ZES100 - Latchup Detection and Protection (LDAP) IC

Enabling Advanced Commercial-Off-The-Shelf (COTS) to 'Space-Grade'

Description

ZES100 Radiation Hardened LDAP-IC is an integrated solution designed to detect Single-Event Latchup (SEL) in a target device and subsequently provides a power-cycling/ recovery. It can be used to protect power supply and Commercial-Off-The-Shelf (COTS) devices from anomalous current due to SEL/micro-SEL.

ZES100 is based on ZES's proprietary technology, offering an unprecedented means to protect COTS from SEL – enabling advanced COTS devices to Space. Specifically, ZES100 incorporates two levels of protections. First, ZES100 can detect the early onset of SEL occurrence, including micro-SEL, a localized SEL whose current is often relatively low. Second, ZES100 can also provide an overall current limit protection. Collectively, two levels of protection efficiently remove SEL by an appropriate power cycling.

ZES100 is radiation hardened chip, immune to Single-Event Transient (SET) and Single-Event Upset (SEU) and is unaffected by long-term drift current due to Total Ionized Dose (TID).

Internal power switch with low on-resistance (R_{DSONP}) of 60mΩ at V_{gs}= -4.5V with 500mA output.

High integration makes ZES100 an ideal candidate for SEL protection of advanced COTS devices in space.

Applications

- Protecting any COTS for Space applications.
- SEL/micro-SEL detection and protection of any COTS-devices (MCU/FPGA/GPU).

Features

- Fast response to SEL
- Detection of the SEL occurrence at on-set
- Detection of micro-SEL/ SEL
- Automatic power-cycling, adjustable timing
- External control power-cycling (MCU/OBC)
- Immune from current drift due to aging and TID effects
- Wide-range supply voltage and internal MOSFET for loading current (~500mA)
- Higher load-currents (>500mA) with external-MOSFET
- Over current short protection
- Space qualified technology
- Radiation Hardened by Design (RHBD)
- Qualified Space Enhanced Plastic (SEP)
- ITAR free
- Evaluation Kit available

Electrical Performance

Input Voltage	1.2V~5V
Continuous Loading Current	1mA~500mA*
Power Cycling Time	Adjustable
Operating Temperature	-55°C to 125°C
Voltage Drop	0.03V @ 500mA, 5V

Radiation Performance (Cyclotron Verified)

TID	300 Krad (Si)
SEL	110 MeV.cm^2/mg
SEFI	110 MeV.cm^2/mg
SEU	110 MeV.cm^2/mg
Ion Fluence	Up to 10^7/cm^2

Ordering Information

Part No.	Description	Form Factor	Size
ZES100LDPFQ-EP	ZES100 LDAP Flight Model	QFN32L	5mm × 5mm
ZES100LDPGQ-EP	ZES100 LDAP Ground Model†	QFN32L	5mm × 5mm
ZES100LDPGEV-EP	ZES100 LDAP Evaluation Board†	PCBA	80mm x 80mm

For price, delivery, and ordering information please contact sales@zero-errorsystems.com

* Higher current (>0.5A) can be achieved with an external switch (MOSFET).

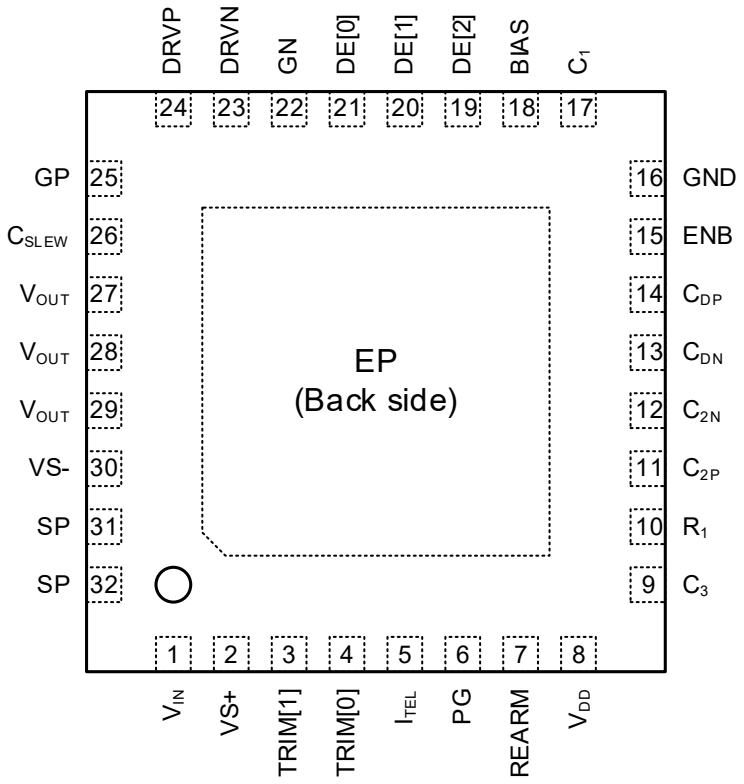
† Ground Model units are intended for engineering evaluation only. These units are not suitable for qualification, production, radiation testing or flight use.

† Ground Models parts are tested only for room temperature, and hence not warranted for performance over the full specified temperature range of –55°C to 125°C or operating life.

1 Pin Configuration

1.1 ZES100 Pin Connections (QFN32L: 5mm x 5mm)

TOP VIEW



1.2 Pin Description

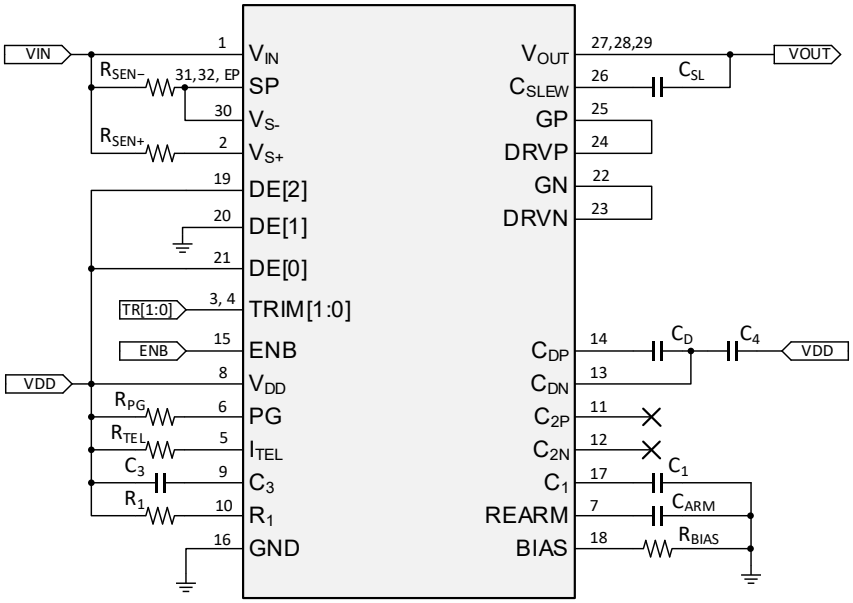
Table 1 ZES100 Pin Description

*In – input, Out – Output

Pin	In/Out*	Name	Description
1	In	V_{IN}	**Input voltage**.
2	In	V_{S+}	**Current sensing** pin. Connect a resistor R_{SEN+} to this pin and V_{IN}.
3, 4	In	TRIM[1:0]	Input **Trimming bit** to determine SEL detection rate.
5	Out	I_{TEL}	**Telemetry** output is proportional to sensed current. Connect a resistor to this pin and V_{DD}.
6	Out / In	PG	**Power Good** Connect a resistor to this pin and V_{DD} (required). An open-drain output that goes low when V_{OUT} is outside a specified regulation window, i.e. a power-good (PG).
7	In	REARM	Use during Power recycle/recovery, connect a capacitor to this pin and GND to set the delay before rearming detection.
8	In	V_{DD}	**Supply** of ZES100.
9	In	C_3	Connect a capacitor to this pin and V_{DD}.
10	In	R_1	Connect a resistor to this pin and V_{DD} to set **max I_{OUT} current threshold**.
11, 12	NA	C_{2P}, C_{2N}	Not connected
13, 14	In	C_{DN}, C_{DP}	Connect a capacitor to these pins to set the **power-cycle duration**.
15	In	ENB	***Enable pin** (active low) of the DRVP and DRVN pins. When ENB = "0", the internal circuitry controls the DRVP and DRVN pins. When ENB = "1", DRVP = V_{DD}, DRVN = V_{DD}. (switched off)
16	NA	GND	**Ground**.
17	In	C_1	Connect a capacitor to this pin and GND to set the **blank period** of overcurrent event.
18	Out	BIAS	**Bias current**, connect a resistor to this pin and GND.
19 - 21	In	DE[2:0]	**Detection Enable** input pins.
22	In	GN	**Gate** pin of internal power **NFET**.
23	Out	DRVN	**NFET driver** output.
24	Out	DRVP	**PFET driver** output.
25	In	GP	**Gate** pin of internal power **PFET**.
26	In	C_{SLEW}	Connect a capacitor to this pin and to set the **slew rate of V_{OUT}** when the power transistor is switched on.
27 - 29	Out	V_{OUT}	**Output** of power switch.
30	In	V_{S-}	**Current sensing** pin. Connect a resistor R_{SEN-} to this pin and V_{IN}. It is recommended to connect V_{S-} and SP only at the R_{SEN-} pin.
31, 32 and EP	In	SP	**Source of power** PFET. Connect a resistor R_{SEN-} to this pin and V_{IN}. It is recommended to connect V_{S-} and SP only at the R_{SEN-} pin.

*ENB pin (active low), when ENB=”0” means 0V(GND) and when ENB =”1” means V_{DD}.

2 Typical Application Diagram



ZES100 LDAP

Figure 1 Typical application circuit

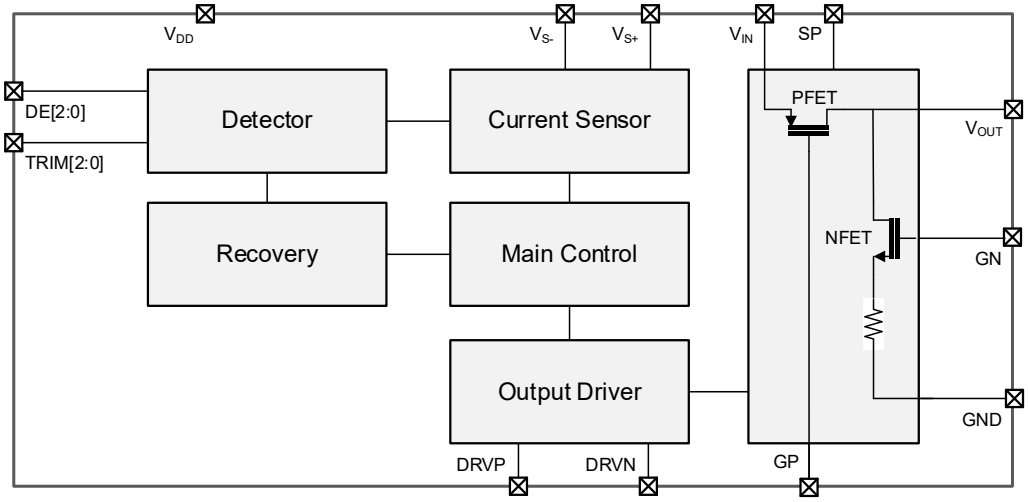


Figure 2 Simplified block diagram

3 Maximum Ratings

Absolute maximum ratings are limits beyond which damage to the device may occur. Exposure to absolute maximum rating conditions for extended periods may affect device reliability. Functional operation of the device at these conditions is not implied.

Table 2 Absolute maximum ratings

Parameter	Min.	Max.	Unit
V_{IN} Voltage	−0.3	5.5	V
V_{OUT} Voltage	−0.3	5.5	V
V_{DD} Voltage	−0.3	5.5	V
DE[2:0], TRIM[1:0] Voltages	−0.3	5.5	V
PG Voltage	−0.3	5.5	V
ENB Voltage	−0.3	5.5	V
SP Voltage	−0.3	5.5	V
C_{SLEW} Voltage	−0.3	5.5	V
REARM Voltage	−0.3	5.5	V
R_1, BIAS Voltages	−0.3	5.5	V
C_1, C_{2P}, C_{2N}, C_3, C_{DP}, C_{DN}, C_4 Voltages	−0.3	5.5	V
DRVP, DRVN Voltages	−0.3	5.5	V
GP, GN Voltages	−0.3	5.5	V
V_{S+}, V_{S-} Voltages	−0.3	5.5	V
I_{TEL} Voltage	−0.3	5.5	V
Maximum continuous switch current I_{max}		1	A
Maximum pulsed switch current I_{pulse} †		1.4	A
I_{TEL} Current	0	2	mA
I_{BIAS} Current	0	100	µA
ESD Susceptibility (Human Body Model)	-	+/-2000	V
Maximum junction temperature, T_j	-55	+150	°C
Soldering Temperature recommendation		+260	°C
Storage temperature T_{STG}	−55	+150	°C

† Maximum pulse switch current is RMS value tested with repetitive sine pulse.

4 Electrical Characteristics

Typical values correspond to T_a = 25˚C. V_{IN} = V_{DD} = 5V unless otherwise specified.

Table 3 Electrical Characteristics

Symbol	Parameter	Test Conditions	Min.	Typ.	Max.	Unit
Supply Specifications						
V_{IN}‡	Input voltage		1.2	5.0	V_{DD}	V
I_{IN}	Input Current		1		500	mA
V_{DD}	Voltage Supply of ZES100		2.5	5.0	5.0	V
I_{DD}	Input Current for ZES100	V_{DD} = 5V		10		mA
I_{BIAS}	Bias Current			50	60	µA
Input Specifications						
TRIM[1:0]$_{(th)}$	TRIM[1:0] Threshold			0.5V_{DD}		V
DE[2:0]$_{(th)}$	DE[2:0] Threshold			0.5V_{DD}		V
ENB$_{(th)}$	ENB Threshold	Enable ("0")	0		0.5	V
		Disable ("1")	V_{DD}-0.5		V_{DD}	V
Output Specifications						
V_{OUT}	Output Voltage				V_{IN}	V
I_{OUT}	Output Current		1		500	mA
$V_{GS(th)}$	Gate-Source Threshold Voltage	V_{DS} = V_{GS}, I_D = -300uA			-1	V
I_{GSS}	Gate-Source Leakage	V_{DS} = 0V, V_{GS} = -5V			5	uA
I_{SB}	Standby current	ENB = 5V, V_{OUT} = 0V			4	uA
I_Q	Quiescent current	ENB = 0V, V_{IN} = 0V = V_{OUT}	2.6	3.8	5	mA
t_{ON}	Turn on time	ENB = 0V, R_L=10ohm, C_L = 10uF			200	us
t_{OFF}	Turn off time	ENB = 5V , R_L=10ohm, C_L = 10uF			60	us
R_{DSONP}	Power PFET R_{DSON}	Vin=1.2V		100		mΩ
		Vin=2.5V and 5V		60		mΩ
Detection						
I_{TH}	Max Current Threshold	R_1 = 18kΩ		500		mA
T_{BLANK}	Blank Period	C_1 = 10nF		0.24		ms
Timing						
T_{CYCLE}	Power-Cycle Duration	**C_D = 10nF		2.0		ms
SLR	Slew Rate of V_{OUT}	C_{SLEW} = 10nF		16.2		V/ms
Telemetry						
PG	Power-Good Voltage	R_{PG} = 100kΩ	0		V_{DD}+0.3	V
I_{TEL}	Telemetry Voltage	R_{TEL} = 1.5kΩ	0.6		V_{DD}+0.3	V

** For external P-channel MOSFET application circuit, recommended capacitor C_D = 100 ±5% nF and verify the T_{OFF}.

Please refer to section 5.7 for details.

‡ V_{IN} must be always equal to or lower than V_{DD} at any time.

5 Device Description and Operation

5.1 Overview

The ZES100 is a versatile monolithic device designed for satellite applications to provide radiation protection on both power supply and COTS devices in case of anomalous current demand due to SEL. This device can be configured to detect SEL and micro-SELs using ZES's proprietary technology, in addition to the basic current limiter function. With both detection mechanisms, power supplies which work in harsh radiation environment are protected from damage caused by SELs.

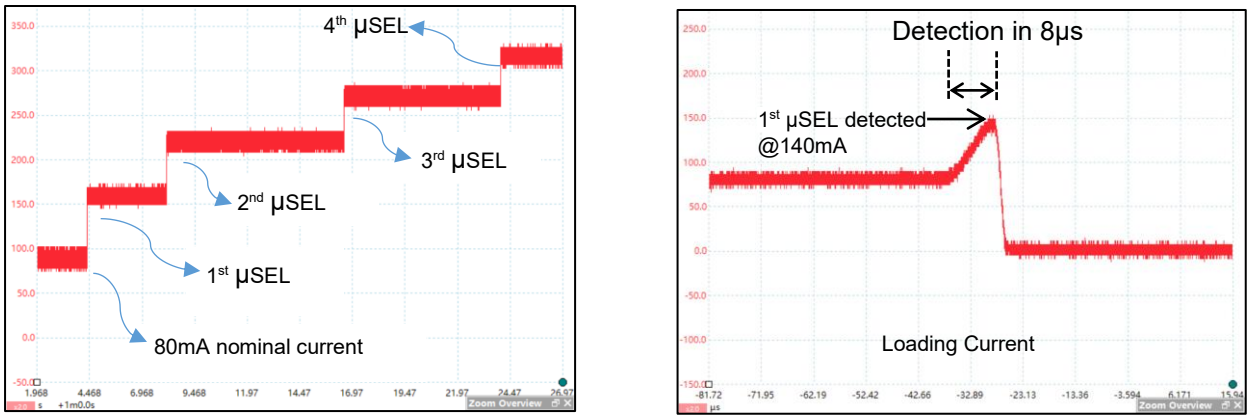
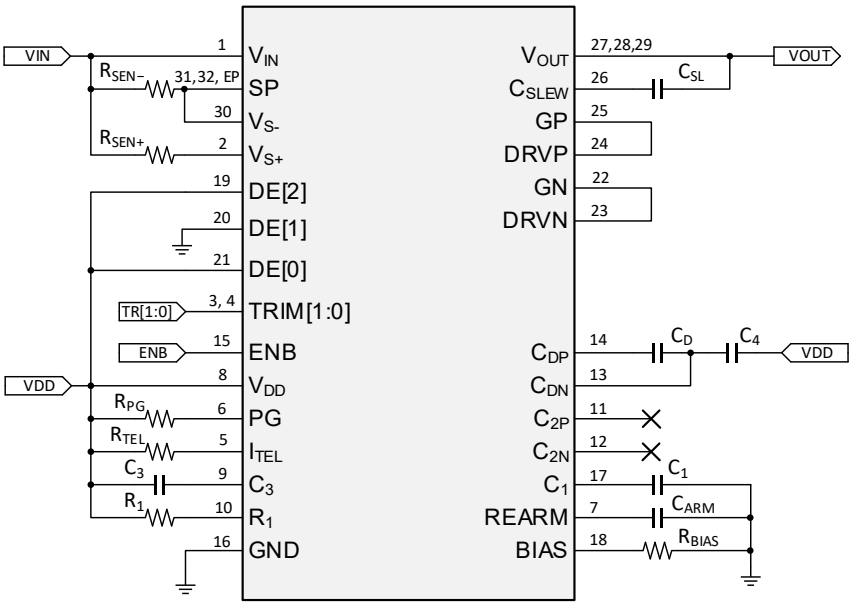


Figure 3 Demonstrations of accumulated micro-SELs induced by Laser, detection by LDAP

The core of the device consists of current sensing, latchup detection, recovery, and telemetry functions designed for high reliability system implementation.



ZES100 LDAP

Figure 4 Typical LDAP application circuit implementation

Table 4 Typical values of implementation for current limit of ~500mA, current ratio of ~510

Symbol	Typical Value	Unit
R_{SEN-}	10 ±1%	mΩ
R_{SEN+}	5.1 ±1%	Ω
R_{PG}	100	kΩ
R_{TEL}	1 ±1%	kΩ
R_1	18 ±1%	kΩ
R_{BIAS}	470 ±1%	Ω
C_1	10 ±5%	nF
C_3	10 ±5%	nF
C_4	10 ±5%	nF
**C_D	10 ±5%	nF
C_{SL}	10 ±5%	nF
C_{ARM}	1 ±5%	nF

** For external P-channel MOSSFET application circuit, recommended capacitor C_D = 100 ±5% nF and verify the T_{OFF}.

Please refer to section 5.7 for details.

5.2 Current Sensing

ZES100 has a built-in current sensor to read the current through V_{OUT}, i.e., the output/load current I_{OUT} as the sensed current I_{SEN} with a certain current sensing ratio. The current sensing ratio between I_{OUT} and I_{SEN} can be customized using R_{SEN-} and R_{SEN+} resistors by the following relationship.

$$r = \frac{I_{OUT}}{I_{SEN}} = \frac{I_{OUT,MAX}}{I_{SEN,MAX}} = \frac{R_{SEN+}}{R_{SEN-}}$$

The current sensing ratio depends on the load and the absolute maximum rating ZES100's internal sense current branch (~2mA). For example, a Device Under Protection (DUP) with the requirement of maximum supply current, **I_{OUT}** of 500mA, we can limit the maximum sensed current **I_{SEN}** to 0.98mA (additional derating) to obtain current sensing ratio of 510. If the R_{SEN-} resistance is set to be 10mΩ, then the R_{SEN+} resistance is 5.1Ω. It is recommended to design the minimum voltage drop across R_{SEN-} of 5mV with refer to below **Table 5**.

Table 5 Recommended Current Sensing ratio

Max $I_{OUT(th)}$ (mA)	MOSFET	R_{SEN-} mΩ	R_{SEN+} Ω	Current sensing ratio, **r**	I_{OUT} x R_{SEN-} (**mV** ≥5mV)	(I_{OUT} x R_{SEN-})/ R_{SEN+} (I_{SEN} **mA** <2mA)
1	Internal	5000	5.1	1.02	5	0.98
5	Internal	1000	5.1	5.10	5	0.98
10	Internal	500	5.1	10.20	5	0.98
50	Internal	100	5.1	51.00	5	0.98
100	Internal	50	5.1	102.00	5	0.98
250	Internal	20	5.1	255.00	5	0.98
500	**Internal**	**10**	**5.1**	**510.00**	**5**	**0.98**
1000	External	5	5.1	1020.00	5	0.98
1500	External	3.3	5.1	1545.45	4.95	0.97
2000	External	**2.5**	**5.1**	**2040.00**	**5**	**0.98**
5000	External	1	5.1	5100.00	5	0.98
10000	External	0.5	5.1	10200.00	5	0.98
20000	External	0.25	5.1	20400.00	5	0.98

Note: The above $R_{SEN+/-}$ values are for reference only.

The current sensing ratio accuracy may be affected by several factors such as parasitic resistance of PCB traces, resistors tolerance, internal offset, etc. To mitigate the impact of parasitic resistance of PCB traces, it is recommended that the PCB route from R_{SEN-} to V_{S-} (low current path for sensing) is isolated from the route from R_{SEN-} to SP (high current path). **Figure 5** depicts a PCB layout example where the two paths are only connected together at one of the R_{SEN-} pads such that the voltage sensed by V_{S-} will be less affected by the voltage drop due to parasitic resistance of the PCB trace.

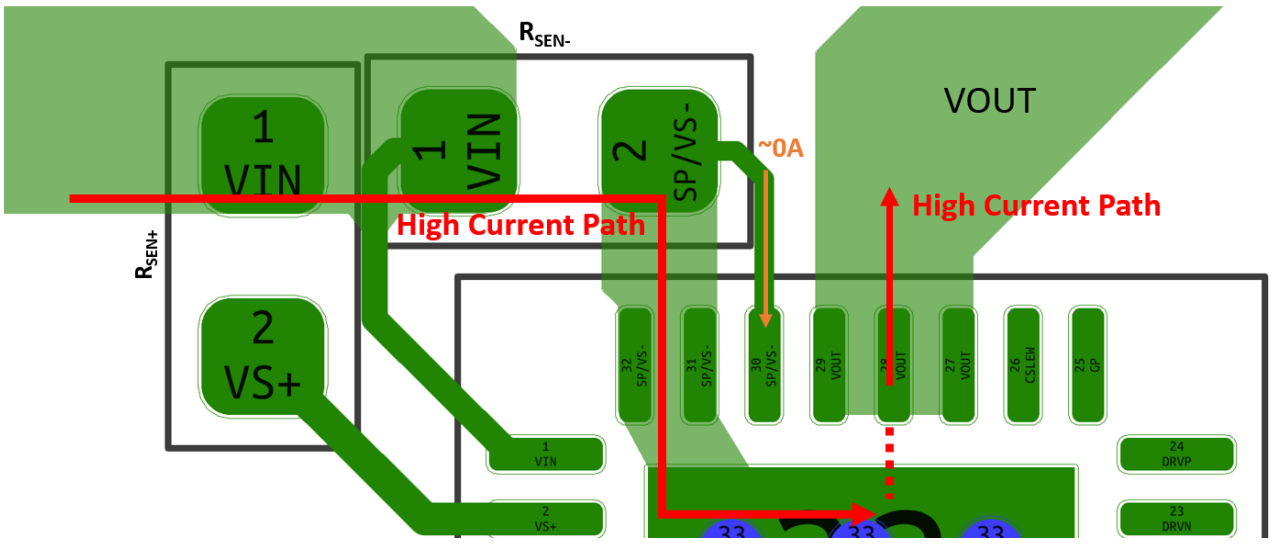


Figure 5 PCB layout recommendation for a better current sensing accuracy

5.3 Latchup Detection

5.3.1 Major-SEL, Micro-SEL and Overcurrent Detection

The ZES100's major-SEL/micro-SEL detections can be activated with detection enable DE[2:0] pins. **To maximize the benefits of ZES100, it is highly recommended to set DE[2:0] = '101'.**

Figure 6 depicts the V_{OUT} and PG signals during a power cycling when a major-SEL/micro-SEL occurs. The V_{OUT} remains stable after the power cycling as the latter removes the unwanted state. Under general scenarios, a power cycling is appropriate to remove all SELs.

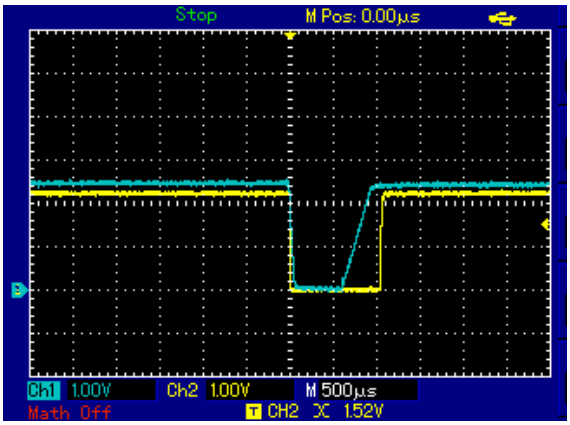


Figure 6 Waveforms of V_{OUT} (blue) and PG (yellow) during a power cycling when an SEL occurs.

The SEL/µSEL detection configuration depends on the TRIM[1:0], and C_3 capacitance. The TRIM[1:0] is a 2-bit (MSB...LSB) signal that set the built-in monotonic threshold levels. A lower TRIM[1:0] value increases the detection sensitivity; typical TRIM[1:0] is set to "00". A higher C_3 also increases the detection sensitivity; typical C_3 is set to 10nF.

ZES100 also operates as a current limiter that detects a general overload current event (e.g. Short circuit at the Load), and subsequently initiates a recovery sequence after a blank period T_{BLANK}. If the Device Under Protection (DUP) remains in the overcurrent state after T_{BLANK}, ZES100 will initiate another recovery sequence that primarily consists of a power cycling.

In a scenario where a power cycling could not remove the overcurrent state, e.g. permanent damage, the power cycling sequence will be repeated until the overcurrent state is removed or the ZES100 is disabled. **Figure 7** depicts the V_{OUT} and PG signals when overcurrent occurs and could not be removed.

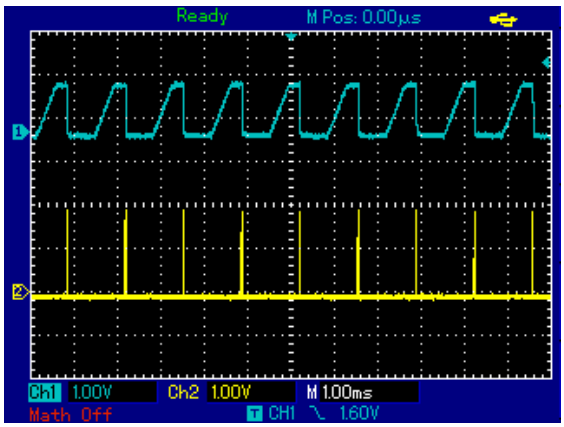


Figure 7 Waveforms of V_{OUT} (blue) and PG (yellow) during power cycling when an overcurrent occurs and sustains after a power cycling.

A. Blank Time

The detection BLANK time is the duration between the event when an overcurrent is first detected and the recovery action is initiated. It enables additional filtering of unwanted supply current noise or glitches that may cause false detection.

The BLANK time can be programmed by setting the C_1 value with the following relationship.

$$C_1 \cong \frac{T_{BLANK}(\text{in seconds})}{25000} \quad F \tag{1}$$

5.4 Recovery

ZES100 initiates a recovery sequence when it detects overcurrent/major-SEL/μSEL events. The recovery sequence consists of power cycling, rearm of detection, and V_{OUT} ramp-up control or slew rate.

5.4.1 Power Cycling and Slew Rate Control

The power cycling duration T_{CYCLE} can be broken down into fall, 'OFF', and rise times as tabulated in **Table 6**.

Table 6 The breakdown of power cycling duration

Time	Dependencies
fall time	Internal $R_{PULL-DOWN}$ ≈ 50Ω, output capacitor C_{OUT}, and V_{IN}
"OFF" time	Delay capacitor C_D
rise time	Slew rate control, R_{DSONP}, R_{SEN-}, C_{OUT}, and V_{IN}

Depending on the required accuracy of T_{CYCLE}, users may need to consider the above dependencies. In typical application, the T_{CYCLE} can be approximated by the "OFF" time duration by the following equation.

$$T_{CYCLE} \cong T_{OFF} \approx 7 \times 10^4 C_D \tag{2}$$

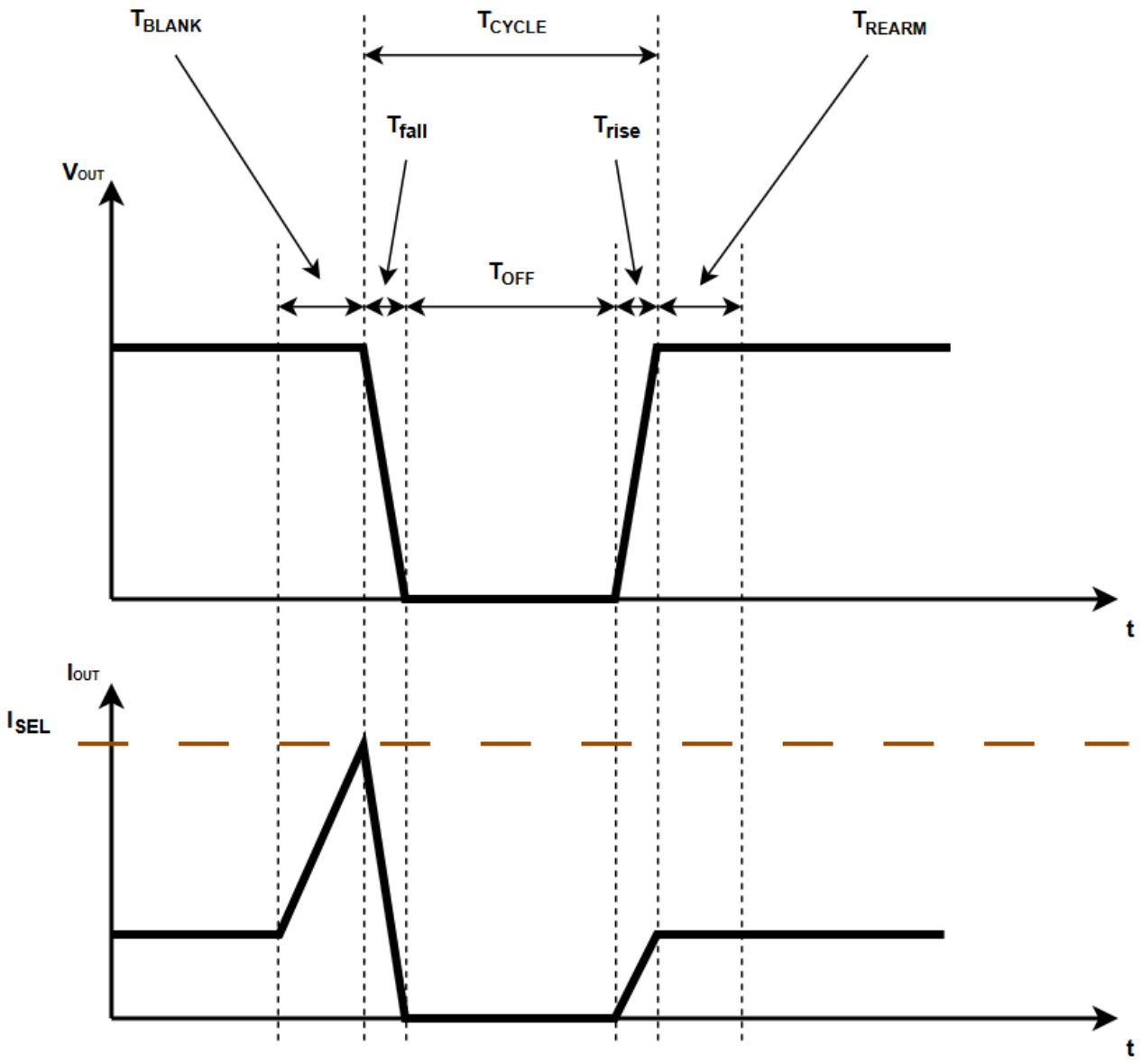
Additionally, ZES100 can program the V_{OUT} ramp-up rate (slew rate) for devices that require controlled supply voltage ramp-up during start up or power cycling. The V_{OUT} ramp up slew rate can be configured by C_{SL} capacitance and their relationship is approximated by:

$$SR = \frac{dV_{OUT}}{dt} \approx \frac{V_{IN} - 0.9}{2.5 \times 10^4 \times C_{SL}} \quad V/s \tag{3}$$

5.4.2 Rearm of Detection

At the end of power cycling sequence, the inrush supply current of DUP may inadvertently introduce a false detection. The REARM pin can be used to temporarily disable ZES100's detection block when the output is not ready. The rearm of detection will start after a delay T_{REARM} that can be estimated as follows.

$$T_{REARM} \cong C_{ARM} \times \frac{VDD}{2 \times I_{BIAS}} \quad (4)$$



5.5 Status Telemetry

5.5.1 PG (Power Good)

The ZES100 includes an open-drain power good PG pin that provides the status of V_{OUT}. PG is '1' when V_{OUT} is approximately >0.9V_{IN}, otherwise PG is '0' or pulled-down. The pull-up R_{PG} value can range 10k-100kΩ.

5.5.2 I_{TEL} (Telemetry)

The telemetry circuit provides information about the load current. The current that flows through I_{TEL} pin is proportional to the current flowing from the bus supply line to the load. The voltage V_{RTEL} across an external resistor R_{TEL} that is connected between V_{DD} and I_{TEL}, is proportional to load current.

The relationship between V_{RTEL} and load current is as follows.

$$V_{RTEL} = VDD - R_{TEL}\left(\frac{I_{OUT}}{r} + 2 \text{ x } I_{BIAS}\right)$$

Where r is the current sensing ratio, and
I_{BIAS} is the current through BIAS pin. (5)

5.6 Enable Pin (ENB)

The ZES100 includes an enable ENB pin (active low) to indirectly control the power switches through DRVP and DRVN pins. **Table 7** tabulates the truth table of ENB pin. By setting ENB to "1", the power switches can be switched off.

Table 7 Truth table of EN

EN	Operation Mode
0	Normal operation, DRVP and DRVN outputs depend on ZES100's control
1	DRVP = V_{DD}, DRVN = V_{DD} (switch off)

5.7 External Power Switches (for higher I_{OUT})

The ZES100 has a built-in power PFET switch, and a pull-down NFET switch (in series with a 50Ω resistor). Both the built-in switches are de-rated and their gates are accessible through GP and GN, respectively. The max drain-source current of the power PFET is 500mA at 125°C. These power switches can be driven by ZES100's driver pins DRVP and DRVN. To use the built-in power switches, simply connect pins DRVP to GP, DRVN to GN and SP to V_S- as depicted in **Figure 4**.

The ZES100 also supports the use of an external power switch MOSFET (P-type) to deliver higher $\mathbf{I_{OUT}}$ (>500mA) to load. **Figure 8** depicts an example circuit configuration to implement ZES100 with an external power transistor.

*Recommendation for the selection of external switch MOSFET, the Gate-Source Threshold Voltage $V_{gs(th)} > V_{IN} – 0.2V$ and the capacitor C_D = 100 ±5% nF and verify T_{OFF}.

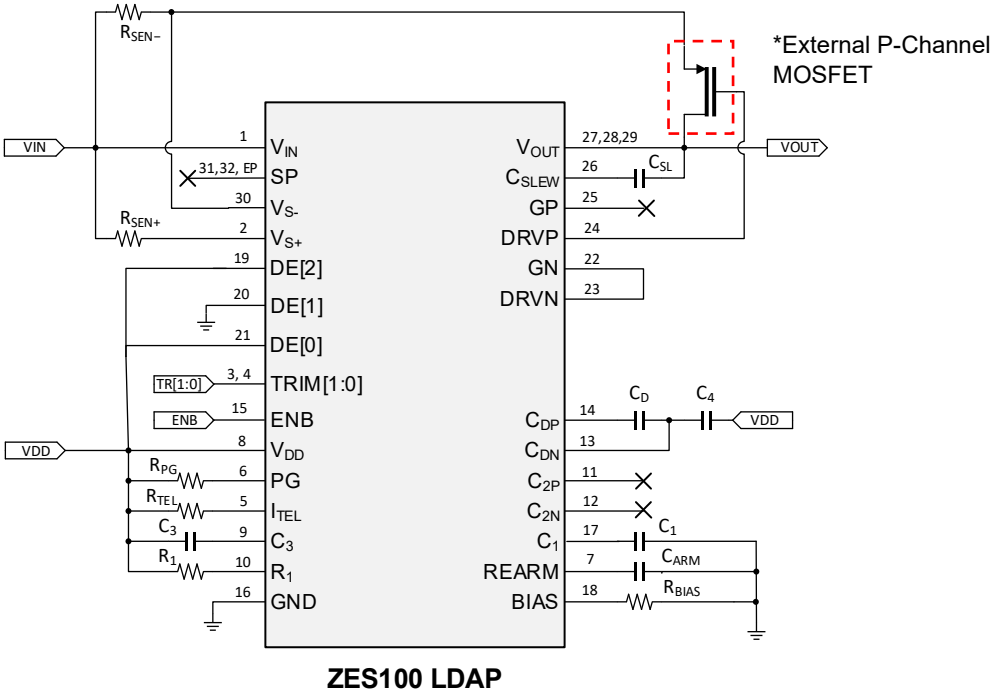


Figure 8 Example circuit configuration to implement ZES100 with an external power switch.

(1)

6 Design Recommendations

6.1 Input and Output Capacitors

Integration of ZES100 into a system requires some considerations in the selection of both input capacitor C_{IN} and output capacitor C_{OUT} as these capacitors could induce sensitivity and reliability issues. **Figure 9** depicts the typical placement of C_{IN} and C_{OUT}. It is recommended to keep C_{OUT} to a lower value (<<100nF) when possible.

A high C_{OUT} may hinder the ZES100's current sensing, as most of the DUP's dynamic supply current will be drawn from C_{OUT} instead of ZES100. Furthermore, it is strongly recommended that C_{IN} >> C_{OUT} to prevent reverse bias current from V_{OUT} to V_{IN}.

For higher reliability, V_{OUT} should remain lower than V_{IN} such that there is no reversed bias internally.

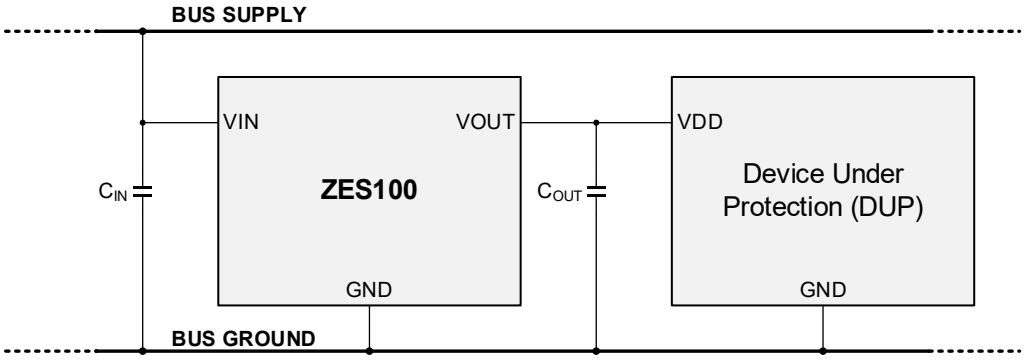


Figure 9 Input and output capacitors placement in a typical application circuit

7 Application Examples

7.1 External Control (MCU/OBC/FPGA) of Power Cycling (counting SEL occurrence)

In some applications, there is a need for extra flexibility in controlling the power cycling sequence as it could be disruptive to other parts in a system. There are several ways to configure ZES100 for such application.

Figure 10 depicts an example of ZES100 configuration where the recovery sequence (power cycling) is externally controlled by a microcontroller unit (MCU). The DRVN pin serves to provide a flag signal to the MCU. DRVN = "1" means an SEL/overcurrent is detected, while DRVN = "0" means no overcurrent/SEL is detected.

When there is SEL/overcurrent flag signal detected by MCU, the MCU can count the number of SELs and delay the power cycling until the suitable time to activate the power cycle.

The MCU can activate the power cycling through both O1 and O2 (Output1 and 2) pins to ZES100 GP and GN pin. GP and GN pins are the gate pin of the internal power PFET and NFET switches, respectively.

O1 = “0” means turn on internal PFET and O2 = “0” means turn off internal NFET switches to turn ON V_{OUT}.

O1 = “1” means turn off internal PFET and O2 = “1” means turn on internal NFET switches to turn OFF V_{OUT}.

When the pull-down switch is unnecessary, the internal NFET switch can be disabled by connecting GN pin to GND instead.

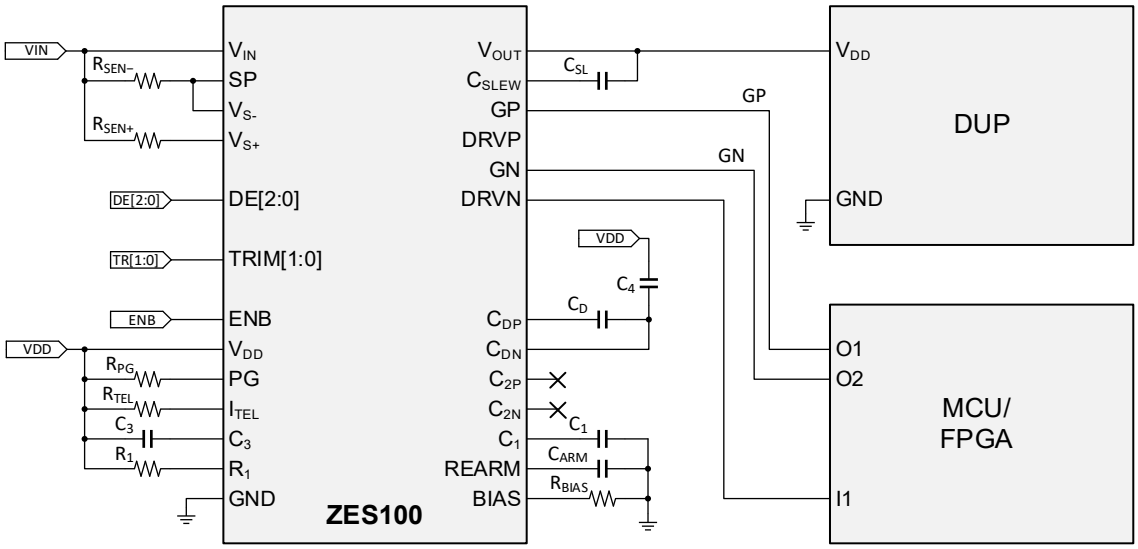


Figure 10 An example of ZES100 configuration with external control of power cycling

7.2 Limit to Single Power Cycle

In some applications, during the over-current state there is a need to just have a single power cycle instead of having power cycling sequence repeated until the overcurrent state is removed.

Figure 13 depicts an example of ZES100 configuration where the recovery sequence (power cycling) is limited to just one single cycle. The PG pin serves to provide a flag signal to the On-board computer (OBC). The OBC will disable the ENB pin when there is PG negative pulse detected. This will limit the power cycling sequence from repeating.

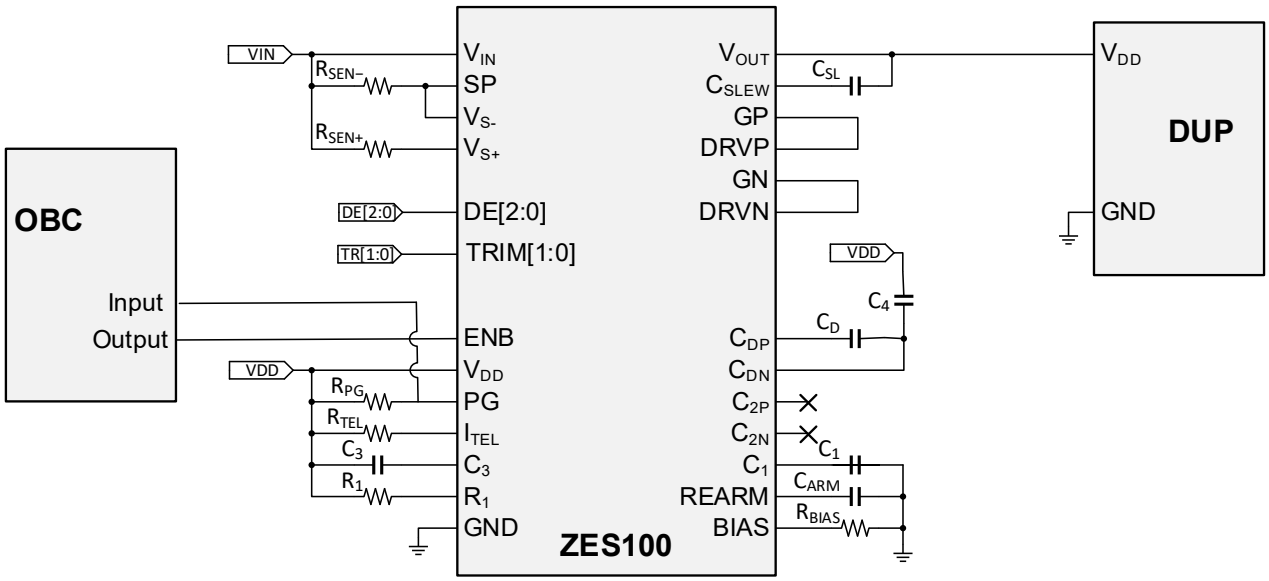
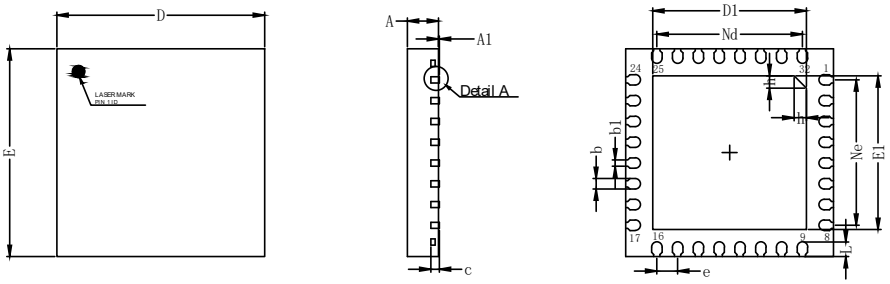


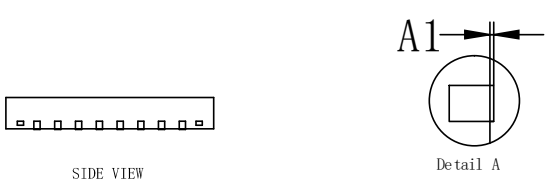
Figure 11 An example of ZES100 configuration with Single power cycle

8 Package Information

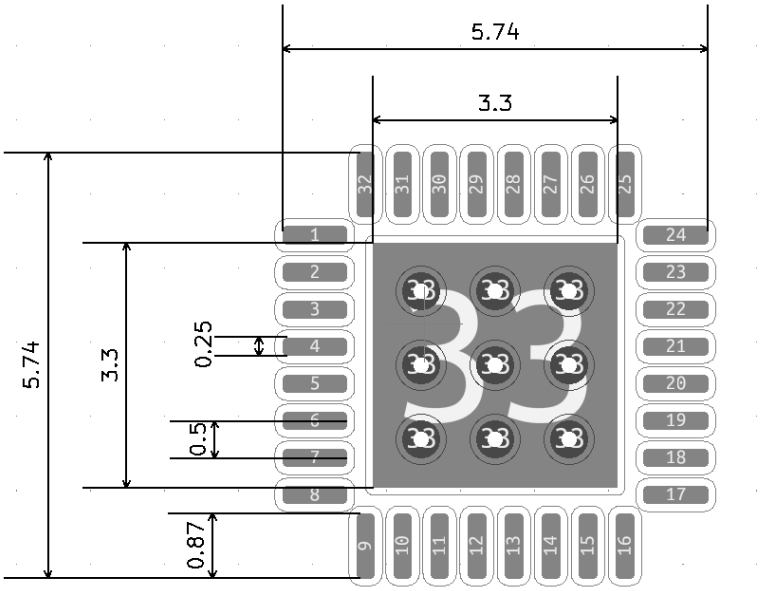
8.1 Package Outline (QFN32L 5mm×5mm)



SYMBOL	MILLIMETER		
	MIN	NOM	MAX
A	0.70	0.75	0.80
A1	—	0.02	0.05
b	0.20	0.25	0.30
b1	0.150REF		
c	0.203REF		
D	4.90	5.00	5.10
D1	3.60	3.70	3.80
e	0.50BSC		
Ne	3.50BSC		
Nd	3.50BSC		
E	4.90	5.00	5.10
E1	3.60	3.70	3.80
L	0.30	0.35	0.40
h	0.25	0.30	0.35



8.2 Land Pattern (QFN32L 5mm×5mm)



Dimensions are in millimeters
Recommended dimensions for thermal vias:
- Pad size: 1mm
- Hole size: 0.5mm
- Pitch: 1mm

8.3 Tape and Reel Information (TBD)

9 Revision History

Version No.	Notes	Date
Rev 0.1	Preliminary version	May, 2022
Rev 1.0	Initial Release	Oct, 2022
Rev 1.1	Added peripheral values	Dec, 2022
Rev 1.2	Recommended schematics amended	June, 2023
Rev 1.3	Removal of Mode selections	Sept, 2023
Rev 1.4	Added current sensing ratio table	Jan, 2024
Rev 1.5	Formula table update	Feb, 2024
Rev 1.6	Ordering part number revision	Apr, 2024
Rev 1.7	ENB = "1", DRVP = V_{DD}, DRVN = V_{DD}. (switch off)	June, 2024
Rev 1.8	Updated with current sensing ratio table	Aug, 2024
Rev 1.9	Added single power cycle application mode	Oct, 2024
Rev 2.0	Increase C_D to 100nF in Ext. MOSFET and R_{SEN} table updated	Jul, 2025
Rev 2.1	For pin-description PG/Sync; Changed to PG pin	Nov, 2025
Rev 2.2	Updated current sensing ratio table	Jan, 2026
Rev 2.3	Amended of R_{DSONP} value in Table 3	June, 2026
Rev 2.4	Updated R1 value to 18k ohm	July, 2026

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