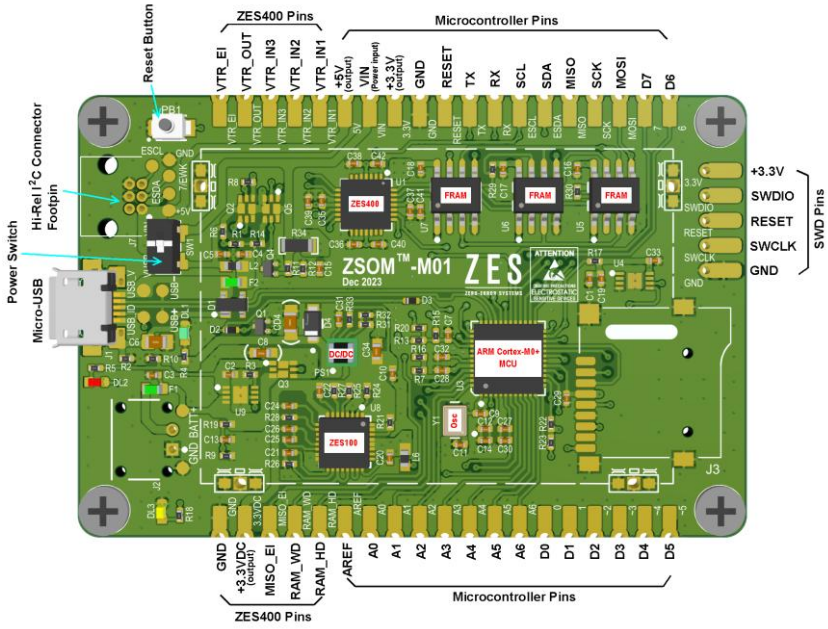
ZSOM-M01
ARM Cortex-M0+ Based System-on-Module

V1.6a, Dec. 2024

Radiation-Tolerant MCU Based System-on-Module (ZSOM-M01)

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



Overview

ZSOM™-M01 is a radiation-tolerant system-on-module (SOM) embodying an ARM Cortex-M0+ microcontroller and ZES proprietary radiation-hardened technology for mitigating Single-Event-Latchup (SEL) and Single-Event-Upset (SEU) in irradiation environments. It can be configured within the Arduino-Compatible platform, leveraging available open-source code. ZSOM™-M01 enables a quick and reliable payload development platform for space-based applications.

ZSOM™-M01 module is integrated with **ZES100** Latchup Detection and Protection (LDAP-IC) to mitigate the SEL, and **ZES400** Voter-IC (TMR) and EDAC code for soft-errors correction induced due to SEU in radiation environments.

Applications

- Low power embedded applications for CubeSat payloads for Low-Earth-Orbit (LEO)
- Telemetry/data communication applications
- Low error-rate data protection applications
- Instrumentation and control for high reliability applications

Key Features

- Low power embedded microcontroller-based SOM with SEL protection and SEU protection
- SEL protection enabled by ZES100 Radiation-Hardened Latchup Detection and Protection (LDAP) chip
  - ➢ **Extendable to protect other external COTS part(s) operated at 3.3V**
- External FRAM with SEU protection in Triple-Modular-Redundancy (TMR): enabled by ZES400 Radiation-Hardened Voters
- Proprietary error-detection-and-correction (EDAC) C-code for detecting/correcting multiple errors in SRAMs/Flash within the ARM Cortex-M0+ microcontroller
  - ➢ **2,200x lesser soft error than Single-Error-Correction-Double-Error-Detection (SECDED)**
- High Reliability Manufacturing PCB (Class III)
- Arduino-Compatible Integrated Design Environment (IDE)
- **Proton test up to 200MeV @ fluence > 10^{11} particles/cm^2**
- **Total Ionizing Dose (TID): 20k rad @ Co-60**

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1 Overview

ZSOM™-M01 is a radiation-tolerant system-on-module (SOM) embodying an ARM Cortex-M0+ microcontroller, a Triple-Modular-Redundancy (TMR) 256kB FRAM with a ZES400 radiation hardened Voter, and a ZES proprietary ZES100 Latchup Detection and Protection (LDAP) chip. ZSOM™-M01 can be configured within an Arduino-Compatible platform, leveraging the growing list of open-source codes available for Space-based applications. ZSOM™-M01 provides a quick and reliable payload development platform for developers' Space-based applications.

1.1 Features

- SAMD21 ARM Cortex-M0+ Microcontroller (Automotive Grade), 256kB Flash, 32kB SRAM, 48MHz clock rate
- Single-Event-Latchup (SEL) protection: enabled by ZES100 Radiation-Hardened Latchup Detection and Protection (LDAP) – extendable to protect other external COTS part(s) operated at 3.3V
- External non-volatile memory with Single-Event-Upset (SEU) protection: 32kB FRAMs configured in TMR enabled by ZES400 Radiation-Hardened Voters
- Proprietary error-detection-and-correction (EDAC) C-code for detecting/correcting multiple errors (SEUs) within Flash/SRAM of the microcontroller – 2,200x lower soft-error than the conventional Single-Error-Correction-Double-Error-Detection (SECDED) approach per 1kB data block
- Common communication ports: Micro-USB, UART, SPI, I^2C
- Single power source: 5V (I/O voltage Interface @3.3V)
- Programing platform: C/C++ in Arduino-Compatible platform
- High Reliability Manufacturing (PCB Class III)
- Proton-tested up to 200MeV @ fluence > 10^{11} particles/cm^2
- TID test: 20k rad (Si) @ Co-60

1.2 Block Diagram

Fig. 1 depicts the simplified diagram showing various key components and their interface signals/ connections. The primary inputs/outputs are shown in blue; their pin definitions are delineated in Section 2.1 Table 1.

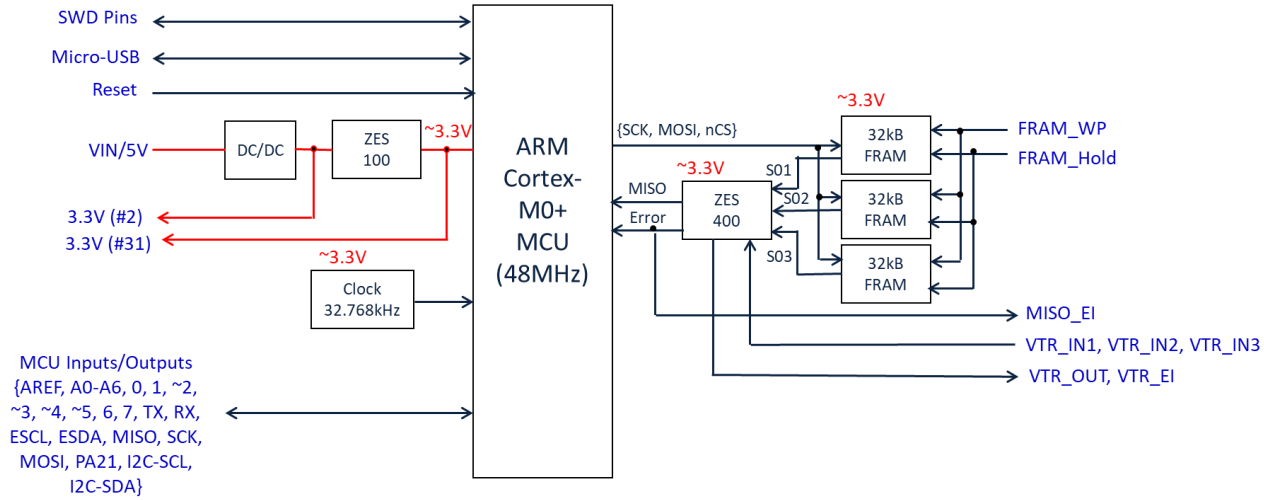


Fig. 1: The simplified block diagram of ZSOM™-M01

1.3 Ordering Information

Ordering Information

Part Number	Description	Size
ZSOM-M01	ZSOM-M01 ARM Cortex-M0+ Based System-on-Module	70 mm x 50 mm
ZSOM-M01-T01*	ZSOM-M01-T01 Carrier board for ZSOM-M01	95.89 mm x 90.17 mm
ZSOM-NS01A	ZSOM-NS01A Evaluation Carrier Board Kit for ZSOM-M01	95.89 mm x 90.17 mm

*ZSOM-M01-T01 is the corresponding carrier board (no parts mounted) for ZSOM-M01.

The ZSOM-NS01A is the corresponding Evaluation carrier board Kit (EVK) for ZSOM-M01. It is designed and tested only for ground conditions and at room temperature.

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

2 Signal/Pins and System Control

Fig. 2 depicts the pin assignment and the power switch control of ZSOM™-M01.

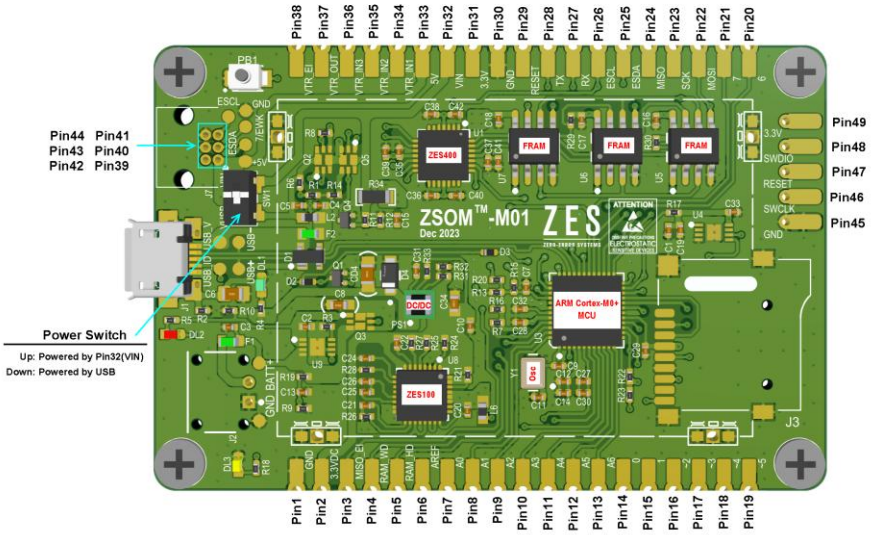


Fig. 2: Pin assignment and power switch control of ZSOM™-M01

2.1 Board to Board I/O

Table 1: **I/O Signals**

S/N	Pin Name	I/O Type	Pin Description	Remark
1	GND	Power	Ground	See Fig. 1 for the locations
2	3.3VDC	Output	3.3V Output from DC/DC	
3	MISO_EI	Output	Error Indicator for FRAM MISO (from ZES400)	
4	FRAM_WP	Input	FRAM Write Protect	
5	FRAM_HD	Input	FRAM Hold	
6	AREF	Input	AREF (PA03)	
7	A0	Input/Output	A0/ D15/ DAC0 (PA02)	
8	A1	Input/Output	A1/ D16 (PB02)	
9	A2	Input/Output	A2/ D17 (PB03)	
10	A3	Input/Output	A3/ D18~ (PA04)	
11	A4	Input/Output	A4/ D19~ (PA05)	
12	A5	Input/Output	A5/ D20 (PA06)	
13	A6	Input/Output	A6/ D21 (PA07)	
14	0	Input/Output	D0~ (PA22)	
15	1	Input/Output	D1~ (PA23)	
16	~2	Input/Output	D2~ (PA10)	
17	~3	Input/Output	D3~ (PA11)	
18	~4	Input/Output	D4~ (PB10)	
19	~5	Input/Output	FRAM CS/ D5~ (PB11)	
20	6	Input/Output	~D6 (PA20)	See Fig. 1 for the locations
21	7	Input/Output	~D7 (PA21)	
22	MOSI	Output	FRAM MOSI/ SPI-MOSI/ ~D8 (PA16)	
23	SCK	Output	FRAM SCK/ SPI-SCK/ D9 (PA17)	
24	MISO	Input	FRAM MISO/ SPI-MISO/ ~D10 (PA19)	

25	ESDA	Input/Output	I2C-SDA/ D11 (PA08)	
26	ESCL	Input/Output	I2C-SCL/ ~D12 (PA09)	
27	RX	Input/Output	UART-RX/ D13 (PB23)	
28	TX	Input/Output	UART-TX/ D14 (PB22)	
29	RESET	Input	Board Reset	
30	GND	Power	Ground	
31	3.3V	Output	3.3V Output from ZES100	
32	VIN	Input	5V Input to Board	
33	5V	Output	5V Output	
34	VTR_IN1	Input	Voter Input 1 – User Channel – See ZES400 dat	
35	VTR_IN2	Input	Voter Input 2 – User Channel	
36	VTR_IN3	Input	Voter Input 3 – User Channel	
37	VTR_OUT	Output	Voter Output – User Channel	
38	VTR_EI	Output	Error Indicator – User Channel (From ZES400)	
39	5V Output	Output	5V Output	For Hi-Rel I²C Connector
40	PA21	Input	PA21	
41	I2C-SCL (PA09)	Output	I2C-SCL (PA09)	
42	I2C-SDA (PA08)	Input/Output	I2C-SDA (PA08)	
43	Ground	Power	Ground	
44	Ground	Power	Ground	
45	GND	Power	Ground	For SWD Pins
46	SWCLK	Input	SWCLK (PA30)	
47	RESET	Input	Board Reset	
48	SWDIO	Input/Output	SWDIO (PA31) (SWD pins)	
49	3.3V	Power	3.3V (Microcontroller Power for SWD pins)	

2.2 System Control

Table 2: **Power Up Options**

No	Power Option	Remark
1	Via micro-USB	Default power-up [Make the Power Switch away from the USB]
2	Via Vin	Using Pin 32 [Make the Power Switch closer to the USB]

A power LED indicator will be on when power is on.

Table 3: **Resets**

No	Reset Option	Remark
1	Reset Button	Part PB1
2	Pin 29	User control

Table 4: **Communications**

No	Option	Remark
1	Via micro-USB	With micro-USB connector (included)
2	UART (Pin 27 and 28)	Via SAMD21 ARM Cortex-M0+ Microcontroller
3	I²C (Pins 39-44)	Via the Hi-Rel I²C Connector (Harwin connector - G125-MH10605L1P – not included)
4	SPI	Self-configurable via SAMD21 ARM Cortex-M0+ Microcontroller – referring the SAMD21 datasheet

3 Software/Programming

3.1 Software Installation

The software development platform is fully compatible with Arduino Integration Design Environment (IDE). The Arduino IDE is available from the Arduino link - Software | Arduino. The recommended version is Arduino IDE 2.2.1.

During the setting and installation, please set the following:

(i) "Tool" -> "Board" -> "Board Manager" -> "Arduino SAMD Board"

(ii) "Tool" -> "Board" -> "Arduino SAMD Boards (32-bits ARM Cortex-M0+)" -> "Arduino MKRZERO"

3.2 Programming

The programing languages used are C and C++. For learning how to program/configure the SAMD21 ARM Cortex-M0+ microcontroller, please refer to the document associated with SAMD21G18A.

3.3 ZES Error Detection and Correction (EDAC) Code

ZES provides the proprietary error-detection-and-correction (EDAC) C-code for detecting/correcting multiple errors in Flash/SRAM. Please contact info@zero-errorsystems.com for obtaining the C-code (.zip format) and the user guide.

Figs. 3 (a) and (b) depict the pictorial steps to add the EDAC code (zesEDAC) into the Arduino IDE platform.

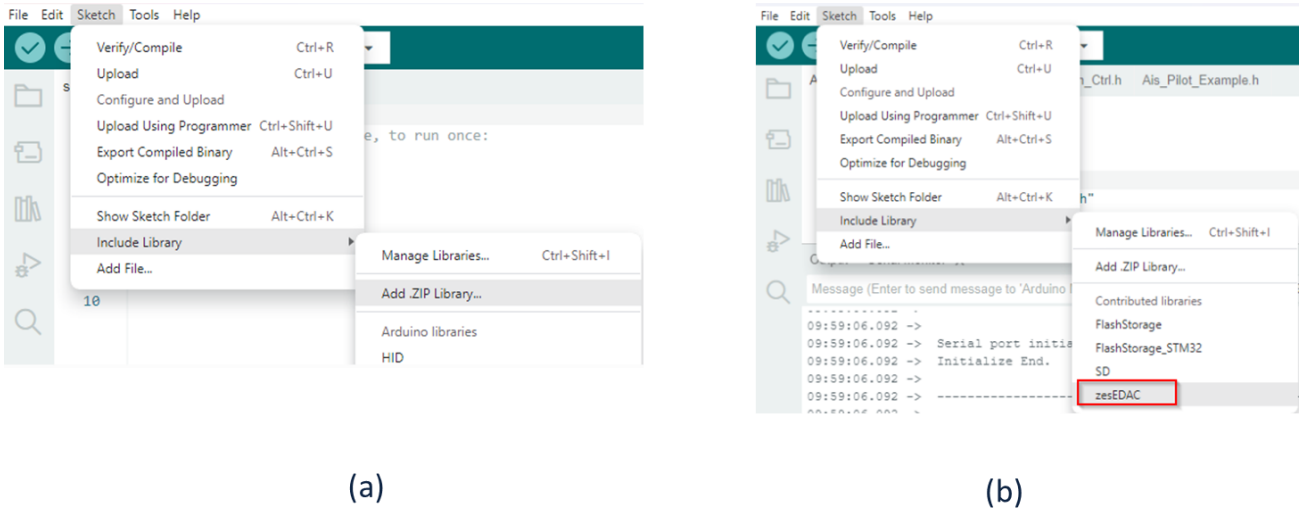


Fig. 3: (a) To locate a .zip library location, and (b) to include ZES EDAC code (zesEDAC) into the platform

4 Technical Specifications

4.1 Overall Specs

Table 5 depicts the overall specification for ZSOM™-M01.

Table 5: **Overall specification for ZSOM™-M01**

Item		Specs/Info
PCB Board		PCB Class-III, 6-layers – Size: 45mm (W) x 68 mm (L) @ 13g
Microcontroller		SAMD21 Cortex®-M0+ 32bit low power ARM MCU @ 48MHz (SAMD21G18A with Flash=258kB and SRAM=32kB)
External Memory		FRAMs (32kB) implemented in TMR
USB Connector		Micro-USB (Type B)
I/O connector		Surface Mount (ZIPPER Holes/PAD stack)
Pin	**Digital I/Os**	8
	Analog Inputs	7 (ADC 8/10/12 bits)
	Analog Outputs	1 (DAC 10 bits)
	PWM Pins	12 (0 -8, 10, 12, A3, A4)
	Interrupt	10 (0, 1, 4, 5, 6, 7, 8, 9, A1, A2)
Communication	**UART**	Yes
	I²C	Yes (2: one with GPIO, the other with Hi-Rel I²C Connector)
	SPI	Yes
Power	**Board Voltage**	4.5 – 5.5V (default: 5V)
	I/O Voltage	3.3V
	DC/DC	5V/3.3V SEL protected by ZES100 – maximum protection rating: 500mA @ 5V
	DC current per IO	7mA

4.2 Recommending Conditions

Table 6: Tabulates the recommended conditions for operating ZSOM™-M01

Table 6: **Recommended Conditions**

No	Item	Spec
1	Supply Voltage	5V
2	Temperature	-40°C to 105°C
3	Power Rating	≤ 500mA @ 5V

4.3 Reliability Tests

The following test results are summarized below in Table 7.
For detailed test results, please contact info@zero-errorsystems.com

Table 7: **Reliability Tests**

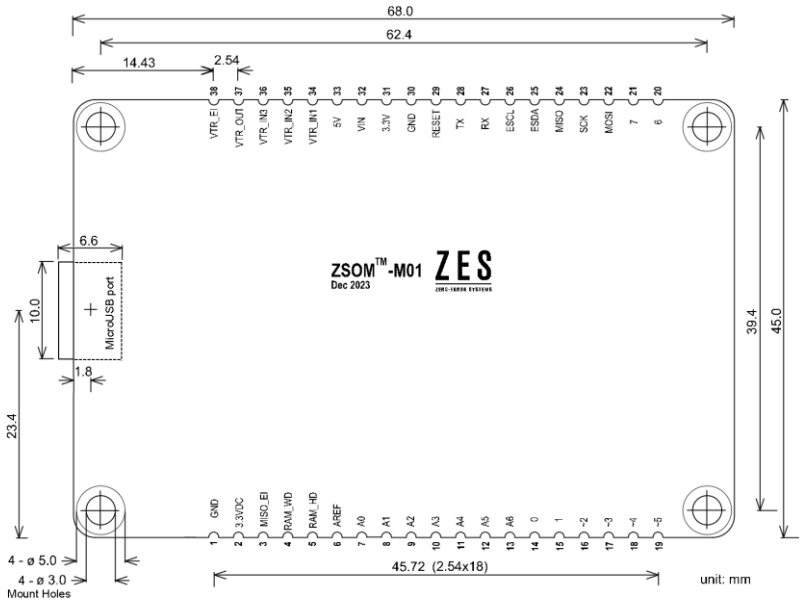
Parameter	Condition	Value*	Units
Proton Testing	Proton @ fluence = 2.5×10^{11} particles/cm² (@ Kaohsiung Chang Gung Memorial Hospital, Taiwan)	Up to 200	MeV
Total Ionizing Dose	Cobalt-60 @ Kyushu University, Japan	20,000	rad

* The value was the characterized data during the test was observed.

4.4 Physical Dimensions

Fig. 4 depicts the physical outline dimension for ZSOM™-M01.

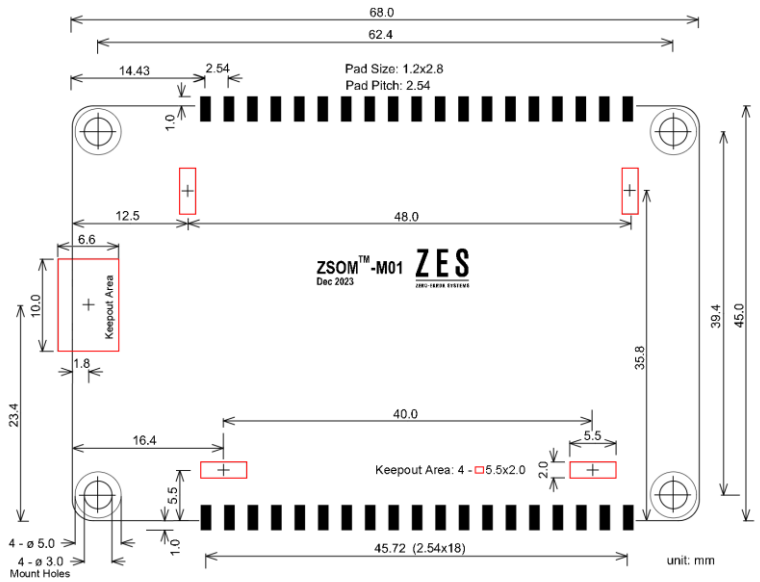
Fig. 5 depicts the recommended footprint while integrating ZSOM™-M01 into another module/ carrier board.



ZSOM-M01 Outline Dimension

All dimensions are measured in mm, and the tolerances for dimensions without tolerance values are ±0.05mm

Fig. 4: Physical outline dimensions



ZSOM-M01 Recommended Footprint

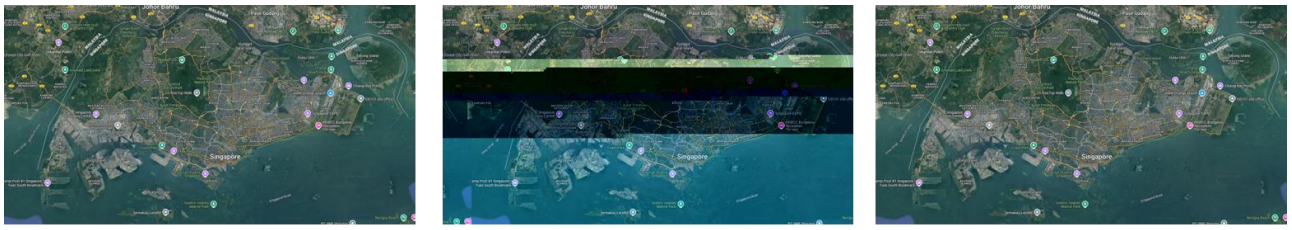
All dimensions are measured in mm, and the tolerances for dimensions without tolerance values are ±0.05mm

Fig. 5: Recommended footprint to integrate into carrier board

5 Application Examples

5.1 Data Protection Example

An image is stored inside the SRAMs of the ZSOM™-M01 and the data are protected by ZES EDAC code. Hypothetically the data is then randomly corrupted with 14 errors (14-bits flipped out of 29kB). The corrupted data would be recovered by the ZES EDAC. Figs. 6 (a) – (c) depict the original picture, the corrupted picture with 14-bits flipped, and the corrected picture.



(a) Original Picture (b) Corrupted Picture with 14-bit errors (c) Corrected Picture

Fig. 6: Data protection demonstration (picture data) in SRAMs:
(a) Original data, (b) Corrupted Data (14-bit errors), and (c) Corrected data (with ZES EDAC)

5.2 Prototype Evaluation Carrier-Board for Supporting CubeSat Development (ZSOM-M01-T01)

A prototype Evaluation carrier board ZSOM-M01-T01 is available to embody ZSOM™-M01 for quicky prototyping with some active components (e.g., sensors or other ICs based on SOIC or DIP packages). The prototype carrier board is designed based on CubeSat specifications (< 10cm x 10cm). Fig. 7 depicts the prototype carrier board based on the CubeSat PCB standard. ZSOM™-M01 can be put in (during tests) or taken off (after tests) from the carrier board. The carrier board has the footprints for SOIC and DIP packages. Developers can mount their application specific ICs (e.g., sensors or other ICs) on the carrier board and connect them with ZSOM™-M01.
For more information about the carrier board, please contact sales@zero-errorsystems.com

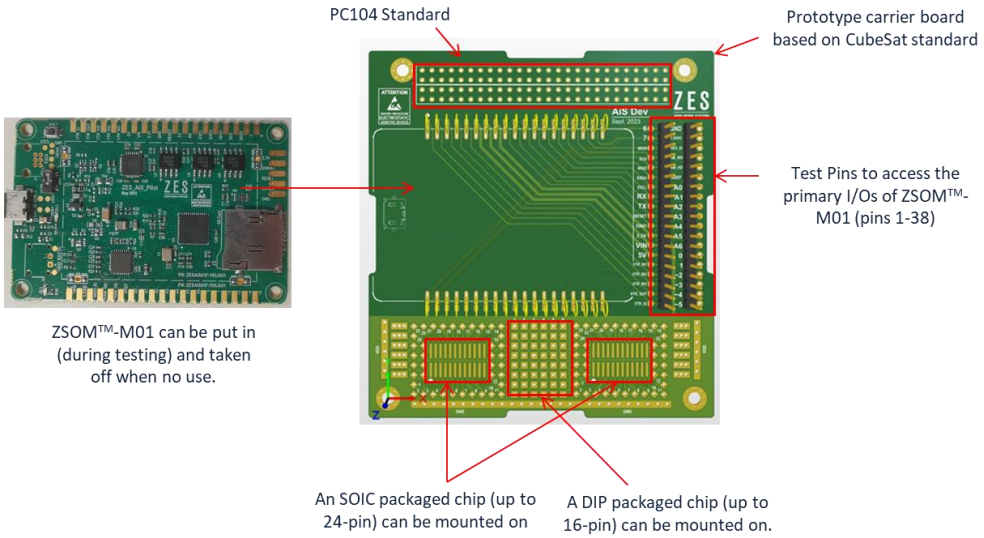


Fig. 7: A prototype carrier board ZSOM-M01-T01 to embody ZSOM™-M01 for quick testing for CubeSat prototype

5.3 CubeSat Payload Evaluation Kit Designs: ZSOM-NS01 (Application example)

Fig. 8 depicts a CubeSat scientific payload evaluation kit ZSOM-NS01 in part embodying a ZSOM™-M01 for a Space mission of characterizing the radiation-effect on a COTS component.
The ZSOM™-M01 performs two basic functions:

(a) Controlling/Monitoring the COTS component under test (i.e., device under test)
The ZSOM ™-M01 aims to detect the anomaly (including SEL, SEU, and SEFI) of the COTS component during the targeted orbit , and stores the associated anomaly data. The operations involve data control, data motoring, data management and data protection.

(b) Interfacing the On-board Computer (OBC) of the satellite
ZSOM™-M01 communicates with the On-board Computer (OBC) for telemetry. The operations involve powering on/off the CubeSat payload, sending specific commands to control the CubeSat, and transferring data from ZSOM™-M01 to the On-board Computer (OBC).

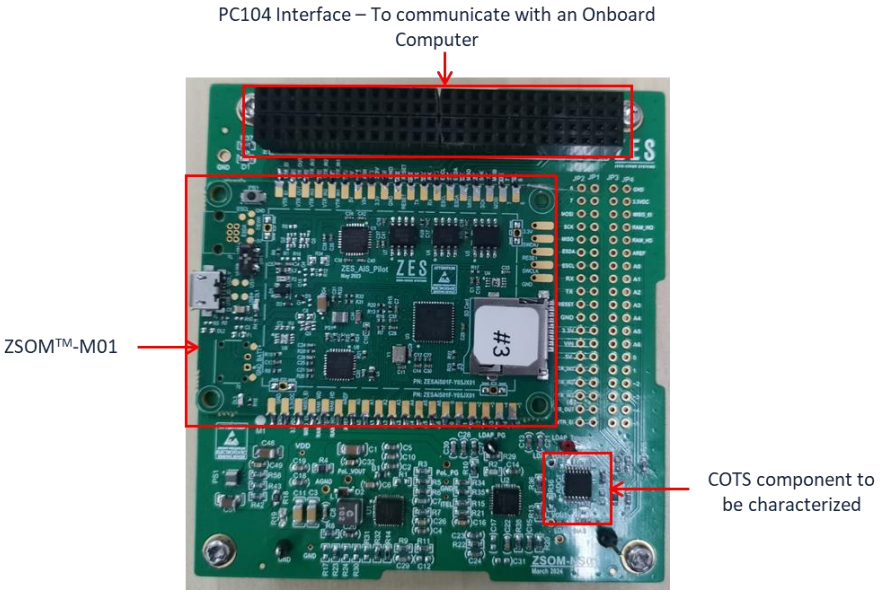


Fig. 8: ZSOM-NS01 A scientific CubeSat payload application embodying ZSOM™-M01

Other CubeSat payload designs for Space missions include but limited to:

- Scientific payloads with TID characterization, SEE characterization, temperatures, etc.
- Navigation payloads (e.g., with star-trackers, gyroscopes, accelerometers, etc.)
- Observation payloads (e.g., sensors, dosimeters attached)
- Application-specific software-enabled payloads (e.g. security codes/protocols, etc.)

5.4 Extendable SEL Protection for External COTS Components

ZSOM™-M01 can be further configured to protect external COTS components (if needed) from SEL if the external COTS components are operated at 3.3V. Fig. 9 depicts the connection where the pin #31 can be used to power external COTS components. The COTS components could be sensors, analog circuits, digital circuits or mixed signal circuits. The COTS components will share the SEL protection by the ZES100

LDAP mounted on ZSOM™-M01. Please refer to the maximum power rating in Section 4.2, and refer to the datasheet of ZES100 LDAP for recommended decoupling capacitors.

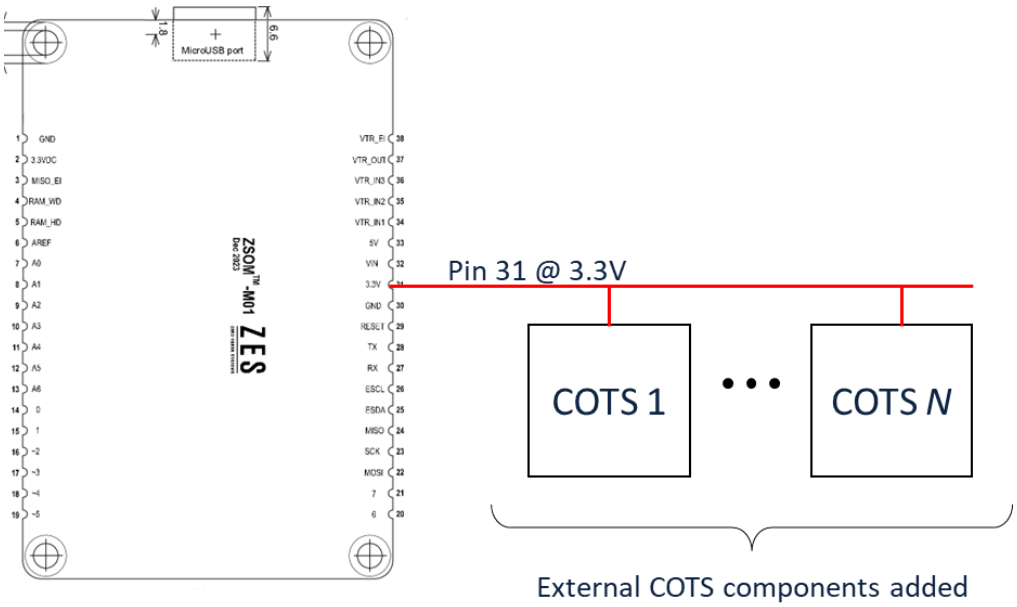


Fig. 9: An extendable SEL protection for other external COTS components

5.5 Instrumentation and Control for High Reliability Applications

ZSOM™-M01 is applicable for high-reliability applications, including but limited to:

- Instrumentation and control for irradiation testing
- Instrumentation and control for unmanned/autonomous vehicles, including drones
- Instrumentation and control for harsh environments

6 Revision History

Version	Description	Date
V1.3	First version	Jan-2024
V1.4	Ordering Information	Apr-2024
V1.5	TID test result included Application examples updated	May-2024
V1.6a	Section 5.1, picture updated	Nov-2024

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