400kHz, 18V, 6A Synchronous COT Step-Down Converter

Features

- 39mΩ/20mΩ Low $R_{DS(ON)}$ internal FETs
- High Efficiency Synchronous-Mode Operation
- Wide Input Range: 4.5V to 18V
- Feedback Voltage Accuracy 0.6V±1.5%
- 400kHz Switch Frequency Typical
- Up to 6A Output Current
- COT control to achieve fast transient responses
- Power Save Mode at Light Load
- 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

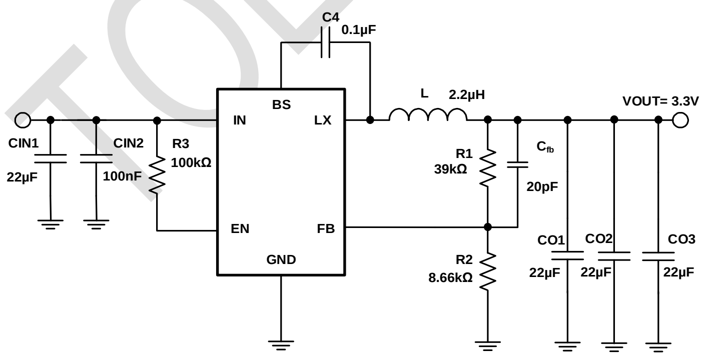
The TMI3256S is a high efficiency, Constant on-Time (COT) control mode synchronous step-down DC-DC converter capable of delivering up to 6A current. TMI3256S integrates main switch and synchronous switch with very low $R_{DS(ON)}$ to minimize the conduction loss. Low output voltage ripple and small external inductor and capacitor size are achieved with typical 400kHz switching frequency. It adopts the COT architecture to achieve fast transient responses for high voltage step down applications.

The TMI3256S requires a minimum number of readily available standard external components and is available in a 6-pin SOT23-6 RoHS compliant package.

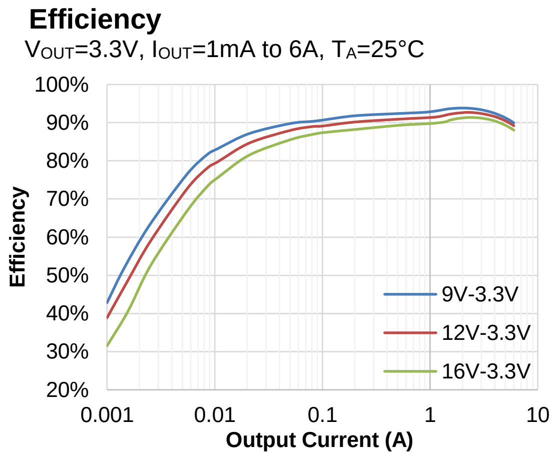
Application

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

Typical Application



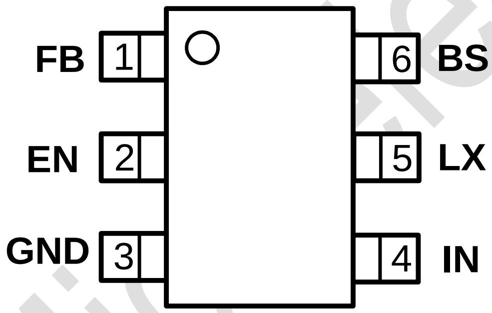
TMI3256S Typical Application Circuits



Absolute Maximum Ratings (Note 1)

Parameter	Min	Max	Unit
Input Supply Voltage IN, 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 and Pin Map



Top View

SOT23-6
Top Marking: T5SXXX
T5S: Device Code
XXX: Inside Code

Order Information

Part Number	Package	Top Marking	Quantity/Reel
TMI3256S	SOT23-6	T5SXXX	3000

TMI3256S devices are Pb-free and RoHS compliant.

Pin Functions

Pin	Name	Function
1	FB	Output Voltage feedback input. Connect FB to the center point of the external resistor divider.
2	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.
3	GND	Ground Pin
4	IN	Power supply Pin
5	LX	Switching Pin
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	40	°C/W
θ_{JC}	Junction-to-case(top) thermal resistance	14.4	°C/W
ψ_{JC}	Junction-to-case(top) characterization parameter	5.2	°C/W

Electrical Characteristics

V_{IN}=12V, V_{OUT}=3.3V, T_A = 25°C, unless otherwise noted.

Parameter	Conditions	Min	Typ	Max	Units
Input Voltage Range		4.5		18	V
OVP Threshold		18.2	19	20	V
OVP Hysteresis			0.45		V
UVLO Rising Threshold		4.0	4.2	4.4	V
UVLO Hysteresis		0.45	0.6	0.75	V
Quiescent Current	V_{EN}=2V, V_{FB}=V_{REF} x 105%		340	600	μA
Shutdown Current	V_{IN}=12V, EN=0V		5	15	μA
Regulated Feedback Voltage		0.591	0.6	0.609	V
FB Input Leakage Current		-0.5		0.5	μA
High-Side Switch On-Resistance			39		mΩ
Low-Side Switch On-Resistance			20		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			7		A
On Time	V_{IN}=12V, V_{OUT}=3.3V, I_{OUT}=1A		450		ns
Oscillation Frequency		300	400	500	kHz
Maximum Duty Cycle			84		%
Minimum On-Time(Note 4)		70	85	100	ns
Soft Start Time	10%xV_{OUT} to 90%xV_{OUT}	0.4	0.6	0.9	ms
Hiccup on Time(Note 4)			1		ms
Hiccup Time Before Restart(Note 4)			12		ms
EN Enable Delay Time (Note 4)			300		μs
EN Rising Threshold		0.90	1.05	1.20	V
EN Hysteresis			120		mV
EN Input Leakage Current	V_{EN}=2V	-1		1	μA
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: Device mounted on TMI3256S 4-Layer Evaluation Board(60mm*60mm). PCB Characteristics: FR-4 substrate; top/bottom 1oz copper, 2nd/3rd 0.5oz copper; 1.6mm total thickness.

Note 4: Guaranteed by design.

Block Diagram

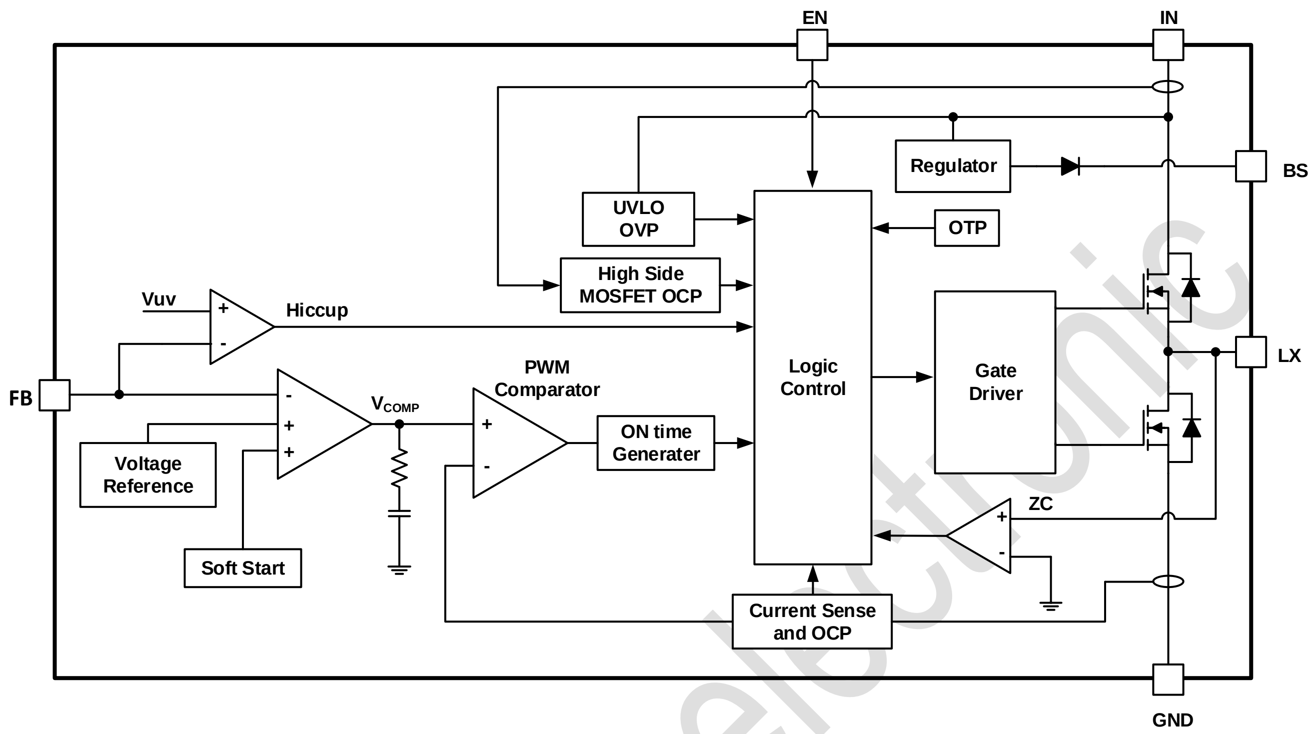


Figure 1. TMI3256S Block Diagram

Operation Description

Internal Regulator

The TMI3256S 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 typical 400kHz operating frequency to ensure a compact, high efficiency design with excellent AC and DC performance.

Error Amplifier

TMI3256S 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 0.6ms typically.

Over-Current-Protection and Short Circuits Protection

The TMI3256S 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 60% of V_{REF}, TMI3256S 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 TMI3256S hiccup mode is typically 13ms.

In the application with high output voltage, when the input voltage is close to input UVLO threshold voltage, TMI3256S operates in maximum duty condition and the FB voltage may be lower than V_{UV} and the hiccup mode may be triggered during power on and off process. Using external divider resistor from VIN to EN and GND to set external UVLO could avoid this application issue.

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 R1 to be around 39kΩ for optimal transient response. R2 is then given by:

Table 1: Selection for Common Output Voltages (V_{FB}=0.6V)

V_{OUT} (V)	R1 (kΩ)	R2 (kΩ)	C_{FB}(pF)	L (μH)
5	39	5.36	20	2.2 - 3.3
3.3	39	8.66	20	1.0 - 3.3
2.5	39	12.4	20	1.0 - 2.2
1.8	39	19.6	20	0.68 - 2.2
1.5	39	26.1	20	0.68 - 2.2
1.2	39	39	20	0.47 - 2.2
1	39	59	20	0.47 - 2.2

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

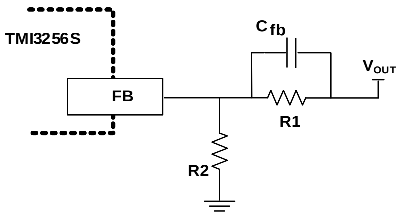


Figure 2. Feedback Network

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 $1/2\pi \cdot R1 \cdot C_{fb}$ to increase bandwidth of the system. 20pF 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

An 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 6A. The maximum inductor peak current is:

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

Under light load conditions below 100mA, larger inductance is recommended for improved efficiency.

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 TMI3256S can be optimized for a wide range of capacitance and ESR values. Three or more 22μF ceramic output capacitors for most application are sufficient.

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.

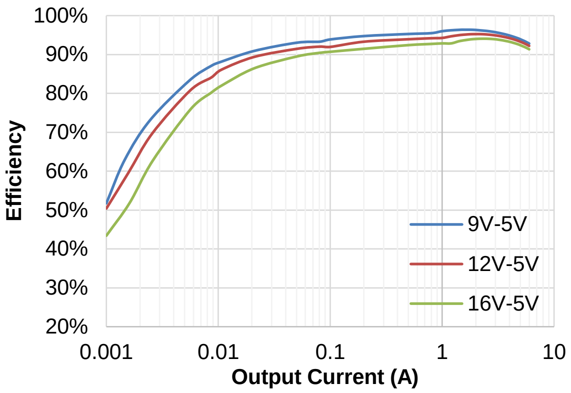
4) VOUT, LX away from sensitive analog areas such as FB.

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

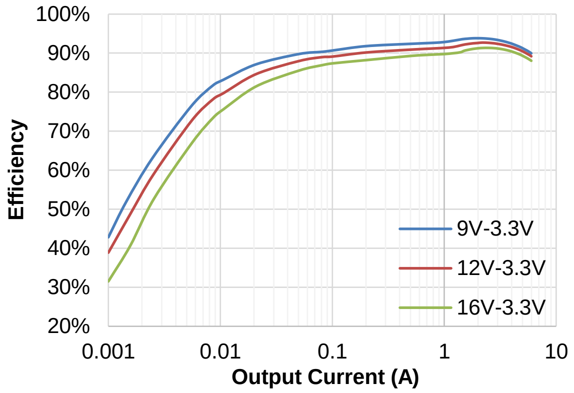
Efficiency

V_{OUT} =5V, L=3.3μH



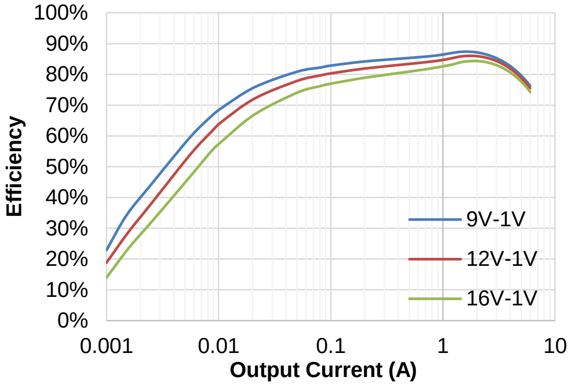
Efficiency

V_{OUT} =3.3V, L=2.2μH



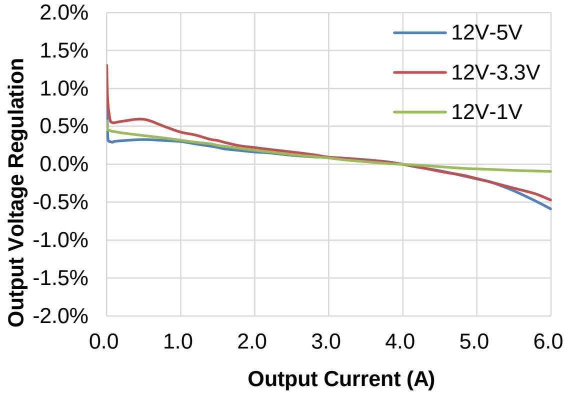
Efficiency

V_{OUT}=1V, L=1.0μH



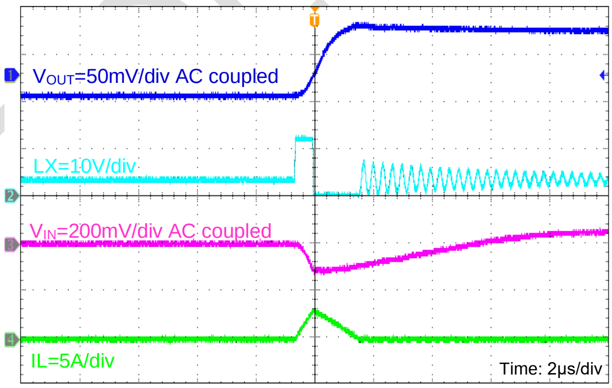
Load Regulation

V_{IN}=12V, T_A=25°C



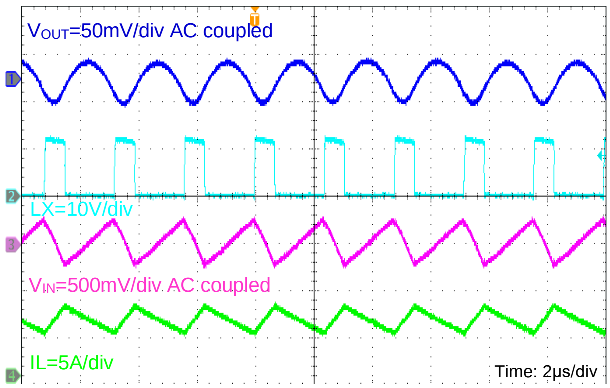
Steady State Operation

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



Steady State Operation

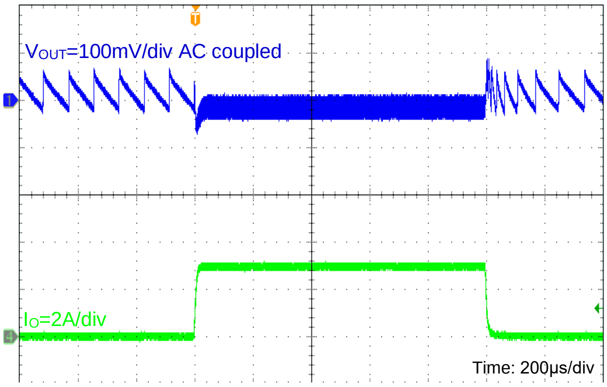
V_{IN} =12V, V_{OUT} =3.3V, I_o = 6A



Typical Performance Characteristics(continued)

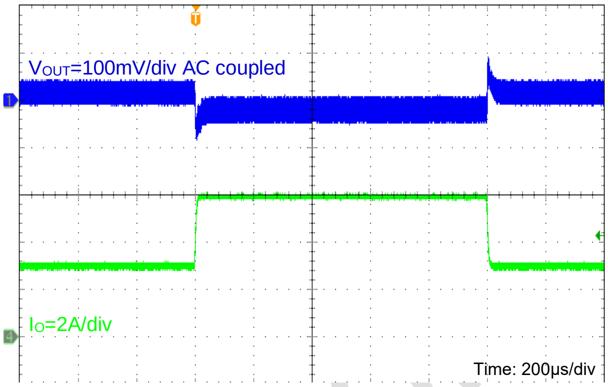
Load Transient

V_{IN} =12V, V_{OUT} =3.3V, I_o = 0A to 3A



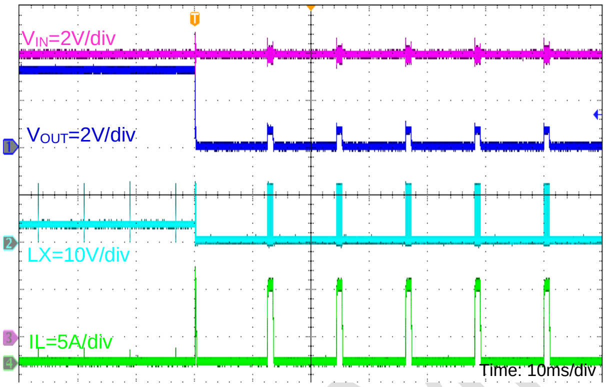
Load Transient

V_{IN} =12V, V_{OUT} =3.3V, I_o = 3A to 6A



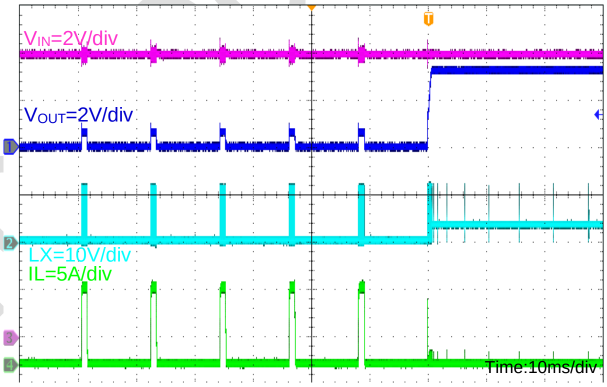
Output Short Entry

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



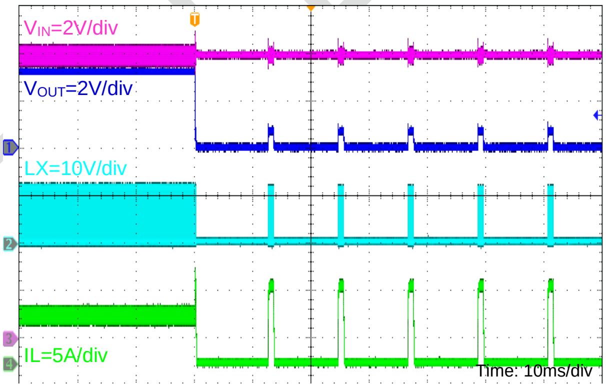
Output Short Recovery

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



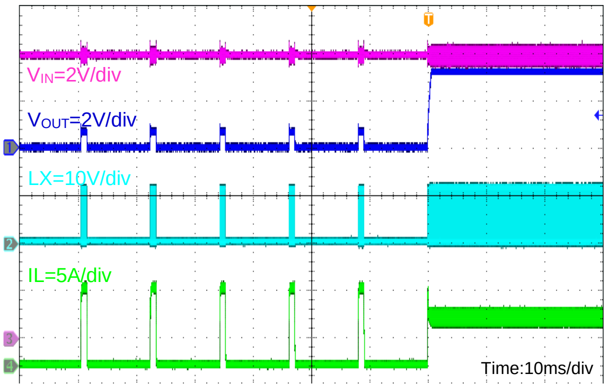
Output Short Entry

V_{IN} =12V, V_{OUT} =3.3V, I_o = 6A



Output Short Recovery

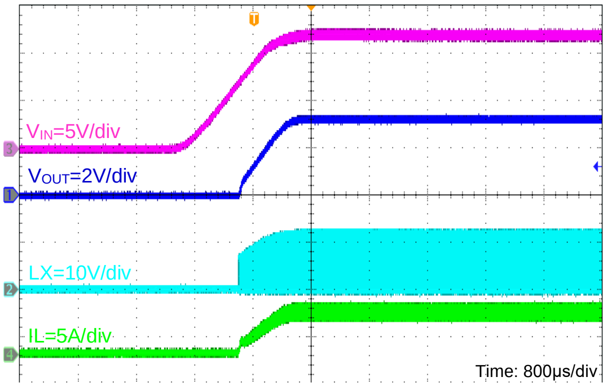
V_{IN}=12V, V_{OUT} =3.3V, I_o = 6A



Typical Performance Characteristics(continued)

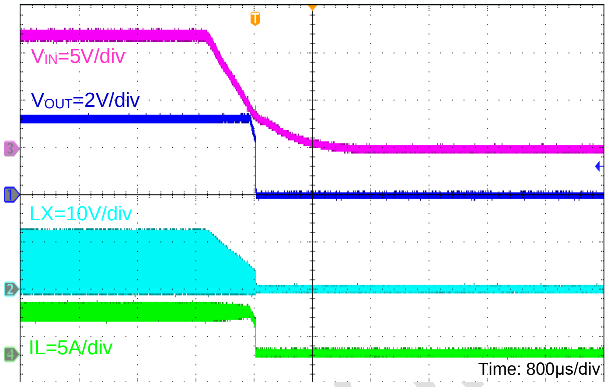
Input Power On

V_{IN} =12V, V_{OUT} =3.3V, I_o = 6A



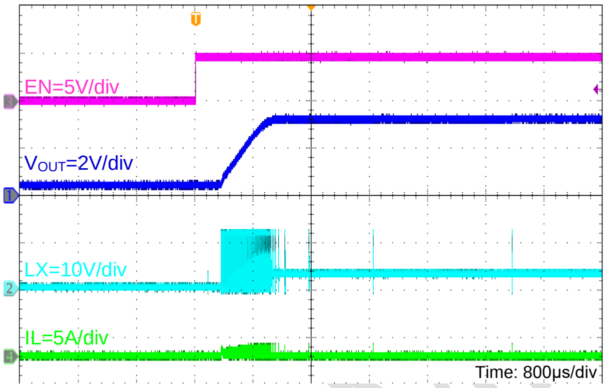
Input Power Down

V_{IN} =12V, V_{OUT} =3.3V, I_o = 6A



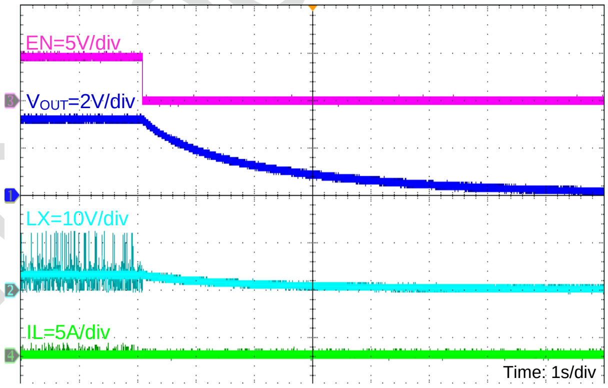
EN Enable

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



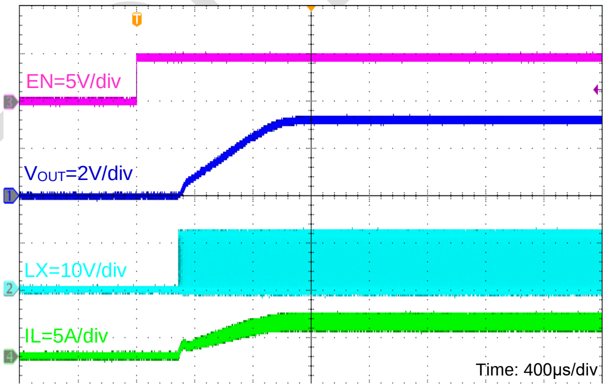
EN Disable

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



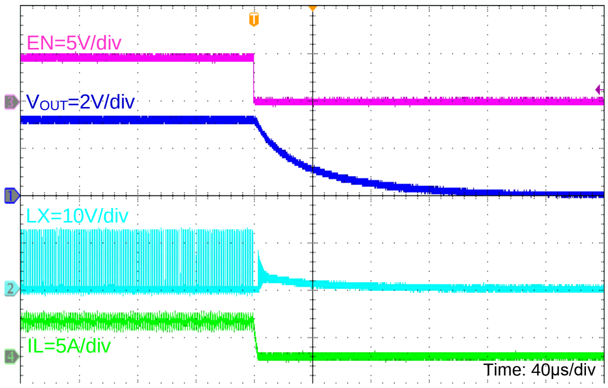
EN Enable

V_{IN} =12V, V_{OUT} =3.3V, I_o = 6A



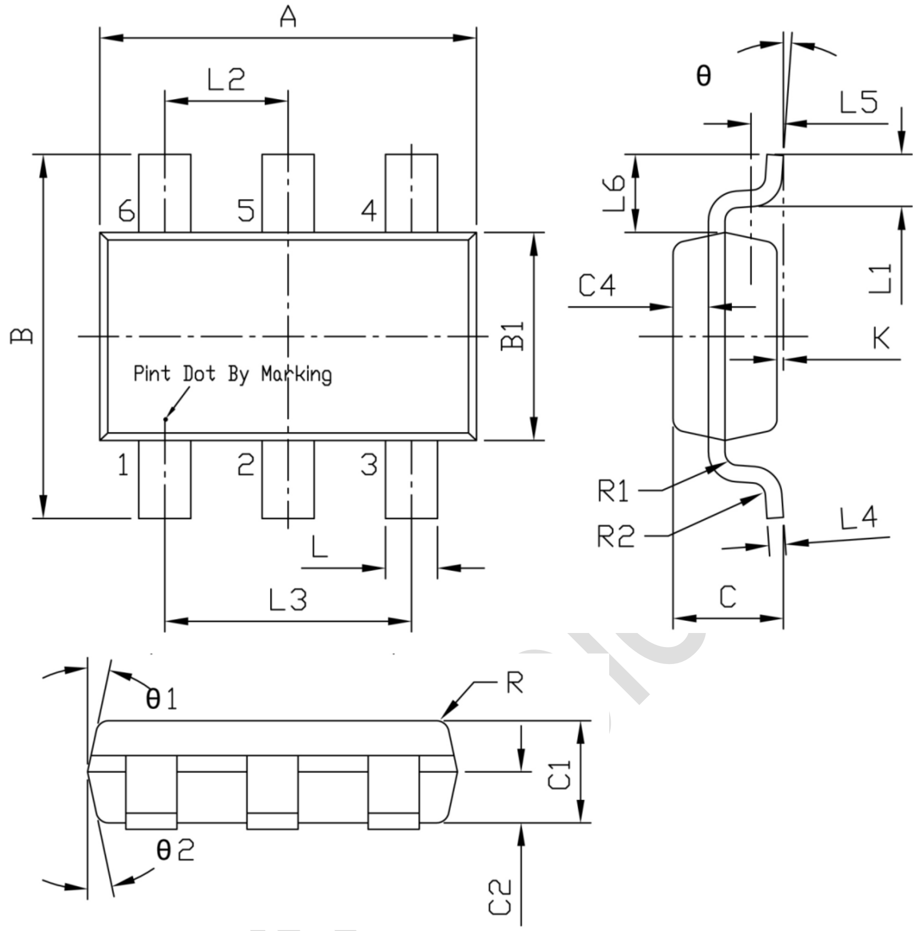
EN Disable

V_{IN} =12V, V_{OUT} =3.3V, I_o = 6A



Package Information

SOT23-6

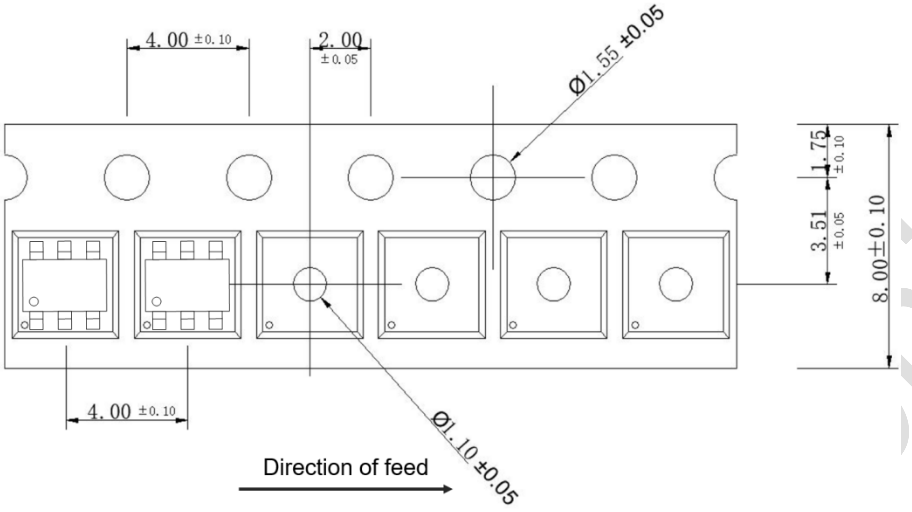


Unit: mm

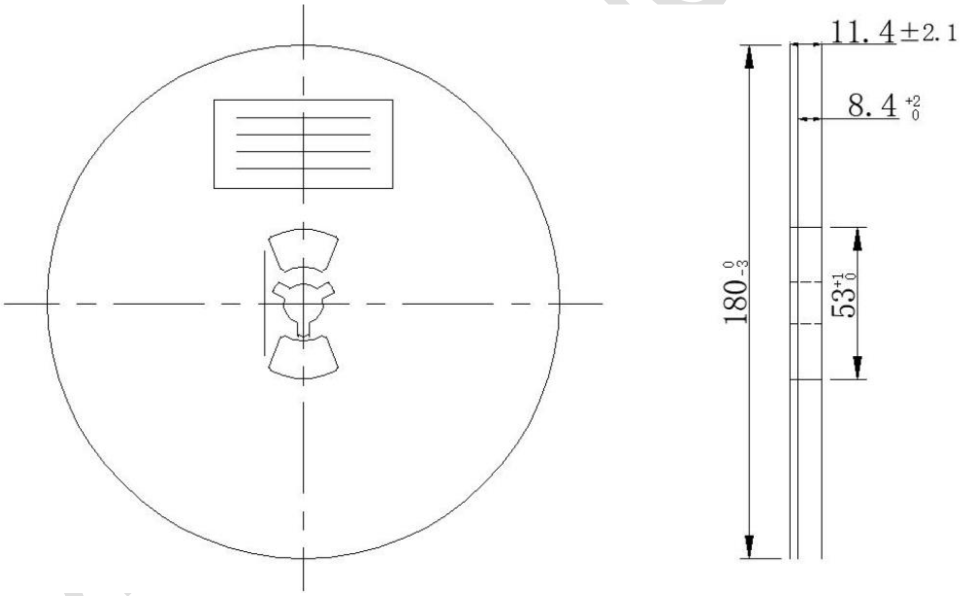
Symbol	Dimensions In Millimeters			Symbol	Dimensions In Millimeters		
	Min	Typ	Max		Min	Typ	Max
A	2.80	2.90	3.00	L3	1.800	1.900	2.000
B	2.60	2.80	3.00	L4	0.077	0.127	0.177
B1	1.50	1.60	1.70	L5	-	0.250	-
C	-	-	1.05	L6	-	0.600	-
C1	0.60	0.80	1.00	θ	0°		0°
C2	0.35	0.40	0.45	θ1	10°	12°	14°
C4	0.223	0.273	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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