High-Current Over-voltage Protectors with Adjustable OVLO

General Description

The ET9931 is an advanced 5A unidirectional power switch for USB PD. It includes under voltage lockout, over voltage lockout, reverse current protection and over-temperature protection circuits. It is designed to automatically isolate the power switch terminals when a fault condition occurs. Both VBUS and VINT pins have 29V tolerance in shutdown mode. Two ET9931 chips can be used in parallel to support dual power inputs connecting to the same charging circuit. The device has a default 22V over voltage protection threshold, and the OVP threshold can be adjusted by using an external resistor divider on OVLO pin. A 20ms De-bounce time is deployed every time before the device is switched ON, followed by a soft start to limit the inrush current. Designed for operation from 2.9V to 29V, it is used in USB PD power control applications to offer essential protection and enhance system reliability. ET9931 is offered in a small WLCSP15 (2.530mm ×1.510mm ×0.555mm) package.

Features

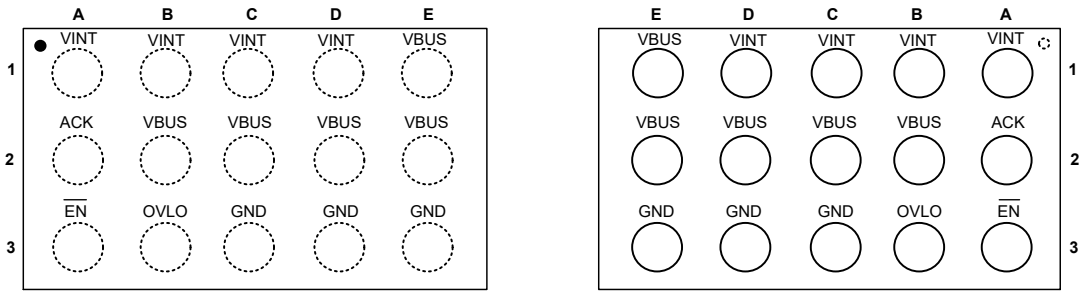
- Wide Voltage Operation: 2.9V to 20V
- I_{SW} Maximum 5 A Continuous Current
- 29V Tolerance on Both V_{BUS} and V_{INT} Pin
- Ultra Low on-Resistance: 27mΩ (TYP)
- Adjustable V_{BUS} Over Voltage Protection
- Built in Slew Rate Control for Inrush Current Limit
- All Time Two Level Reverse-Current Protection
- Protection Circuitry
  - -- Over-Temperature Protection
  - -- Over-Voltage Protection
  - -- Under-Voltage Lockout
  - -- Reverse Current Protection
- Surge protection
  - -- IEC61000-4-5 exceeds ±100V on VBUS Pin
- ESD protection
  - -- IEC61000-4-2 Contact Discharge exceeds 8kV on VBUS Pin
  - -- HBM ESDA/JEDEC JS-001-2023 Class 2 exceeds ±2KV
  - -- CDM ESDA/JEDEC JS-002-2022 exceeds ±500V
- Specified from -40°C to +85°C
- Package Information

Part No.	Package	MSL
ET9931	WLCSP15 (2.53mm × 1.51mm)	Level 1

Application

- Smart and Feature Phones
- Tablets, E-Books
- Notebooks

Pin Configuration



TOP VIEW BOTTOM VIEW

Figure 1. Pin Configuration

Pin Function

Pin	Name	I/O	Description
B2,C2,D2,E1,E2	VBUS	I	VBUS (Power Input)
A1,B1,C1,D1	VINT	O	VINT (Power Output)
B3	OVLO	I	V_{OVLO} Threshold Input
A2	ACK	O	Power Good Acknowledge (Open-drain Output)
C3,D3,E3	GND	O	Ground(0V)
A3	$\overline{EN}$	I	Enable Input (Active Low)

Function Table

Table1:Function Table of Switch 1

$\overline{EN}$	V_{BUS}	V_{INT}	ACK	Operation mode
L	$<V_{UVLO}$	X	Z	UVLO; Switch Open
L	$2.9V<V_{BUS}<V_{OVLO}$	X	L	Enable; Switch Closed
L	X	X	Z	OTP; Switch Open
L	$>V_{OVLO}$	X	Z	OVLO; Switch Open
H	X	X	Z	Disable; Switch Open
X	X	$V_{INT}>V_{BUS}$	Z	RCP; Switch Open

Block Diagram

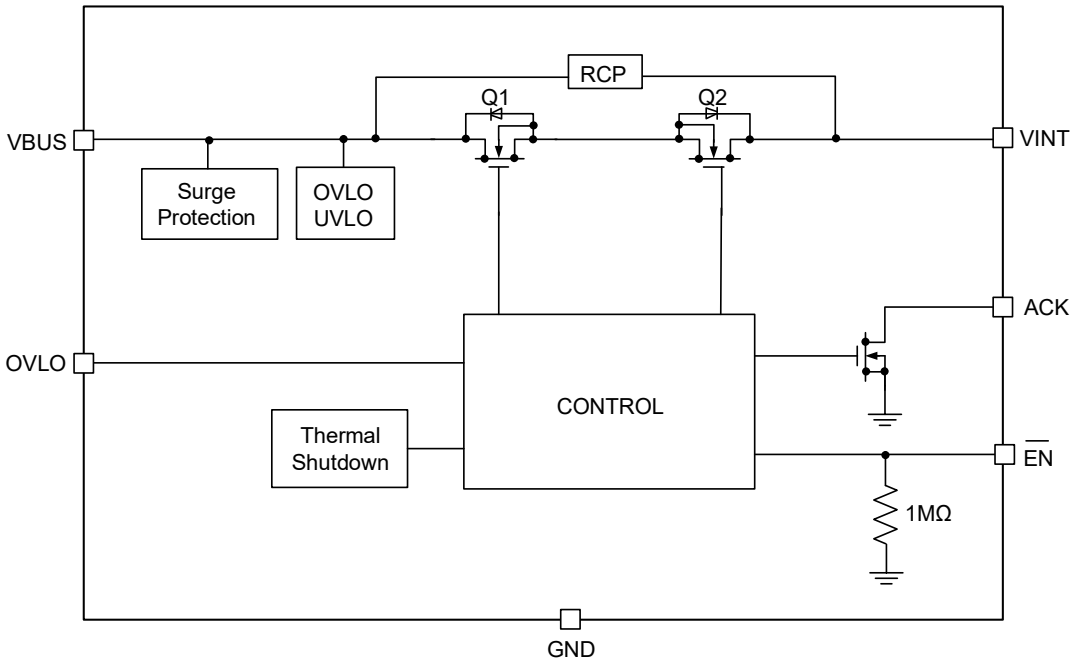


Figure 2. Block Diagram

Functional Description

$\overline{EN}$ Input

A high on $\overline{EN}$ disables the channel MOSFET and all protection circuits, putting the device into Low power mode. A Low on $\overline{EN}$ enables the protection circuits and the MOSFET. There is an internal 1MΩ pull-down resistor on the $\overline{EN}$ pin to ensure the power switch conduction in a dead-battery situation. A 20ms Debounce time has been deployed before device turn-on. $\overline{EN}$ pin has 29V tolerance.

UVLO

When $\overline{EN}$ is low and V_{BUS} < V_{UVLO}, the Under-Voltage Lock-Out (UVLO) circuits disable the power MOSFET. Once V_{VBUS} exceeds V_{UVLO} and no other protection circuit is active, the channel MOSFET state is controlled by the $\overline{EN}$ pin.

OVLO

When $\overline{EN}$ is low and V_{BUS} > V_{OVLO}, the Over-Voltage Lock-Out (OVLO) circuit disables the power MOSFET. Once V_{VBUS} drops below V_{OVLO} and no other protection circuit is active, the power MOSFET resumes operation. OVLO pin is used to set the over-voltage threshold. The default over-voltage threshold is 22V when OVLO pin shorts to GND. Connecting a resistor divider to the OVLO pin adjusts the over voltage threshold from 4V to 24V using Equation 1:

$$V_{IN\_OVLO} = V_{OVLO\_TH} \times (1 + R1/R2) \quad (1)$$

When the voltage on OVLO pin is below 0.1V, the device defaults to the 22V OVP threshold.

OTP

When $\overline{EN}$ is Low and the device temperature exceeds 150°C the Over-Temperature Protection (OTP) circuit disables the power MOSFET and sets the ACK output Hi-Z. Once the device temperature decreases below 130°C and no other protection circuit is active, the state of the N-channel MOSFET is controlled by the $\overline{EN}$ pin again.

ACK Output

The ACK output is an open-drain output that requires an external pull-up resistor. The ACK pin indicates the state of the power switch. When no fault is detected and power switch is conducting, ACK goes output low, otherwise it stays at high impedance. The pull up resistor value is recommend to be 10KΩ to 200KΩ.

RCP

ET9931 has all time reverse current protection regardless of the $\overline{EN}$ logic level. Once the voltage on VINT is higher than VBUS for 45mV, the RCP circuit is triggered after a 3.7ms De-Glitch time. If the voltage gap is greater than 120mV, RCP triggers immediately to switch off the power MOSFET.

During the start up De-Glitch time, if the device detects the VINT voltage is higher than VBUS by 45mV, the power MOSFET does not turn on.

The RCP circuit helps by providing the capability of parallel connection of two USB charging ports to a single charger input, without backward leakage.

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	Condition	Min	Max	Unit
V_I	Input Voltage	VBUS	-0.5	+29	V
		VINT	-0.5	+29	V
		OVLO	-0.5	V_{BUS}	V
		EN	-0.5	+29	V
V_O	Output Voltage	ACK	-0.5	+6	V
I_{SW}	Continuous Switch Current	T_A=25°C	-	5	A
	Peak Switch Current	10ms	-	10	A
T_{STG}	Storage Temperature		-65	+150	°C
P_D	Total Power Dissipation	T_A=25°C	-	1.78	W
$R_{\theta JA}$	Thermal Resistance, Junction-to-Air(1)	T_A=25°C		56	°C/W
V_{ESD}	Electrostatic Discharge Voltage	IEC 61000-4-2 Contact Discharge; VBUS	-8	+8	KV
		IEC 61000-4-2 Air Discharge;VBUS	-15	+15	KV
		HBM (JEDEC JS-001-2023); All pins	-2	+2	KV
		CDM (JEDEC JS -002-2022); All pins	-500	+500	V
Surge	Surge Protection	IEC 61000-4-5, VBUS (No DC)	-100	+100	V

Note1: The $R_{\theta JA1}$ is dependent on the PCB heat dissipation. Board used to drive this data was a 2Layer 60mm×42mm 1oz JEDEC PCB standard;

Recommended Operating Conditions

The Recommended Operating Conditions table defines the conditions for actual device operation. Recommended operating conditions are specified to ensure optimal performance to the datasheet specifications. ETEK does not recommend exceeding them or designing to Absolute Maximum Ratings.

Symbol	Parameters	Condition	Min	Max	Unit
V_I	Input Voltage	VBUS	2.9	20	V
		VINT	2.9	20	V
		EN	0	20	V
V_O	Output Voltage	ACK	0	5.5	V
T_J	Junction Temperature		-40	+125	℃
T_A	Ambient Temperature		-40	+85	℃

Electrical Characteristics

Unless otherwise noted, V_{BUS}=2.9V to 20V, T_A=-40°C to 85°C, Typical values are at V_{IN}=5V, I_{IN}≤2A, C_{IN}=1μF and T_A=25°C.

Symbol	Parameters	Conditions	Min	Typ	Max	Unit
TVS Characteristics						
V_{BR}	Reverse Breakdown Voltage	I_T=10mA, T_A=25°C	29	32	36	V
V_{BUS}	Input Voltage		2.9		29	V
I_Q	V_{BUS} Quiescent Current	V_{BUS}=5V, $V_{\overline{EN}}$=0V, I_O=0A		90	150	μA
		V_{BUS}=20V, $V_{\overline{EN}}$=0V, I_O=0A		105	170	μA
		V_{BUS}=5V, $V_{\overline{EN}}$=5V, I_O=0A		3	10	μA
		V_{BUS}=20V, $V_{\overline{EN}}$=5V, I_O=0A		15	30	μA
I_{S_OFF}	V_{BUS} Off-state Leakage Current	V_{BUS}=5V, $V_{\overline{EN}}$=5V, V_{INT}=0V		3	10	μA
		V_{BUS}=20V, $V_{\overline{EN}}$=5V, V_{INT}=0V		15	30	μA
	V_{INT} Off-state Leakage Current	V_{BUS}=0V, $V_{\overline{EN}}$=5V,V_{INT}=5V		0.1	5	μA
		V_{BUS}=0V, $V_{\overline{EN}}$=5V,V_{INT}=20V		2	16	μA
R_{ON}	On-Resistance of Switch IN-OUT	V_{BUS}=5.0V, I_{OUT}=1A, T_A=25°C		27	43	mΩ
		V_{BUS}=20V, I_{OUT}=1A, T_A=25°C		27	43	
V_{OVLO}	Default Over Voltage Lockout Voltage	V_{BUS} Rising; $V_{\overline{EN}}$ = 0V; OVLO short to GND	20.5	22	23.5	V
		V_{BUS} Falling; $V_{\overline{EN}}$ = 0V; OVLO short to GND	20.0	21.5	23.0	V
	Hysteresis of Over Voltage Lockout Voltage			0.5		v
	Adjust Range		4		24	V

Electrical Characteristics(Continued)

Symbol	Parameters	Conditions	Min	Typ	Max	Unit
V_{OVLO_TH}	OVLO Set Threshold		1.18	1.2	1.22	V
V_{OVLO_ST}	External OVLO Select Threshold			0.1		V
V_{UVLO}	Under Voltage Protect	V_{BUS} Rising	2.0	2.45	2.85	V
		V_{BUS} Falling	1.9	2.35	2.75	V
	Hysteresis of Under Voltage Protect			0.1		V
I_{OVLO}	OVLO Input Leakage Current	$V_{OVLO} = V_{OVLO\_TH}$	-100		100	nA
V_{IH}	$\overline{EN}$ Input Logic High Voltage	V_{BUS} = 2.9V to 20V	1.2		20	V
V_{IL}	$\overline{EN}$ Input Logic Low Voltage	V_{BUS} = 2.9V to 20V	0		0.4	V
V_{TRIG}	RCP trigger voltage	$V_{TRIG} = V_{INT} - V_{BUS}$	10	45	80	mV
V_{TRIG_H}	RCP High Trigger Voltage(2)	$V_{TRIG} = V_{INT} - V_{BUS}$		120		mV
T_{SHDN}	Thermal Shutdown(2)			150		°C
T_{SHDN_HYS}	Thermal-Shutdown Hysteresis(2)			20		°C
Dynamic Characteristics: see figure						
t_{ACK}	ACK response time	From $\overline{EN}$ to V_{ACK} goes output low C_{LOAD}=100uF; R_{LOAD}=100Ω	10	15	20	ms
t_{DEB}	Debounce Time	Time from $V_{UVLO}<V_{BUS}<V_{OVLO}$ to V_{OUT}=10% of V_{BUS}; C_{LOAD}=100uF; R_{LOAD}=100Ω	10	20	25	ms
t_{EN}	Enable Time	From $\overline{EN}$ to V_{INT} = 10% V_{BUS}; V_{BUS} = 5V & 20V; C_{LOAD}=100uF; R_{LOAD}=100Ω	10	20	25	ms
t_{TLH}	V_{INT} Rise Time	V_{BUS} = 5V & 20V; C_{LOAD}=100uF; R_{LOAD}=100Ω	1	5	10	ms
$t_{DIS(OVP)}$	Switch Turn-off Response Time(2)	From V_{BUS} >V_{OVLO} to V_{INT} stop rising; R_{LOAD}=100Ω, C_{LOAD}=NL; V_{BUS}= 20V; OVLO pin short to GND		120		ns
t_{DEGL}	RCP De-glitch Time	From $V_{INT}>V_{BUS}$ +45mV to Switch Off	2.6	3.7	4.8	ms
$t_{DIS(RCP)}$	RCP Turn Off Time(2)	From $V_{INT}>V_{BUS}$ +120mV to Switch Off		2	10	μs

Electrical Characteristics(Continued)

t_{ON}	Turn-on Time	$\overline{EN}$ to V_{INT} = 90% V_{BUS}; V_{BUS} = 5V & 20V; C_{LOAD}=100uF; R_{LOAD}=100Ω		25	35	ms
t_{OFF}	Turn-off Time	$\overline{EN}$ to V_{INT} = 10% V_{BUS}; V_{BUS} = 5V & 20V; C_{LOAD}=100uF; R_{LOAD}=100Ω		23	33	ms

Note2:This parameter is guaranteed by design and characterization.

Timing Waveform

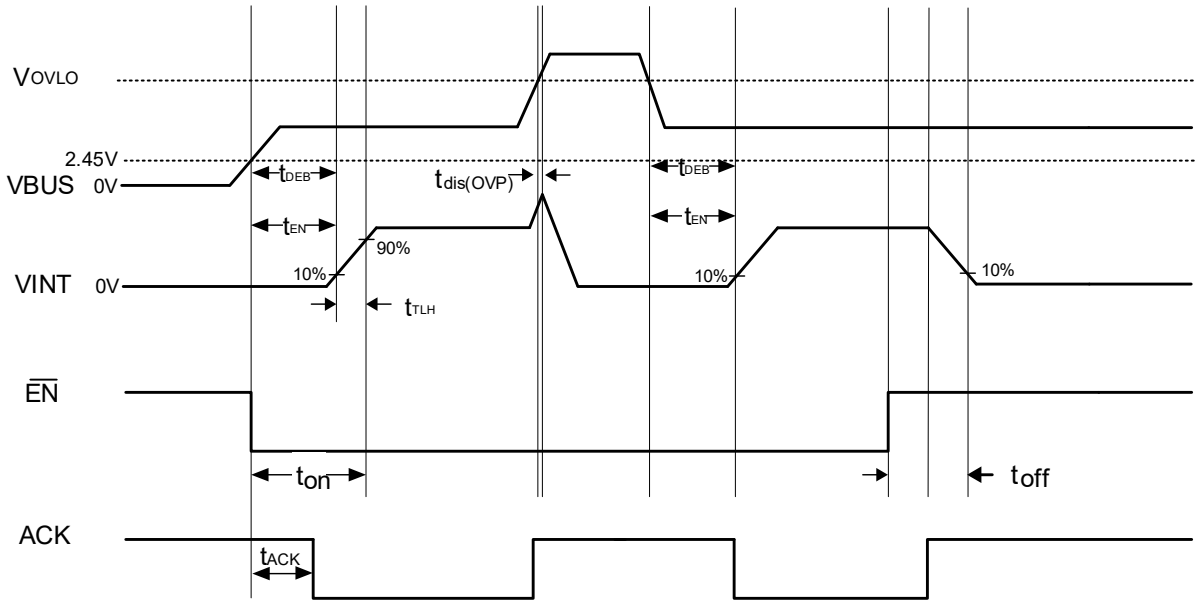


Figure 3. Timing Waveform

Application Circuits

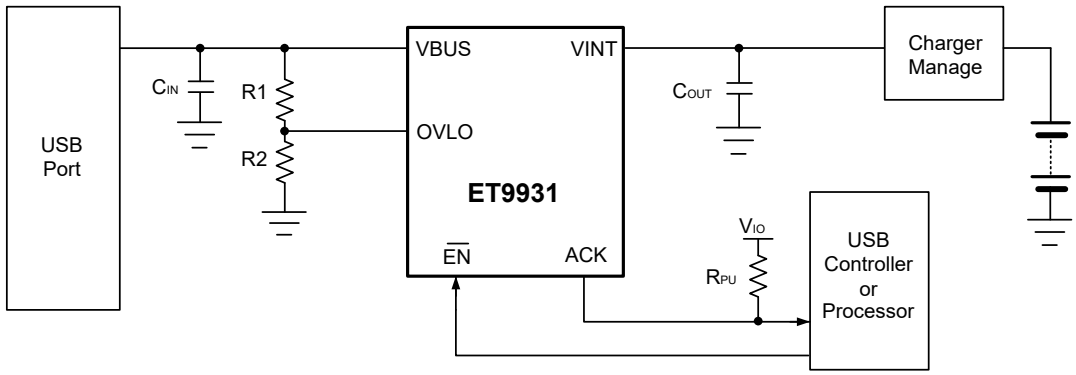


Figure 4. Application Circuit 1

Note: R1 and R2 are only required for adjustable OVLO; otherwise connect OVLO to GND.

Application Circuits(Continued)

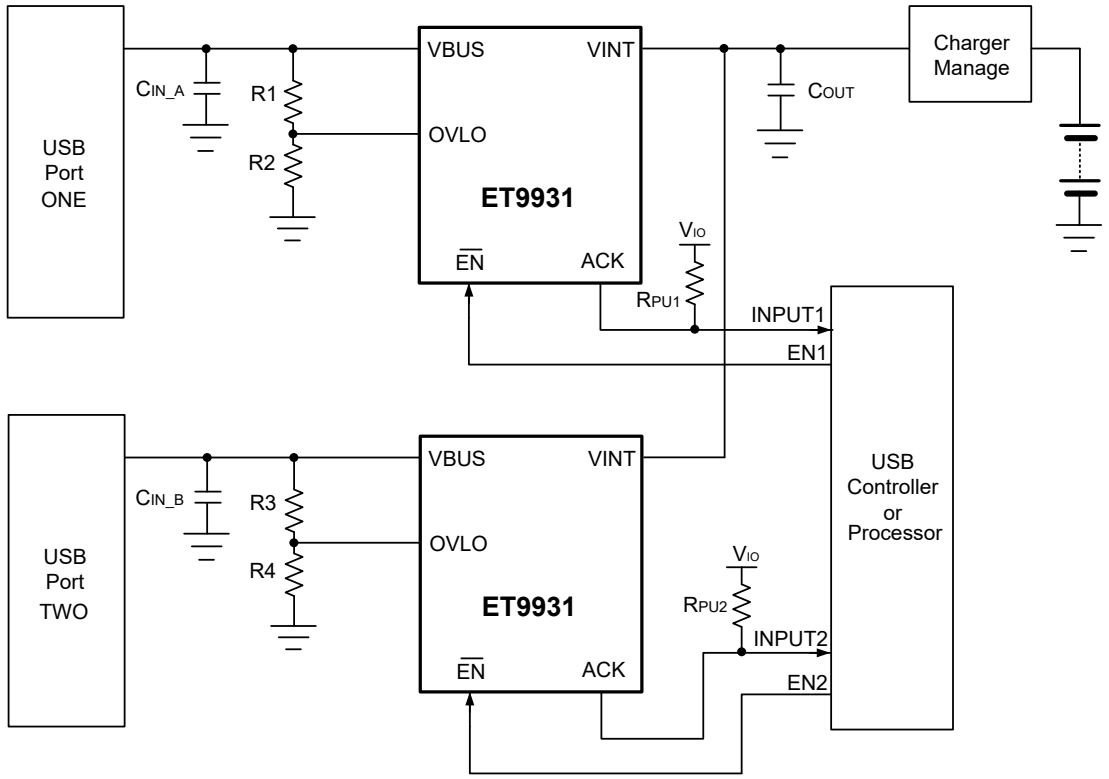
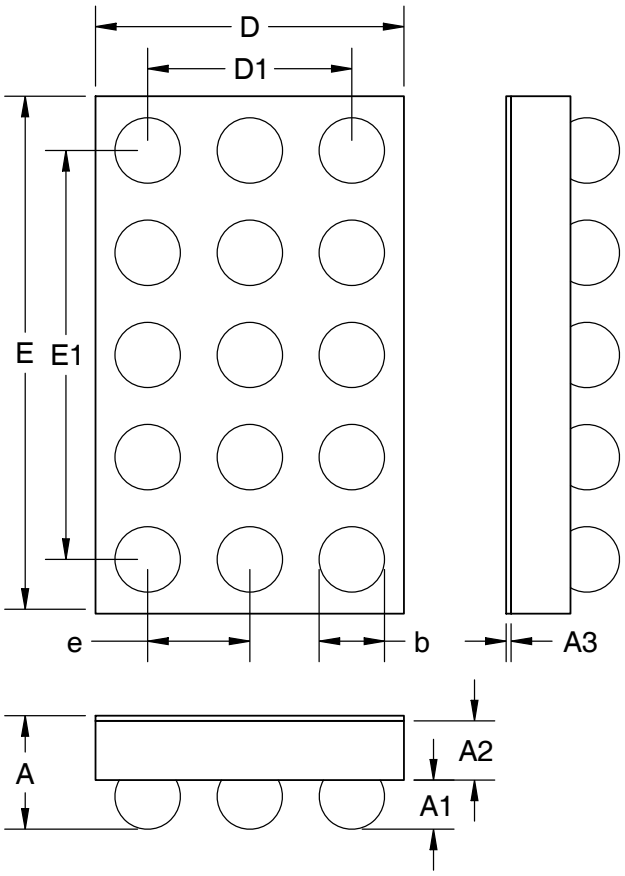


Figure 5. Application Circuit 2

Note: R1 R2 R3 R4 are only required for adjustable OVLO.

Package Dimension

WLCSP15



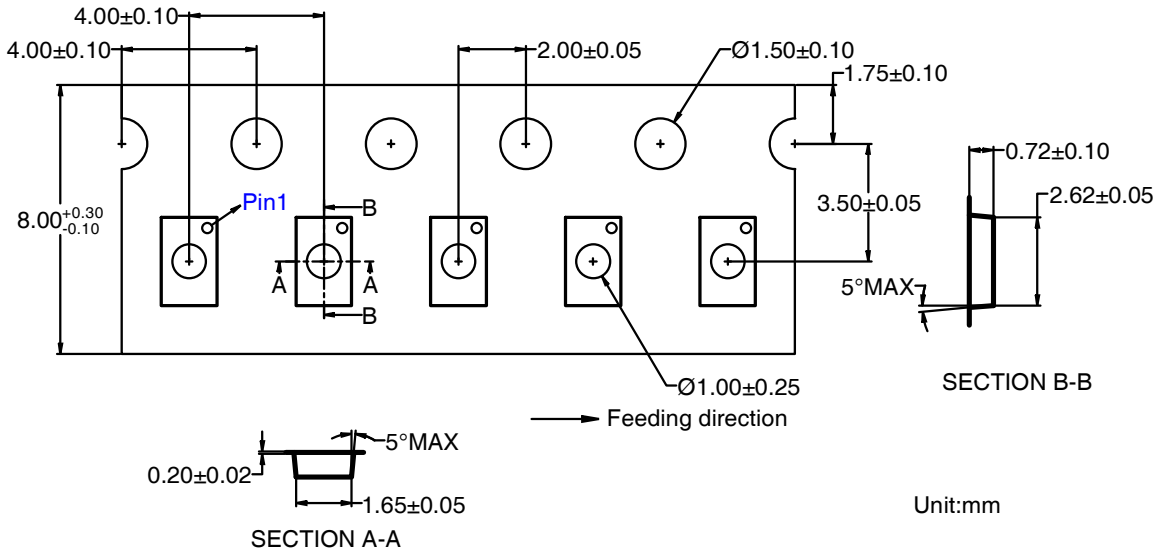
COMMON DIMENSIONS

(UNITS OF MEASURE=MILLIMETER)

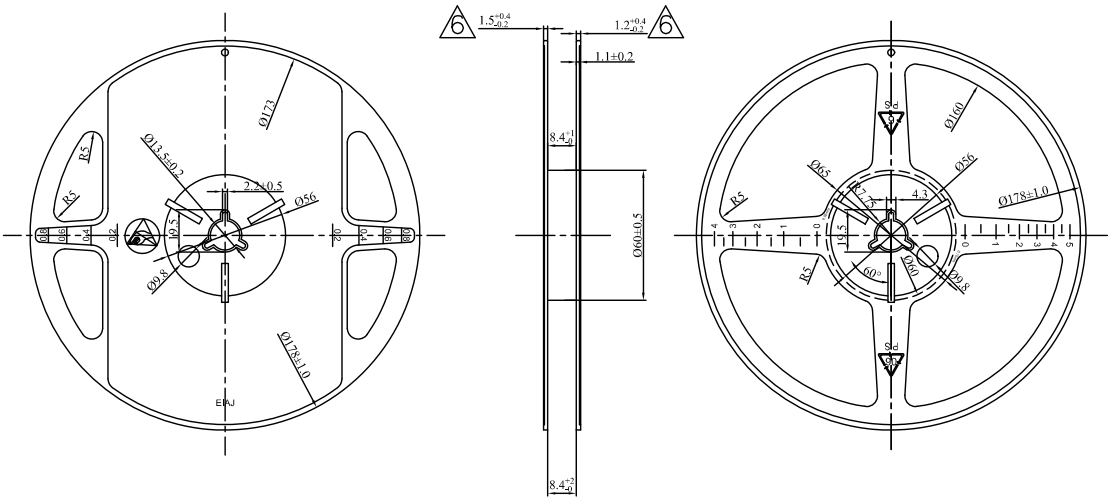
SYMBOL	MIN	NOM	MAX
A	0.502	0.555	0.608
A1	0.215	0.240	0.265
A2	0.265	0.290	0.315
A3	0.022	0.025	0.028
D	1.480	1.510	1.540
D1	1.000BSC		
E	2.500	2.530	2.560
E1	2.000BSC		
b	0.295	0.320	0.345
e	0.500BSC		

Unit: mm

Tape Information

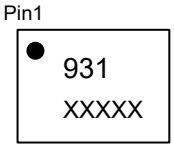


Reel Information



Unit: mm

Marking



931- Part Number

XXXXX - Tracking Number

Revision History and Checking Table

Version	Date	Revision Item	Modifier	Function & Spec Checking	Package & Tape Checking
0.0	2023-03-24	Original Version	Guoy	Wuhs	Liujy
0.1	2023-04-20	Update	Shibo	Wuhs	Liujy
0.2	2024-3-11	Update Package	Wuhs	Wuhs	Liujy
0.3	2024-5-22	Update some picture	Shibo	Wuhs	Liujy
0.4	2024-5-25	Modify some electrical parameters and fix some typing errors	Guoy	Wuhs	Liujy
1.0	2024-7-19	Update EC Table & Timing Waveform	Zoucm	Guoy	Liujy
1.1	2025-6-21	Update Marking	Caojc	Guoy	Liujy