ET8307 - Ultra-Low Quiescent Current Buck Converter

General Description

The ET8307 series is a high efficiency synchronous step-down converter featuring typical 360nA quiescent current. It provides high efficiency at light load down to 10μA. Its input voltage ranges from 2.2V to 5.5V and provides eight programmable output voltages between 1.2V and 3.3V while delivering output current up to 600mA, peak to 1A (ET8307) / 400mA, peak to 0.5A (ET8307A).

The Adaptive-Constant-On-Time (ACOT) operation with internal compensation allow the transient response to be optimized over a wide range of loads and output capacitors.

The ET8307 is a available in WLCSP8 (0.8 ×1.6 ,0.4 pitch) package.

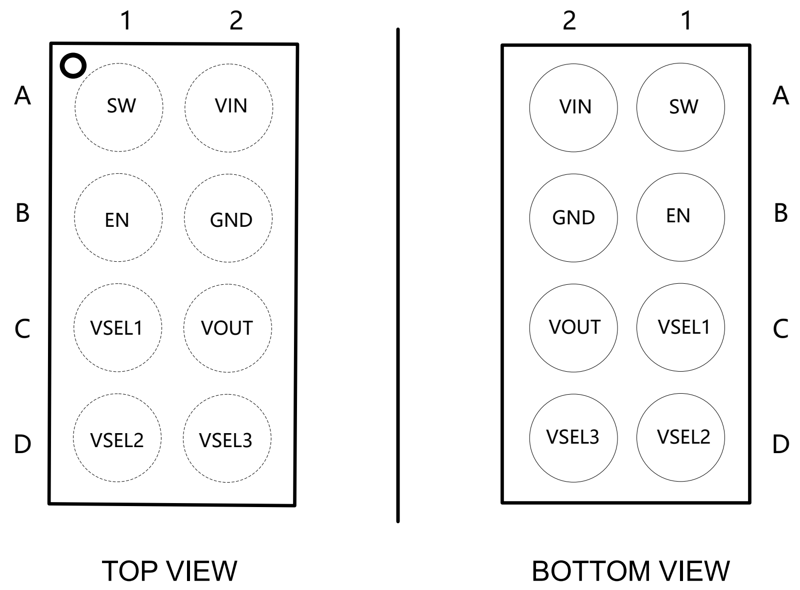
Features

- Input Voltage Range : 2.2V to 5.5V
- Programmable Output Voltage 8-Level
  - ET8307 1.2V to 3.3V
  - ET8307A 0.7V to 3.1V
- Typ. 360nA Quiescent Current
- PFM Operation With Light Load
- Up to 94% Efficiency
- Internal Compensation
- Output Discharge
- Over-Current Protection
- Over-Temperature Protection
- Output Current:
  - ET8307 600mA, Peak to 1A
  - ET8307A 400mA, Peak to 0.5A
- Automatic Transition to 100% Duty Cycle Operation

Applications

- Hand-Held Devices
- Portable Information
- Battery Powered Equipment
- Wearable Devices
- Internet of Things

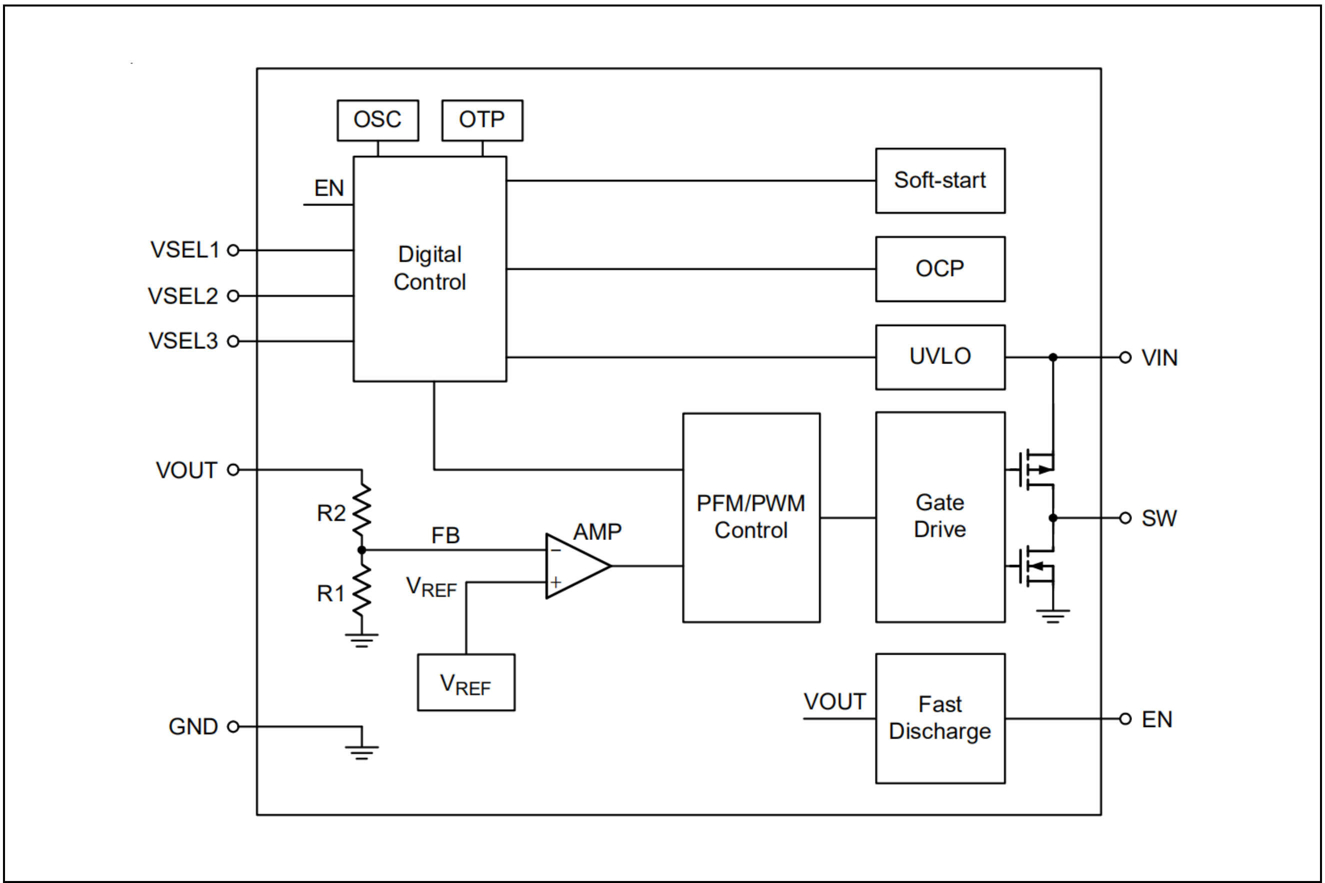
Pin Configuration



Pin Function

Pin No.	Pin Name	Pin Function
A1	SW	This pin is the connection between two build-in switches in the chip, which should be connected to the external inductor. The inductor should be connected to this pin with the shortest path.
A2	VIN	Input voltage pin. The input capacitor C_{IN} should be connected to this pin with the shortest path.
B1	EN	Chip enable input pin. High level voltage enables the device while low level voltage turns the device off. This pin must be terminated.
B2	GND	Device ground pin. This pin should be connected to input and output capacitors with the shortest path.
C1	VSEL1	Output voltage selection pin. This pin must be terminated.
C2	VOUT	Output voltage feedback pin. This pin should be connected close to the output capacitor terminal for better voltage regulation.
D1	VSEL2	Output voltage selection pin. This pin must be terminated.
D2	VSEL3	Output voltage selection pin. This pin must be terminated.

Block Diagram



Functional Description

The ET8307 is a adaptive constant on time (ACOT) switching buck converter. It can support input range from 2.2V to 5.5V and 8 level output voltages with output current up to 600mA, peak to 1A (ET8307) / 400mA, peak to 0.5A (ET8307A). The ET8307 provides Over-Temperature Protection (OTP) and Over-Current Protection (OCP) mechanisms to prevent the device from damage with abnormal operations. When the EN voltage is logic low, the IC will be shut down with low input supply current less than 0.2uA.

Absolute Maximum Ratings (1)

Items	Rating	Unit
VIN, SW, EN, VSEL1, VSEL2, VSEL3, VOUT	-0.3 to 7	V
Power Dissipation, P_D @ T_A = 25°C WLCSP8 (0.8×1.6)	0.84	W
Package Thermal Resistance (2) WLCSP8 (0.8×1.6) ,θ_{JA}	118.5	°C/W
Max Junction Temperature	150	°C
Storage Temperature	-65 to 150	°C
Lead Temperature (Soldering, 10 sec)	260	°C
ESD Susceptibility (3) HBM (Human Body Model)	±2000	V

Note1. Stresses beyond those listed “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 in the operational sections of the specifications is not implied. Exposure to absolute maximum rating conditions may affect device reliability.

Note 2. θJA is measured under natural convection (still air) at T_A = 25°C with the component mounted on a high effective thermal-conductivity four-layer test board on a JEDEC 51-7 thermal measurement standard.

Note 3. Devices are ESD sensitive. Handling precaution is recommended.

Recommended Operating Range (4)

Symbol	Item	Rating	Unit
V_{IN}	Supply Input Voltage	2.5 to 5.5	V
T_J	Junction Temperature	-40 to 125	ºC
T_A	Ambient Temperature	-40 to 85	ºC

Note 4. The device is not guaranteed to function outside its operating conditions.

Electrical Characteristics

V_{IN} = 3.6V, C_{IN} = 10μF, L1 = 2.2μH, T_A = 25°C, unless otherwise specified.

Symbol	Item	Conditions	Min	Typ	Max	Unit
BUCK Regulator						
V_{UVLOR}	Under-Voltage Lockout Rising Threshold		--	2	2.15	V
V_{UVLO_HYS}	Under-Voltage Lockout Hysteresis		--	0.1	0.4	V
V_{OUT_ACC10}	V_{OUT} Voltage Accuracy	V_{OUT} = 1.8V, I_{OUT} = 10mA	-2.0	--	3.0	%
V_{OUT_ACC100}		V_{OUT} = 1.8V, I_{OUT} = 100mA	-2.0	--	2.0	
I_{QVIN}	Input Quiescent Current	V_{OUT} = 1.8V, I_{OUT} = 0A, EN = V_{IN}, non-switching	--	360	800	nA
I_{QSW}		V_{OUT} = 1.8V, I_{OUT} = 0A, EN = V_{IN}, switching	--	460	1200	
I_{SHDN}	Shutdown Current	EN = GND	--	0.2	1	μA
f_{SW}	Switching Frequency	V_{OUT} = 1.8V, CCM mode	--	1.2	--	MHz
I_{CLUG}	UGATE Current Limit	ET8307	1	1.2	1.4	A
		ET8307A	0.58	0.68	0.8	
I_{CLLG}	LGATE Current Limit	ET8307	1	1.2	1.4	A
		ET8307A	0.55	0.68	0.8	
R_{ON_UG}	UGATE R_{ON}	I_{OUT} = 50mA	--	350	--	mΩ
R_{ON_LG}	LGATE R_{ON}	I_{OUT} = 50mA	--	250	--	mΩ
R_{ON_DIS}	Output Discharge R_{ON}	EN = GND, I_{OUT} = 10mA	--	10	--	Ω
I_{VOUT}	V_{OUT} Pin Input Leakage	V_{OUT} = 2V, EN = V_{IN}	--	100	--	nA
t_{OFF_MIN}	V_{OUT} Minimum Off Time		--	80	--	ns
t_{ON_MIN}	V_{OUT} Minimum On Time	V_{OUT} = 1.8V, V_{IN} = 3.6V	--	420	--	ns
V_{OUT}_LineReg	Line Regulation	V_{OUT} = 1.8V, I_{OUT} = 100mA, V_{IN} = 2.2V to 5.5V	--	0.1	--	%/V
V_{OUT}_LoadReg1	Load Regulation	V_{OUT} = 1.8V, including PFM operation	--	0.002	--	%/mA
V_{OUT}_LoadReg2		V_{OUT} = 1.8V, only CCM operation	--	0.0005	--	

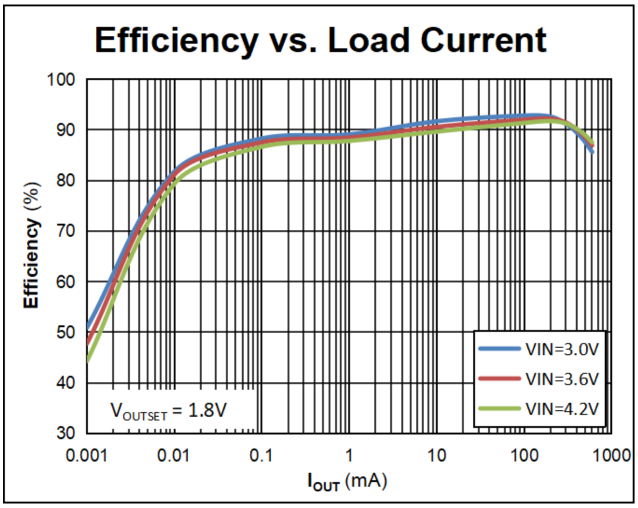
Electrical Characteristics (Continued)

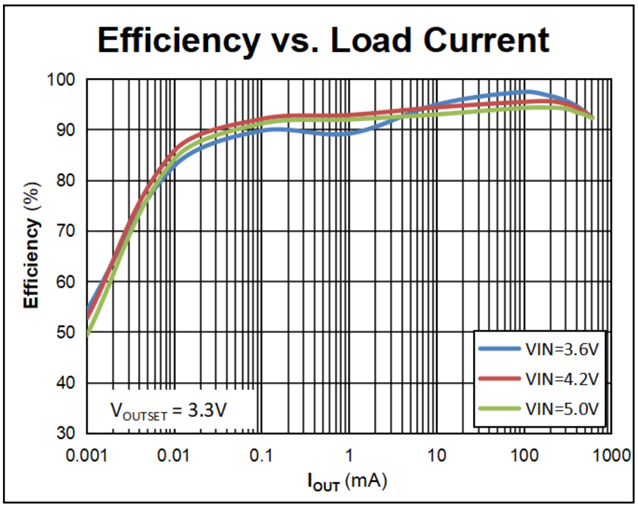
V_{IN} = 3.6V, C_{IN} = 10µF, L1 = 2.2µH, T_A = 25°C, unless otherwise specified.

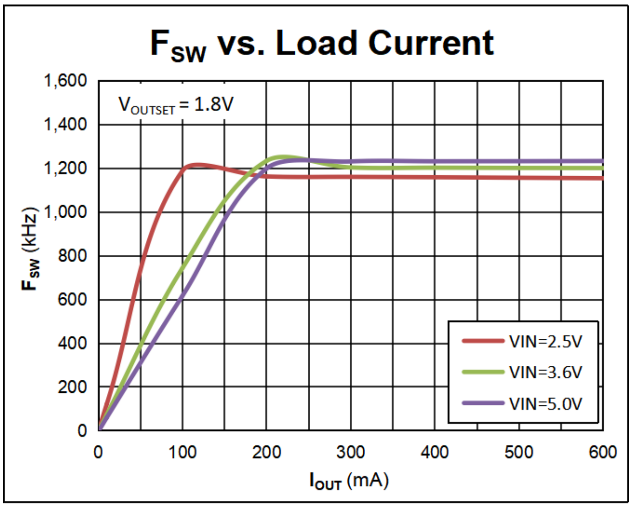
Symbol	Item	Conditions	Min	Typ	Max	Unit
T_{OTP}	Over-Temperature Protection	I_{OUT} = 100mA	--	150	--	°C
T_{OTP_HYS}	Over-Temperature Protection Hysteresis		--	20	--	°C
Timing						
t_{SS_EN}	Regulator Start Up Delay Time	I_{OUT} = 0mA, EN = GND to V_{IN}, V_{OUT} starts rising	--	0.8	--	ms
t_{SS}	Regulator Soft Start Time	V_{OUT} = 1.8V, I_{OUT} = 10mA, EN = V_{IN}	--	0.7	--	ms
Logic Input (EN, VSEL1, VSEL2 and VSEL3)						
V_{IH}	Input High Threshold	V_{IN} = 2.2V to 5.5V	1.2	--	--	V
V_{IL}	Input Low Threshold	V_{IN} = 2.2V to 5.5V	--	--	0.4	V
I_{IN}	Input Pin Bias Current		--	10	--	nA

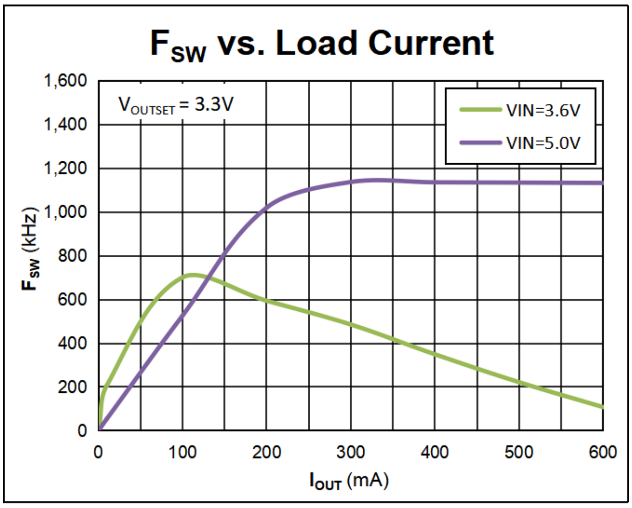
Typical Operating Characteristics

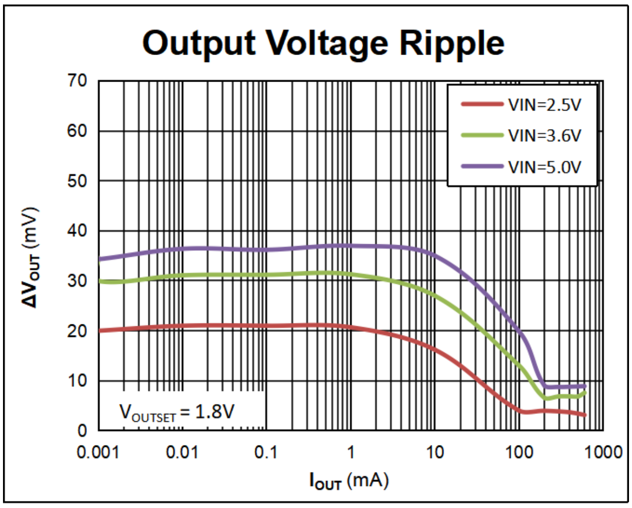
C_{IN} = 10μF, L1 = 2.2μH, T_A = 25°C, unless otherwise specified.

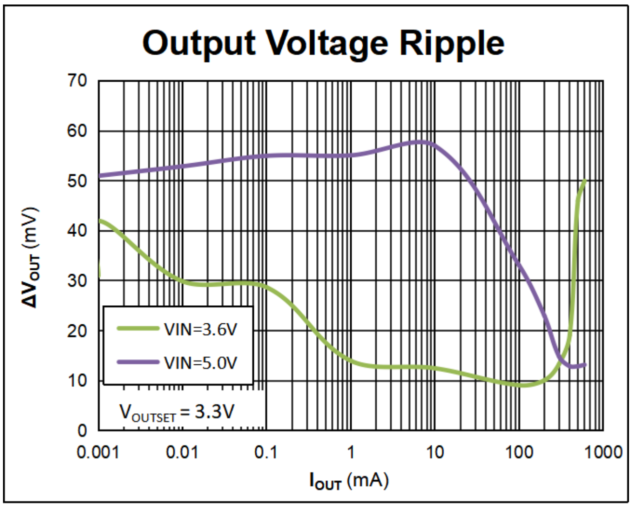






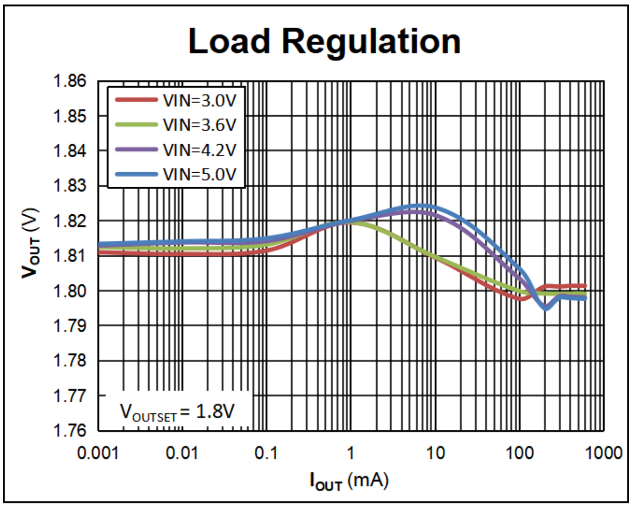


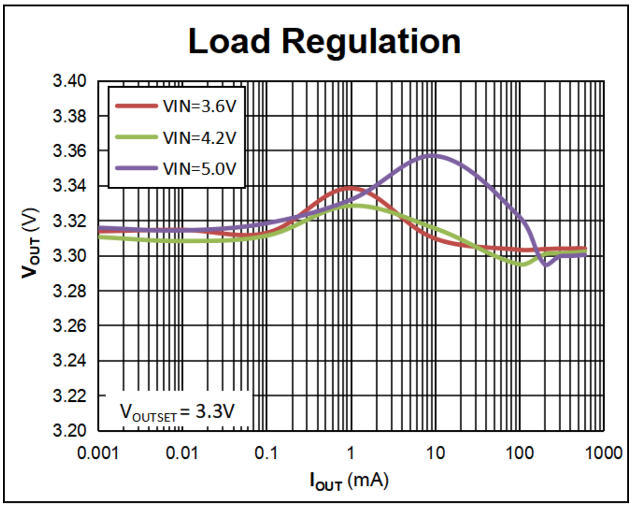


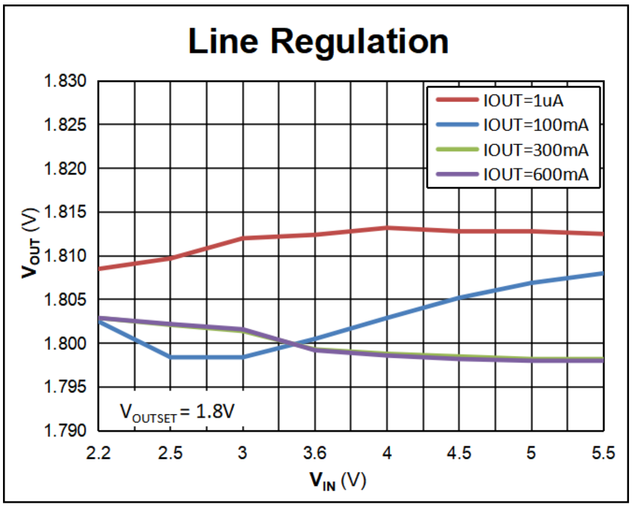


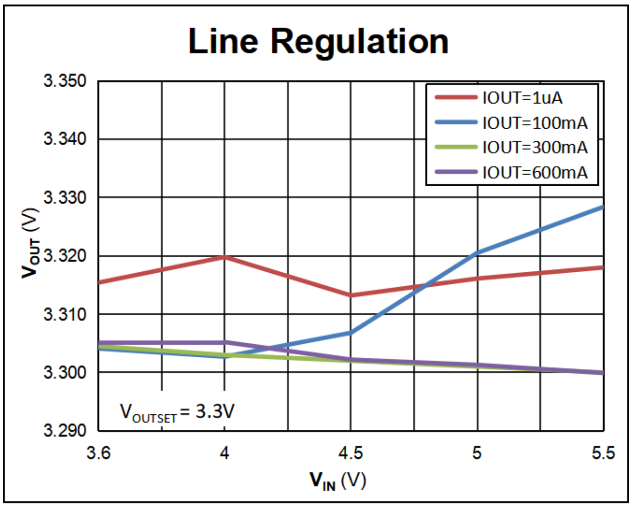
Typical Operating Characteristics (Continued)

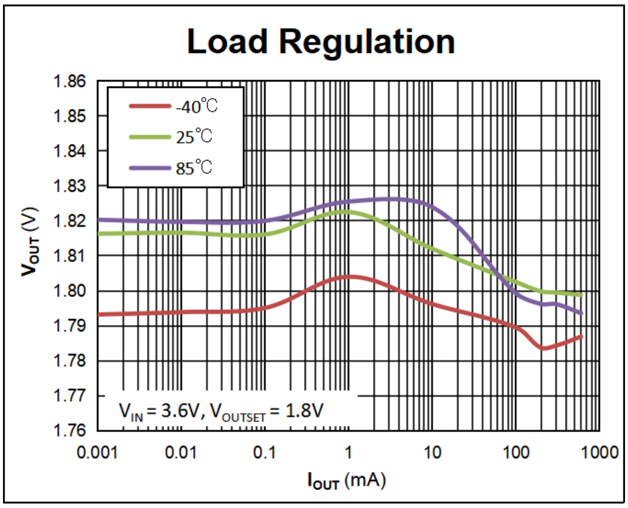
C_{IN} = 10μF, L1 = 2.2μH, T_A = 25°C, unless otherwise specified.

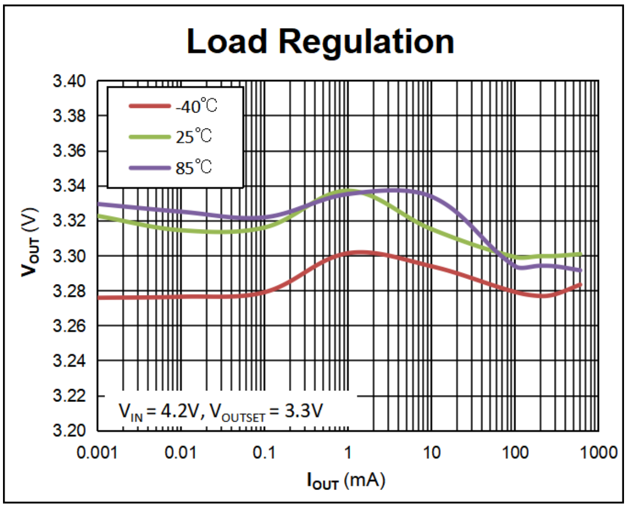






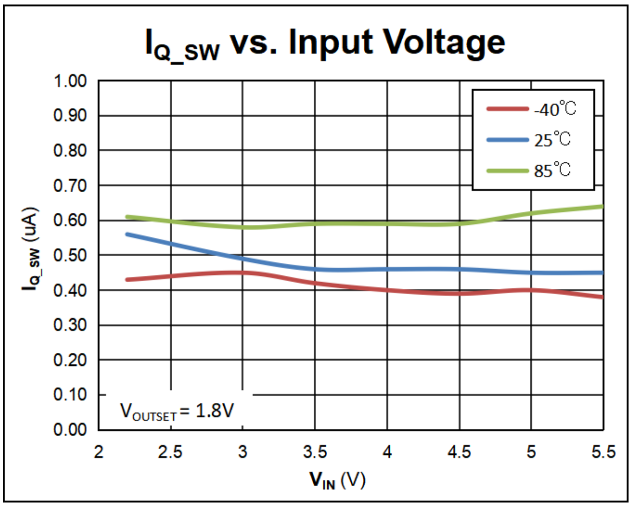


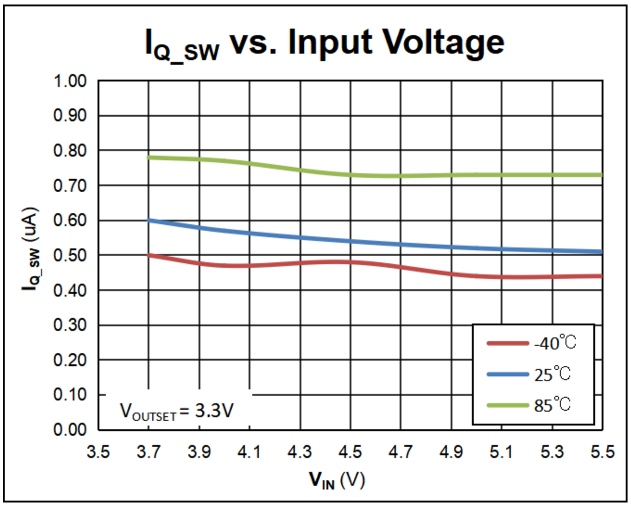


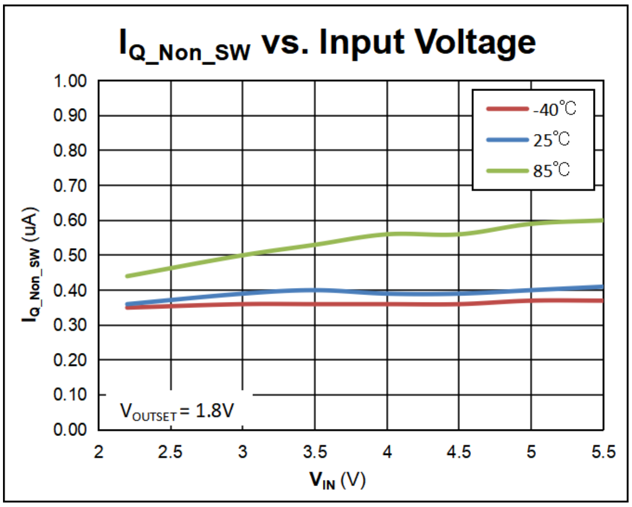


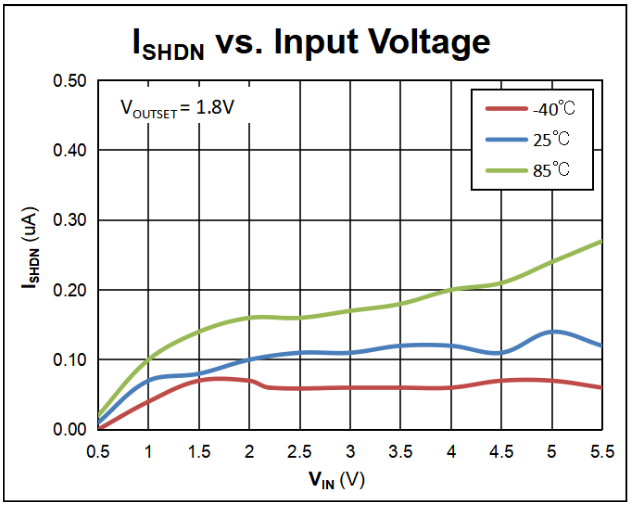
Typical Operating Characteristics (Continued)

C_{IN} = 10µF, L1 = 2.2µH, T_A = 25°C, unless otherwise specified.





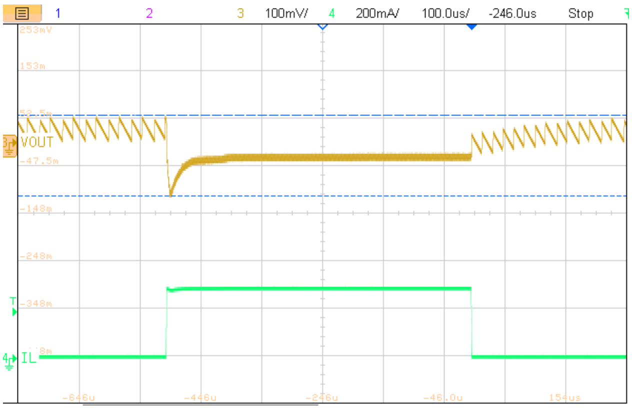




Typical Operating Characteristics (Continued)

C_{IN} = 10μF, L1 = 2.2μH, T_A = 25°C, unless otherwise specified.

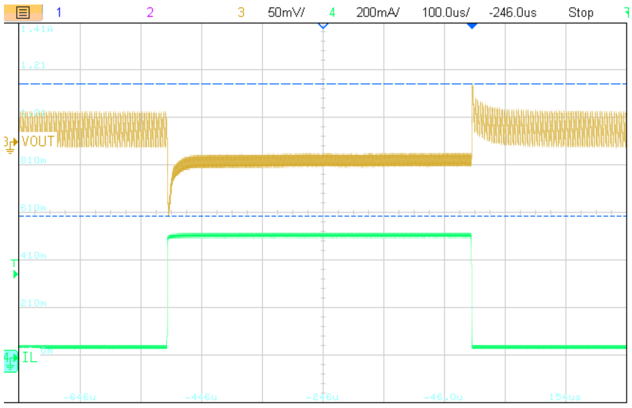
Load Transient Response



V_{IN} = 5.0V, V_{OUT} = 3.3V.

I_{LOAD} from 5mA to 300mA, t_R = t_F = 1μs.

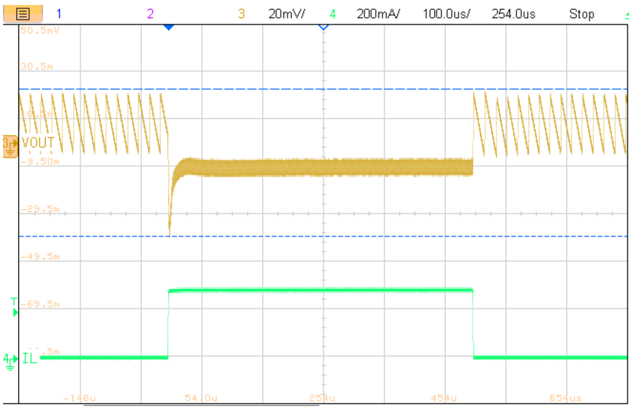
Load Transient Response



V_{IN} = 5.0V, V_{OUT} = 3.3V.

I_{LOAD} from 50mA to 500mA, t_R = t_F = 1μs.

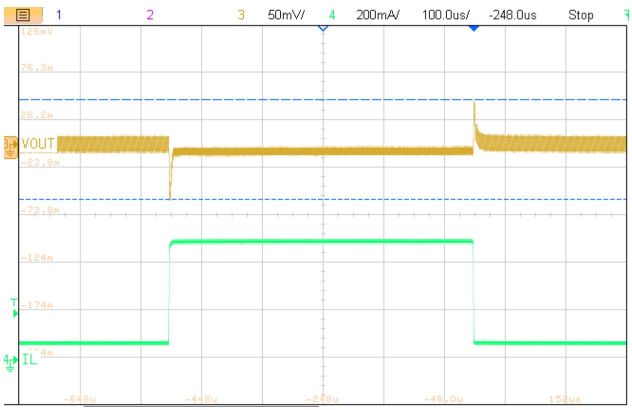
Load Transient Response



V_{IN} = 3.6V, V_{OUT} = 1.2V.

I_{LOAD} from 5mA to 300mA, t_R = t_F = 1μs.

Load Transient Response



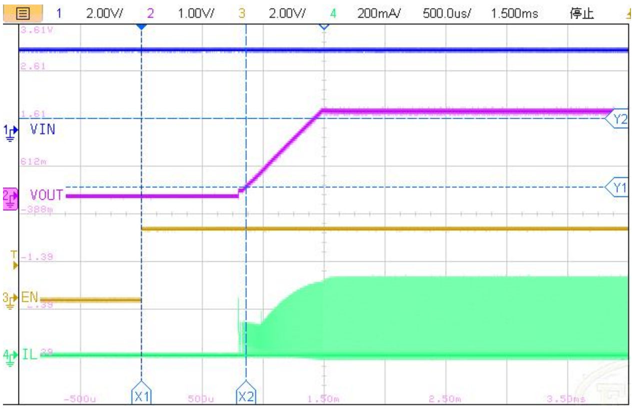
V_{IN} = 3.6V, V_{OUT} = 1.2V.

I_{LOAD} from 50mA to 500mA, t_R = t_F = 1μs.

Typical Operating Characteristics (Continued)

C_{IN} = 10μF, L1 = 2.2μH, T_A = 25°C, unless otherwise specified.

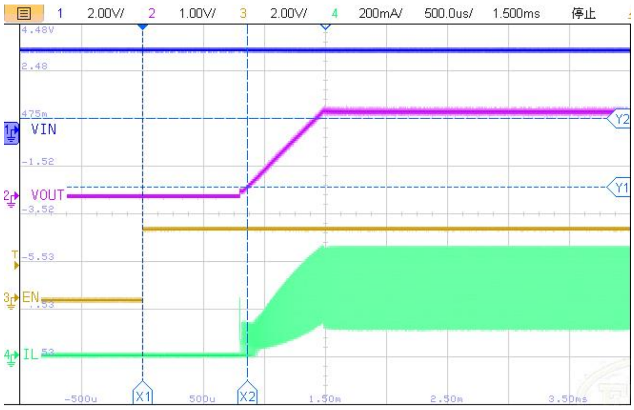
Soft Start Sequence



V_{IN} = 3.6V, V_{OUT} = 1.8V, R_{LOAD} = 18Ω

I_{LOAD} = 100mA, EN step from 0 to 3V.

Soft Start Sequence



V_{IN} = 3.6V, V_{OUT} = 1.8V, R_{LOAD} = 6Ω

I_{LOAD} = 300mA, EN step from 0 to 3V.

Application Circuits

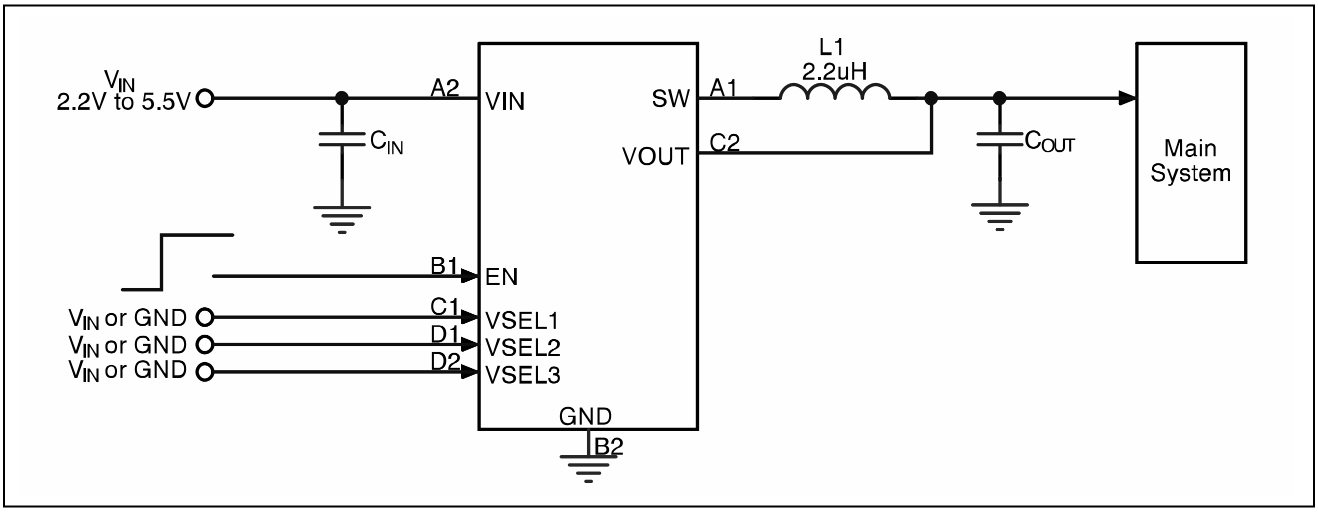


Table 1. Recommended Components

Component		P/N	Description	Package	Vendor
C_{IN}	ET8307	GRM155R60J106ME15	10μF/6.3V/X5R	0402	Murata
	ET8307A	GRM155R60J475ME47	4.7μF/6.3V/X5R		
C_{OUT}	$V_{OUT} \leq 3V$	GRM155R60J106ME15	10μF/6.3V/X5R		
	$V_{OUT} = 3.3V$	GRM155R60J226ME11	22μF/6.3V/X5R		
L1	ET8307	1239AS-H-2R2M	2.2μH	2520	
	ET8307A	DFE201610E-2R2M=P2		2016	

Table 2. Output Voltage Setting

Device	VOUT (V)	VSEL3	VSEL2	VSEL1
ET8307	1.2	0	0	0
	1.5	0	0	1
	1.8	0	1	0
	2.1	0	1	1
	2.5	1	0	0
	2.8	1	0	1
	3	1	1	0
	3.3	1	1	1
ET8307A	0.7	0	0	0
	1	0	0	1
	1.3	0	1	0
	1.6	0	1	1
	1.9	1	0	0
	2	1	0	1
	2.9	1	1	0
	3.1	1	1	1

Application Information

The ET8307/A is a synchronous low voltage step-down converter that can support the input voltage range from 2.2V to 5.5V and the output current can be up to 600mA, peak to 1A (ET8307) / 400mA, peak to 0.5A (ET8307A). Internal compensation are integrated to minimize external component count. Protection features include over-current protection, under-voltage protection and over-temperature protection.

UVLO Protection

To protect the chip from operating at insufficient supply voltage, the UVLO is needed. When the input voltage is lower than the UVLO falling threshold voltage, the device will be lockout.

Output Voltage Selection

The ET8307/A provides 8 level output voltages which can be programmed via the voltage select pin VSEL1 to VSEL3. Table 1 indicates the setting to individual output voltage.

100% Duty Cycle Operation

When the input voltage decreases, the on-time of high side power FET increases automatically. When the input voltage is close to target output voltage, the switch cycle becomes larger than the setting value, and the on time of low side power FET decreases to minimum on-time. The converter enters 100% duty cycle operation once the input voltage is lower than target output voltage.

Over-Current Protection

The OCP function is implemented by UGATE and LGATE. When the inductor current reaches the UGATE current limit threshold, the high-side MOSFET will be turned-off. The low-side MOSFET turns on to discharge the inductor current until the inductor current trips below the LGATE current limit threshold. After UGATE current limit triggered, the max inductor current is decided by the inductor current rising rate and the response delay time of the internal network.

During OCP period, the output voltage drops below the setting threshold (typ. 0.4V) and the current limit value is reduced for lowering the devices loss, reducing the heat and preventing further damage of the chip.

Over-Temperature Protection

When the junction temperature exceeds the OTP threshold value, the IC will shut down the switching operation. Once the junction temperature cools down and is lower than the OTP lower threshold, the converter will automatically resume switching.

Inductor Selection

The recommended power inductor is 2.2μH and inductor saturation current rating choose follow over current protection design consideration. In applications, it needs to select an inductor with the low DCR to provide good performance and efficiency.

C_{IN} and C_{OUT} Selection

The input capacitance, C_{IN}, is needed to filter the trapezoidal current at the source of the top MOSFET. To prevent large ripple voltage, a low ESR input capacitor sized for the maximum RMS current should be used. RMS current is given by :

$$I_{RMS} = I_{OUT(MAX)} \times \frac{V_{OUT}}{V_{IN}} \times \sqrt{\frac{V_{IN}}{V_{OUT}} - 1}$$

This formula has a maximum at $V_{IN} = 2V_{OUT}$, where $I_{RMS} = I_{OUT} / 2$. This simple worst-case condition is commonly used for design because even significant deviations do not offer much relief. To choose a capacitor rated at a higher temperature than required.

Several capacitors may also be paralleled to meet size or height requirements in the design.

The selection of C_{OUT} is determined by the Effective Series Resistance (ESR) that is required to minimize voltage ripple and load step transients, as well as the amount of bulk capacitance that is necessary to ensure that the control loop is stable. Loop stability can be checked by viewing the load transient response as described in a later section.

The output ripple, ΔV_{OUT}, is determined by :

$$\Delta V_{OUT} \le \Delta I_L \left[ESR + \frac{1}{8 \times f_{SW} \times C_{OUT}} \right]$$

Thermal Considerations

The junction temperature should never exceed the absolute maximum junction temperature $T_{J(MAX)}$, listed under Absolute Maximum Ratings, to avoid permanent damage to the device. The maximum allowable power dissipation depends on the thermal resistance of the IC package, the PCB layout, the rate of surrounding airflow, and the difference between the junction and ambient temperatures. The maximum power dissipation can be calculated using the following formula:

$$P_{D(MAX)} = (T_{J(MAX)} - T_A) / \theta_{JA}$$

where $T_{J(MAX)}$ is the maximum junction temperature, T_A is the ambient temperature, and θ_{JA} is the junction-to-ambient thermal resistance.

For continuous operation, the maximum operating junction temperature indicated under Recommended Operating Conditions is 125°C. The junction-to-ambient thermal resistance, θ_{JA}, is highly package dependent. For a WLCSP8 package, the thermal resistance, θ_{JA}, is 118.5°C/W on a standard JEDEC 51-7 high effective thermal-conductivity four-layer test board. The maximum power dissipation at T_A = 25°C can be calculated as below $P_{D(MAX)}$ = (125°C − 25°C) / (118.5°C/W) = 0.84W for a WLCSP8 package.

The maximum power dissipation depends on the operating ambient temperature for the fixed $T_{J(MAX)}$ and the thermal resistance, θ_{JA}. The derating curves allows the designer to see the effect of rising ambient temperature on the maximum power dissipation.

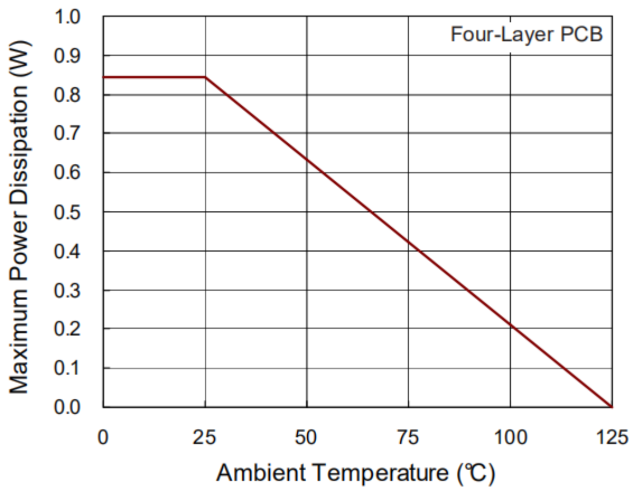


Table 3. Protection Trigger Condition and Behavior

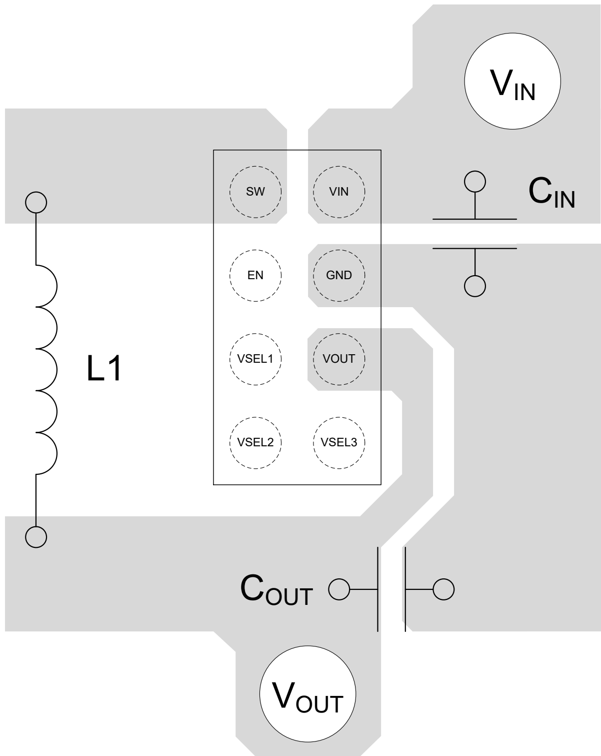
Protection Type		Threshold Refer to Electrical Spec.	Protection Method	Reset Method
ET8307	UGATE Current Limit	I_{LX} > 1.2A	Turn off high-side MOS	I_{LX} < 1.2A
	LGATE Current Limit	I_{LX} > 1.2A	Turn on low-side MOS	I_{LX} < 1.2A
ET8307A	UGATE Current Limit	I_{LX} > 0.68A	Turn off high-side MOS	I_{LX} < 0.68A
	LGATE Current Limit	I_{LX} > 0.68A	Turn off low-side MOS	I_{LX} < 0.68A
UVLO		V_{UVLOF} < 1.9V	Shutdown	V_{UVLOR} > 2V
OTP		Temperature > 150°C	Shutdown	Temperature < 130°C

Layout Considerations

For high frequency switching power supplies, the PCB layout is important to get good regulation, high efficiency and stability. The following descriptions are the guidelines for better PCB layout.

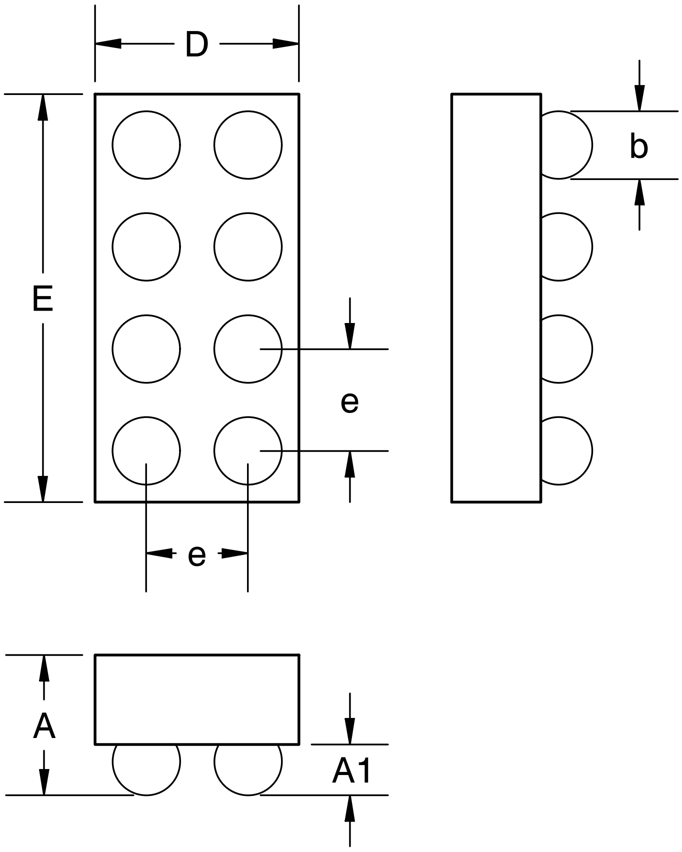
For good regulation, place the power components as close as possible. The traces should be wide and short enough especially for the high-current loop.

Shorten the SW node trace length and make it wide.



Package Dimension

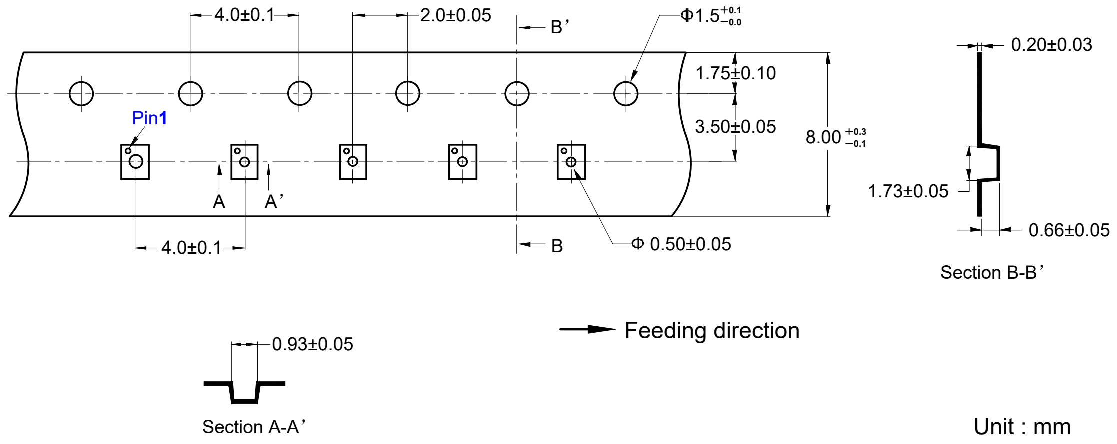
WLCSP8



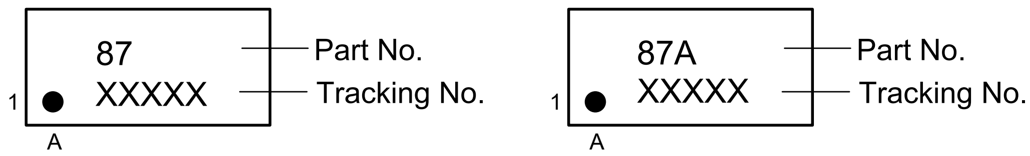
COMMON DIMENSIONS
(UNITS OF MEASURE=MILLIMETER)

SYMBOL	MIN	NOM	MAX
A	0.502	0.550	0.598
A1	0.175	0.200	0.225
b	0.240	0.265	0.290
D	0.770	0.800	0.830
E	1.570	1.600	1.630
e	0.400BSC		

Tape Information



Marking



ET8307 ET8307A

Revision History and Checking Table

Version	Date	Revision Item	Modifier	Function & Spec Checking	Package & Tape Checking
1.0	2020.11.16	Preliminary Version	Liu-Jiaying	You-Yingquan	Liujy
1.1	2022.5.26	Format adjustment	You-Yingquan	You-Yingquan	Liujy
1.2	2022.7.04	Parameters adjustment	You-Yingquan	You-Yingquan	Liujy
1.3	2022.7.22	Add Curves ， Tape	You-Yingquan	You-Yingquan	Liujy
1.4	2023.3.28	Updata EC table	Wu-Hesong	Wu-Hesong	Liujy
1.5	2023.7.16	Updata Soft Start	Wu-Hesong	Wu-Hesong	Liujy
1.6	2024.7.17	Add Marking	Shibo	Wu-Hesong	Liujy