

## Anomaly Detection by K-means

### Introduction

This example runs on AT32F403A MCU and uses LSM6DS3TR-C nine-axis sensor to collect vibration data (X-axis acceleration). It establishes normal operating state characteristics through a self-learning model and detects abnormal vibrations during operation.

Main functions of system:

- Self-learning: Collect sensor signals under normal conditions and establish a model
- Real-time detection: Calculate the deviation between the real-time signal and the model
- Anomaly alert: Turn on the LED and display a prompt when deviation exceeds the threshold

Applicable products:

Part number	AT32F403A series
	AT32F407 series

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# 1 Resources

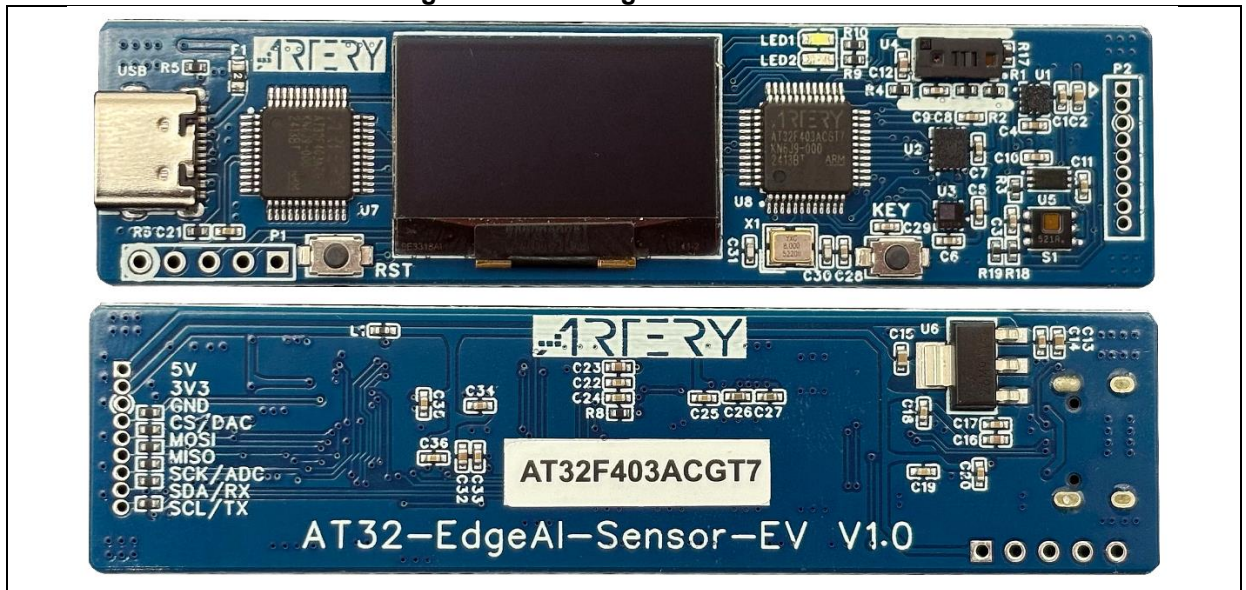
This section mainly introduces the required hardware/software resources and on-board devices.

## 1.1 Hardware requirements

One AT32-EdgeAI-Sensor-EV Board is required. It is a development board based on AT32F403A, integrated with multiple sensors, and it includes the following devices:

- Main control MCU (AT32F403ACxT7)
- AT\_Link\_EZ
- 0.96' OLED display
- 3D magnetometer (LIS2MDL)
- 3D accelerometer / gyroscope (LSM6DS3TR)

Figure 1. AT32-EdgeAI-Sensor-EV Board



## 1.2 Software requirements

The below application code is required. Path:

- SourceCode\AN0287\_SourceCode\_V2.x.x\project

*Note:* All projects are built around Keil 5. If users want to use in other compiling environment, refer to AT32F403A\_407\_Firmware\_Library\_V2.x.x\project\at\_start\_f403a\templates (such as IAR6/7, Keil 4/5) for a simple modification.

## 1.3 On-board devices

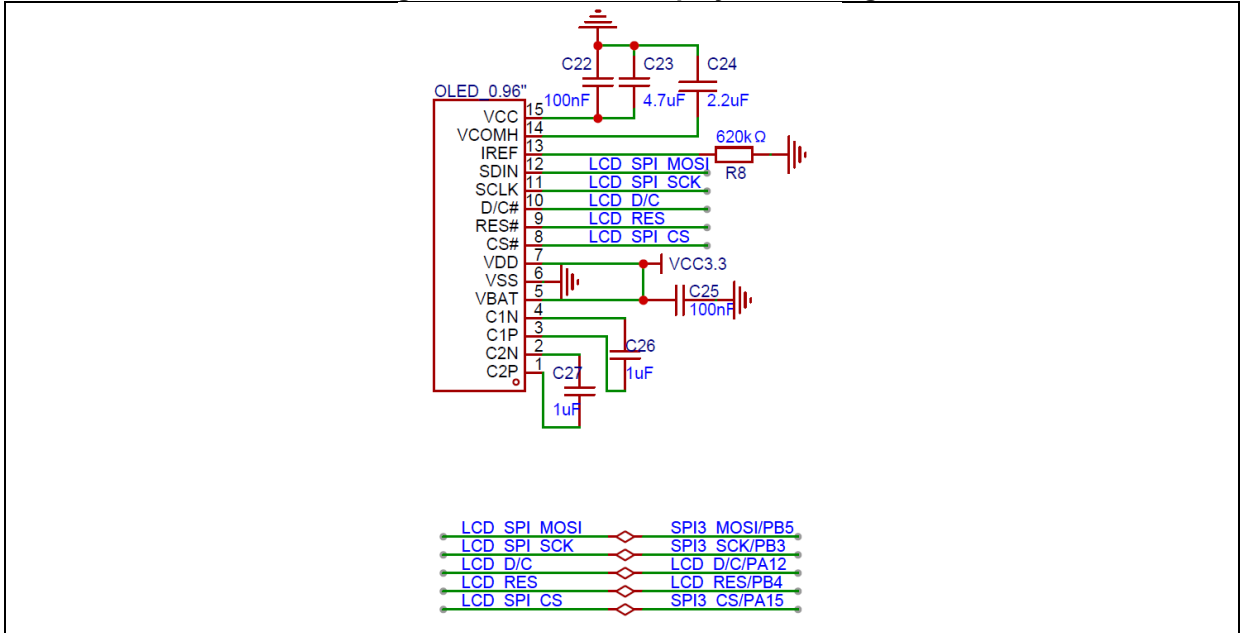
### 1.3.1 0.96' OLED display

A single-chip SPI OLED display with 128\*64-bit GDDRAM (Graphic Display Data RAM) is used. For detailed specifications and the MCU user manual, please refer to the documents in the following directory:

- SensorDataSheet\0.96\_OLED

Circuit of 0.96' OLED display on AT32-EdgeAI-Sensor-EV Board:

Figure 2. 0.96' OLED display circuit diagram



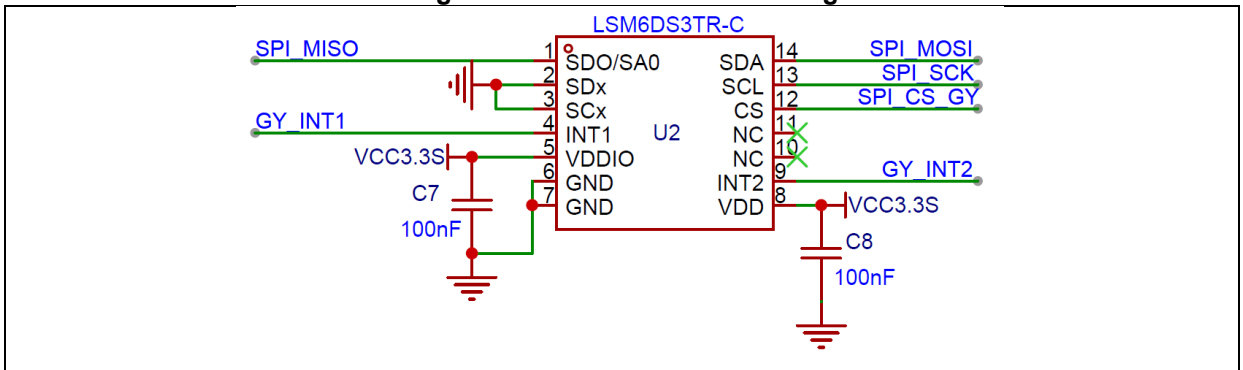
### 1.3.2 3D accelerometer / gyroscope (LSM6DS3TR)

The 3D accelerometer / gyroscope (LSM6DS3TR) is a system-in-package featuring a 3D digital accelerometer and a 3D digital gyroscope performing at 0.90 mA in high-performance mode and enabling always-on low-power features for an optimal motion experience for the consumer. For detailed datasheet, please refer to the documents in the following directory:

- SensorDataSheet\LSM6DS3TR

Circuit of LSM6DS3TR on AT32-EdgeAI-Sensor-EV Board:

Figure 3. LSM6DS3TR circuit diagram



## 2 System working flow

### ■ Power On

Initialize sensors, OLED, serial ports and other peripherals.

Read the last saved model from Flash.

Model found → Enter DETECT mode

Model not found → Enter LEARN mode automatically

### ■ Learning Mode

The system collects 200 sets (LEARN\_WINDOWS = 200) of normal state data.

Extract 8-dimensional features (mean value, variance, RMS, extreme values, skewness, kurtosis, etc.)

Adaptive update of the model centroid.

Calculate after the learning is completed:

$\text{threshold} = \text{mean} + K * \text{std}$

where,

K: refers to the macro definition "AUTO\_THRESHOLD\_K" used to adjust sensitivity

OLED display switches to "Mode: DETECT".

### ■ Detection Mode

Real-time sampling data.

Calculate the distance (score) between the current feature and the model centroid.

Smoothing processing (average of the latest 10 scores).

Score > threshold → Anomaly detected, and LED turns on.

Otherwise, OLED displays "Status: OK".

### ■ Button Behavior

Press the USER\_BUTTON:

The system waits for 2s (to guarantee stability of vibration).

Clear the old model and restart the learning process.

## 3 Code

### 3.1 Model algorithm

The model uses a simple **online clustering and Euclidean distance detection algorithm**:

1. Feature extraction

$$\text{feature} = [\text{mean}, \text{std}, \text{rms}, \text{max}, \text{min}, \text{skew}, \text{kurt}, \text{rms}/(\text{max}-\text{min})]$$

2. Learning (update rule)

$$C_{new} = C_{old} + \alpha(x - C_{old})$$

3. Detection (distance metric)

$$\text{score} = \min_k ||x - C_k||$$

4. Threshold

$$\text{threshold} = \text{mean} + K \times \text{std}$$

### 3.2 OLED display

Table 1. OLED display information

Display information	Description
Mode: LEARN	Normal learning state
Learn 120/200	Current learning progress
Mode: DETECT	Detection mode
Score: 0.35	Current feature-space distance
Status: OK	Normal state
Status: Anomaly	Abnormal vibration is detected

### 3.3 Macro definitions

Table 2. Macro definitions

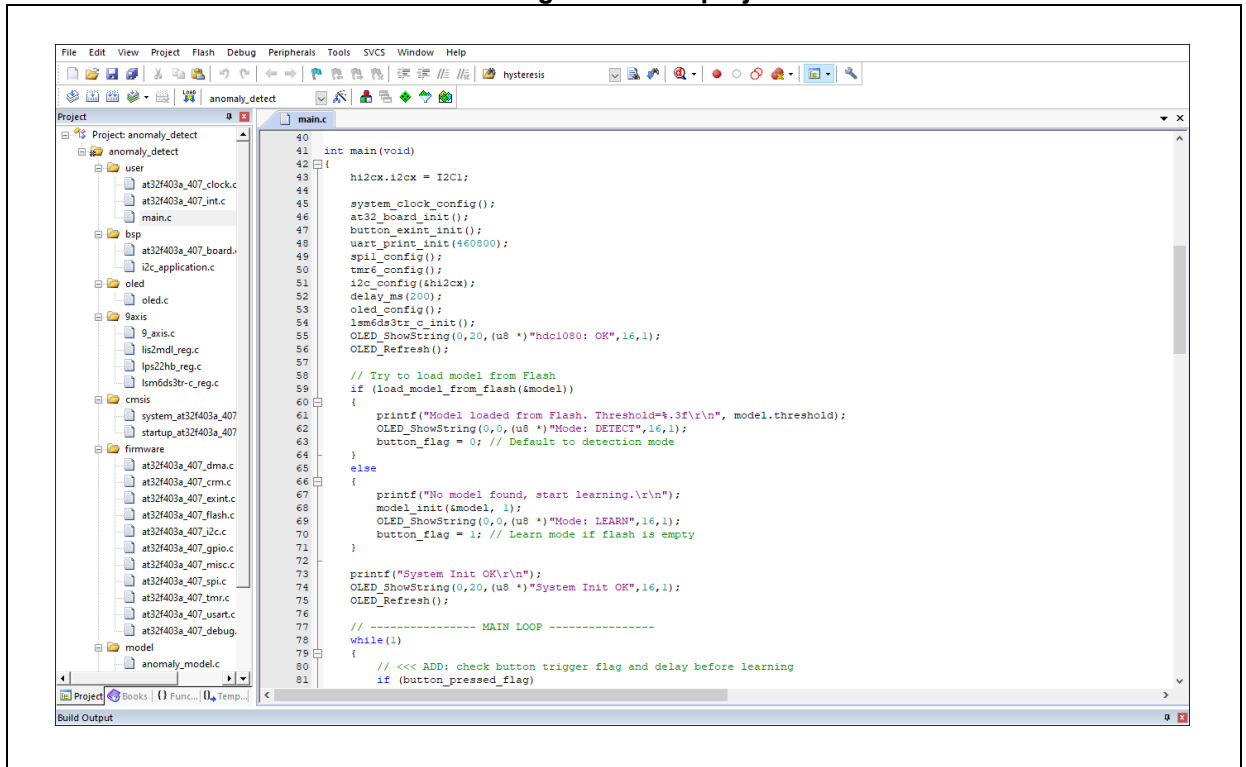
Macro definition	Description	Default value	Recommended range
LEARN_WINDOWS	Number of learning samples	200	100~500
SCORE_AVG_WINDOW	Smoothing window length	10	5~20
LEARN_RATE	Learning rate (centroid update rate)	0.05f	0.01~0.1
AUTO_THRESHOLD_K	Anomaly threshold multiple	3.0f	0.01~5.0

## 4 Example project

This section introduces how to use the example project provided by this application note. The steps are as follows:

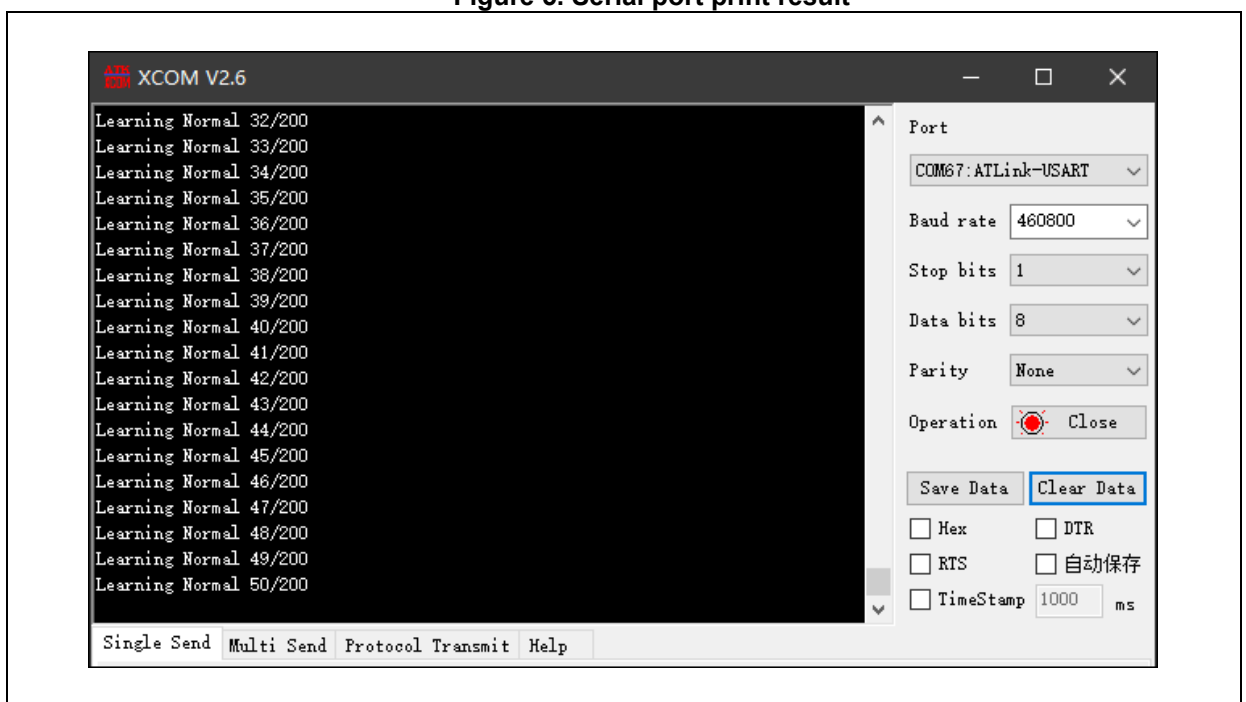
- 1) Open the MDK5 project file under “AN0287\_SourceCode\_V2.0.0\project\anomaly\_detection\mdk\_v5” and then compile. As shown below, the left column displays all the code files required for the project:

Figure 4. MDK project



- 2) After successful compilation, connect to AT\_Link\_EZ for downloading. The serial port runs as follows:

Figure 5. Serial port print result



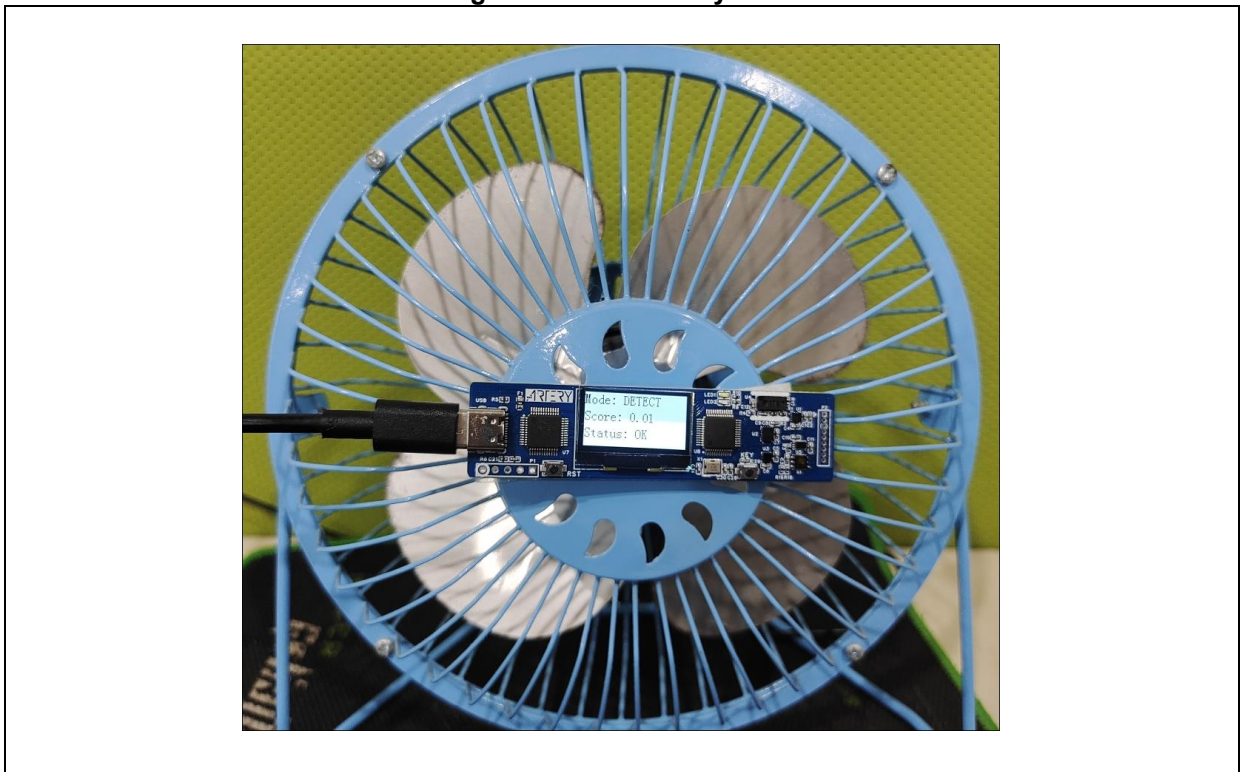
- When an anomaly is detected, the OLED displays the results in real time.

**Figure 6. OLED output result**



- To better align with practical applications, the AT32-EdgeAI-Sensor-EV Board can also be mounted on the device to be monitored for real-time learning and detection. For example, it can be used to detect fan anomalies (as shown in the figure below).

**Figure 7. Fan anomaly detection**



- For a more intuitive understanding of anomaly detection, you can click the below hyperlink to view the video demonstration.

[Anomaly detection by K-means-AT32F403A](#)

## 5 Revision history

Table 3. Document revision history

Date	Version	Revision note
2025.11.07	2.0.0	Initial release.

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