Synchronous Boost Converter with Ultra-Low IQ

General Description

The ET82099x device is a synchronous boost converter with less than 1μA 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 ET82099 offers adjustable output voltage, and ET82099x offers different fixed output voltage versions. Hysteric control topology has been employed to obtain maximal efficiency at minimal quiescent current. ET82099x consumes only 1μA quiescent current in sleep mode and can achieve up to 80% efficiency at 100μA load. It can also support up to 300mA output current from 3.3V to 5V conversion, and achieve up to 93% at 200mA load.

The ET82099x 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 ET82099x exits Down Mode and enters into Pass-Through Mode when V_{IN}>V_{OUT}+0.35V. The ET82099x supports true shutdown function when it is disabled, which disconnects the load from the input supply to reduce the current consumption.

They are available in1.15mm x 0.83mm WLCSP6 Package.

Features

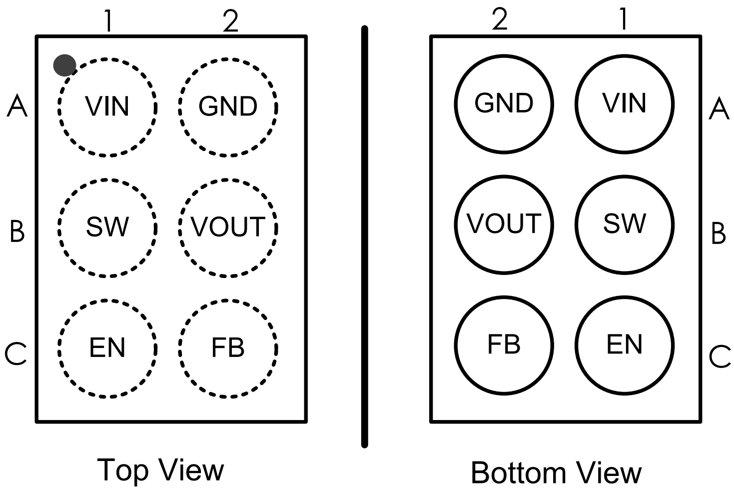
- 250nA Ultra-Low IQ into VIN Pin
- 500nA Ultra-Low IQ into VOUT Pin For ET82099
- 3.5uA IQ into VOUT Pin For ET82099x
- Operating Input Voltage from 0.7V to 5.5V
- ET82099 - Adjustable Output Voltage from 1.8V to 5.5V
- ET82099x - Fixed Output Voltage Versions 2.5V 3.0V 3.3V 3.6V 4.5V 5.0V
- Minimum 0.8A Switch Peak Current Limit
- Regulated Output Voltage in Down Mode
- True Disconnection During Shutdown
- Up to 80% Efficiency at 100μA Load with 3.8V VIN and 5V Output
- Up to 93% Efficiency
- 1.15mm x 0.83mm WCSP6 package

Device Information

ET 82099 X

X Output Voltage					
/	Adjustable by resistive divider	2	2.5V fixed output	3	3.0V fixed output
		4	3.3V fixed output	5	3.6V fixed output
		6	4.5V fixed output	7	5.0V fixed output

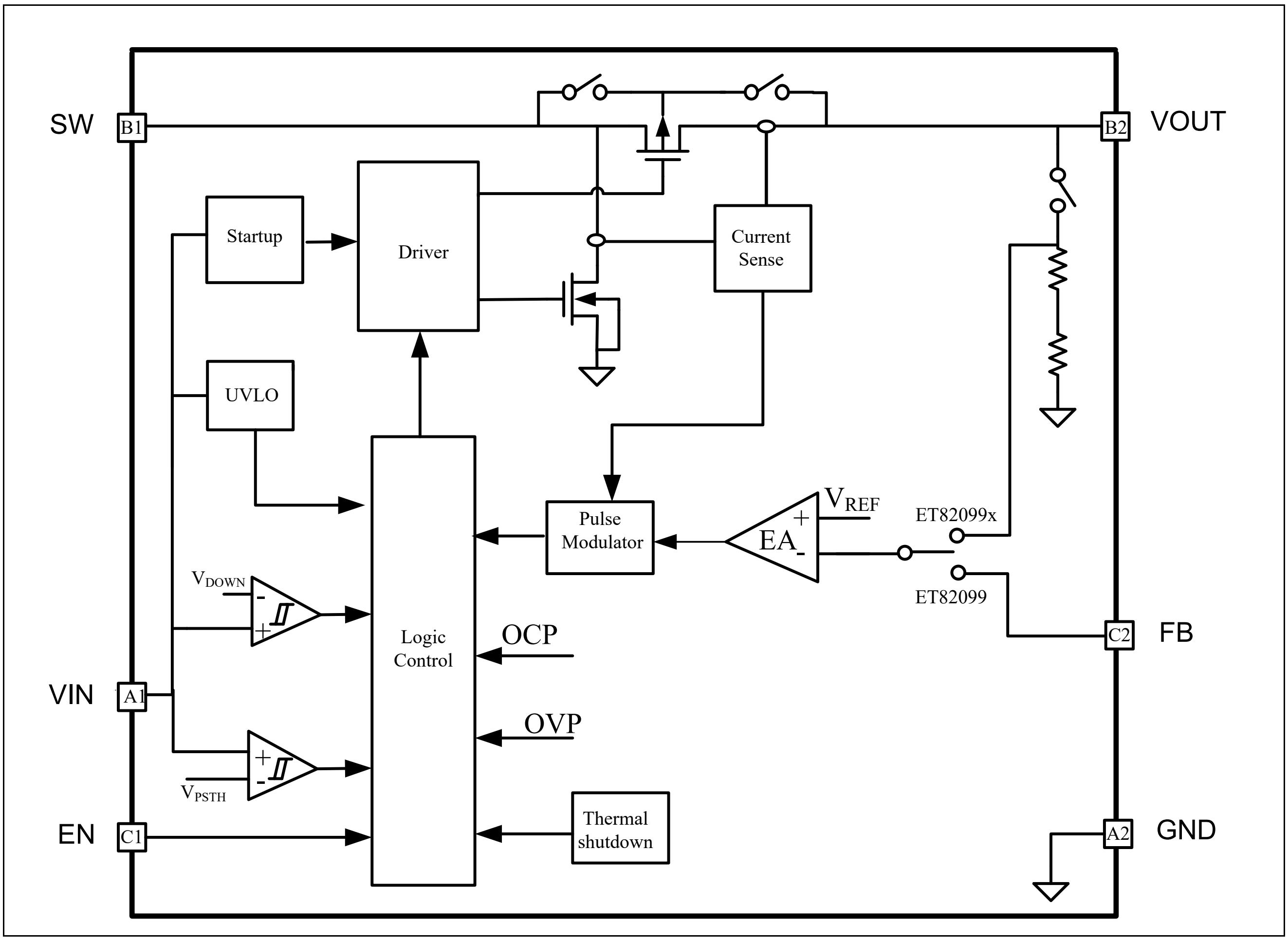
Pin Configuration



Pin Function

Pin Name	Pin No.	Type	Description
VIN	A1	IN	IC power supply input
SW	B1	PWR	Switch pin of the converter
EN	C1	IN	Enable logic input, Logic high voltage enables the device; logic low voltage disables the device.Don't let it floating
GND	A2	PWR	Ground
VOUT	B2	PWR	Boost converter output.
FB	C2	IN	Voltage feedback of adjustable output voltage. Connect to GND pin for fixed output voltage versions.

Block Diagram



Functional Description

Boost Controller Operation

The ET82099x 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 300mA 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 VOUT 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 0.4V. A hysteresis of 200mV is added so that the device cannot be enabled again until the input voltage goes up to 0.6V. This function is implemented in order to prevent malfunctioning of the device when the input voltage is between 0.4V and 0.6V.

Enable and Disable

When the input voltage is above UVLO rising threshold and the EN pin is pulled to high voltage, the ET82099x is enabled. When the EN pin is pulled to low voltage, the ET82099x 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 0.5μA input current is consumed in shutdown mode.

Soft Start

After the EN pin is tied to high voltage, the ET82099x 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 200mA during this stage. When the output voltage is charged above approximately 1.6V, the device starts the hysteric current mode operation. The soft start function reduces the inrush current during startup. After VOUT 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 ET82099x is able to start up with 0.7V input voltage with larger than 3kΩ load. However, if the load during startup is so heavy that the ET82099x fails to charge the output voltage above 1.6V, the ET82099x 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

ET82099x 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 ET82099x enters into Down Mode. The peak current is still limited by ILIM cycle-by-cycle in Down Mode. If the output drops below 1.6V, the ET82099x 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 85mA. Once the short condition is removed, the ET82099x goes back to soft start again and regulates the output voltage.

Over Voltage Protection

ET82099x 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 ET82099x exceeds the OVP threshold of 5.8V, the device stops switching. Once the output voltage falls to 0.1V below the OVP threshold, the device starts operating again.

Down Mode Regulation and Pass-Through Operation

The ET82099x 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 VIN>VOUT. 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 V_{IN} ramping up, the ET82099x goes into Down Mode first when $V_{IN}>V_{OUT}$-100mV. It stays in Down Mode until $V_{IN}>V_{OUT}$+0.35V and then goes automatically into Pass-Through operation. In the Pass-Through operation, output voltage follows input voltage.

The ET82099x 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 150mV below the output voltage, returning to normal operation.

Absolute Maximum Ratings

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

Symbol	Parameters	Min	Max	Unit
V_{IN},V_{IO}	VIN, SW, VOUT, FB, EN Voltage range at terminals[(2)]	-0.3	6	V
V_{ESD}	Human Body Model (JEDEC JS-001,All PIN)		±4000	V
	Charged Device Model (JESD22-C101,All PIN)		±1000	V
I_{LU}	Max Latch up current (JESD78E,All PIN)		±300	mA
T_J	Operating junction temperature	-40	150	°C
T_{STG}	Storage temperature range	-65	150	°C

(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.

Electrical Characteristics

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

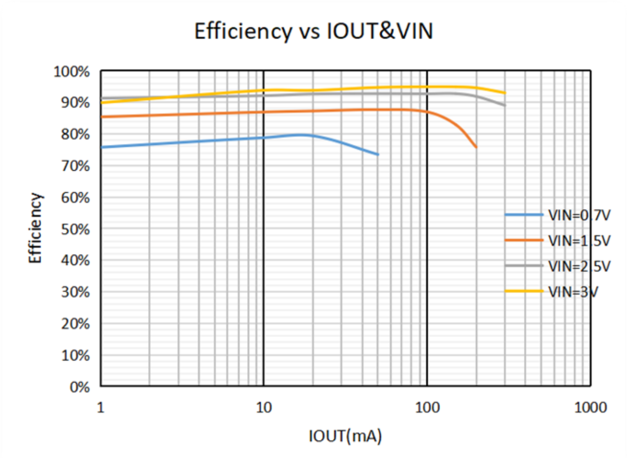
Symbol	Parameters	Test Conditions	Min	Typ	Max	Unit
Power Supply						
V_{IN}	Input voltage range		0.7		5.5	V
V_{UVLO}	Input under voltage lockout threshold	V_{IN} rising		0.6	0.7	V
I_Q	Quiescent current into VIN pin	EN = H, no Load, no Switching T_A = -40°C to 85°C		0.25	1.1	uA
	Quiescent current into VOUT pin (ET82099)	EN = H, no Load, no Switching, Boost or Down Mode T_A = -40°C to 85°C	0.2	0.5	1.5	uA
	Quiescent current into VOUT pin (ET82099x)	EN = H, no Load, no Switching, Boost or Down Mode T_A = -40°C to 85°C	3	3.5	4.5	uA
I_{SD}	Shutdown current into VIN pin	EN = L, V_{IN} = 3.7V, V_{OUT} = 0V, T_A = -40°C to 85°C		0.5	1.4	uA
Output						
V_{OUT}	Output voltage range		1.8		5.5	V
V_{OUT} Accuracy	ET820997	V_{IN} < V_{OUT}, PWM mode	4.9		5.1	V
		V_{IN} < V_{OUT}, PFM mode		5.15		V
	ET820996	V_{IN} < V_{OUT}, PWM mode	4.4	4.5	4.6	V
		V_{IN} < V_{OUT}, PFM mode		4.63		V
	ET820995	V_{IN} < V_{OUT}, PWM mode	3.53	3.6	3.67	V
		V_{IN} < V_{OUT}, PFM mode		3.71		V
	ET820994	V_{IN} < V_{OUT}, PWM mode	3.23	3.3	3.37	V
		V_{IN} < V_{OUT}, PFM mode		3.4		V
	ET820993	V_{IN} < V_{OUT}, PWM mode	2.94	3	3.06	V
		V_{IN} < V_{OUT}, PFM mode		3.1		V
	ET820992	V_{IN} < V_{OUT}, PWM mode	2.45	2.5	2.55	V
		V_{IN} < V_{OUT}, PFM mode		2.58		V
V_{REF}	Feedback reference voltage	ET82099 V_{IN} < V_{OUT}, PWM mode	0.98	1	1.02	V
V_{OVP}	Output over-voltage protection threshold	V_{OUT} rising	5.6	5.8	6	V
I_{FB_LKG}	Leakage current into FB pin	V_{FB} = 1.0V		10	50	nA

Electrical Characteristics (Continued)

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

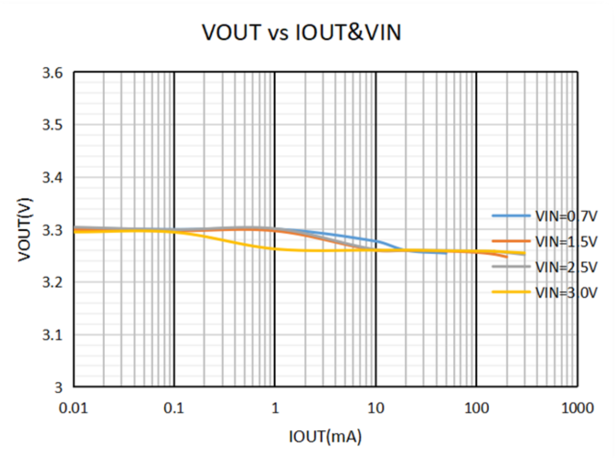
Symbol	Parameters	Test Conditions	Min	Typ	Max	Unit
Power Switch						
$R_{DS(on)\_LS}$	Low side switch on resistance	V_{OUT} = 3.3V		300		mΩ
$R_{DS(on)\_HS}$	Rectifier on resistance	V_{OUT} = 3.3V		350		mΩ
I_{LH}	Inductor current ripple	V_{OUT} = 3.3V		300		mA
I_{LIM}	Current limit threshold	V_{OUT} ≥ 2.5V, boost operation		1		A
I_{SW_LKG}	Leakage into SW Pin (No switching)	V_{SW} = 5.0V, no switch, T_A = -40°C to 85°C			200	nA
Control Logic						
V_{IL}	EN input low voltage threshold	V_{IN} ≤ 1.5V	0.2×V_{IN}			V
		V_{IN} > 1.5V	0.4			V
V_{IH}	EN input high voltage threshold	V_{IN} ≤ 1.5V			0.8×V_{IN}	V
		V_{IN} > 1.5V			1.2	V
I_{EN_LKG}		V_{EN} = 5.0V			50	nA
T_{OTP}	Over temperature protection			150		ºC
T_{OTP_HYS}	Over temperature hysteresis			25		ºC

Typical Characteristics



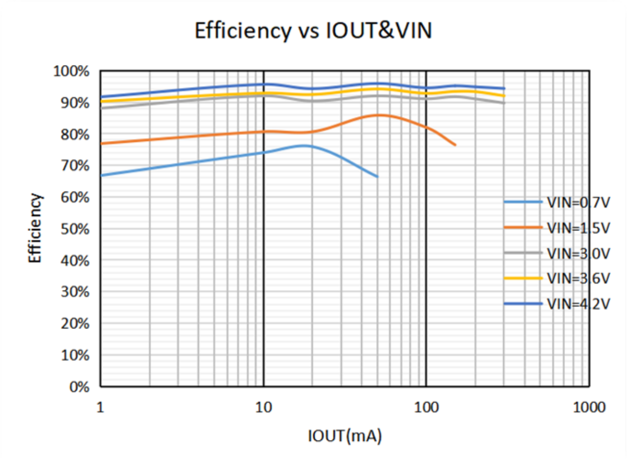
V_{IN}=0.7V,1.5V,2.5V,3.0V,V_{OUT}=3.3V

Figure1.Load Efficiency with Different Input



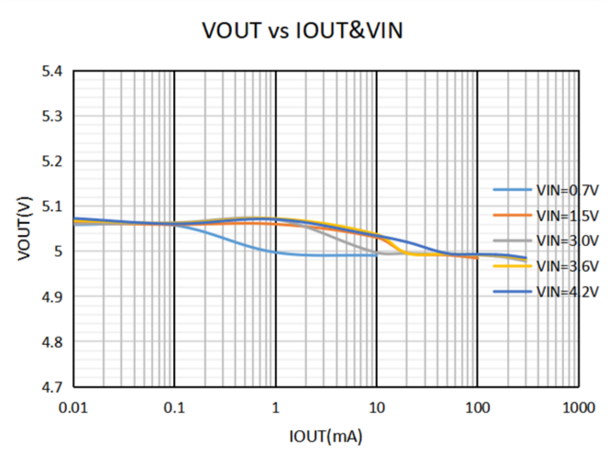
V_{IN}=0.7V,1.5V,2.5V,3.0V,V_{OUT}=3.3V

Figure2.Load Regulation



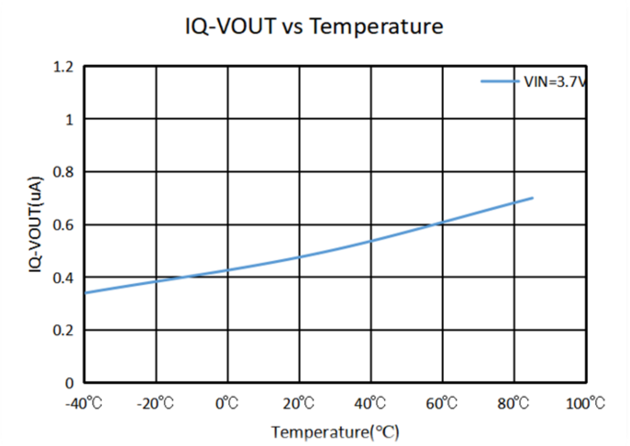
V_{IN}=0.7V,1.5V,3.0V,3.6V,4.2V,V_{OUT}=5.0V

Figure3.Load Efficiency with Different Input



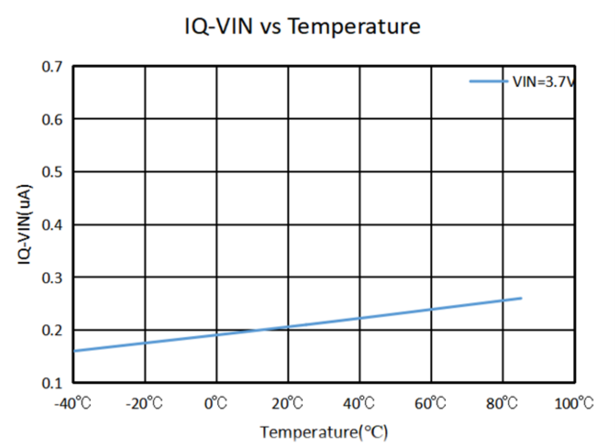
V_{IN}=0.7V,1.5V,3.0V,3.6V,4.2V,V_{OUT}=5.0V

Figure4.Load Regulation



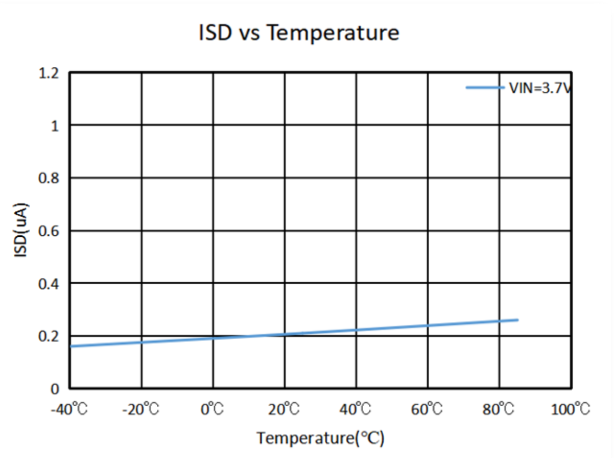
V_{IN}=3.7V,V_{OUT}=5.0V,No Switching

Figure5.Quiescent Current into V_{OUT} vs Temperature



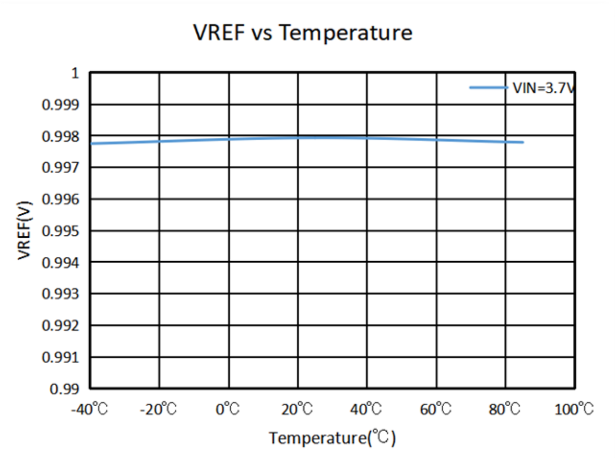
V_{IN}=3.7V,No Switching

Figure6.Quiescent Current into V_{IN} vs Temperature



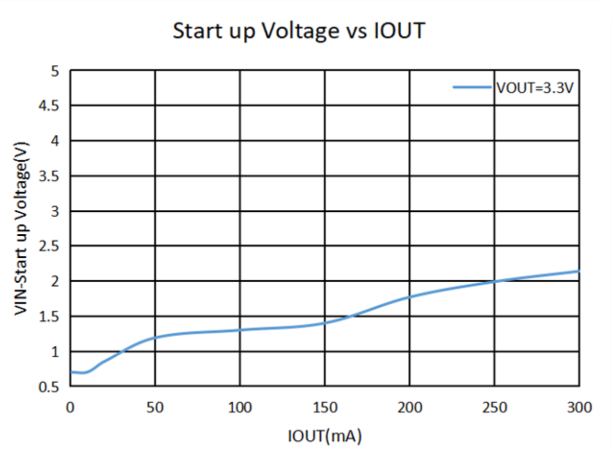
V_{IN}=3.7V,Into V_{IN} and SW

Figure7.Shutdown Current vs Temperature



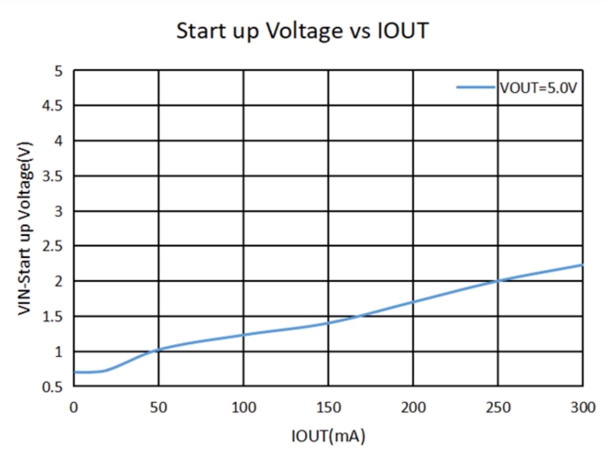
ET82099,V_{IN}=3.7V T_A=-40℃~85℃

Figure8.Reference Voltage vs Temperature



V_{OUT}=3.3V,V_{EN}=3.0V,V_{IN} Start up

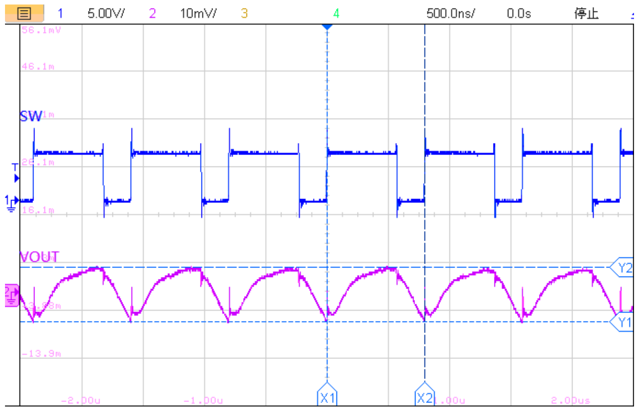
Figure9.V_{IN} Start up Voltage vs Different I_{OUT}



V_{OUT}=5.0V,V_{EN}=5.0V,V_{IN} Start up

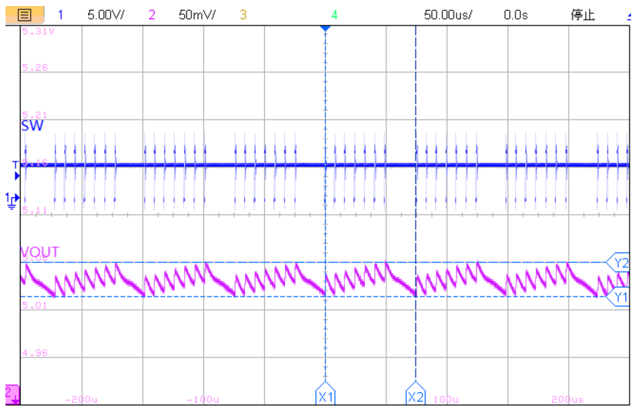
Figure10.V_{IN} Start up Voltage vs Different I_{OUT}

Application Curves



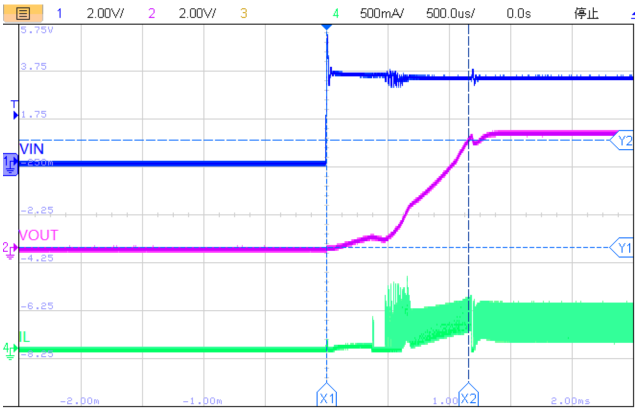
V_{IN}=3.7V V_{OUT}=5V I_{OUT}=300mA

Figure11.Switching Waveform at Heavy Load



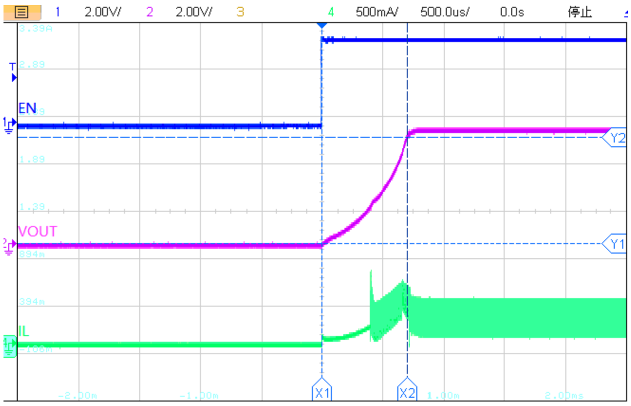
V_{IN}=3.7V V_{OUT}=5V I_{OUT}=10mA

Figure12.Switching Waveform at Light Load



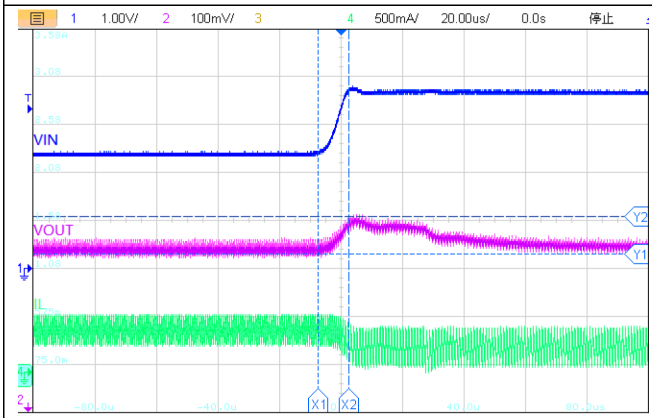
V_{IN}=3.7V V_{OUT}=5V R_{OUT}=25Ω

Figure13.Startup by V_{IN}



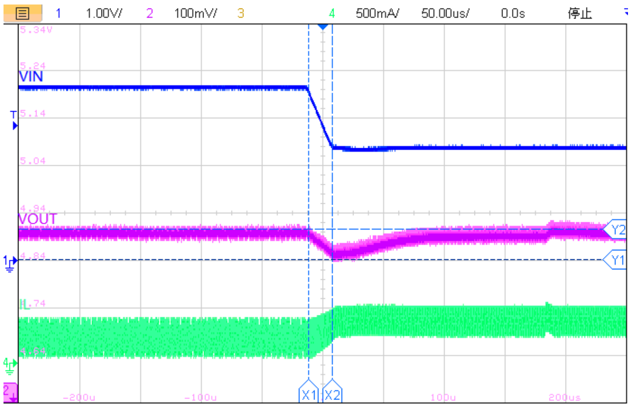
V_{IN}=3.7V V_{OUT}=5V R_{OUT}=25Ω

Figure14.Startup by EN



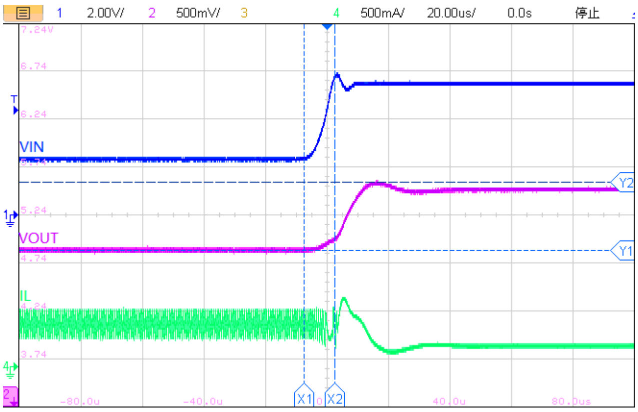
V_{IN}=2.4V to 3.7V V_{OUT}=5V I_{OUT}=200mA

Figure15.Line Transient



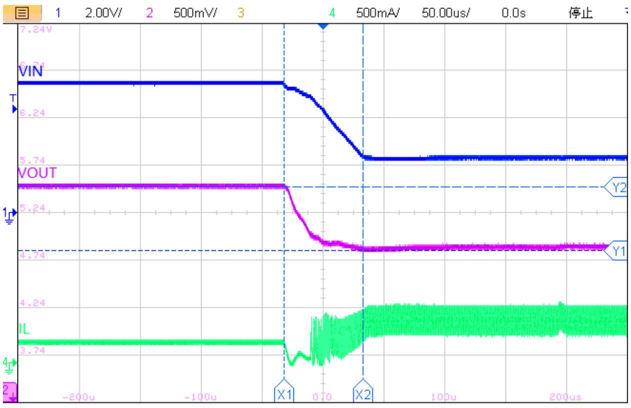
V_{IN}=3.7V to 2.4V V_{OUT}=5V I_{OUT}=200mA

Figure16.Line Transient



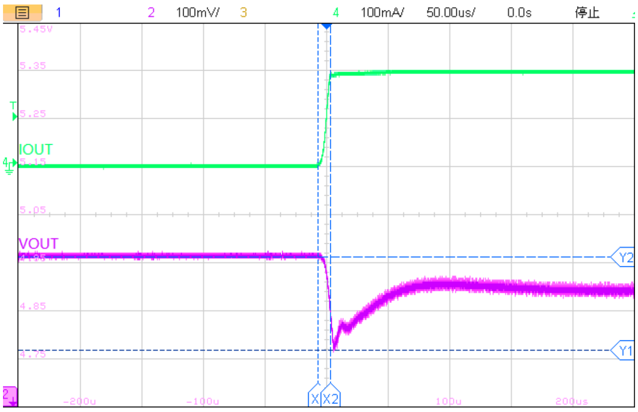
V_{IN}=2.4V to 5.5V V_{OUT}=5V I_{OUT}=200mA

Figure17.Line Transient



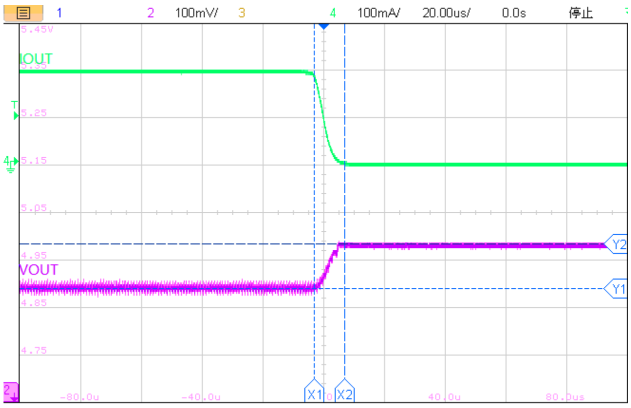
V_{IN}=5.5V to 2.4V V_{OUT}=5V I_{OUT}=200mA

Figure18.Line Transient



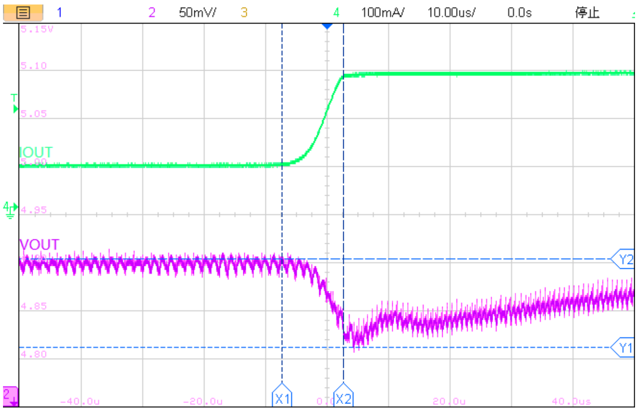
V_{IN}=3.7V V_{OUT}=5V I_{OUT}=0mA to 200mA

Figure19.Load Transient



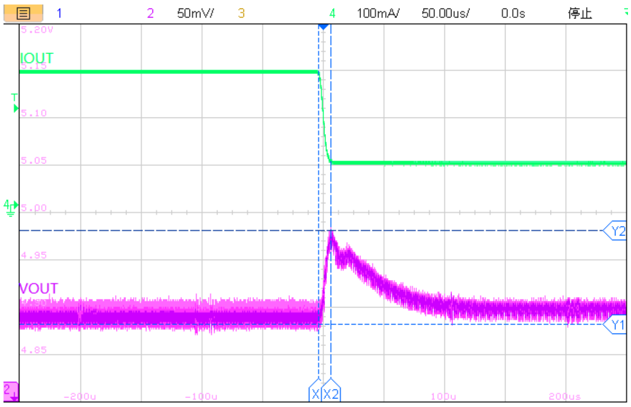
V_{IN}=3.7V V_{OUT}=5V I_{OUT}=200mA to 0mA

Figure20.Load Transient



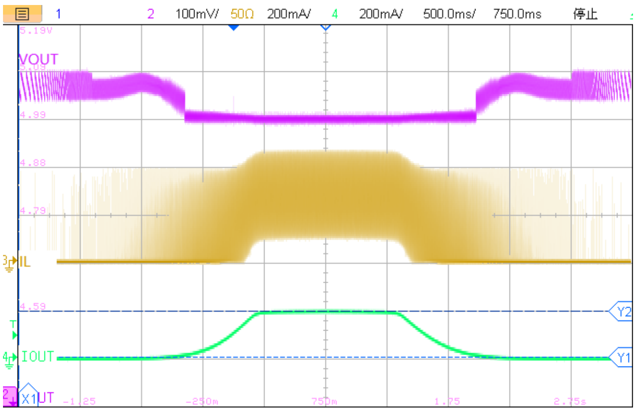
V_{IN}=3.7V V_{OUT}=5V I_{OUT}=100mA to 300mA

Figure21.Load Transient



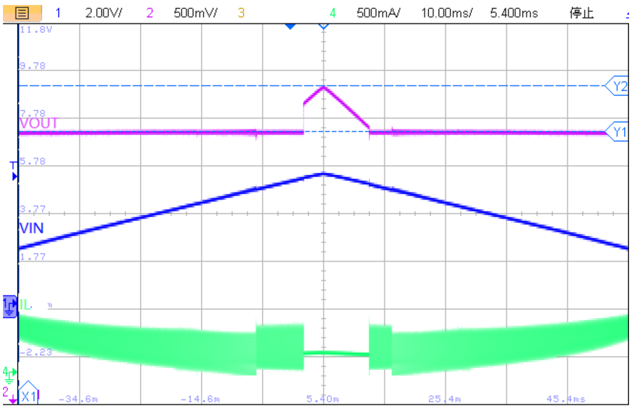
V_{IN}=3.7V V_{OUT}=5V I_{OUT}=300mA to 100mA

Figure22.Load Transient



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

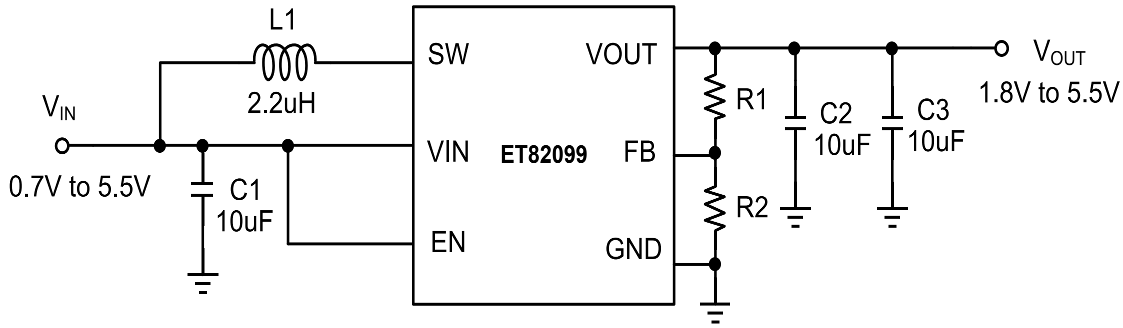
Figure23.Load Transient



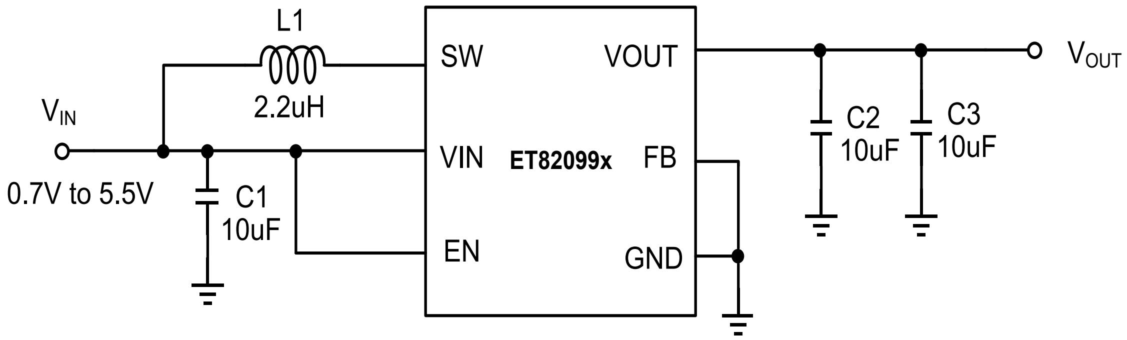
V_{IN}=2.4V to 5.5V V_{OUT}=5V I_{OUT}=200mA

Figure24.Line Transient

Application Circuits



ET82099 Application Circuit



ET82099x Application Circuit

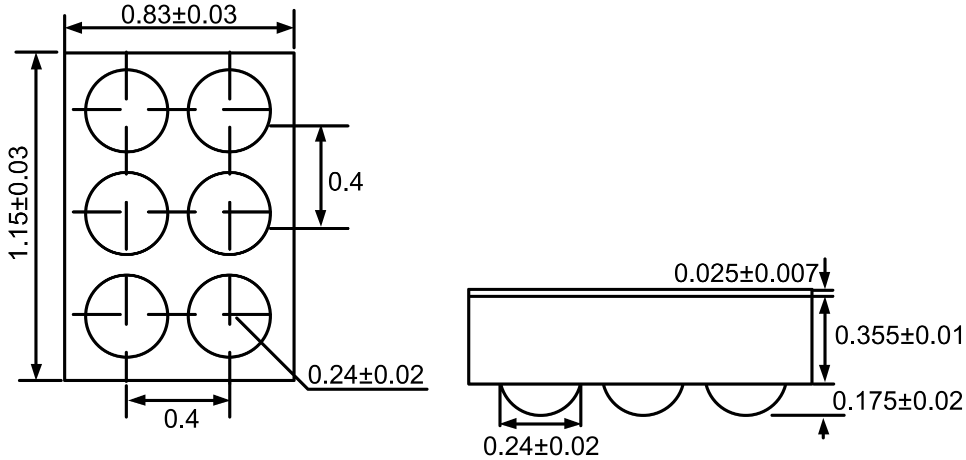
*** :** ET82099 $V_{OUT}=V_{REF}\times(1+R1/R2), V_{REF}=1V$

Application Recommend

Part No.	Output Voltage	R1	R2
ET82099	2.50V	374kΩ	249kΩ
	3.00V	499kΩ	249kΩ
	3.31V	576kΩ	249kΩ
	3.61V	649kΩ	249kΩ
	4.48V	866kΩ	249kΩ
	5.02V	1000kΩ	249kΩ

Package Dimension

WLCSP6



Revision History and Checking Table

Version	Date	Revision Item	Modifier	Function & Spec Checking	Package & Tape Checking
0.0	2020-03-12	Preliminary Version	Xielh	Xielh	Zhujl
0.1	2020-12-15	Update Package Size	Xielh	Xielh	Zhujl
1.0	2021-5-7	Initial Version	Xielh	Xielh	Zhujl
1.1	2021-10-9	Add Part No. Information	Xielh	Xielh	Zhujl
1.2	2022-6-10	Add Part Information and Typical Characteristics	Xielh	Xielh	Zhujl
1.3	2022-6-20	Update Typesetting	Shibo	Xielh	Zhujl
1.4	2024-2-21	Update AMR	LiuCong	Xielh	Zhujl