18V, 50mΩ $R_{ds(on)}$ Power Switch with Programmable Soft-start

FEATURES

- 2.7V to 18V Input Voltage Range
- Low $R_{ds(on)}$: 50mΩ at V_{IN}=12V typical
- Low Operation Current: 48μA typical at V_{IN}=12V
- Low Shutdown Current:
  - 2.5μA typical at V_{IN}=12V
  - 0.8μA typical at V_{IN}=5V
- Externally Programmable Soft-start Time
- Output Auto Discharge Function
- Over Current Protection
- Output Short Protection
- Thermal Shutdown Protection
- Input Over Voltage Protection (OVP)
- TMI6240: SOT23-5 Package

GENERAL DESCRIPTION

The TMI6240 is single channel line power switch with low on-resistance. Input voltage range could support from 2.7V to 18V. The switch is controlled by an active high enable pin. A programmable soft-start function could be used to set the proper rising time to reduce inrush current caused by large load capacitance. Current protection and thermal shutdown function protect the device against over current and high junction temperature.

TMI6240 is available in a space-saving SOT23-5 package.

APPLICATIONS

- Flat Panel Television and Monitor
- Digital Set Top Boxes
- Industrial Systems
- Distributed Power Systems
- Surveillance Systems

TYPICAL APPILCATION

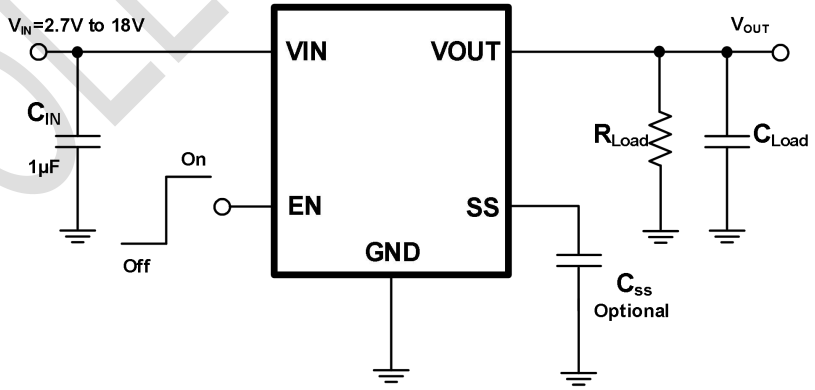
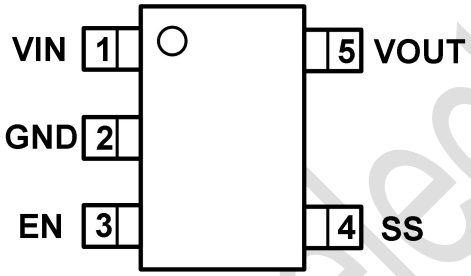


Figure 1. Typical Application Circuits

ABSOLUTE MAXIMUM RATINGS (Note 1)

Parameter	Min	Max	Unit
Input Supply Voltages	-0.3	20	V
V_{OUT}, EN Voltages	-0.3	20	V
SS pin Voltage	-0.3	6.0	V
Storage Temperature Range	-65	150	°C
Junction Temperature (Note 2)	-40	150	°C
Power Dissipation		1000	mW
Lead Temperature Soldering, 10sec		260	°C

PIN CONFIGURATION



SOT23-5

TMI6240

Top Mark: TOAXXX (TOA: Device Code, XXX: Inside Code) for TMI6240

Part Number	Package	Top Mark	Quantity/Reel
TMI6240	SOT23-5	TOAXXX	3000

TMI6240 devices are Pb-free and RoHS compliant.

PIN FUNCTIONS

Pin	Name	Function
1	VIN	Power supply pin.
2	GND	Ground pin.
3	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 float this pin.
4	SS	Soft-Start program pin. Connect a capacitor to Ground to set Soft-start time. Floating this pin is default soft-start time.
5	VOUT	Switch output 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	V_{IN}	2.7	18	V
T_J	Operating Junction Temperature Range	-40	125	°C
I_{OUT}	Output Current	0	3.5	A

THERMAL RESISITANCE (Note 3)

Items	Description	Value	Unit
θ_{JA}	Junction-to-ambient thermal resistance of SOT23-5	140	°C/W
θ_{JC}	Junction-to-case(top) thermal resistance of SOT23-5	42	°C/W

ELECTRICAL CHARACTERISTICS

(V_{IN}=12V, V_{EN}=5V, T_A = 25°C, unless otherwise noted.)

Parameter	Test Conditions	Min	Typ	Max	Unit
Input Voltage Range		2.7		18	V
UVLO Threshold		2.25	2.40	2.65	V
UVLO Hysteresis			0.15		V
OVP Threshold			19.1		V
OVP Hysteresis			0.8		V
Operation Current	V_{IN}=12V, V_{EN}=5V, I_{OUT}=0A		48	110	μA
Shutdown Current	V_{IN}=12V, V_{EN}=0V		2.5	6	μA
	V_{IN}=5V, V_{EN}=0V		0.8	1.5	μA
Soft-start Time	V_{IN}=12V, SS pin is floating		0.15		ms
	V_{IN}=12V, C_{SS}=4.7nF		1.1		ms
	V_{IN}=12V, C_{SS}=10nF		2.4		ms
Switch On-Resistance	V_{IN}=12V, I_{OUT}=1A, T_A=25°C		50	80	mΩ
Switch On-Resistance (Note 4)	V_{IN}=5V, I_{OUT}=1A, T_A=25°C		55	90	mΩ
Over Current Limit		4			A
Over Current Protect Deglitch Time(Note 4)	Time from I_{OUT}>I_{OCP} to MOSFET turns off	2.5	3.5	4.5	ms
Over Current Recovery Time(Note 4)	Time from OCP to V_{OUT} start rising	150	180	210	ms
Output Short Current Limit(Note 4)	MOSFET is turning on	8			A
Output Short Protect Deglitch Time(Note 4)	Time from I_{OUT}>I_{SC} to MOSFET turns off	2	3	4	μs
Output Auto Discharge Current	V_{IN}=12V, V_{EN} =0V		30		mA
EN Rising Threshold		0.8	1.0	1.2	V
EN Falling Threshold		0.7	0.9	1.1	V
EN Hysteresis Voltage			0.1		V
Hiccup Cycle Time after Over Current (Note 4)			180		ms
Thermal Shutdown Threshold (Note 4)			145		°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: $T_J = T_A + (P_D) \times \theta_{JA}$.

Note 3: Measured on JESD51-7, 2-layer PCB.

Note 4: Guaranteed by design.

FUNCTION DESCRIPTION

Input Under-Voltage-Lock-Out

The TMI6240 is single channel line power switch with low on-resistance N-channel MOSFET that reduces drop out voltage through the device. Input voltage range could support from 2.7V to 18V. When V_{IN} voltage is higher than Under voltage lockout rising threshold, the device could be turned on by EN pin. When V_{IN} voltage is lower than Under voltage lockout rising threshold minus UVLO hysteresis, the device is turned off.

Input Over Voltage Protection

TMI6240 has input over voltage protection function to prevent output from high voltage damage. When V_{IN} voltage is higher than fixed OVP threshold 19.1V typically, the MOSFET turns off immediately. When V_{IN} voltage drops down to the OVP threshold minus hysteresis, TMI6240 restart to turn on again.

Enable ON/OFF and Auto-discharge Function

TMI6240 is controlled by an active high enable pin. When V_{IN} voltage is exceeds UVLO threshold and the EN pin is higher than EN rising threshold, the internal MOSFET starts turning on and the current starts flowing from V_{IN} to V_{OUT}. When EN is lower than EN falling threshold, the MOSFET is turned off and output discharge circuits discharges V_{OUT} with 30mA typical discharging current.

Programmable Soft-start Time

A programmable soft-start function could be used to set the proper rising time to reduce inrush current caused by large load capacitance. The external capacitors attached on SS pin to ground program soft-start time. When SS pin is floating, after device is enabled, V_{OUT} rises up with default minimum soft-start time.

Over Current Protection

The device has over current protection and output short protection function to protect over current condition or output short condition. When the current flowing through the device is larger than over current limitation I_{OCP} and the OCP duration time is larger than t_{OCP} 3.5ms typical, the MOSFET is turned off immediately. After typical 180ms OCP recovery time, the MOSFET restart turning on automatically. if the over current is continuous, the MOSFET is turned off again.

The OCP deglitch time avoid the MOSFET is turned off unexpectedly in load current transient condition, however, it cannot turn off MOSFET during output short condition with large short current. TMI6240 adds the second output short protection to prevent short current. If the short current is larger than I_{SC} typical 8A, the MOSFET is turned off within 3μs to shut off short current. After short current protection, the MOSFET is turned on and output restart automatically after 180ms power on delay time.

Thermal Shutdown Protection

The device also has thermal shutdown function. It can protect the device against thermal damage due to high junction temperature. When the device junction temperature is higher than thermal shutdown threshold, the MOSFET is turned off immediately, and when junction temperature drops thermal shutdown hysteresis value, the MOSFET turns on again.

FUNCTIONAL BLOCK DIAGRAM

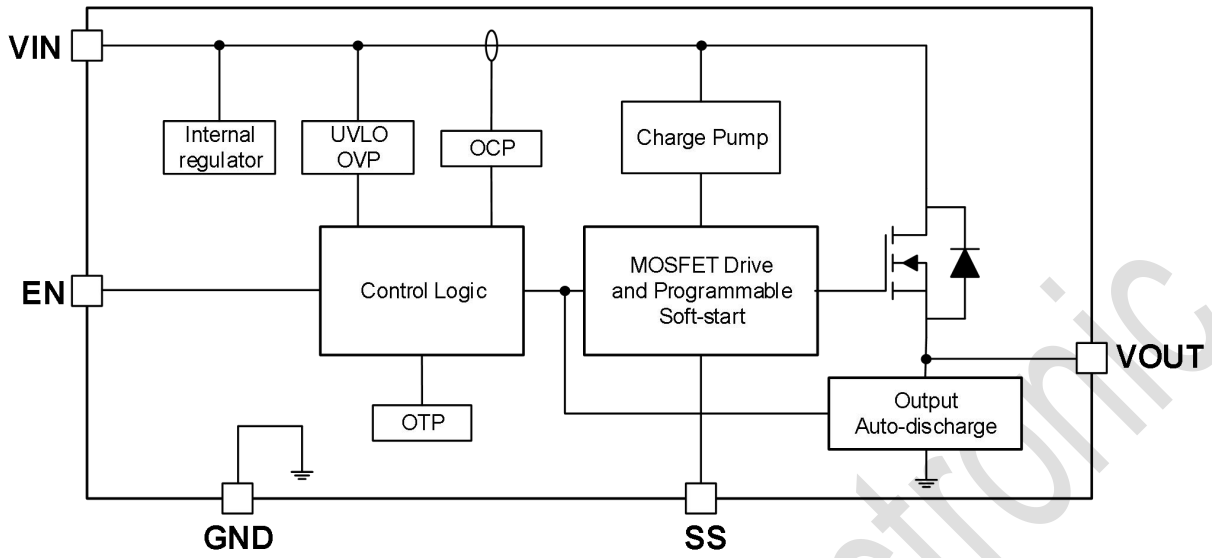


Figure 2. TMI6240 Block Diagram

APPLICATION INFORMATION

Input and Output Capacitors

The input capacitor of TMI6240 needed to reduce input voltage drop caused by input inrush current during switch turning on or load current transient and to reduce input voltage spike during MOSFET turn-off transient with OCP. In normal design a 1μF effective value ceramic capacitor as input capacitor placed close to V_{IN} pin is usually sufficient. Higher value of input capacitance can be used to limit voltage drop and spike in high current application.

In transient protection, for example output short to ground or over current protection, the current flow from input to output side is interrupts very quickly, the input side inductance could generate a positive voltage spike on the input. The peak amplitude of the transient voltage spike is dependent on the value of inductance in series to the input side and the value of input capacitor. As shown in Figure 1, before MOSFET in TMI6240 turns off, the current flow from TMI6240 is I_{MAX}, the energy in input inductance L_{IN} is: $\frac{1}{2}\times I_{MAX}{}^2\times L_{IN}$.

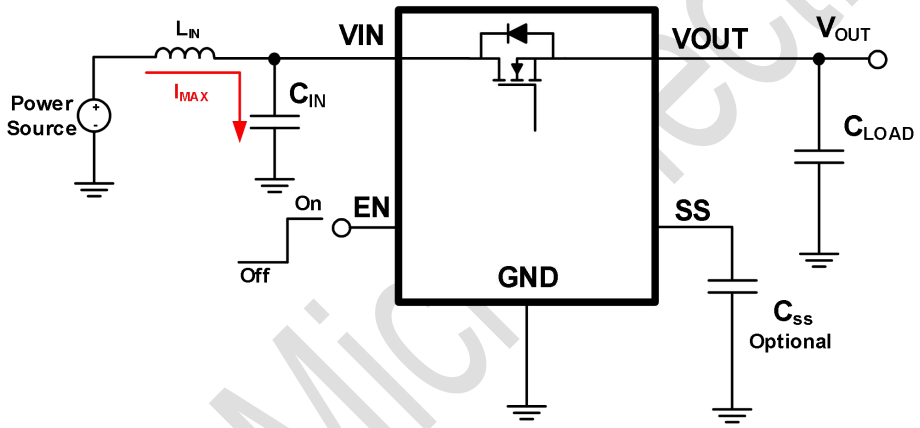


Figure 3. Influence of input inductance and input capacitance

When protection is responded and MOSFET is turned off, the energy in input inductance will transmit to input capacitance, so we have:

$$\frac{1}{2}\times I_{MAX}{}^2\times L_{IN}=\frac{1}{2}\times \Delta V_{IN\_spike}{}^2\times C_{IN}$$

$$\Delta V_{IN\_spike}=I_{MAX}\times\sqrt{\frac{L_{IN}}{C_{IN}}}$$

In the case of output hot short to ground, the current flow from TMI6240 is rising rapidly and the value is very large. The large value C_{IN} is needed to absorb input voltage spike caused by input parasitic inductance. In some application, the additional transient voltage suppressor is required on input side to prevent the device from exceeding the absolute maximum ratings.

In output side, the capacitor is the load capacitance. If the load capacitor in output side is larger than input side capacitance, the V_{OUT} voltage may exceed V_{IN} voltage when input power supply is removed and it cause that current flows through body diode of MOSFET in TMI6240 from V_{OUT} to V_{IN}. If there is requirement of reverse current limitation to input side in the system application, higher input capacitance than output capacitance is recommended in practical application.

Programming Soft-start Capacitor

The capacitor C_{SS} on SS pin to GND sets the output rising slew rate and soft-start time also. With floating SS pin, the minimum soft-start time is provided. The larger C_{SS} capacitance, the longer soft-start time. In practical application, when there are large output load capacitors, the device may enter thermal shutdown with large soft-start time since the power consumption on MOSFET is too high during power up process. Meanwhile, with small soft-start time, the over current protection may happen during soft-start process since large inrush current with large output capacitance. The table 1 provide typical measured soft-start time with different input voltage and C_{SS} value for the reference.

Table 1. Soft-start Time Table

C_{SS}	Soft-start time (μs) 10% to 90%, C_{Load}=0.1μF, C_{IN}=1μF, I_O=0.5A				
	V_{IN}=3.3V	V_{IN}=5V	V_{IN}=9V	V_{IN}=12V	V_{IN}=18V
NC	100	120	140	150	190
1nF	110	125	190	235	360
2.2nF	146	202	348	442	666
4.7nF	376	536	886	1132	1652
6.8nF	565	792	1290	1628	2392
10nF	836	1148	1852	2470	3226

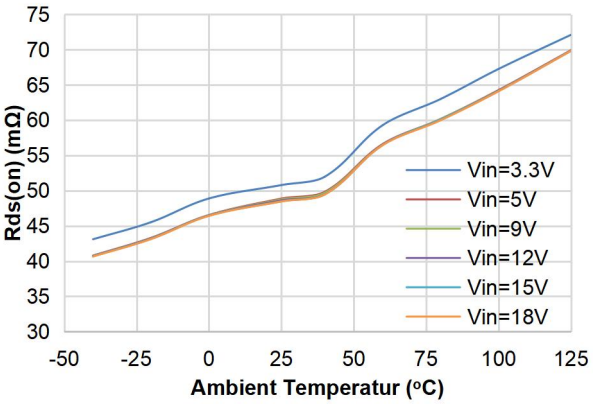
Layout Consideration

When laying out the printed circuit board, the Following checking should be used to ensure proper operation of the TMI6240. Check the following in your layout:

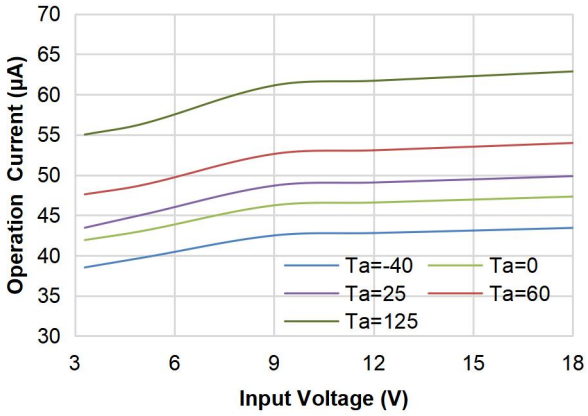
1. The power traces V_{IN} and V_{OUT} must be as short and wide as possible to minimize input inductance and input voltage spike value during over current protection condition.
2. The V_{IN} pin must be bypassed with low ESR ceramic capacitors to ground. The typical recommended bypass capacitance is effective value 1μF or larger ceramic with X5R or X7R. The capacitor must be placed as close to the V_{IN} pin as possible.

TYPICAL PERFORMANCE CHARACTERISTICS

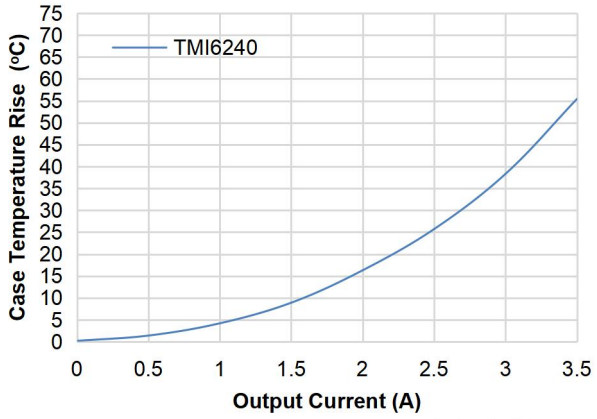
$R_{DS(ON)}$ vs. Temperature



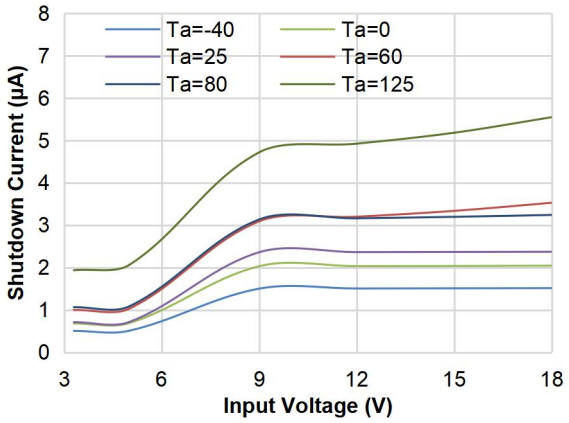
Operation Current vs. Input Voltage



Temperature Rise vs. Output Current

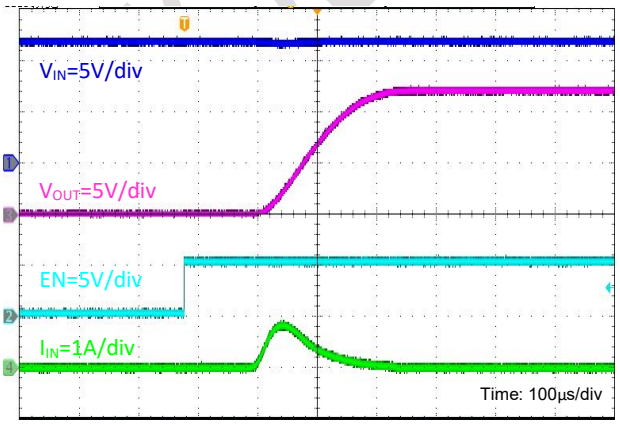


Shutdown Current vs. Input Voltage



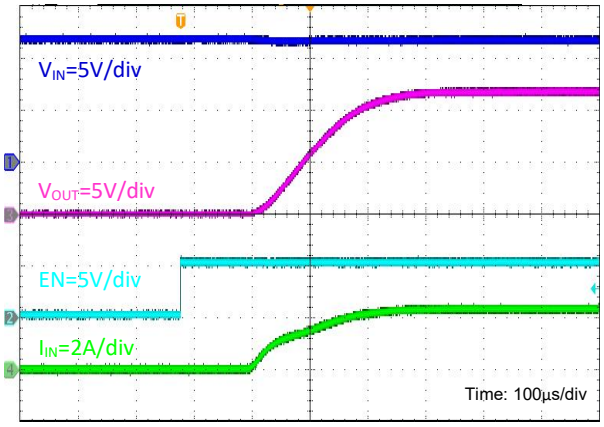
Soft-start

V_{IN} =12V, C_{SS} = NC, C_{Load}=10μF, No Load



Soft-start

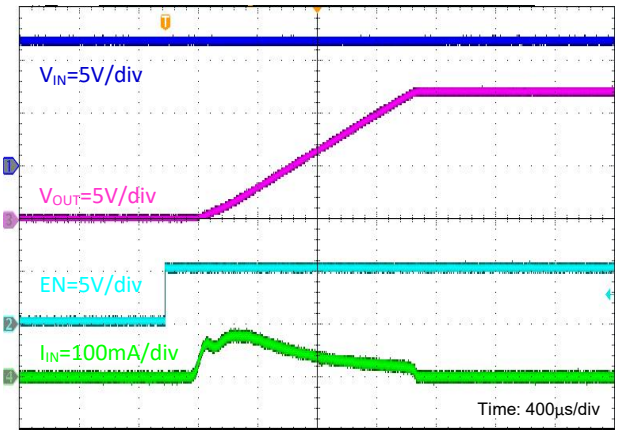
V_{IN} =12V, C_{SS} = NC, C_{Load}=10μF, R_{Load}=5Ω



TYPICAL PERFORMANCE CHARACTERISTICS (Continued)

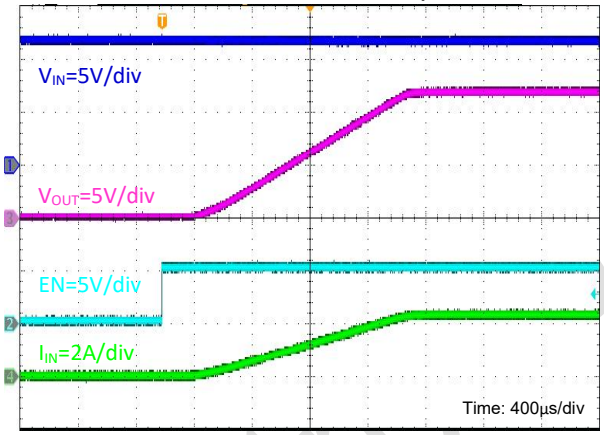
Soft-start

V_{IN} =12V, C_{SS} = 4.7nF, C_{Load}=10μF, No Load



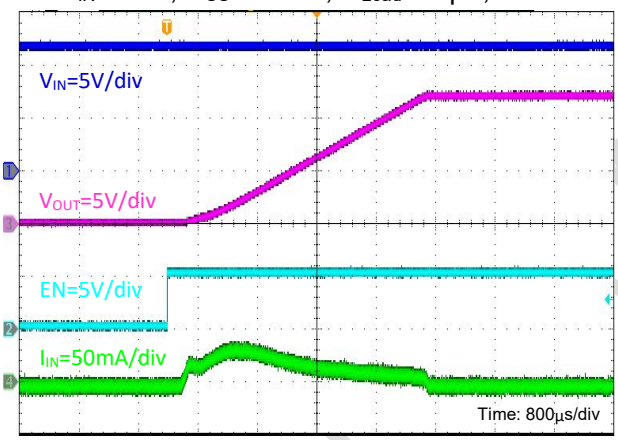
Soft-start

V_{IN} =12V, C_{SS} = 4.7nF, C_{Load}=10μF, R_{Load}=5Ω



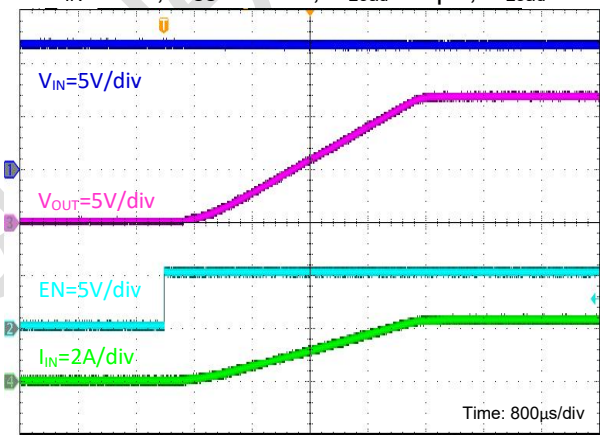
Soft-start

V_{IN} =12V, C_{SS} = 10nF, C_{Load}=10μF, No Load



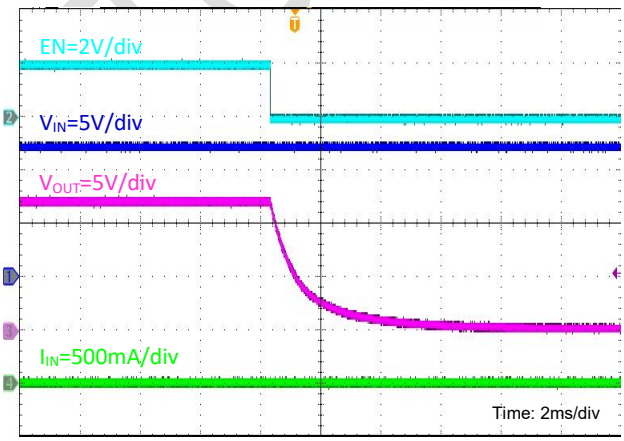
Soft-start

V_{IN} =12V, C_{SS} = 10nF, C_{Load}=10μF, R_{Load}=5Ω



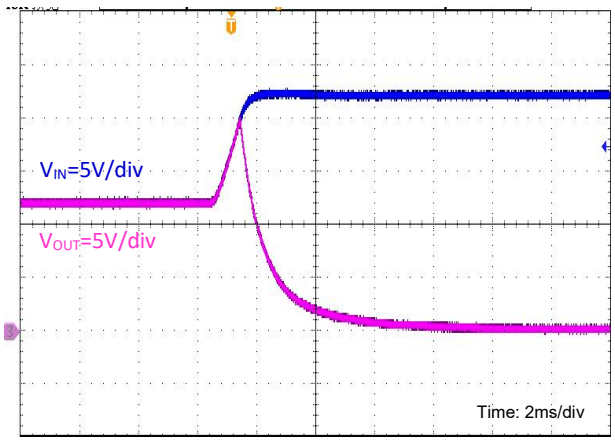
EN disable

V_{IN} =12V, C_{SS} = 10nF, C_{Load}=10μF, No Load



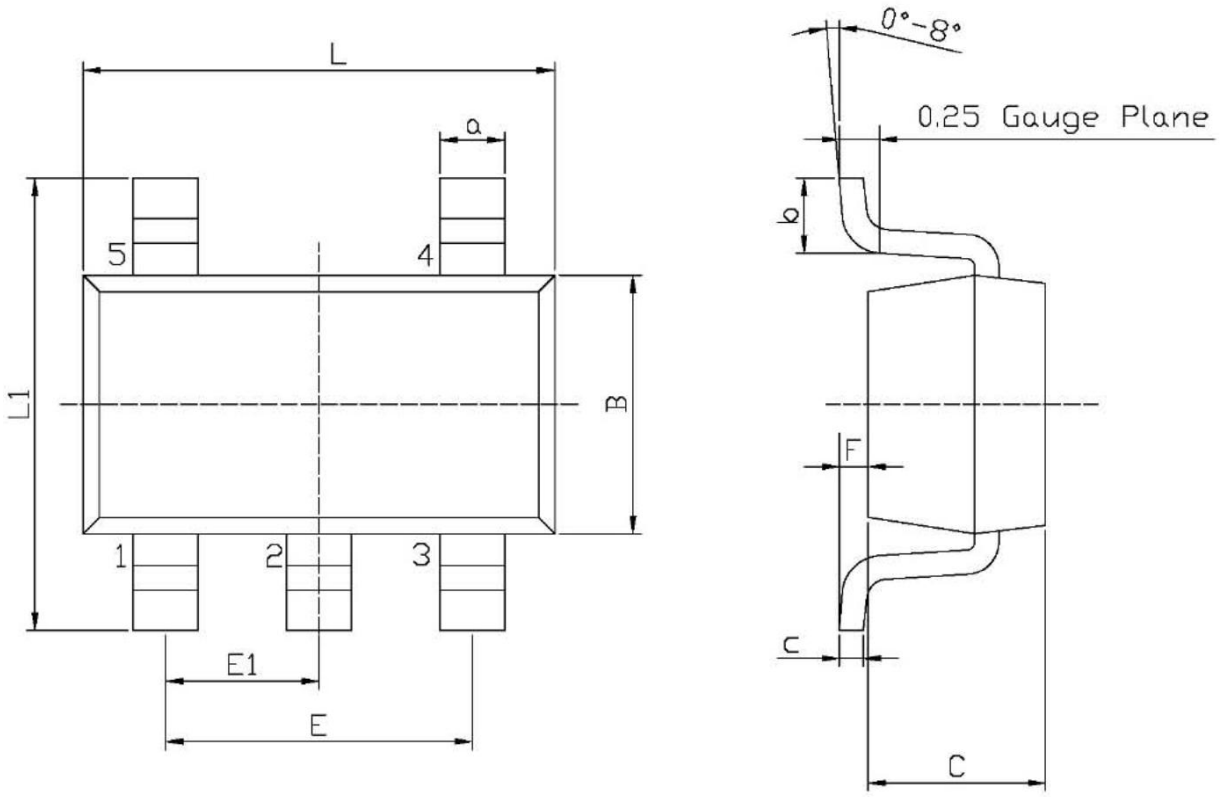
Input OVP

V_{IN} =12V to 22V, C_{SS} = 10nF, C_{Load}=10μF, No Load



PACKAGE INFORMATION

SOT23-5



Unit: mm

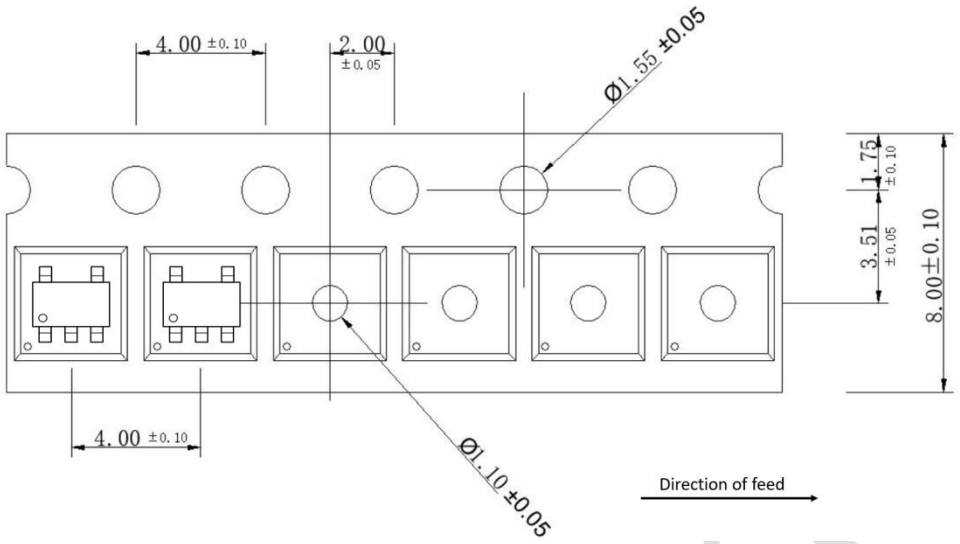
Symbol	Dimensions In Millimeters			Symbol	Dimensions In Millimeters		
	Min	Typ	Max		Min	Typ	Max
L	2.82	2.92	3.02	E1	0.85	0.95	1.05
B	1.50	1.60	1.70	a	0.35	0.425	0.50
C	0.90	1.10	1.30	c	0.10	0.15	0.20
L1	2.60	2.80	3.00	b	0.35	0.45	0.55
E	1.80	1.90	2.00	F	0	0.075	0.15

Note:

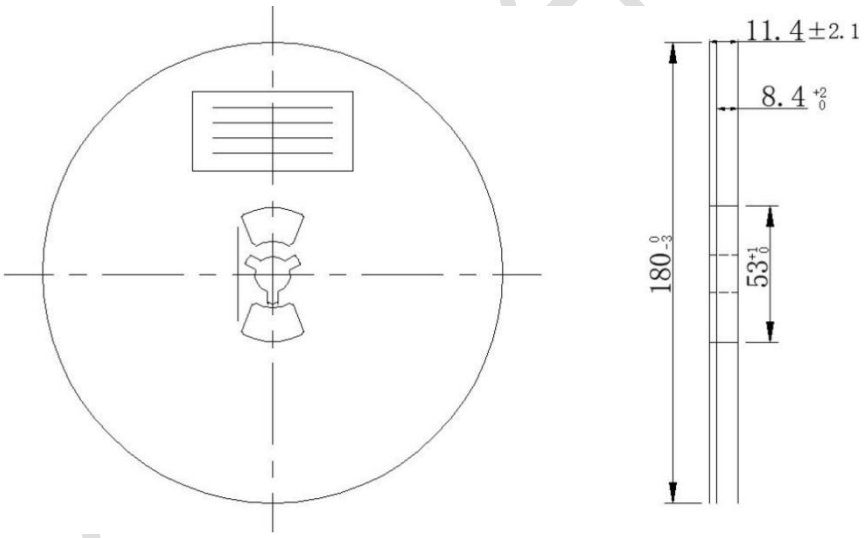
1) All dimensions are in millimeters.
2) Package length does not include mold flash, protrusion or gate burr.
3) Package width does not include inter lead flash or protrusion.
4) Lead popularity (bottom of leads after forming) shall be 0.10 millimeters max.
5) Pin 1 is lower left pin when reading top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

TAPE AND REEL INFORMATION

TAPE DIMENSIONS:



REEL DIMENSIONS:



Note:

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

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