Adjustable Current Limit Load Switch

General Description

The ET2097A is a precision adjustable current-limited load switch for USB PD application. It features True Reverse-Current Blocking (TRCB) capability to isolate the output from the system. The 29V tolerance on VBUS pin ensures the device is able to work on a USD PD port. A current limit input (ILIM) pin defines the over-current limit threshold from 640mA to 3.3A. The internal switch features low 32mΩ on-resistance and operate from a 4.0V to 5.5V input voltage range. ET2097A also has under-voltage protection and over-temperature protection.

ET2097A is available in an ultra-small WLCSP16 (1.932mm ×1.932mm) package .

Features

- V_{IN} Operating Range from 4.0V to 5.5V
- All Time Reverse Current Protection with Ultra Fast RCP Recovery
- Absolute Maximum Voltage of VBUS up to 29V
- Adjustable Current Limit from 640mA to 3.3A
- Clamped Current Output in Over-Current Condition
- Typical R_{ON} is 32mΩ N-Channel MOSFET
- Over Temperature Protection
- Surge Protection

  --IEC61000-4-5 Exceeds ±80V on VBUS
- ESD Protection

  -- HBM ESDA/JEDEC JS-001-2024 Exceeds ±2kV

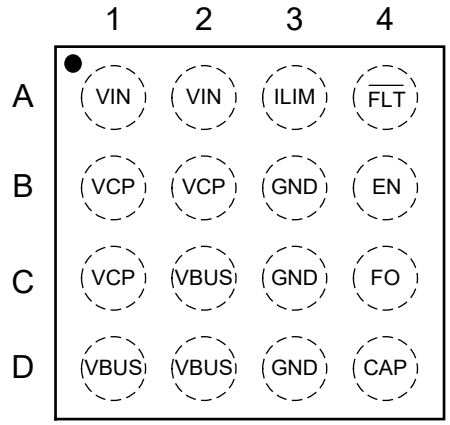
  -- CDM ESDA/JEDEC JS -002-2022 Exceeds ±500V
- Part No. and Package Information

Part No.	Package	Packing Option	MSL
ET2097A	WLCSP16 (1.932mm ×1.932mm)	Tape and Reel, 3K/Reel	1

Application

- Notebook, Ultra-Book and Desktop
- USB PD and Type-C Port/Hubs
- Tablet and Smart Phone

Pin Configuration

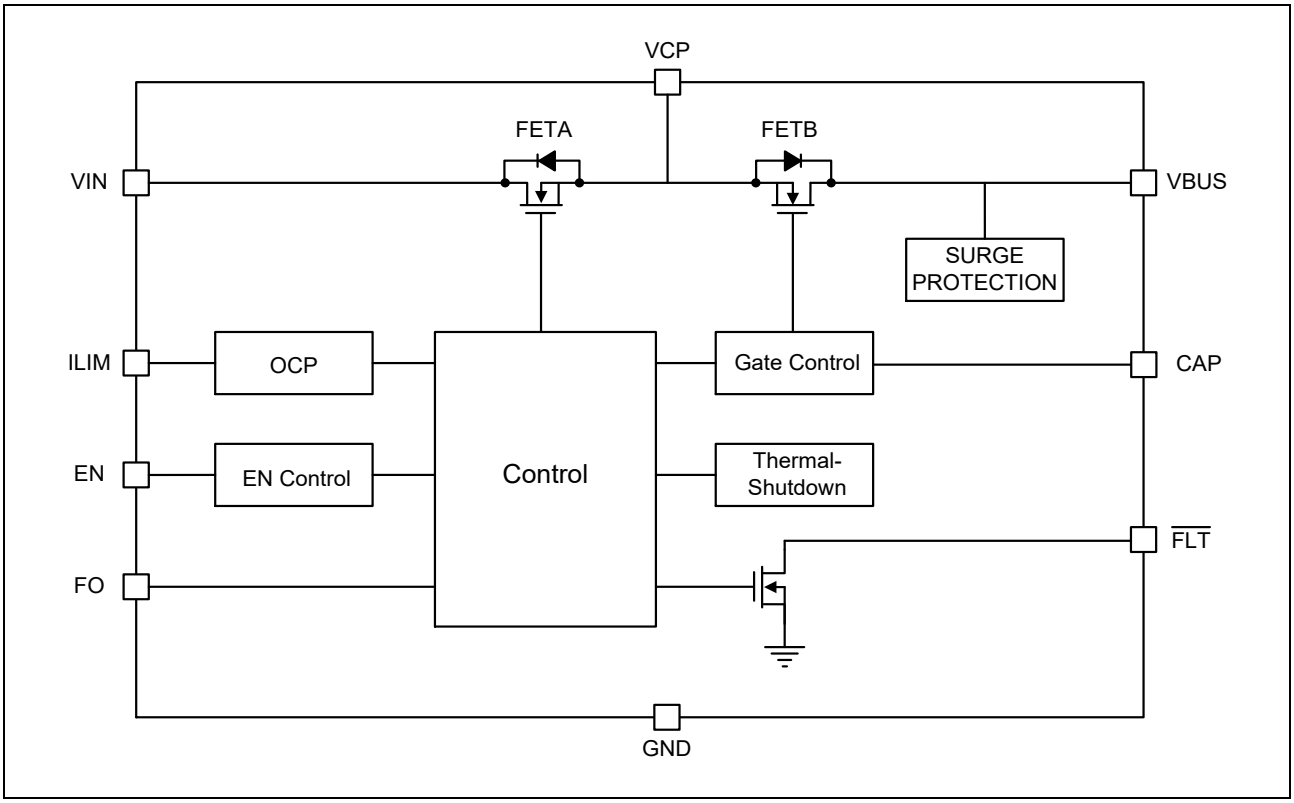


TOP VIEW

Pin Function

Pin	Name	Description
A1,A2	VIN	Voltage Input.
B1,B2,C1	VCP	Central point of two power MOSFETs.
C2,D1,D2	VBUS	Voltage Output.
A3	ILIM	Current limit programming pin. Connecting a resistor to GND to set the limiting current threshold.
B3,C3,D3	GND	Ground Pin.
A4	$\overline{FLT}$	Fault Indicator Pin. (Open Drain Output)
B4	EN	Enable Input Pin. (Active High)
C4	FO	Fast turn on Input Pin. (Active High)
D4	CAP	Connecting a capacitor to GND.

Block Diagram



Functional Description

Fast Recovery Reverse-Current Protection (RCP)

The ET2097A is a programmable current limit switch for USB PD application. A fast RCP recovery circuit has been added to the switch to prevent reverse current flowing back to power source at all time. ET2097A uses dynamic gate drive control loop to implement reverse-current protection. During normal operation, device will always try to regulate the V_{BUS} output voltage to be V_{IN}-70mV. When the load current produces a drop voltage greater than 70mV, the gate control loop will drive the power MOS to lower its Rdson to try to achieve the 70mV.

In the heavy load condition, the gate control loop will keep increasing the gate driving current of the MOSFET until it is fully on and will remain fully on if the voltage drop at that time still exceeds 70mV.

In light load condition, when the drop voltage is below 70mV, the gate control loop will reduce the gate driving current to increase the Rdson to try to achieve the 70mV drop voltage, which leads to the complete shutdown of the power MOSFET in reverse voltage condition.

If V_{BUS} voltage is higher than V_{IN} when enabling the device, the power MOSFET will never turn on. The device will always do pre-check before switching on the power MOSFETs. In the RCP state, EN is High; when the V_{BUS} drops below V_{IN}, the device will exit the RCP state and turn on the power FET again within 60μs. The fast recovery of the power MOSFET is assisted by the external boost capacitor at CAP pin. The boost capacitor will be charged whenever EN is pulled High.

Input Capacitor

To limit the voltage drop on the input supply caused by transient inrush current when the switch turns on into a discharged load capacitor or short-circuit, a capacitor 10μF or lager must be placed between the VIN and GND pins.

Output Capacitor

A 10μF or lager capacitor should be placed between the VBUS and GND pins.

EN Input

When the EN is set Low, ET2097A will be disabled, the device will enter low power mode disabling all protection circuits and setting the $\overline{FLT}$ output high impedance. When EN is set High, all protection circuits will be enabled and then, if no fault condition exists, the main power MOSFETs will be turn on.

Fast Turn ON

In order to reduce the power on inrush current, ET2097A has deployed slew rate control for normal turn on; there will be around 1.5ms rising time. However, in the quick-swap application, fast turn on is requested. A customer can achieve this by pulling FO pin High. By doing this, rise time will be reduced to the 50μs level. There is an internal 1MΩ pull-down resister on this pin.

ILIM

The over-current protection circuit's (OCP) trigger value I_{OCP} can be set using an external resistor R_{ILIM} connected between ILIM pin and GND pin. When EN is set High and the ILIM pin is grounded, the N-channel MOSFET will be disabled and the $\overline{FLT}$ output set Low.

$\overline{FLT}$ Output

The $\overline{FLT}$ output is an open-drain output that requires an external pull-up resistor. The $\overline{FLT}$ output will be set Low to indicate an OCP or OTP condition has occurred. The $\overline{FLT}$ output will return to the high impedance state automatically once the fault condition is removed. An internal 10ms de-glitch circuit for the over-current protection is used when entering fault conditions. Over temperature condition doesn't have de-glitch time, the $\overline{FLT}$ signal will be asserted immediately. The RCP circuit won't trigger $\overline{FLT}$ signal.

Under-Voltage Lock-Out (UVLO)

Independently of the logic level on the EN pin, the under-voltage lockout circuit disables the N-channel MOSFET and enters low power mode until the input voltage reaches the UVLO turn-on threshold $V_{UVLO.}$

Over-Current Protection (OCP)

In the over-current condition, because the device clamps the output current rather than completely shut down the switch, the power dissipation on the device might be increased which could lead to over temperature protection.

Short Circuit Protection (SCP)

If the device senses I_{SW} > 10A when enabled, a short circuit is detected. The device disables the N-channel MOSFET immediately. It then enables the N-channel MOSFET again, output current is limited and after the de-glitch time the $\overline{FLT}$ output is set Low. Thermal protection will be triggered due to the big power consumption on the device.

Over Temperature Protection (OTP)

If the device temperature exceeds 140°C when EN is set High, the over-temperature protection (OTP) circuit will disable the Power MOSFET and indicate a fault condition by setting the $\overline{FLT}$ pin Low. Any transition on the EN pin will have no effect. Once the device temperature decreases to below 115°C the device will return to the defined state.

In the over-current limiting condition, the increased power dissipation on the device will result the OTP, especially in the output short to GND error.

Absolute Maximum Ratings

Stresses exceeding the absolute maximum ratings may damage the device. The device may not function or be operable above the recommended operating conditions and stressing the parts to these levels is not recommended. In addition, extended exposure to stresses above the recommended operating conditions may affect device reliability. The absolute maximum ratings are stress ratings only.

Symbol	Parameters		Min	Max	Unit
V_{IN}	VIN to GND		-0.3	6	V
V_{BUS}	VBUS to GND		-0.3	29	V
V_{CAP}	CAP to GND		-0.3	12	V
V_{OTHERS}	ILIM, EN, FO, $\overline{FLT}$ to GND		-0.3	6	V
I_{SW1}	Maximum Continuous Current of Switch IN-OUT			3.6	A
P_D	Power Dissipation			1.5	W
T_{STG}	Storage Junction Temperature		-65	+150	°C
T_A	Operating Temperature Range		-40	+85	°C
T_J	Junction Temperature		-40	+125	°C
T_{SOLD}	Soldering Temperature (Reflow).			+260	°C
V_{ESD}	Electrostatic Discharge Capability	Human Body Model, ESDA/JEDEC JS-001-2024	-2	+2	KV
		Charged Device Model, ESDA/JEDEC JS-002-2022	-0.5	+0.5	V

Recommended Operating Conditions

Symbol	Parameters	Conditions	Min	Max	Unit
V_I	Input Voltage	V_{IN}	4.0	5.5	V
		V_{EN};V_{FO}	0	5.5	V
		V_{BUS} (OFF state)	0	23	V
V_O	Output Voltage	V_{BUS} ; $V_{\overline{FLT}}$	0	5	V
I_{SW}	Switch Current	T_A =-40°C to 85°C	0	3	A
$I_{O(SINK)}$	Output Sink Current	$\overline{FLT}$	0	10	mA
R_{ILIM}	Current Limit Resistance	I_{LIM} to GND	16	100	kΩ
C_{BUS}	V_{BUS} Output Capacitance	V_{BUS} to GND	10	100	μF
T_A	Ambient Temperature		-40	+85	°C

Electrical Characteristics

Unless otherwise noted, typical values are at V_{IN}=5V and T_A=25°C.

Symbol	Parameters	Conditions	Min	Typ	Max	Unit
Basic Operation						
V_{IN}	Input Voltage		4.0		5.5	V
V_{IH}	EN; FO; High-Level Input Voltage	V_{IN} = 4.0V to 5.5V;	1.2		5.5	V
V_{IL}	EN; FO; Low-Level Input Voltage	V_{IN} = 4.0V to 5.5V;	0		0.4	V
I_I	EN; FO; Input Leakage Current	V_{IN} = 5V;		5	10	μA
I_S	V_{IN} Standby Current	EN=GND, V_{IN}=5V, V_{BUS} Floating	2	4	40	μA
I_{IN}	V_{IN} Quiescent Current	EN=V_{IN}=5V, V_{BUS} Floating, R_{LIM}=33KΩ	0.4	0.85	1.65	mA
I_{OFF1}	V_{BUS} OFF-State Leakage Current	V_{IN}=5V;V_{BUS}=0V; EN=GND (2)	-5	-0.1		μA
	V_{IN} OFF-State Leakage Current	V_{BUS}=5V;V_{IN}=0V; EN=GND (2)	-2	-0.1		μA
		V_{BUS}=20V;V_{IN}=0V; EN=GND (2)	-2	-0.1		μA
$I_{S(ON)}$	FET-B Leakage Current in RCP	EN=5V, V_{IN}=5V, V_{BUS}=20V (1)(2)	-2	-0.1		μA
V_{UVLO}	Under Voltage Lockout Threshold	V_{IN} rising	3.3	3.6	3.8	V
V_{UVLO_HYS}	UVLO Hysteresis		50	100	250	mV
R_{ON}	On-Resistance of Switch V_{IN}-V_{BUS}	V_{IN}=5.0V,I_O=2.5A, R_{FETA}+R_{FETB}	20	32	42	mΩ
		T_A =-40°C to 85°C	15		49	mΩ

Electrical Characteristics (Continued)

Unless otherwise noted, typical values are at V_{IN}=5V and T_A=25°C.

Symbol	Parameters	Conditions	Min	Typ	Max	Unit
R_{PD}	EN; FO; Pull-Down Resistance	V_{IN}=5V,	0.6	1	1.6	MΩ
V_{OL}	Low-Level Output Voltage	$\overline{FLT}$;I_O=4mA	0.01		0.3	V
Current Limit						
I_{OCP}	Over-Current Protection Threshold	R_{ILIM}=54KΩ	980	1100	1320	mA
		R_{ILIM}=33KΩ(3)	1505	1650	1830	mA
		R_{ILIM}=24.5KΩ	2145	2200	2400	mA
		R_{ILIM}=20KΩ (1)	2450	2640	2920	mA
		R_{ILIM}=16KΩ(1)	3020	3300	3500	mA
Dynamic characteristics						
t_{TLH}	Switch Turn-On Time	R_L=100Ω, C_L=10μF, FO=GND,V_{IN}=5V V_{BUS} from 10%V_{IN} to 90%V_{IN}	0.3	1.5	2.5	ms
		R_L=100Ω,C_L=10μF, V_{IN}=FO=5V, V_{BUS} from 10%V_{IN} to 90%V_{IN}		50	100	μs
t_{THL}	Switch Turn-Off Time	R_L=100Ω, C_L=10μF, V_{BUS} from 90%V_{IN} to 10%V_{IN}	1	2.2	4	ms
t_{EN}	Enable Time	R_L=100Ω, C_L=10μF, FO=GND,see Figure 1	0.2	0.75	1.6	ms
		R_L=100Ω, C_L=10μF, FO=5V,see Figure 1		60		μs
t_{DIS}	Disable time	R_L=100Ω, C_L=10μF, see Figure 1		70		μs
$t_{ON(RCP)}$	RCP Recovery Time	C_L=10μF, EN=High From V_{BUS} Below V_{IN} to FET-B ON (1)	10	30	60	μs
$t_{DIS(RCP)}$	RCP Turn Off Time	FET-B RCP Turn Off Time (1)		0.3	3	μs
t_{DEGL}	De-Glitch Time	From OCP to $\overline{FLT}$ Turn Low	5	10	16	ms
$t_{SHORT(OCP)}$	OCP Short Circuit Protection Response Time	V_{IN}= 5.0V; C_{BUS}=10μF; Measure Current at V_{BUS} Side(1)	1	3	8	μs

Electrical Characteristics (Continued)

Unless otherwise noted, typical values are at V_{IN}=5V and T_A=25°C.

Symbol	Parameters	Conditions	Min	Typ	Max	Unit
Over Temperature Protection(OTP)						
T_{SHDN}	Thermal Shutdown(1)	V_{IN}=5V	110	140	160	°C
T_{SHDN_HYS}	Thermal Shutdown Hysteresis(1)	V_{IN}=5V		25		°C

Note1：Guaranteed by design.

Note2：Currents are defined with respect to conventional current flow into the respective terminal. Negative value means the current flows out of the respective terminal of the chip.

Note3：When the load current reaches 85%(Typ) of the current limit value, the FLT signal is triggered.

Timing Waveform

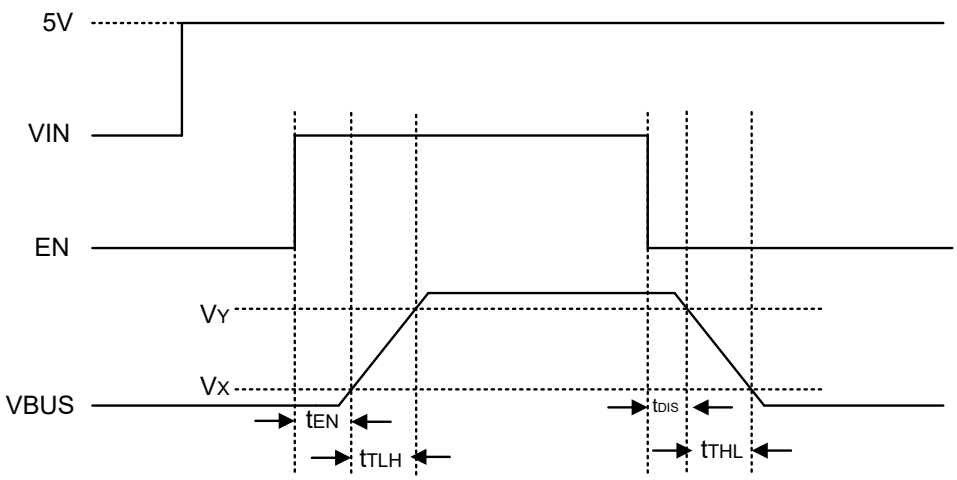


Figure 1. Rise and fall times

Note: V_{IN}=5V,EN=0V to 5V,V_X=10%V_{IN},V_Y=90%V_{IN}.

Typical Characteristics

Unless otherwise noted, typical values are at V_{IN}=5V and T_A=25°C.

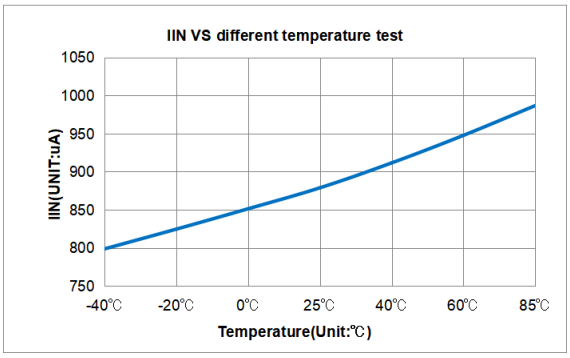


Figure 2.Input Quiescent Current VS Temperature

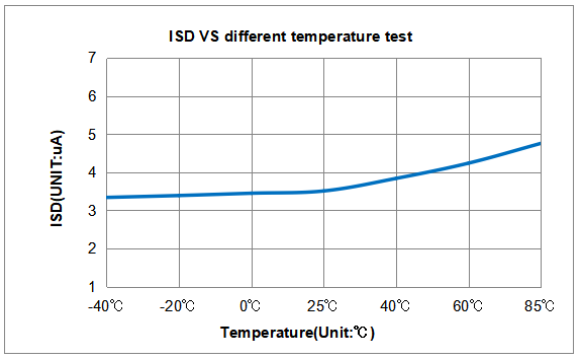


Figure 3.Input Standby Current VS Temperature

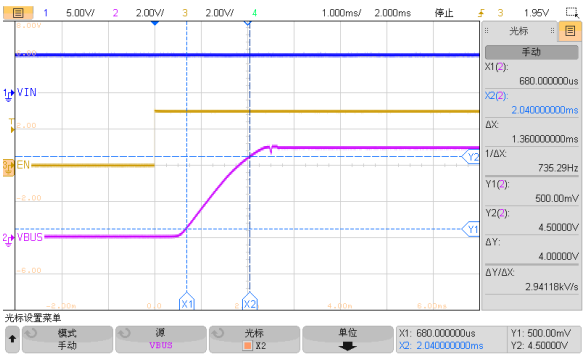


Figure 4.Switch Turn-On Time,V_{IN}=5V,FO=L

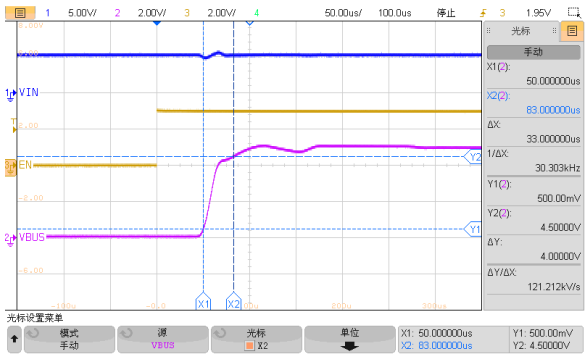


Figure 5.Switch Turn-On Time,V_{IN}=5V,FO=H

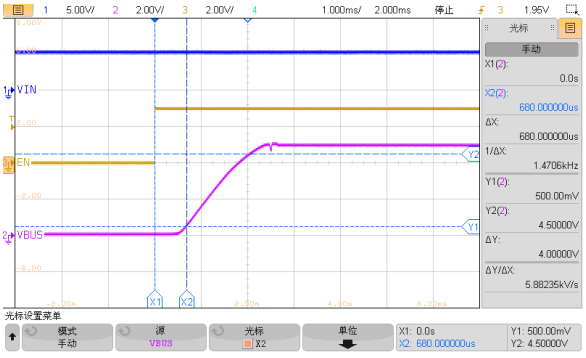


Figure 6.Enable Time,V_{IN}=5V,FO=L

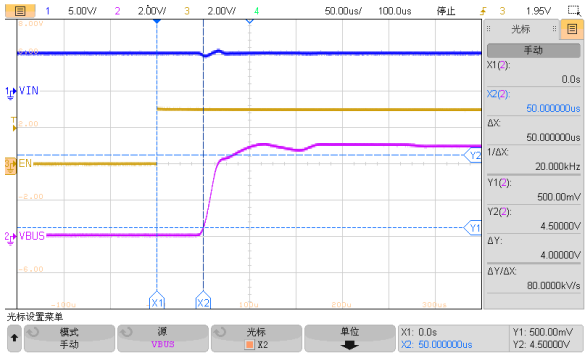


Figure 7.Enable Time,V_{IN}=5V,FO=H

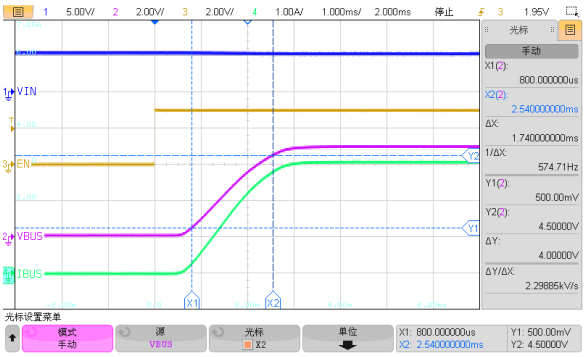


Figure8.Switch Turn-On Time,V_{IN}=5V,FO=L,I_{OUT}=3A

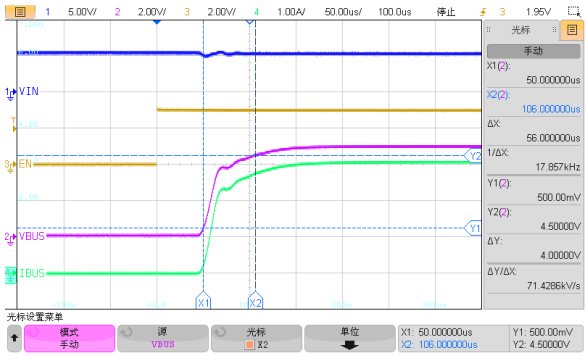


Figure9.Switch Turn-On Time,V_{IN}=5V,FO=H,I_{OUT}=3A

Application Circuits

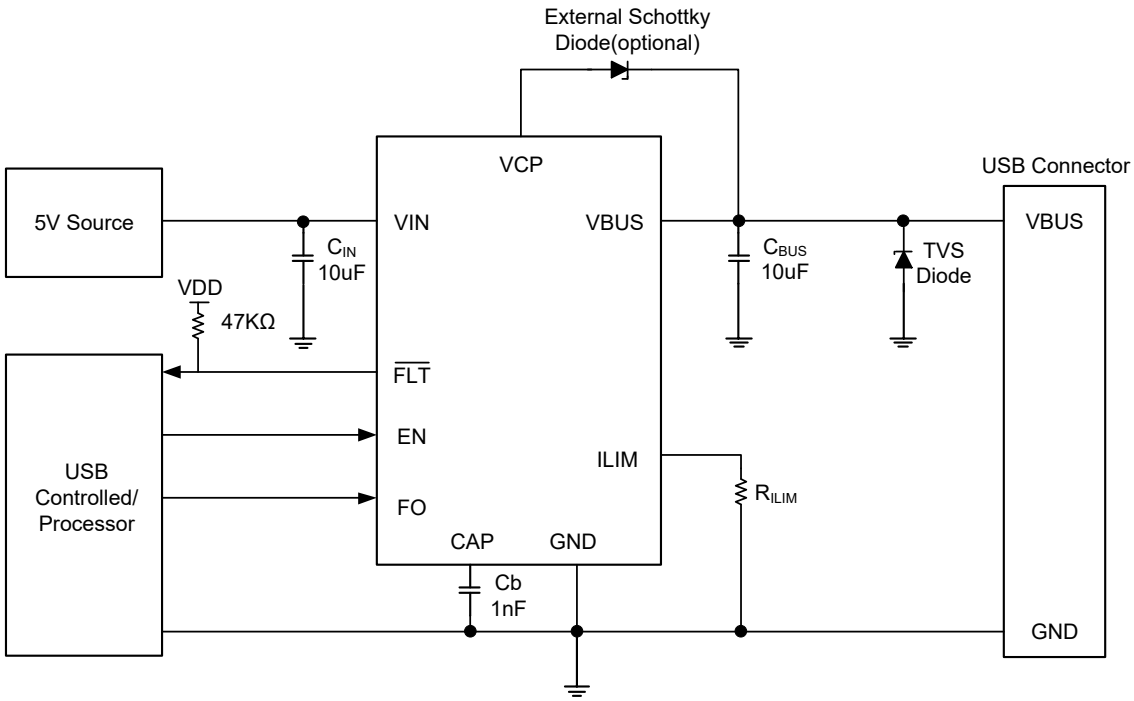
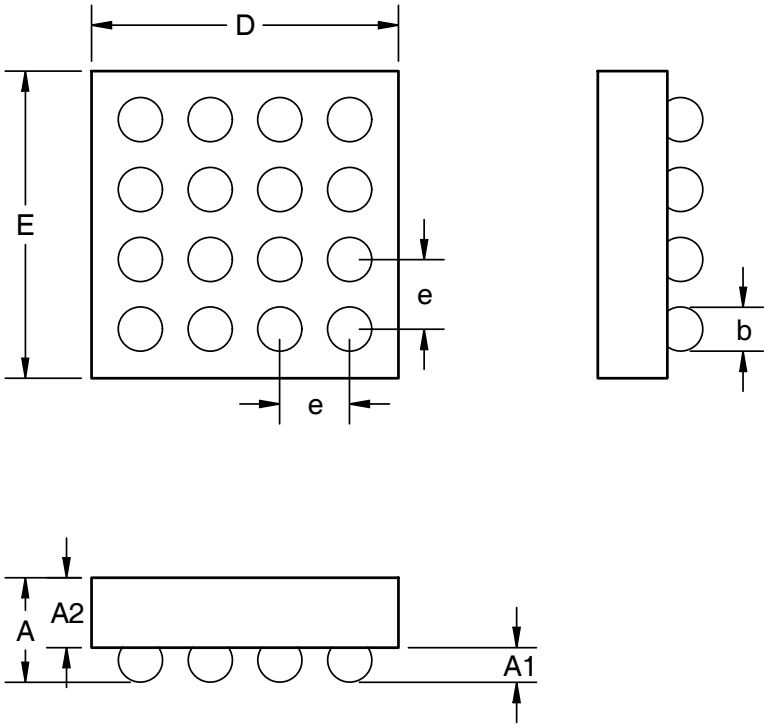


Figure 10. Typical Application Circuit

Note: This electric circuit only supplies for reference.

Package Dimension

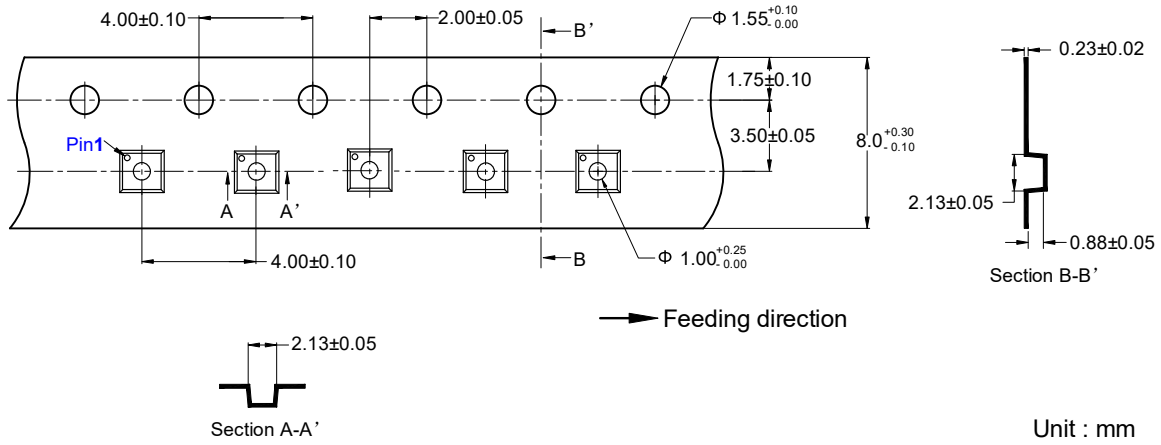
WLCSP16



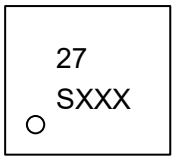
Dimensions Table (Units: mm)

Symbol	Min	Nom	Max
A	0.515	0.555	0.608
A1	0.215	0.240	0.265
A2	0.265	0.290	0.315
b	0.285	0.310	0.335
D	1.902	1.932	1.962
E	1.902	1.932	1.962
e	0.500BSC		

Tape Information



Marking Information



27 - Part Number

SXXX - Tracking Number

Revision History and Checking Table

Version	Date	Revision Item	Modifier	Function & Spec Checking	Package & Tape Checking
1.0	2026-01-28	Initial Version	Cao Jiachen	Zhou Xingyu	Liu jiaying