Synchronous Boost Converter with Ultra-Low Quiescent Current

GENERAL DESCRIPTION

The SUM2097 device is a synchronous boost converter with ultra-low quiescent current. The device is designed for products powered by an alkaline battery, lithium battery or rechargeable Li-Ion battery, for which high efficiency under light load condition is critical to achieve long battery life operation.

The SUM2097 offers different fixed output voltage versions. Hysteric control topology has been employed to obtain maximal efficiency at minimal quiescent current. SUM2097 can achieve up to 80% efficiency at 100 µA load. It can also support up to 300 mA output current from 3.3 V to 5 V conversion, and achieve up to 93% at 200 mA load.

The SUM2097 supplies both Down Mode and Pass-Through operations for different applications. In Down Mode, the output voltage can still be regulated at target value even when input voltage is higher than output voltage. In Pass-Through Mode, the output voltage follows input voltage.

The SUM2097 exits Down Mode and enters into Pass-Through Mode when V_{IN}>V_{OUT} + 0.35 V. The SUM2097 supports true shutdown function when it is disabled, which disconnects the load from the input supply to reduce the current consumption. It is offered in SOT23-5 package.

FEATURES

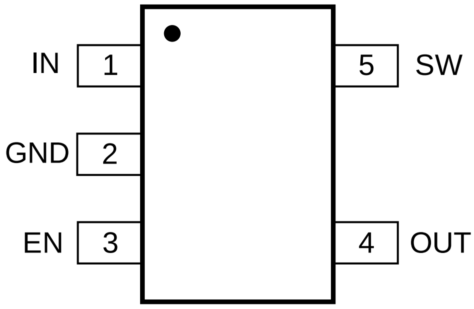
- 3.5 µA I_Q into V_{OUT} Pin For SUM2097
- 250 nA Ultra-Low I_Q into V_{IN} Pin
- Operating Input Voltage from 0.7 V to 5.5 V
- Fixed Output Voltage Versions Available: 2.5V, 3.0V, 3.3V, 3.6V, 4.5V, 5.0V
- Minimum 0.8 A Switch Peak Current Limit
- Regulated Output Voltage in Down Mode
- True Disconnection During Shutdown
- Up to 80% Efficiency at 100 µA Load with 3.8 V Input and 5 V Output
- Up to 93% Efficiency
- Package: SOT23-5

ORDER INFORMATION

Model	Package	Ordering Number	Packing Option
SUM2097	SOT23-5	SUM2097-XXKA5	Tape and Reel, 3000

*XX: When expressed as 30, the output voltage is 3.0 V; when expressed as 33 the output voltage is 3.3 V.

PIN CONFIGURATION (Top View)

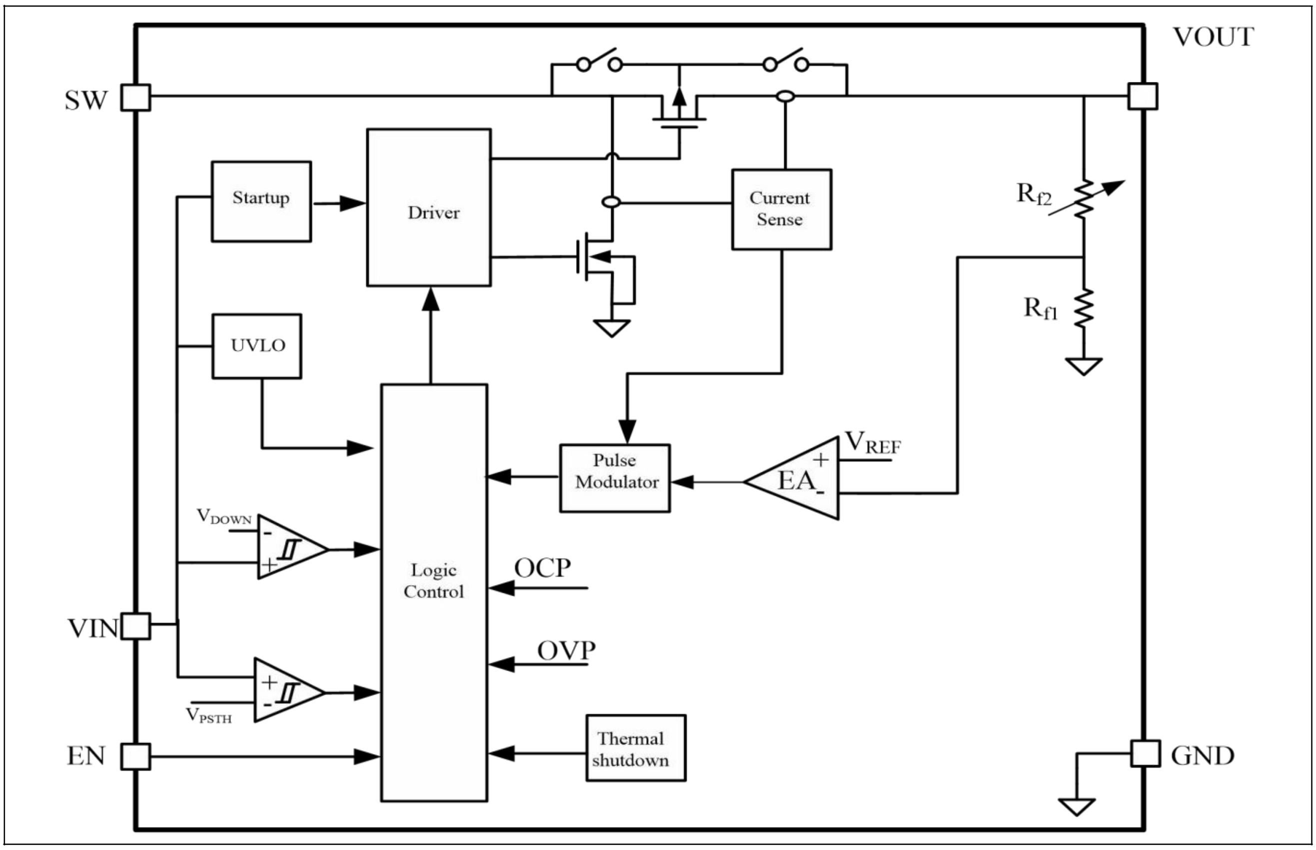


SOT23-5

PIN FUNCTION

PIN		TYPE	DESCRIPTION
NAME	No.		
IN	1	IN	IC power supply input
GND	2	PWR	Ground
EN	3	IN	Enable logic input, Logic high voltage enables the device; logic low voltage disables the device. Don't let it floating
OUT	4	PWR	Boost converter output.
SW	5	PWR	Switch pin of the converter

BLOCK DIAGRAM



FUNCTIONAL DESCRIPTION

Boost Controller Operation

The SUM2097 boost converter is controlled by a hysteretic current mode controller. This controller regulates the output voltage by keeping the inductor ripple current constant in the range of 300 mA and adjusting the offset of this inductor current depending on the output load. Since the input voltage, output voltage and inductor value all affect the rising and falling slopes of inductor ripple current, the switching frequency is not fixed and is determined by the operation condition. If the required average input current is lower than the average inductor current defined by this constant ripple, the inductor current goes discontinuously to keep the efficiency high under light load condition. If the load current is reduced further, the boost converter enters into Burst mode.

In Burst mode, the boost converter ramps up the output voltage with several switching cycles. Once the output voltage exceeds a setting threshold, the device stops switching and goes into a sleep status. In sleep status, the device consumes less quiescent current. It resumes switching when the output voltage is below the setting threshold. It exits the Burst mode when the output current can no longer be supported in this mode.

To achieve high efficiency, the power stage is realized as a synchronous boost topology. The output voltage V_{OUT} is monitored via an external or internal feedback network which is connected to the voltage error amplifier. To regulate the output voltage, the voltage error amplifier compares this feedback voltage to the internal voltage reference and adjusts the required offset of the inductor current accordingly.

Under-Voltage Lockout

An under-voltage lockout (UVLO) circuit stops the operation of the converter when the input voltage drops below the typical UVLO threshold of 0.4 V. A hysteresis of 200 mV is added so that the device cannot be enabled again until the input voltage goes up to 0.6 V. This function is implemented in order to prevent malfunctioning of the device when the input voltage is between 0.4 V and 0.6 V.

Enable and Disable

When the input voltage is above UVLO rising threshold and the EN pin is pulled to high voltage, the SUM2097 is enabled. When the EN pin is pulled to low voltage, the SUM2097 goes into shutdown mode. In shutdown mode, the device stops switching and the rectifying PMOS fully turns off, providing the completed disconnection between input and output. Less than 0.5 µA input current is consumed in shutdown mode.

Soft Start

After the EN pin is tied to high voltage, the SUM2097 begins to startup. At the beginning, the device operates at the boundary of Discontinuous Conduction Mode (DCM) and Continuous Conduction Mode (CCM), and the inductor peak current is limited to around 200 mA during this stage. When the output voltage is charged above approximately 1.6 V, the device starts the hysteric current mode operation. The soft start function reduces the inrush current during startup. After V_{OUT} reaches the target value, soft start stage ends and the peak current is determined by the output of an internal error amplifier which compares the feedback of the output voltage and the internal reference voltage.

The SUM2097 is able to start up with 0.7 V input voltage with larger than 3 kΩ load. However, if the load during startup is so heavy that the SUM2097 fails to charge the output voltage above 1.6 V, the SUM2097 can't start up successfully until the input voltage is increased or the load current is reduced. The startup time depends on input voltage and load current.

Current Limit Operation

SUM2097 features cycle-by-cycle over current protection function. If the inductor peak current reaches the current limit threshold ILIM, the main switch turns off so as to stop further increase of the input current. In this case the output voltage will decrease until the power balance between input and output is achieved. If the output drops below the input voltage, the SUM2097 enters into Down Mode. The peak current is still limited by ILIM cycle-by-cycle in Down Mode. If the output drops below 1.6 V, the SUM2097 enters into startup process again. In Pass-Through operation, current limit function is not enabled.

Output Short-to-Ground Protection

If short to ground condition occurs, the short current is limited at about 85 mA. Once the short condition is removed, the SUM2097 goes back to soft start again and regulates the output voltage.

Over Voltage Protection

SUM2097 has an output over-voltage protection (OVP) to protect the device in case that the external feedback resistor divider is wrongly populated. When the output voltage of the SUM2097 exceeds the OVP threshold of 5.8 V, the device stops switching. Once the output voltage falls to 0.1 V below the OVP threshold, the device starts operating again.

Down Mode Regulation and Pass-Through Operation

The SUM2097 features Down Mode and Pass-Through operation when input voltage is close to or higher than output voltage.

In the Down Mode, output voltage is regulated at target value even when $V_{IN}>V_{OUT}$. The control circuit changes the behavior of the rectifying PMOS by pulling its gate to input voltage instead of to ground. In this way, the voltage drop across the PMOS is increasing as high as to regulate the output voltage.

The power loss also increases in this mode, which needs to be taken into account for thermal consideration. In the Pass-Through operation, the boost converter stops switching. The rectifying PMOS constantly turns on and low side switch constantly turns off. The output voltage is the input voltage minus the voltage drop across the dc resistance (DCR) of the inductor and the on-resistance of the rectifying PMOS. With VIN ramping up, the SUM2097 goes into Down Mode first when $V_{IN} > V_{OUT}$-100 mV. It stays in Down Mode until $V_{IN} > V_{OUT}$ + 0.35 V and then goes automatically into Pass-Through operation. In the Pass-Through operation, output voltage follows input voltage.

The SUM2097 exits Pass-Through Mode and goes back to Down Mode when VIN ramps down to 103% of the target output voltage. It stays in Down Mode until input voltage falls to 150 mV below the output voltage, returning to normal operation.

RECOMMENDED OPERATING CONDITIONS

Parameter	Rating	Unit
Operating Temperature Range	-40 to +85	℃

ABSOLUTE MAXIMUM RATINGS

Over operating free-air temperature range (unless otherwise noted)(1)

Parameter	Rating	Unit
Voltage range at terminals(2)	-0.3 to 6	V
Operating junction temperature	-40 to150	°C
Storage temperature range	-65 to 150	°C
Junction to Ambient Thermal Resistance (θ_{JA}), SOT23-5(3)	250	°C/W

(1) Stresses beyond those listed under Absolute Maximum Ratings may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated under Recommended Operating Conditions is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

(2) All voltage values are with respect to network ground terminal.

(3) This particular frame decreases the total thermal resistance of the package and increases its ability to dissipate power when an appropriate area of copper on the printed circuit board is available for heat-sinking.

CAUTION

This integrated circuit can be damaged by ESD if you don't pay attention to ESD protection. SUMSEMI recommends that all integrated circuits be handled with appropriate precautions. Failure to observe proper handling and installation procedures can cause damage. ESD damage can range from subtle performance degradation to complete device failure. Precision integrated circuits may be more susceptible to damage because very small parametric changes could cause the device not to meet its published specifications.

SUMSEMI reserves the right to make any change in circuit design, specification or other related things if necessary without notice at any time. Please contact SUMSEMI sales office to get the latest datasheet.

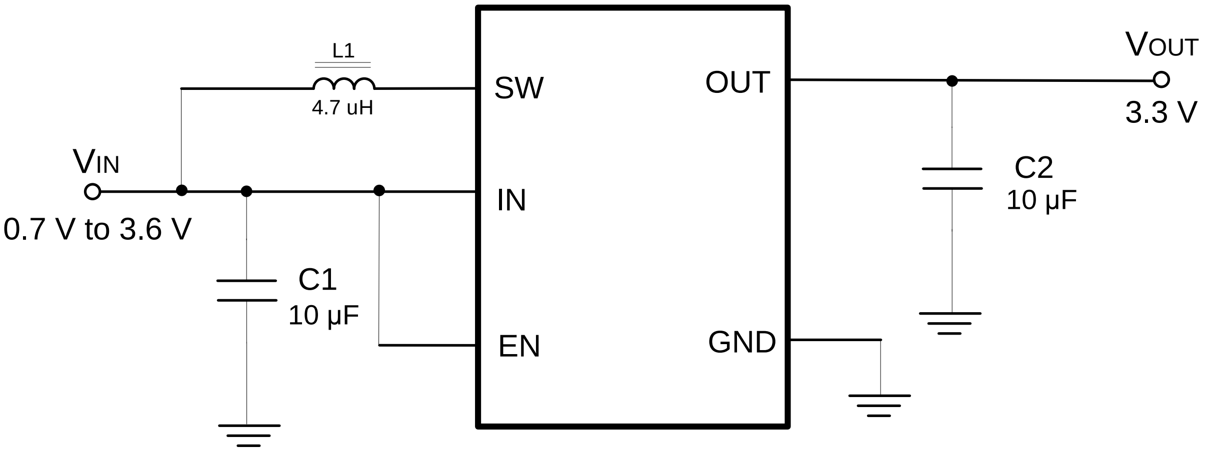
ELECTRICAL CHARACTERISTICS

T_J = -40°C to 85°C and V_{IN} = 0.7 V to 5.5 V. Typical values are at V_{IN} = 3.7 V, T_J = 25°C, unless otherwise noted.

Symbol	Parameters	Test Conditions	Min	Typ	Max	Unit
POWER SUPPLY						
V_{IN}	Input voltage range		0.7		5.5	V
V_{UVLO}	Input under voltage lockout threshold	V_{IN} rising		0.6	0.7	V
I_Q	Quiescent current into V_{IN} pin	IC enabled, no Load, no Switching T_J = -40°C to 85°C		0.25	1.1	μA
	Quiescent current into V_{OUT} pin	IC enabled, no Load, no Switching, Boost or Down Mode T_J = -40°C to 85°C	0.2	0.5	1.5	μA
	Quiescent current into V_{OUT} pin	IC enabled, no Load, no Switching, Boost or Down Mode T_J = -40°C to 85°C	3	3.5	4.5	μA
I_{SD}	Shutdown current into V_{IN} pin	IC disabled, V_{IN} = 3.7 V, V_{OUT} = 0 V, T_J = -40°C to 85°C		0.5	1.4	μA
OUTPUT						
V_{OUT}	Output voltage range		1.8		5.5	V
Output accuracy	SUM2097-25KA5	V_{IN} < V_{OUT} , PWM mode	2.45	2.5	2.55	V
		V_{IN} < V_{OUT} , PFM mode		2.58		V
	SUM2097-30KA5	V_{IN} < V_{OUT} , PWM mode	2.94	3	3.06	V
		V_{IN} < V_{OUT} , PFM mode		3.1		V
	SUM2097-33KA5	V_{IN} < V_{OUT} , PWM mode	3.23	3.3	3.37	V
		V_{IN} < V_{OUT} , PFM mode		3.4		V
	SUM2097-36KA5	V_{IN} < V_{OUT} , PWM mode	3.53	3.6	3.67	V
		V_{IN} < V_{OUT} , PFM mode		3.71		V
	SUM2097-45KA5	V_{IN} < V_{OUT}, PWM mode	4.4	4.5	4.6	V
		V_{IN} < V_{OUT} , PFM mode		4.63		V
	SUM2097-50KA5	V_{IN} < V_{OUT}, PWM mode	4.9	5	5.1	V
		V_{IN} < V_{OUT}, PFM mode		5.15		V
V_{REF}	Feedback reference voltage	V_{IN} < V_{OUT} , PWM mode	0.98	1	1.02	V
V_{OVP}	Output overvoltage protection threshold	V_{OUT} rising	5.6	5.8	6	V

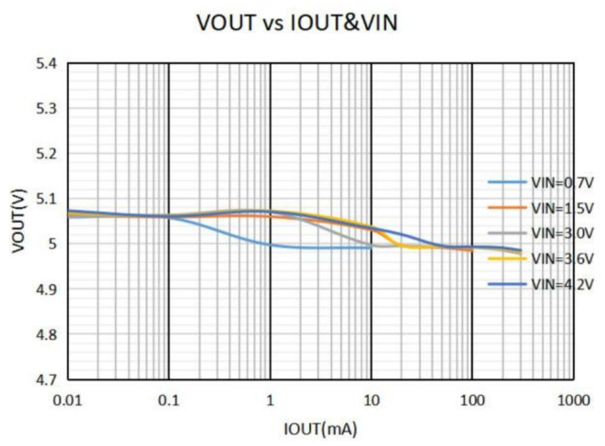
POWER SWITCH						
$R_{DS(on)\_LS}$	Low side switch on resistance	V_{OUT} = 3.3V		300		mΩ
$R_{DS(on)\_HS}$	Rectifier on resistance	V_{OUT} = 3.3V		350		mΩ
I_{LH}	Inductor current ripple	V_{OUT} = 3.3V		300		mA
I_{LIM}	Current limit threshold	$V_{OUT} \geq$ 2.5 V, boost operation		1		A
I_{SW_LKG}	Leakage into SW pin (No switching)	V_{SW} = 5.0 V, no switch, T_J = -40°C to 85°C			200	nA
Control logic						
V_{IL}	EN input low voltage threshold	$V_{IN} \leq$ 1.5 V	0.2 × V_{IN}			V
V_{IH}	EN input high voltage threshold	$V_{IN} \leq$ 1.5 V			0.8 × V_{IN}	V
V_{IL}	EN input low voltage threshold		0.4			V
V_{IH}	EN input high voltage threshold				1.2	V
I_{EN_LKG}		V_{EN} = 5.0 V			5	V
T_{OTP}	Over temperature protection			150		°C
T_{OTP_HYS}	Over temperature hysteresis			25		°C

APPLICATION CIRCUITS

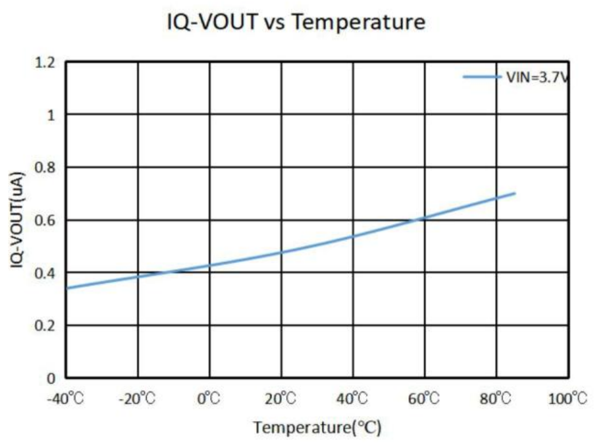


TYPICAL CHARACTERISTICS

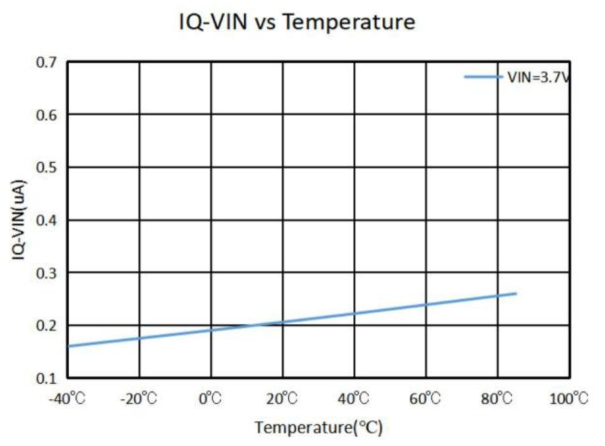
V_{IN} = 0.7 V, 1.5 V, 3.0 V, 3.6 V, 4.2 V, V_{OUT} = 5.0 V
Load Efficiency with Different Input



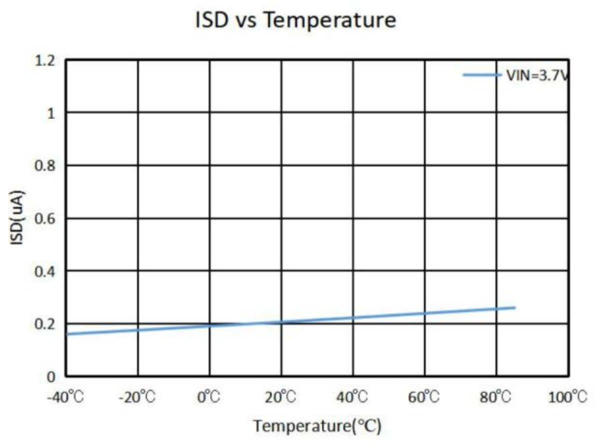
V_{IN} = 0.7 V, 1.5 V, 3.0 V, 3.6 V, 4.2 V, V_{OUT} = 5.0 V
Load Regulation



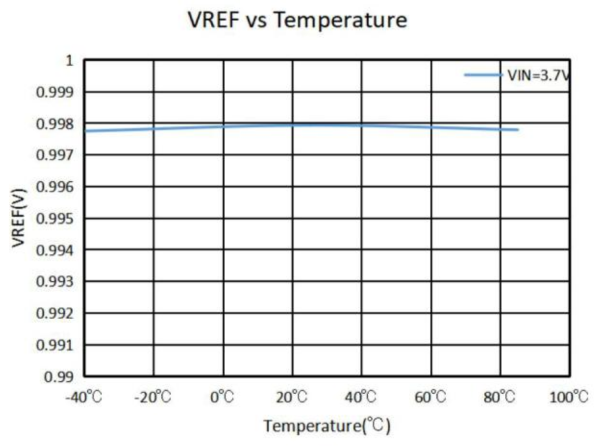
V_{IN} = 3.7 V, V_{OUT} = 5.0 V, No Switching
Quiescent Current into V_{OUT} vs Temperature



V_{IN} = 3.7 V, No Switching
Quiescent Current into V_{IN} vs Temperature

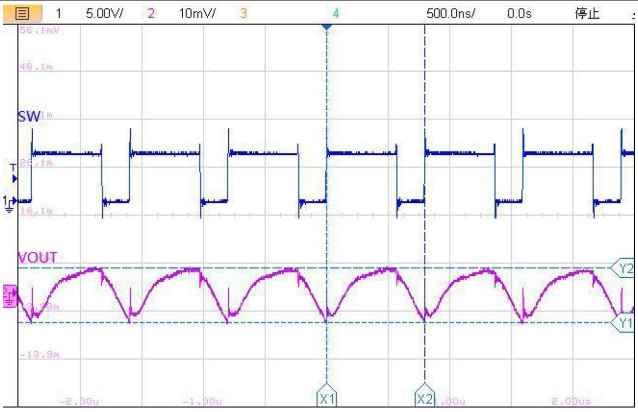


V_{IN} = 3.7 V, Into V_{IN} and SW
Shutdown Current vs Temperature

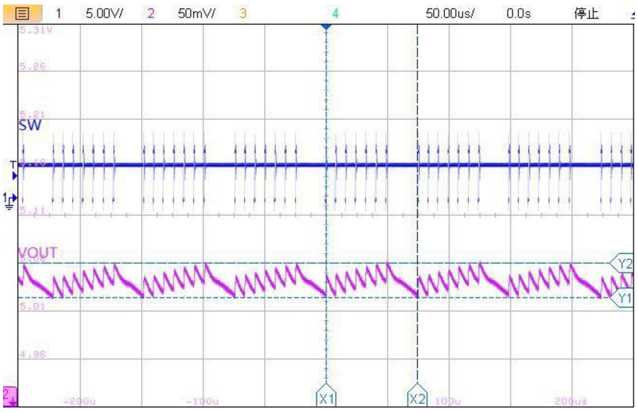


V_{IN} = 3.7 V, T_J = - 40℃~85℃
Reference Voltage vs Temperature

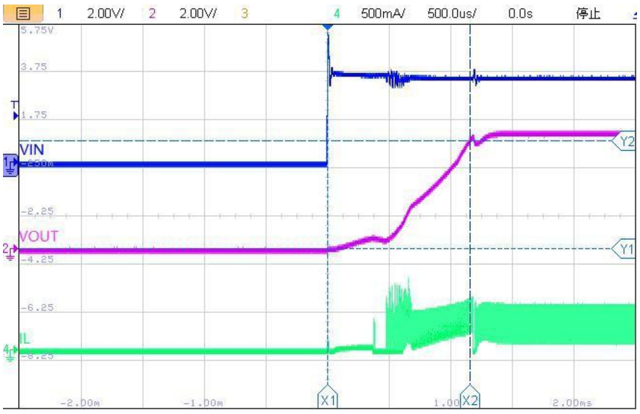
APPLICATION CURVES



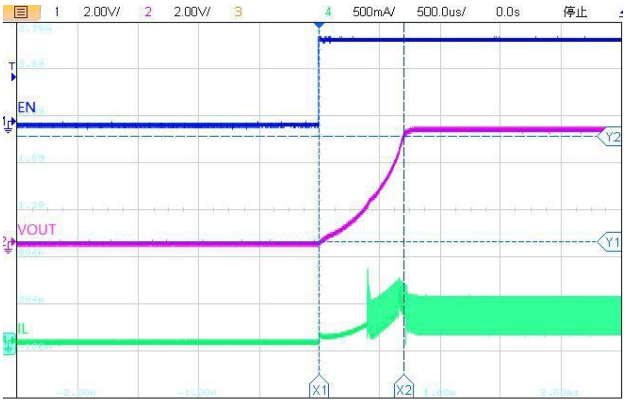
V_{IN} = 3.7 V, V_{OUT} = 5 V, I_{OUT} = 300 mA
Switching Waveform at Heavy Load



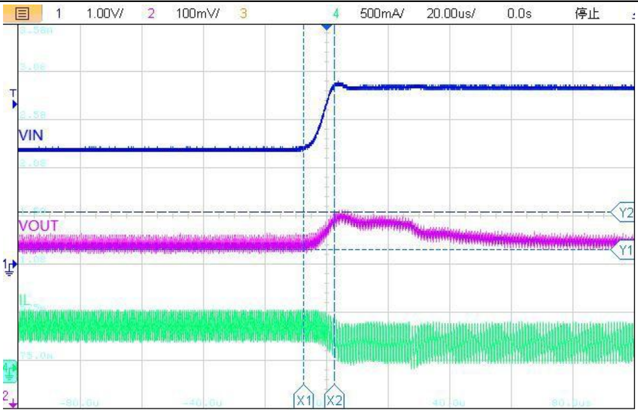
V_{IN} = 3.7 V, V_{OUT} = 5 V, I_{OUT} = 10 mA
Switching Waveform at Light Load



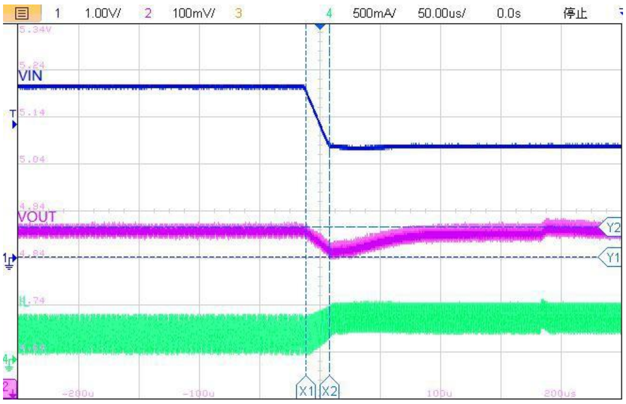
V_{IN} = 3.7 V, V_{OUT} = 5 V,R_{OUT} = 25 Ω
Startup by V_{IN}



V_{IN} = 3.7 V, V_{OUT} = 5 V, R_{OUT} = 25 Ω
Startup by EN

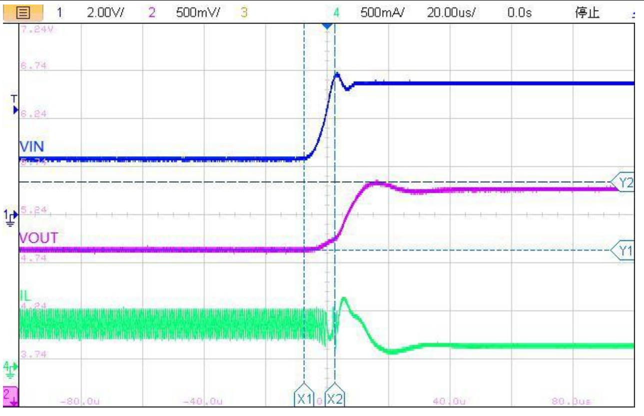


V_{IN} = 2.4 V to 3.7 V, V_{OUT} = 5 V, I_{OUT} = 200 mA
Line Transient

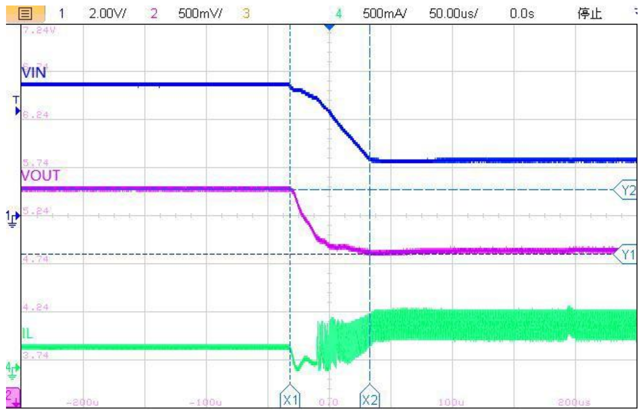


V_{IN} = 3.7 V to 2.4 V, V_{OUT} = 5 V, I_{OUT} = 200 mA
Line Transient

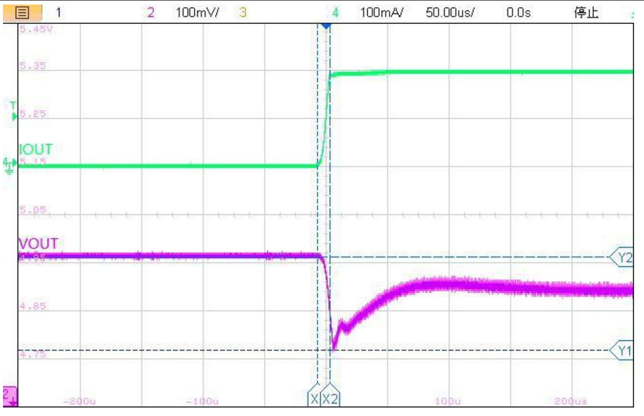
APPLICATION CURVES



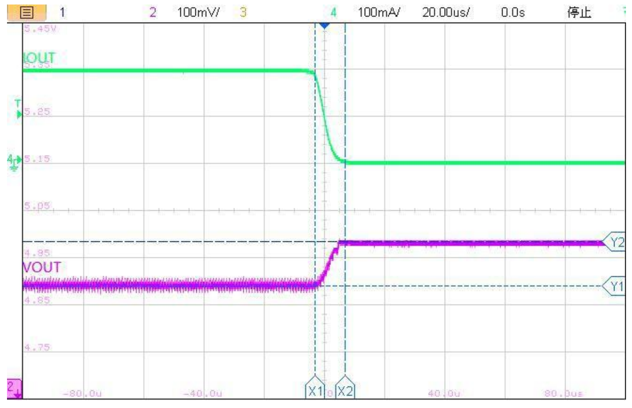
V_{IN} = 2.4 V to 5.5 V, V_{OUT} = 5 V, I_{OUT} = 200 mA
Line Transient



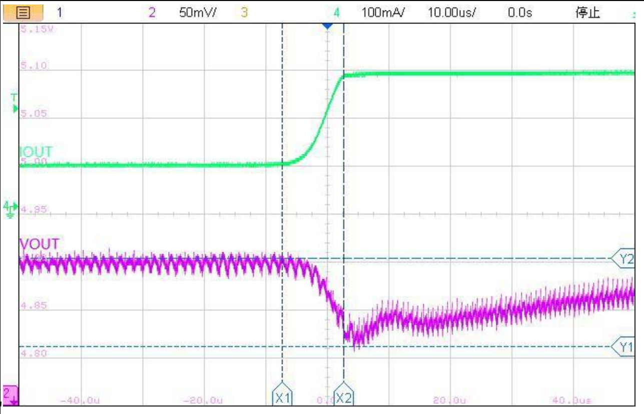
V_{IN} = 5.5 V to 2.4 V, V_{OUT} = 5 V, I_{OUT} = 200 mA
Line Transient



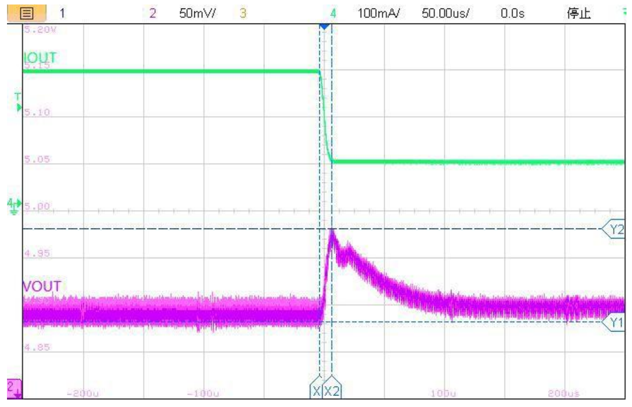
V_{IN} = 3.7 V, V_{OUT} = 5 V, I_{OUT} = 0 mA to 200 mA
Load Transient



V_{IN} = 3.7 V, V_{OUT} = 5 V, I_{OUT} = 200 mA to 0 mA
Load Transient

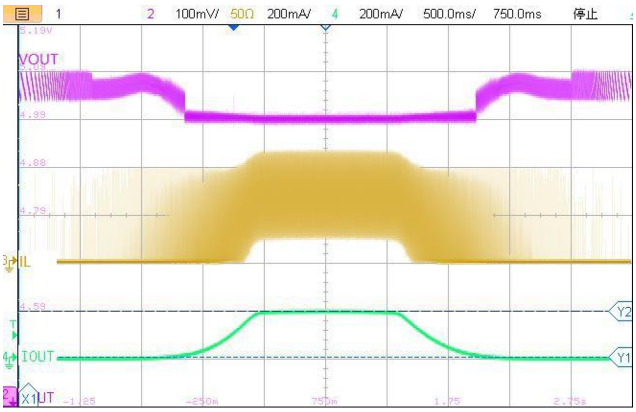


V_{IN} = 3.7 V, V_{OUT} = 5 V, I_{OUT} = 100 mA to 300 mA
Load Transient

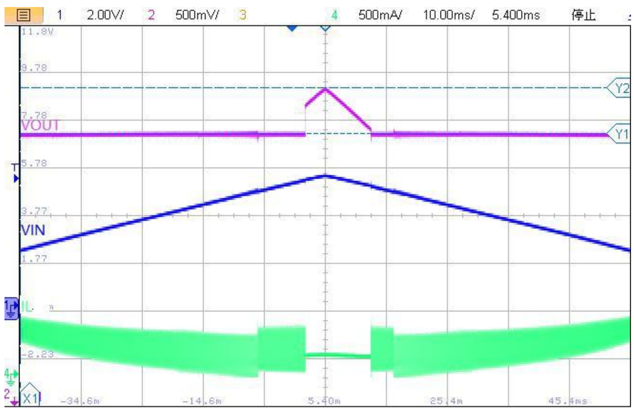


V_{IN} = 3.7 V, V_{OUT} = 5 V, I_{OUT} = 300 mA to 100 mA
Load Transient

APPLICATION CURVES



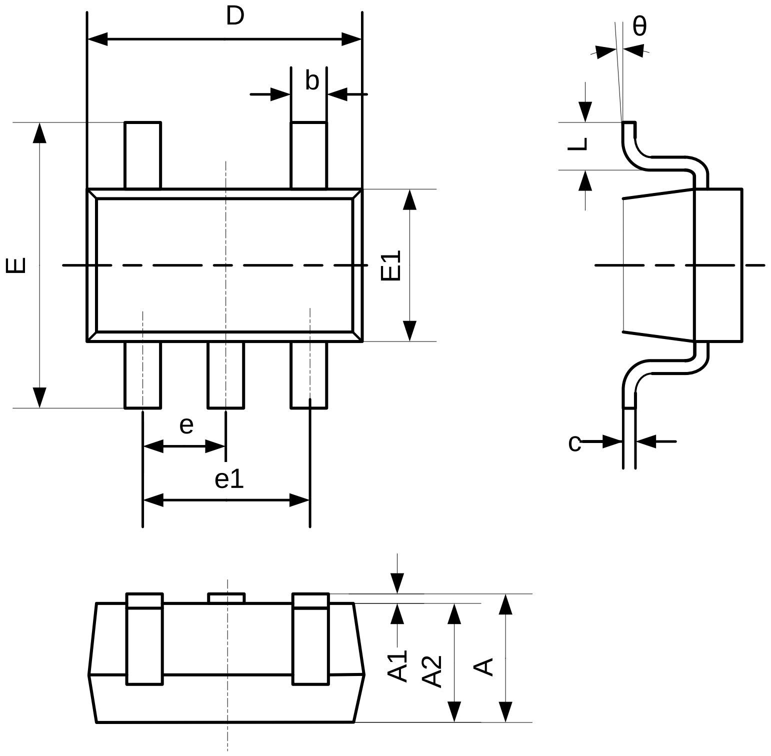
V_{IN} = 3.7 V, V_{OUT} = 5 V, I_{OUT} = 0 mA to 200 mA
Load Transient



V_{IN} = 2.4 V to 5.5 V, V_{OUT} = 5 V, I_{OUT} = 200 mA
Line Transient

PACKAGE DIMENSION

SOT23-5



Symbol	Dimensions In Millimeters	
	MIN	**MAX**
A	0.700	1.250
A1	0.000	0.100
A2	0.700	1.150
b	0.280	0.450
c	0.080	0.200
D	2.820	3.020
E	2.650	2.950
E1	1.500	1.700
e	0.950BSC	
e1	1.800	2.000
L	0.300	0.600
θ	0°	8°

V 1.1