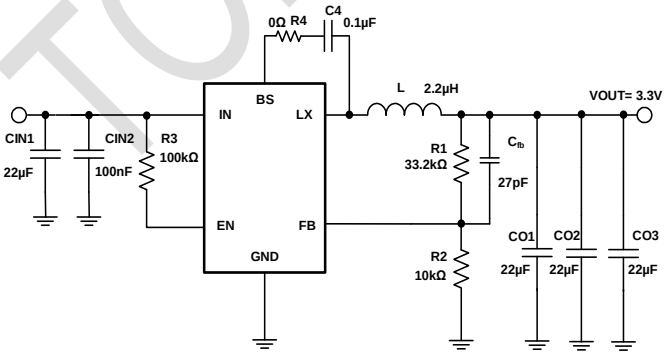
The TMI3255TF is a high efficiency 600kHz, Constant on-Time (COT) control mode synchronous step-down DC-DC converter capable of delivering up to 5A current. TMI3255TF integrates main switch and synchronous switch with very low $R_{DS(ON)}$ to minimize the conduction loss. Low output voltage ripple and small external inductor and capacitor size are achieved with 600kHz switching frequency. It adopts the COT architecture and force PWM operation in steady state to achieve fast transient responses for high voltage step down applications.

The TMI3255TF requires a minimum number of readily available standard external components and is available in a 6-pin SOT23-6 RoHS compliant package.

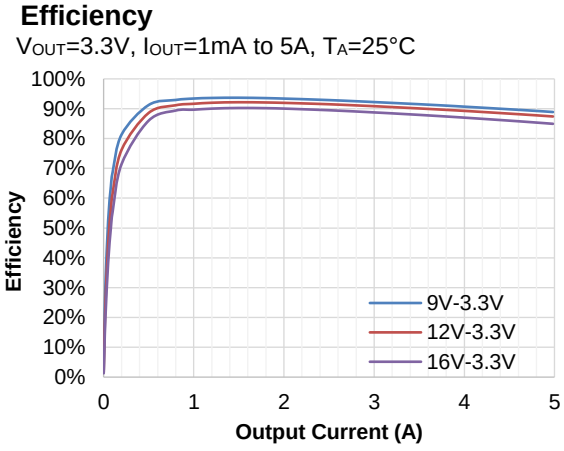
Application

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

Typical Application



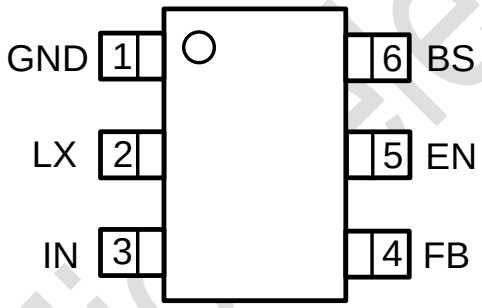
TMI3255TF Typical Application Circuits



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)	-4.5	22	V
FB Voltage	-0.3	6	V
BS Voltage	-0.3	23	V
Storage Temperature Range	-65	150	°C
Junction Temperature (Note2)	-	160	°C
Power Dissipation	-	1500	mW
Lead Temperature (Soldering, 10s)	-	260	°C

Package



Top View

SOT23-6

Top Marking: TF5XXX

TF5: Device Code

XXX: Inside Code

Order Information

Part Number	Package	Top Marking	Quantity/Reel
TMI3255TF	SOT23-6	TF5XXX	3000

TMI3255TF 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. Connect FB to the center point of the external resistor divider.
5	EN	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. A capacitor connected between LX and BS pins 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
Voltage Range	IN	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	100	°C/W
θ_{JC}	Junction-to-case(top) thermal resistance	56	°C/W
ψ_{JC}	Junction-to-case(top) characterization parameter	2.5	°C/W

Electrical Characteristics

V_{IN}=12V, V_{OUT}=1.2V, T_A = 25°C, unless otherwise noted.

Parameter	Conditions	Min	Typ	Max	Units
Input Voltage Range		4.5		18	V
OVP Threshold		18	19	20	V
OVP Hysteresis			0.45		V
UVLO Rising Threshold		4.0	4.2	4.4	V
UVLO Hysteresis		0.35	0.5	0.65	V
Quiescent Current	V_{EN}=2V, V_{FB}=V_{REF} x 105%		340	600	μA
Standby Current	V_{EN}=2V, No load		12		mA
Shutdown Current	V_{IN}=12V, EN=0V		5	15	μA
Regulated Feedback Voltage	T_A=25°C	0.748	0.76	0.772	V
High-Side Switch On-Resistance			40	55	mΩ
Low-Side Switch On-Resistance			20	35	mΩ
High-Side Switch Leakage Current	V_{EN}=0V, V_{LX}=0V	1		10	μA
High-side Switch Peak Current Limit			9		A
Low-side Switch Valley Current Limit		5.2	6		A
Switch Negative Current Limit			-5		A
On Time	V_{IN}=12V, V_{OUT}=1.2V, I_{OUT}=1A	132	166	200	ns
Oscillation Frequency	Maximum Duty	450	600	750	kHz
Maximum Duty Cycle			84		%
Minimum On-Time(Note 4)		5	80	100	ns
Soft Start Time		0.6	1.2	1.8	ms
Hiccup on Time(Note 4)			1.5		ms
Hiccup Time Before Restart(Note 4)			15		ms
EN Rising Threshold		0.95	1.1	1.25	V
EN Hysteresis			140		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: Guaranteed by design.

Block Diagram

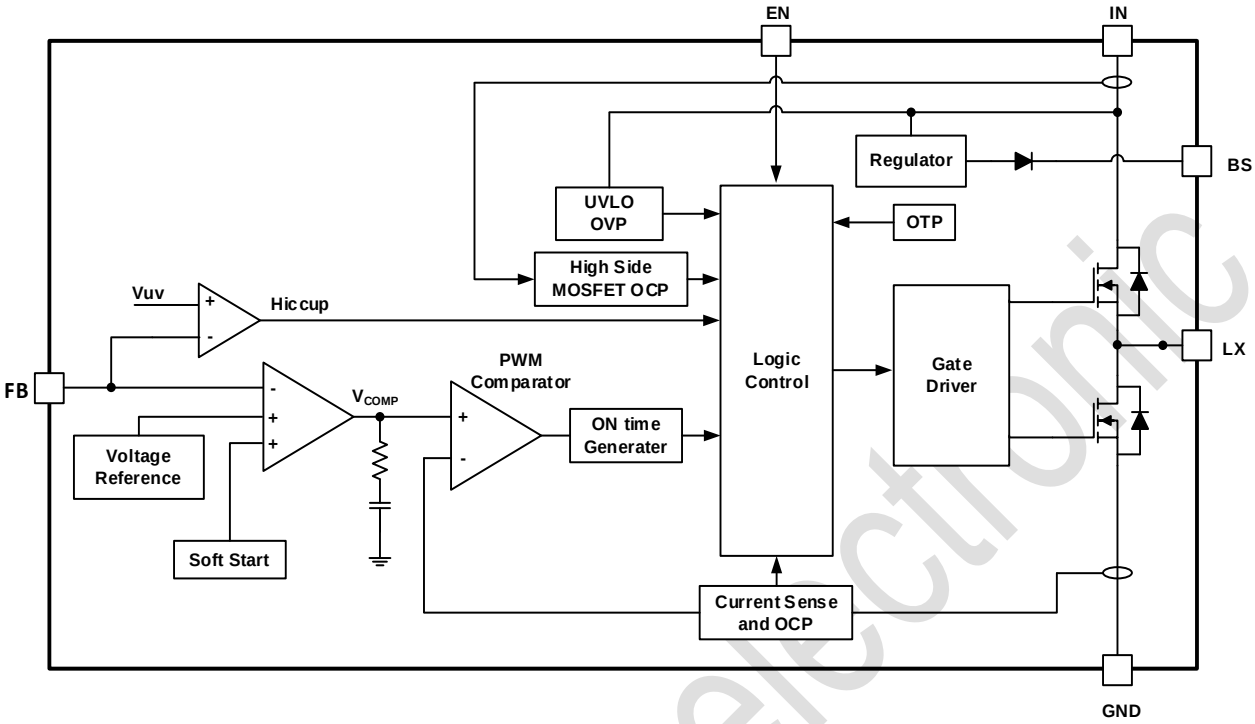


Figure 1. TMI3255TF Block Diagram

Operation Description

Internal Regulator

The TMI3255TF is a constant on-time (COT) step down DC/DC converter 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 600kHz force PWM operating frequency to ensure a compact, high efficiency design with excellent AC and DC performance.

Error Amplifier

TMI3255TF adopts operational transconductance amplifier (OTA) as error amplifier. The error amplifier compares the FB pin voltage with the internal FB reference (V_{REF}) and outputs a current proportional to the difference between the two. This output current is then used to charge or discharge the internal compensation network to form the V_{COMP} voltage, which is used to compare with the low side power MOSFET current sensing signal and trigger on time pulse. The optimized internal compensation network minimizes the external component counts and simplifies the control loop design.

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 V_{REF}. 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 TMI3255TF has both high-side and low-side MOSFET cycle-by-cycle current limit function. When the inductor current peak value is larger than the switch peak current limit after the blinking time, high side MOSFET is turned off immediately. When inductor current valley 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 65% of V_{REF}, TMI3255TF 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 TMI3255TF hiccup mode is typically 16.5ms.

Negative Current Limit

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

TMI3255TF works in force PWM 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 TMI3255TF have energy flowing backward from output side and drive feedback voltage start rise, its inductor current will increase negatively. TMI3255TF 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, TMI3214HF will turn off LS-FET, and the HS-FET is also controlled by internal control loop circuits. If the FB voltage is higher than the internal reference voltage, the HS-FET 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 TMI3255TF keeps HS-FET and LS-FET closing, once output voltage drops down to target voltage, the TMI3255TF 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 V_{COMP} voltage and the internal supply rail are then pulled down. The floating driver is not subject to this shutdown command.

Application Information

Setting the Output Voltage

The external resistor divider is used to set the output voltage (see Typical Application on page 1). Choose R2 to be around 10kΩ for optimal transient response. R1 is then given by:

Table 1: Selection for Common Output Voltages (V_{FB}=0.76V)

V_{OUT} (V)	R1 (kΩ)	R2 (kΩ)	C_{FB}(pF)	L (μH)
5	56.2	10	27	3.3
3.3	33.2	10	27	2.2
2.5	23.2	10	27	2.2
1.8	13.7	10	27	2.2
1.5	9.76	10	27	2.2
1.2	5.76	10	27	1.5
1	3.09	10	27	1.0

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

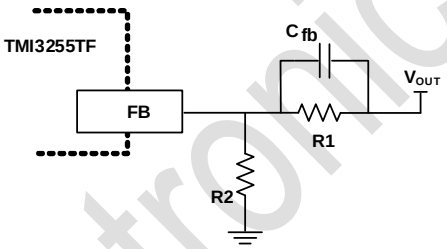


Figure 2. Feedback Network

Selecting the Inductor

A DC current rating of at least 25% percent higher than the maximum load current is recommended for most applications. 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 ΔIL is the inductor ripple current. TMI3255TF is force PWM operation mode. In dull load condition, the average inductor current is zero and valley inductor current is -ΔIL/2. the minus current valley is limited to around -3A, so the inductor ripple current ΔIL should be smaller than 6A, and the minimum inductance value is limited. The maximum inductor peak current is:

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

Such as, for 5V output voltage, the recommended inductor should not be smaller than 1.5μH, and for 3.3V output voltage, the recommended inductor should not be smaller than 1.0μH.

Selecting the Output Capacitor

The output capacitors are 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 TMI3255TF can be optimized for a wide range of capacitance and ESR values.

PCB Layout Guide

PCB layout is very important to achieve stable operation. Please follow these guidelines 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.

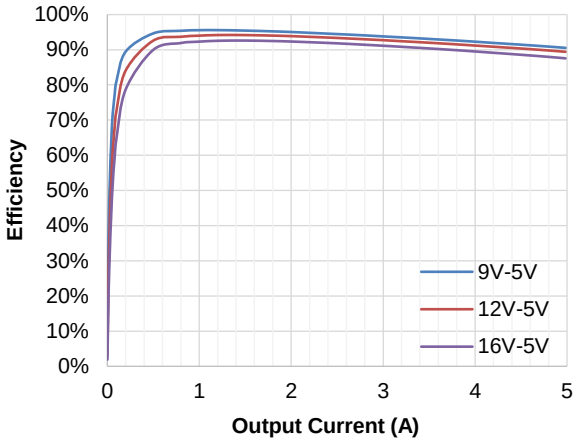
4) VOUT, LX away from sensitive analog areas such as FB.

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.

Typical Performance Characteristics

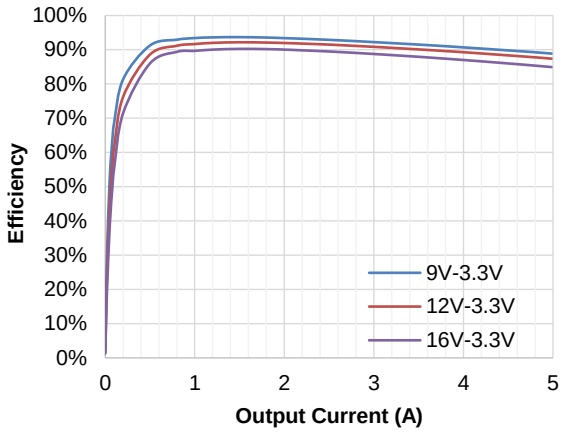
Efficiency

V_{OUT} =5V, L=3.3μH



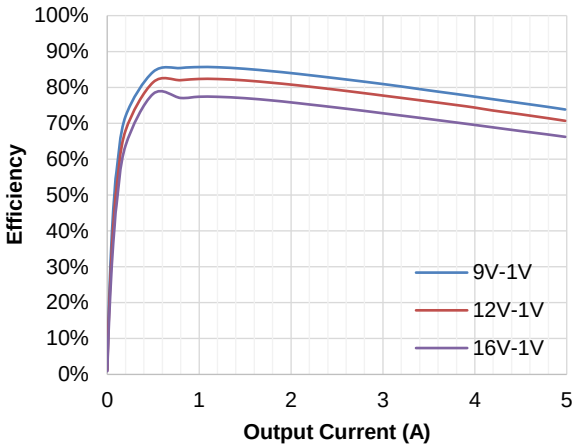
Efficiency

V_{OUT} =3.3V, L=2.2μH



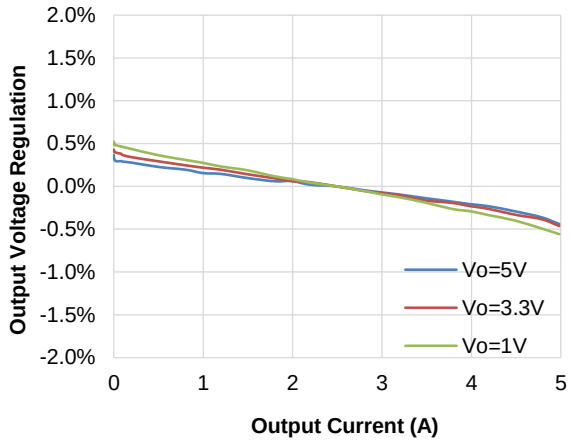
Efficiency

V_{OUT}=1V, L=1μH



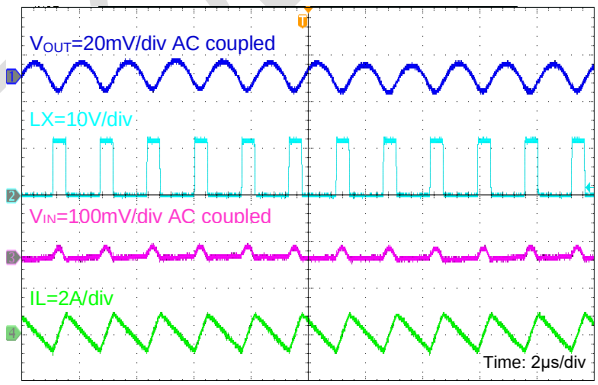
Load Regulation

V_{IN}=12V, T_A=25°C



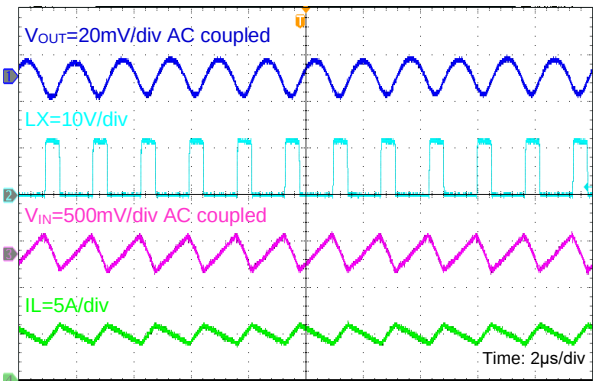
Steady State Operation

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



Steady State Operation

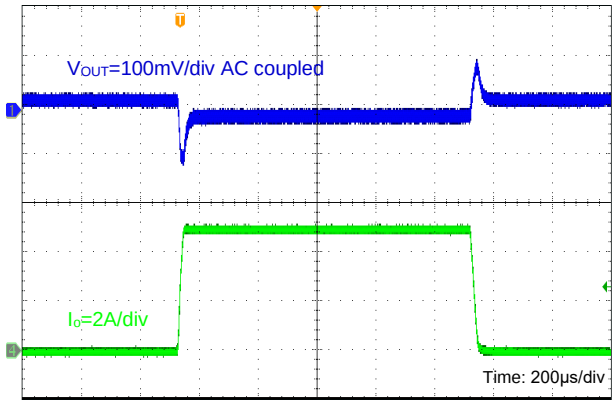
V_{IN} =12V, V_{OUT} =3.3V, I_o=Full Load



Typical Performance Characteristics(continued)

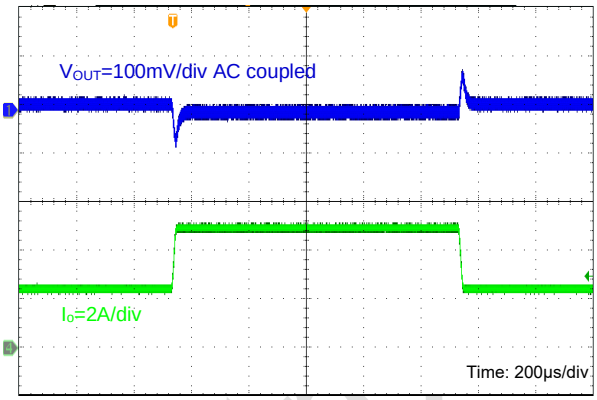
Load Transient

V_{IN} =12V, V_{OUT} =3.3V, I_o =0A to 5A



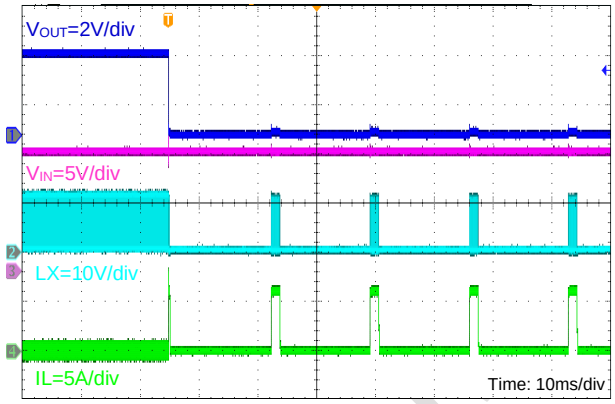
Load Transient

V_{IN} =12V, V_{OUT} =3.3V, I_o =2.5A to 5A



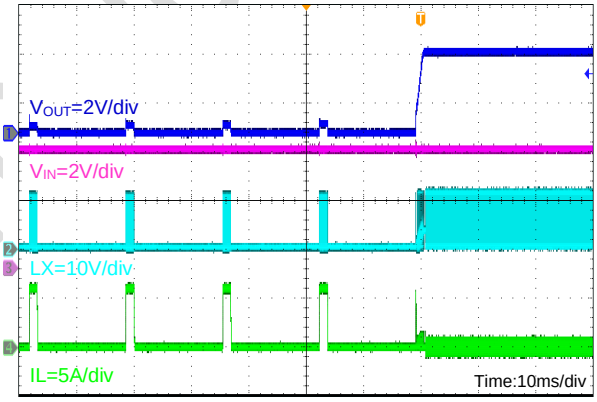
Output Short Entry

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



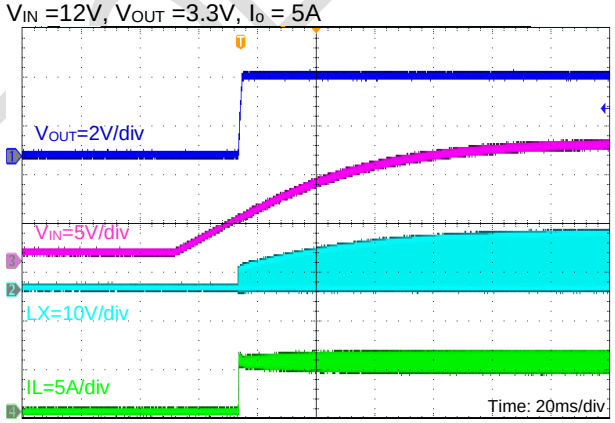
Output Short Recovery

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



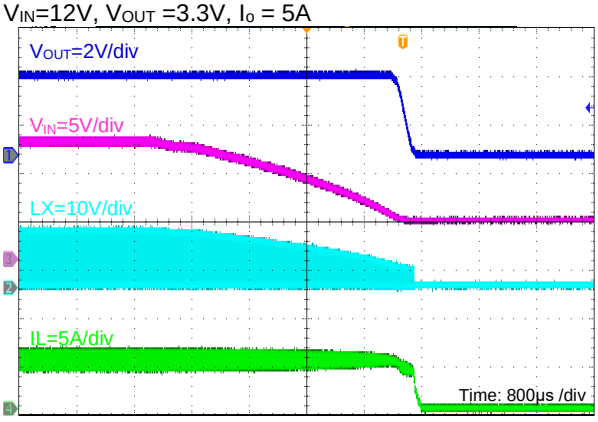
Input Power On

V_{IN} =12V, V_{OUT} =3.3V, I_o = 5A



Input Power Down

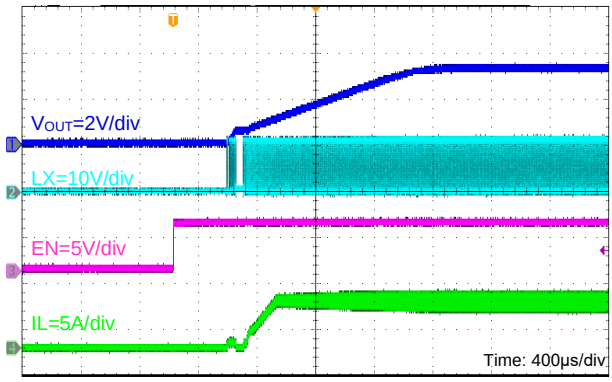
V_{IN}=12V, V_{OUT} =3.3V, I_o = 5A



Typical Performance Characteristics(continued)

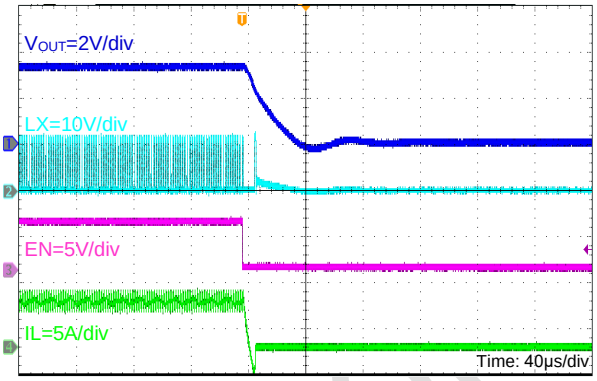
EN Enable

V_{IN} =12V, V_{OUT} =3.3V, I_o = 5A



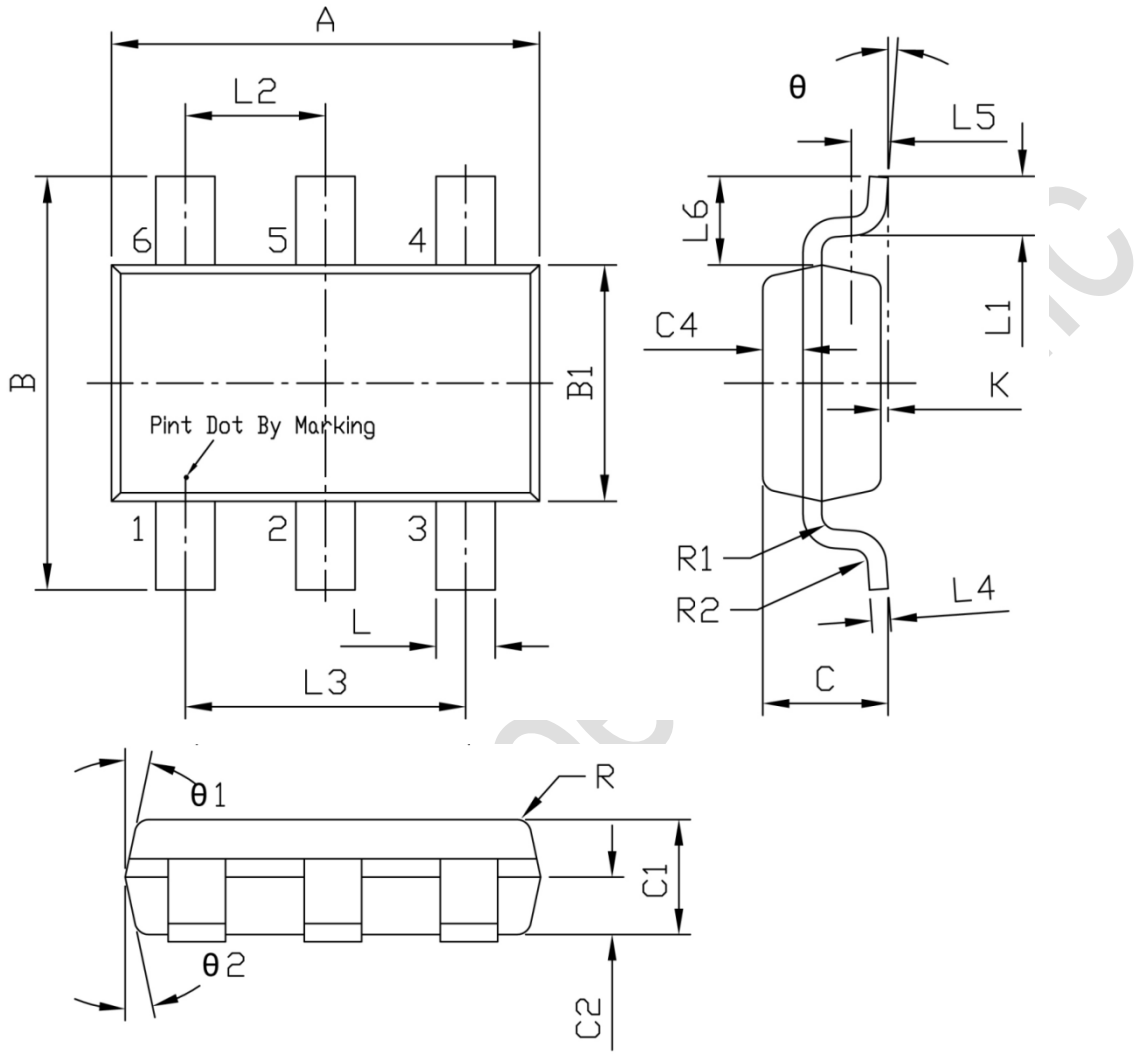
EN Disable

V_{IN} =12V, V_{OUT} =3.3V, I_o = 5A



Package Information

SOT23-6

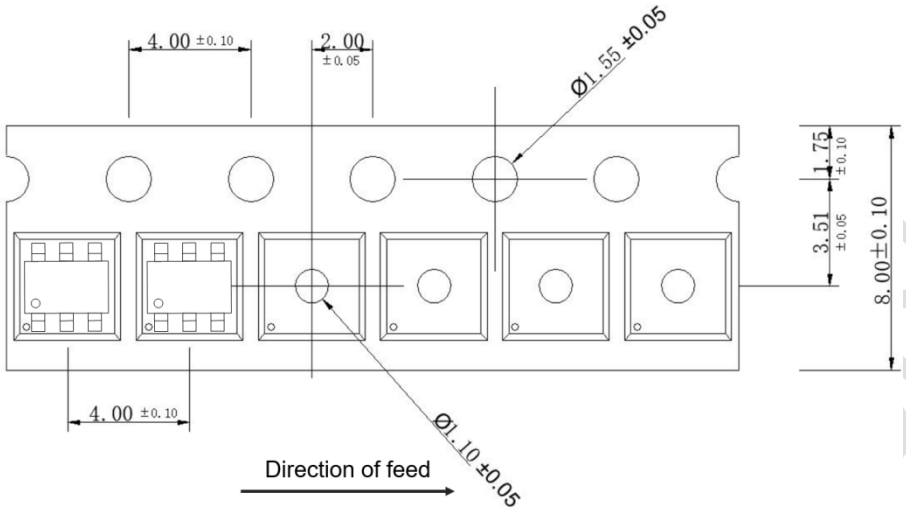


Unit: mm

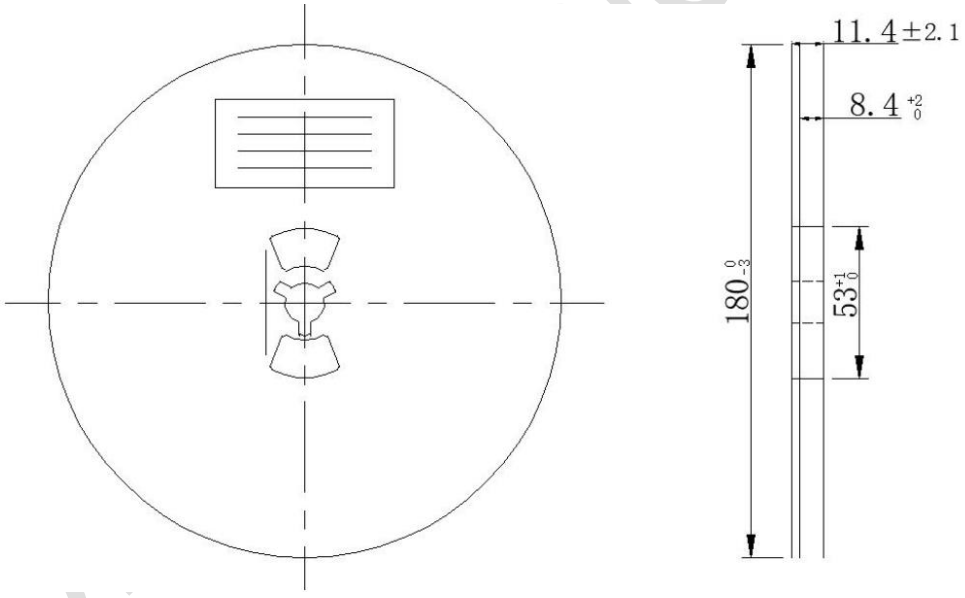
Symbol	Dimensions In Millimeters			Symbol	Dimensions In Millimeters		
	Min	Typ	Max		Min	Typ	Max
A	2.80	2.90	3.00	L3	1.800	1.900	2.000
B	2.60	2.80	3.00	L4	0.077	0.127	0.177
B1	1.50	1.60	1.70	L5	-	0.250	-
C	-	-	1.05	L6	-	0.600	-
C1	0.60	0.80	1.00	θ	0°		0°
C2	0.35	0.40	0.45	Θ1	10°	12°	14°
C4	0.223	0.273	0.323	Θ2	10°	12°	14°
K	0.000	0.075	0.150	R	-	0.100	-
L	0.325	0.400	0.475	R1	-	0.100	-
L1	0.325	0.450	0.550	R2	-	0.100	-
L2	0.850	0.950	1.050				

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.

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