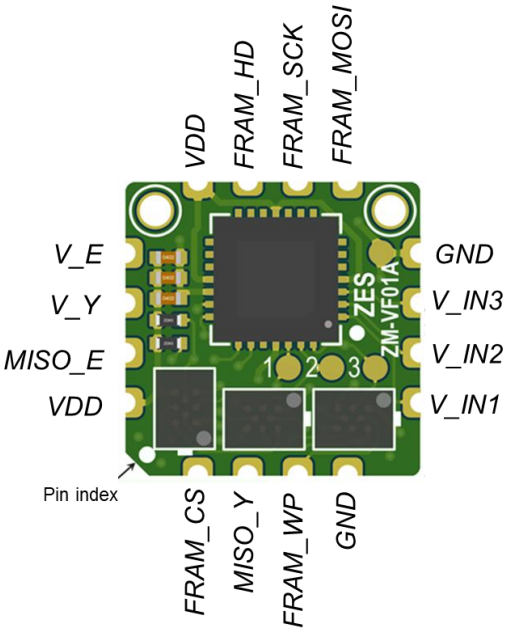
Voter Module ZM-VF01A

Radiation-Hardened TMR Voter with EDAC Software and FRAMs

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



Overview

ZM-VF01A Voter Module is an integrated with a radiation-hardened Voter-IC (ZES400 or ZES401) with Ferroelectric Random Access Memory (FRAM) three pcs 1M-bit implemented in Triple-Modular-Redundancy (TMR). The ZES400 Voter embodies 4-channel voting circuits where one of the channels is used to vote the outputs of the FRAMs. An additional voter channel is available for supporting TMR for another signal where necessary. The ZM-VF01A features ultra-low error, suitable for storing critical data storage and/or supporting ZES error-detection-and-correction (EDAC) algorithms.

Key Features

- Radiation-hardened ZES400/401 Voter-IC:
  Total Ionizing Dose (TID): 300krad (Si),
  Single-Event-Latchup (SEL): 110MeV-cm^2/mg
  Single-Event-Upset (SEU): 83MeV-cm^2/mg
- FRAM with inherent SEU radiation hardness
- Operating voltage: 1.8V ~ 3.6V
- Temperature: -40°C to 85°C
- SPI interface with the FRAMs
- Additional voter channel available for enabling TMR for another customized signal
- **Overall TID: 45krad (Si)**
- **Overall Proton test: no SEU/SEL up to 200MeV**
- **Laser test on FRAMs: no SEL up to 5.5nJ Laser energy**

Applications

- Low power embedded applications for payloads for Low-Earth-Orbit (LEO), MEO, GEO payloads for Error-correction in Memories
- SEU induced Data-flips/ Soft-errors Correction in memories for FPGA/GPU/MCU payloads
- Telemetry/data communication applications
- Low error-rate data protection applications
- Instrumentation and control for high reliability applications
- Support EDAC algorithms for data integrity protection on memories

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1 Overview

Voter-module ZM-VF01A is a radiation-hardened Triple-Modular-Redundancy (TMR) Ferroelectric Random Access Memory (FRAM) module embodying a ZES400 or ZES401 Voter IC and three 1M-bit FRAMs implemented in TMR. The ZES400/ZES401 Voter IC embodies 4-channel voting circuits where one of the channels is used to vote the outputs of the FRAMs. An additional voter channel is available for supporting TMR for another signal where necessary. The ZM-VF01A features ultra-low error, suitable for storing critical data storage and/or supporting ZES error-detection-and-correction (EDAC) algorithms.

1.1 Features

- Radiation-hardened ZES400/401 voter adopted (Total Ionizing Dose @ 300krad (Si), Single-Event-Latchup (SEL) @ 110MeV-cm^2/mg and Single-Event-Upset (SEU) @ 83MeV-cm^2/mg)
- FRAM (Part number: MB85RS1MT) with inherent SEU radiation hardness
- Operating voltage: 1.8V ~ 3.6V
- Temperature: -40^{o}C to 85^{o}C
- SPI interface with the FRAMs
- Additional voter channel available for enabling TMR for another customized signal
- **Overall Total Ionizing Dose (TID): 45krad (Si)**
- **Laser test on FRAMs – no Single-Event-Latchup (SEL) @ up to 5.5nJ laser energy**
- **Overall proton test: no SEU/SEL up to 200MeV**

1.2 Block Diagram

Fig. 1 depicts the simplified diagram of ZM-VF01A, showing various ZES400/401 and FRAM components and their interface signals/connections. The primary inputs/outputs are shown; their pin definitions are delineated in Table 1 of Section 2.1.

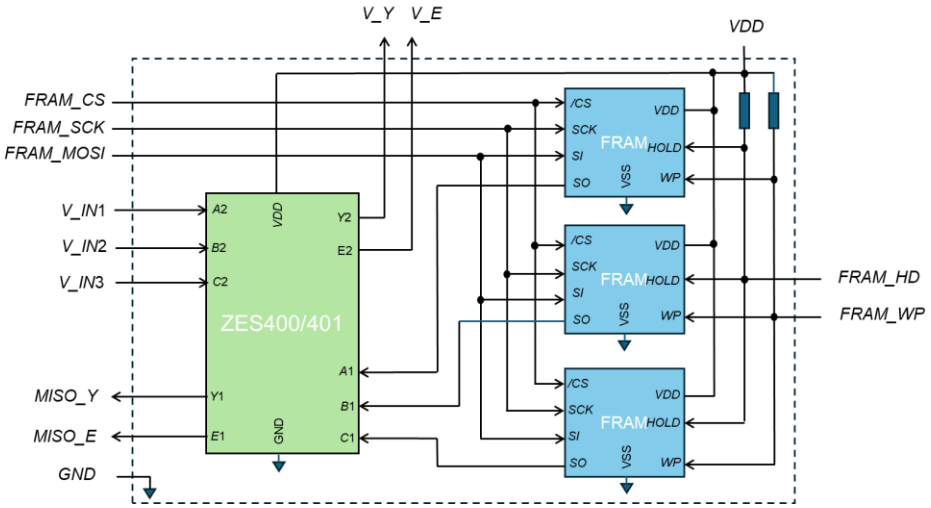


Fig. 1: The simplified block diagram of ZM-VF01A

1.3 Ordering Information

Ordering Information

Part No.	Description	Form Factor	Size
ZM-VF01A	ZM-VF01A Voter Module	Module	11.8mm × 11.8mm
ZM-VF01A-T01	ZM-VF01A-T01 Voter Module Evaluation Board	Module	57mm × 33mm

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

2 Signal/Pins and Operation Control

Fig. 2 depicts the pin assignment of ZM-VF01A.

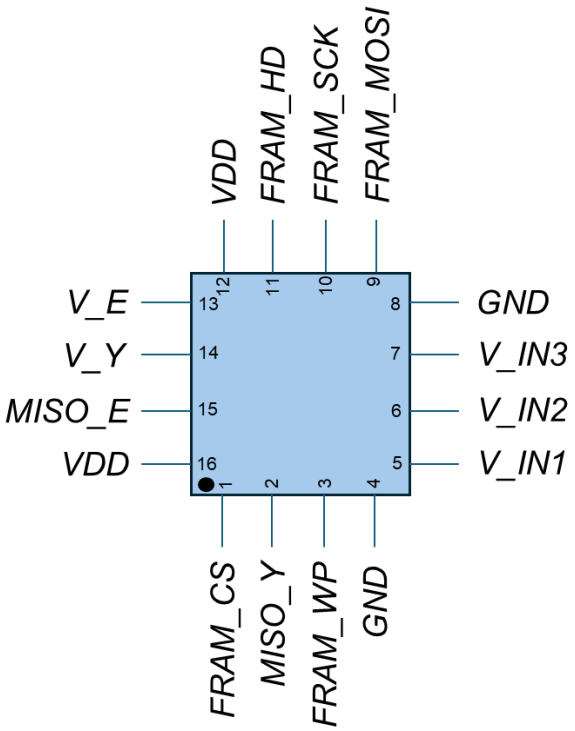


Fig. 2: Pin assignment of ZM-VF01A Voter Module

2.1 Module Input/Output (I/O)

Table 1: I/O Signals

S/N	Pin Name	I/O Type	Pin Description	Remark
1	*FRAM_CS*	Input	FRAM Chip Select pin	See Figs. 1 and 2 for the locations
2	*MISO_Y*	Output	FRAM Serial Data Output pin (through ZES400/401)	
3	*FRAM_WP*	Input	FRAM Write Protect pin (with a pull-up resistor onboard)	
4	*GND*	Ground	Ground pin	
5	*V_IN1*	Input	ZES400/401 Voter Channel Input 1 pin	
6	*V_IN2*	Input	ZES400/401 Voter Channel Input 2 pin	
7	*V_IN3*	Input	ZES400/401 Voter Channel Input 3 pin	
8	*GND*	Ground	Ground pin	
9	*FRAM_MOSI*	Input	FRAM Serial Data Input pin	
10	*FRAM_SCK*	Input	FRAM Serial Clock pin	
11	*FRAM_HD*	Input	FRAM Hold pin (with a pull-up resistor onboard)	
12	*VDD*	Power	Supply Voltage pin	
13	*V_E*	Output	ZES400/401 Voter Channel Output for Error pin	
14	*V_Y*	Output	ZES400/401 Voter Channel Voted Data Output pin	
15	*MISO_E*	Output	FRAM Serial Data Output Error pin (through ZES400/401)	
16	*VDD*	Power	Supply Voltage pin	

2.2 FRAM SPI Operation Control

Fig. 3 depicts the SPI control modes for accessing the FRAMs. Please note that for each operation (e.g., write or read), the three FRAMs are written/read simultaneously.

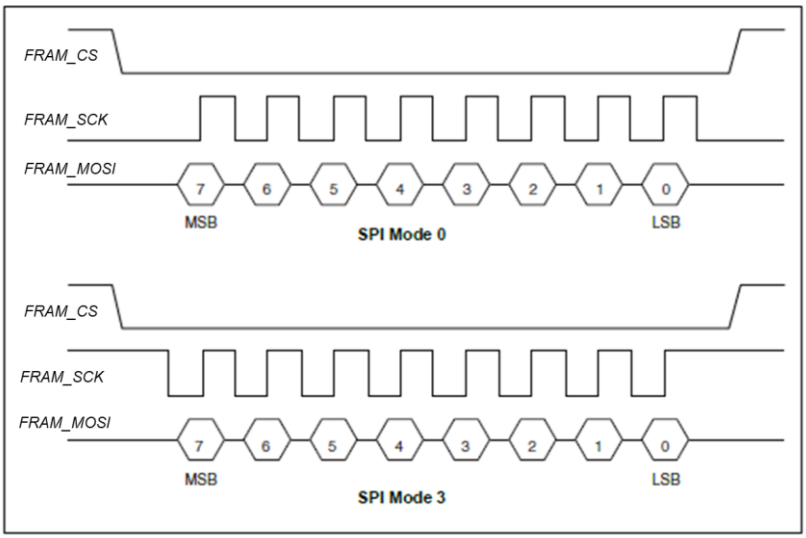
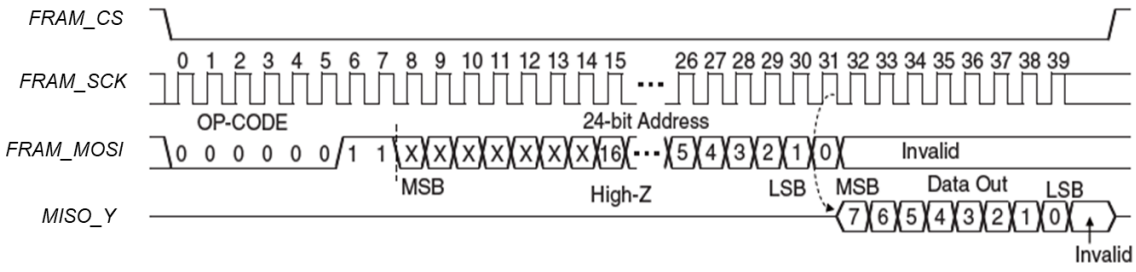


Fig. 3: The SPI modes for accessing FRAMs

2.3 FRAM Access Timing Diagram

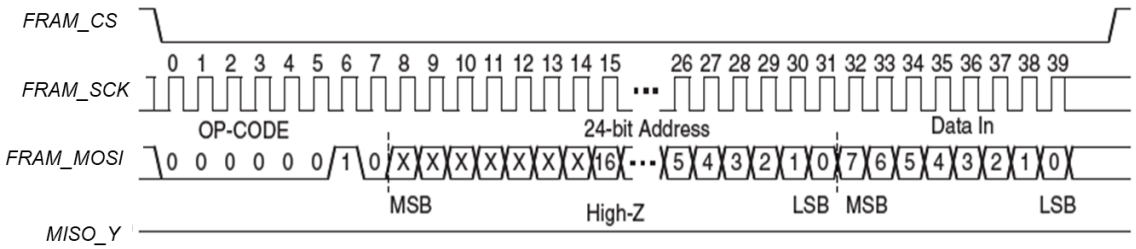
Figs. 4 (a) and (b) depict the access timing diagrams for the read operation and write operation, respectively.

READ Operation



(a)

WRITE Operation



(b)

Fig. 4: The access timing diagram: (a) read operation, and (b) write operation

2.4 Voter Channel Control

Table 2 tabulates the truth table of the voter channel.

Table 2: Voter Channel Truth Table

V_IN1	*V_IN2*	*V_IN3*	*V_Y*	*V_E*
0	0	0	0	0
0	0	1	0	1
0	1	0	0	1
0	1	1	1	1
1	0	0	0	1
1	0	1	1	1
1	1	0	1	1
1	1	1	1	0

3 Technical Specifications

3.1 Recommending Conditions

Table 3 tabulates the recommended conditions for operating ZM-VF01A.

Table 3: Recommended Conditions

Symbol	Parameter		Min	Typ	Max	Unit
T	Temperature range		-40	-	+85	℃
V_{DD}	Voltage supply of the module		1.8	3.3	3.6	V
V_I	Input voltage		0	-	V_{DD}	V
V_O	Output voltage		0	-	V_{DD}	V
f	Maximum frequency (RT*, 3.3V, 4.75pF*)		-	-	20	MHz
I_{CC}	Max. Power Typ. @ RT*, 3.3V, 20MHz FRAM Read/Write, 4.75pF* Max. @ 85℃, 3.6V, 20MHz FRAM Read/Write, 4.75pF*		-	TBD	TBD	mA
V_{IH}	High-level input voltage	V_{DD}=1.8±10% V	1.26	-	-	V
		V_{DD}=3.3±10% V	2.32	-	-	V
V_{IL}	Low-level input voltage	V_{DD}=1.8±10% V	-	-	0.54	V
		V_{DD}=3.3±10% V	-	-	0.99	V
I_{OH}	High-level output current	V_{DD}=1.8±10% V	-	-	-2	mA
		V_{DD}=3.3±10% V	-	-	-4	mA
I_{OL}	Low-level output current	V_{DD}=1.8±10% V	-	-	2	mA
		V_{DD}=3.3±10% V	-	-	4	mA
t_r, t_f	Input rise or fall time (10% to 90%)	V_{DD}=1.8±10% V	-	-	1000	ns
		V_{DD}=3.3±10% V	-	-	400	ns

*Assuming capacitance due to PCB traces is negligible *RT: Room Temperature

3.2 Radiation Performance Reliability Tests

The following test results are summarized below in Table 4.

Table 4: Radiation Performance Reliability Tests

Parameter	Condition	Value*	Units
Proton Testing	Proton fluence = TBD; no SEL/SEU	200	MeV
Total Ionizing Dose	Cobalt-60 @ Kyushu University	45k	rad
SEL @ Laser	Laser Testing on FRAMs; no SEL	5500	pJ

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

For detailed test results, please contact sales@zero-errorsystems.com

3.3 Physical Dimensions

Fig. 5 depicts the physical outline dimension for ZM-VF01A Voter-module.

Fig. 6 depicts the recommended footprint while integrating ZM-VF01A into another PCB/module.

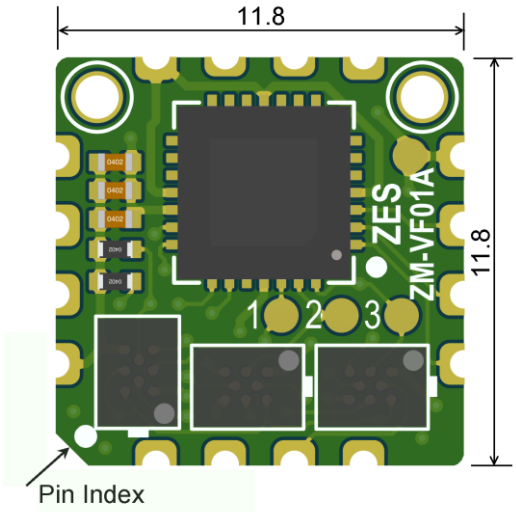


Fig. 5: Physical outline dimension

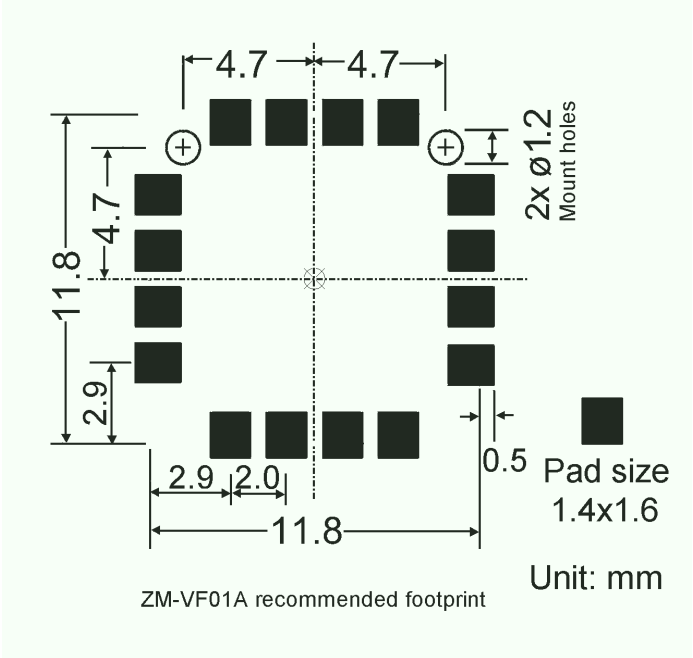


Fig. 6: Recommended footprint

4 Recommended Interface

Fig. 7 depicts the recommended interface connection when a microcontroller or a Field-Programmable-Gate-Array (FPGA) is connected to ZM-VF01A via an SPI interface. Please note that the pull-up resistor R1 and the pull-down resistor R2 could be optional if the microcontroller or the FPGA can provide sufficient current drive to drive ZM-VF01A. If not, please refer back to the datasheet of the microcontroller or the FPGA to provide appropriate R1 and/or R2 values to drive ZM-VF01A.

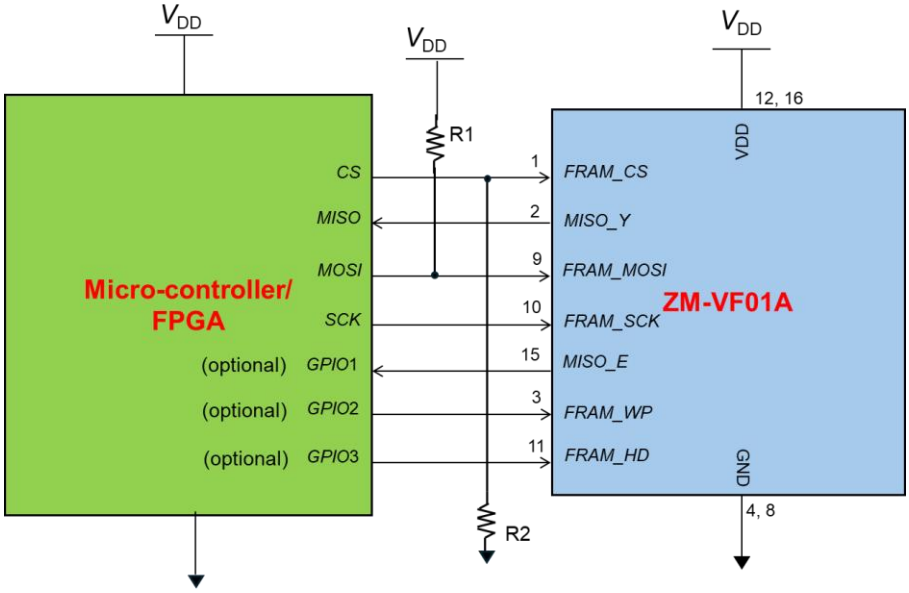


Fig. 7: Recommended interface connection between a microcontroller/FPGA and ZM-VF01A. The pull-up resistor R1 and pull-down resistor R2 could be optional.

5 Application Examples

5.1 Hardware/software co-solution for enabling ZES Error Detection-and-Correction (EDAC) algorithm

ZM-VF01A can be integrated with the ZES error-detection-and-correction (EDAC) algorithm(s) to enable data protection virtually for any memories (e.g., eMMC or DRR4). Fig. 8 briefly depicts the interface setup where a processing unit embodying either a microcontroller (MCU) or an FPGA. The processing unit is interfaced with an external memory and ZM-VF01A. The external memory could be a Commercially-Off-the-Shelf (COTS) memory (e.g.., eMMC or DDR4) whose data need to be protected. The EDAC algorithm is executed within the MCU/FPGA, providing the encoding/decoding process. The ZM-VF01A and the EDAC algorithm collectively serve as a hardware/software co-solution to reduce the soft-error (e.g., bit flips) in the external memory. The hardware/software co-solution provides 50x better error-rate than the hardware-only solution, and 2000x better error-rate than the solution-only solution.

For more information about EDAC, please contact sales@zero-errorsystems.com.

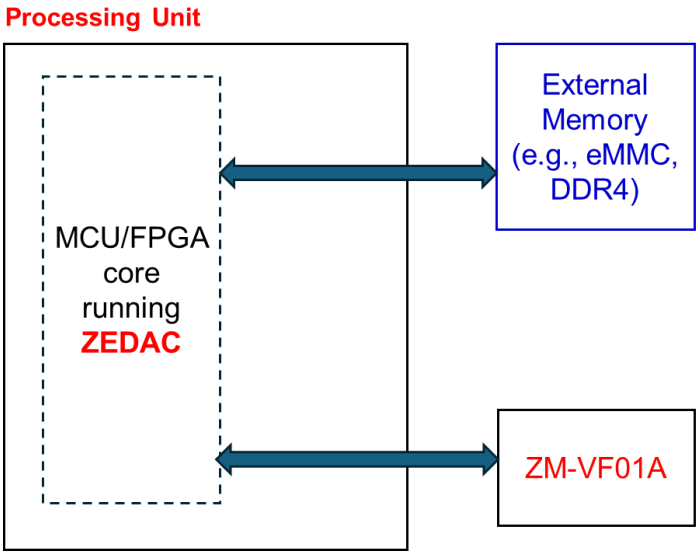


Fig. 8: Setup for enabling hardware/software co-solution to feature ultra-low soft-error rate (in part using ZM-VF01A and EDAC)

5.2 Add-on Connector for Interfacing a System with SPI Ports

ZM-VF01A can be mounted to a customized add-on connector which can be interfaced with a system/subsystem via the GPIO pins. Fig. 9 depicts an example where the add-on connector is designed to embody the ZM-VF01 module, and to have a 40-pin interface compatible with a Nvidia Nano Orin system. With the add-on connector, the ZM-VF01 is inherently connected (via the SPI ports) to the MCU of the Nvidia Nano Orin system. If necessary, the EDAC algorithm can be easily executed in the MCU, checking/recovering the data using the MCU and the ZM-VF01. The data could be embedded SRAMs within the MCU, or the dedicated eMMC/DDR memories within the Nvidia Nano Orin system.

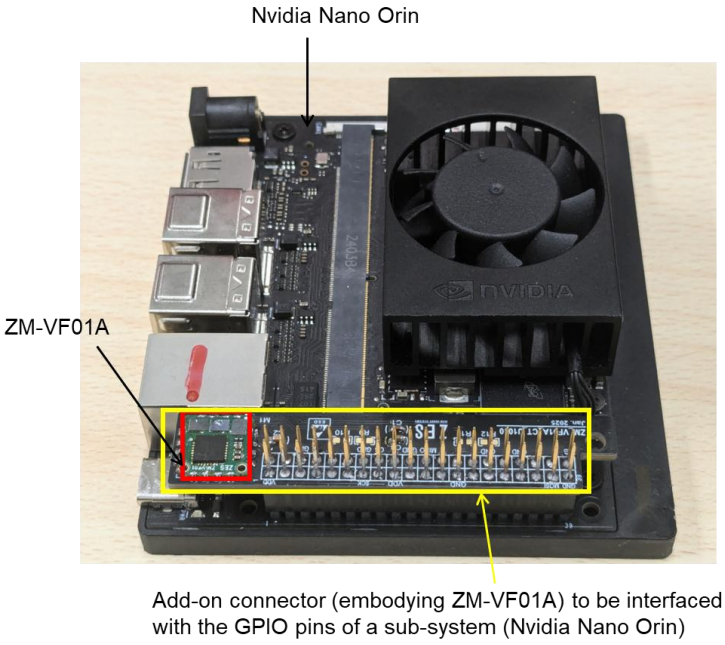


Fig. 9: An example: ZM-VF10A on a connector which is interfaced with a Nvidia Nano Orin module (via its 40-pin GPIOs)

Similarly, the add-on connector can be customized for other systems/subsystems such as Raspberry Pi systems/sub-systems.
For more information about the add-on connector, please contact sales@zero-errorsystems.com

5.3 Critical data storage

ZM-VF01A can be used to store critical data such as the boot programs, critical configuration data, AI-model data, critical output data, and critical operational status information for satellite applications or high reliability applications. Please note the memory capacity limit is 1M-bit.

5.4 Voter Channel Application

ZM-VF01A has an additional voting channel which can enable TMR for two sub-systems. Fig. 10 depicts an example how the data can be transferred, via ZM-VF01A, between the two sub-systems A and B. In the sub-system A, three sub-circuits T1, T2 and T3 generate three same signals T_a, T_b, and T_c which are voted by ZM-VF01A to generate a voted ouput T_y. The three sub-circuits T1, T2 and T3 are usually the same. The voted output T_y is virtually SET-hardened. The voter output T_y is virtually error-free provided that the error possibility to have two errornos signals (out of the three signals T_a, T_b, and T_c) is assumed to be very low. The error indication signal T_e can be used to allert the sub-system B, indicating that at least one of the three signals T_a, T_b, and T_c is different.

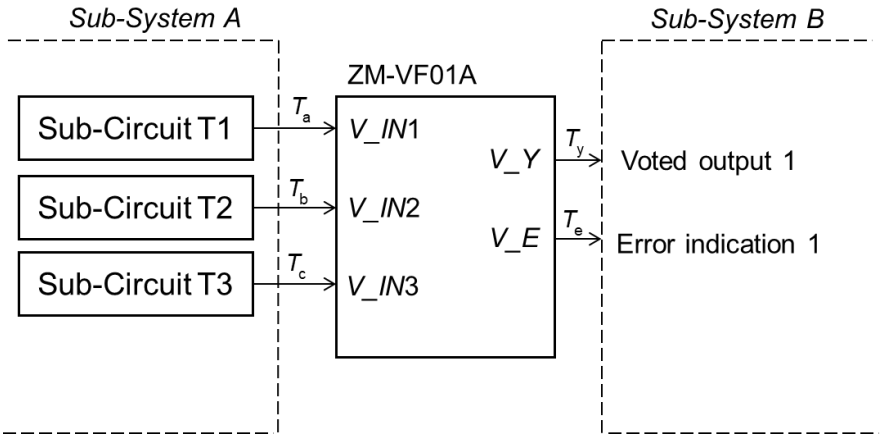


Fig. 10: TMR application example using the voter channel

Voter Module Evaluation Board ZM-VF01A-T01

The ZM-VF01A-T01 is an evaluation-board for Voter-module ZM-VF01A, i.e., a carrier board designed to facilitate rapid prototyping and testing with the ZM-VF01A module in conjunction with the MCP2210 USB-to-SPI converter. The board enables direct connectivity to host systems via USB, supporting both Windows® and Ubuntu® operating environments, as well as ARM-based platforms running Ubuntu Linux.

The carrier board provides mechanical compatibility for mounting the ZM-VF01A module and the MCP2210 board, allowing secure mounting during evaluation and easy removal when not required. Fig. 1 depicts the ZM-VF01A module and MCP2210 board (SPI-USB converter).

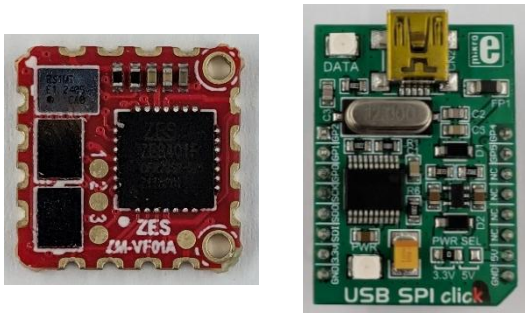


Fig. 1: ZM-VF01A and MCP2210 boards

The overall board dimensions are **57 mm × 33 mm**.

A reference image of the ZM-VF01A-T01 is shown in Fig. 2.

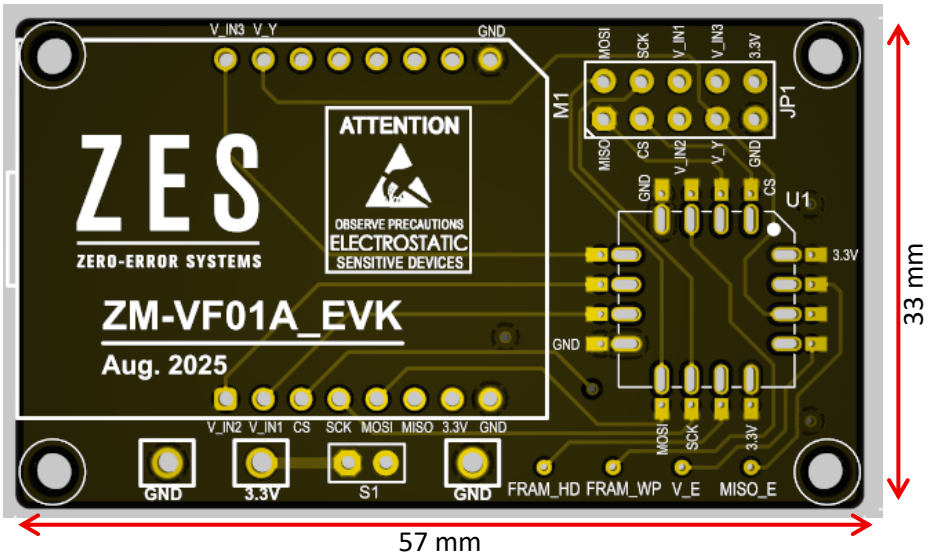


Fig. 2. ZM-VF01A-T01 Evaluation Board

6 Revision History

Version	Description	Date
v1.0	First version	Mar-2025
v1.1	Diagram updated, TID result included	May-2025
V1.2	Ordering Part Description updated	Apr-2026

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