Keyword Spotting Solution

Application Note

based upon AIS240A-EVB01

Document Revision 1.0

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1 General Description

Small electronic devices today are increasingly designed with always-on voice activation capabilities, enabling hands-free control for applications like smart assistants, voice-controlled devices, and ambient intelligence. A key functionality of these systems is keyword spotting - the ability to detect specific trigger words in real time. To achieve this on resource-constrained devices strict power, performance, and privacy requirements have to be met. Cloud-based approaches often introduce unacceptable latency, higher power consumption due to constant data transmission, and potential privacy risks. As a result, the focus has shifted towards executing efficient, low-power keyword spotting directly on-device, to ensure fast, reliable detection with high accuracy and minimal computational overhead.

AIStorm's Keyword Spotting solution directly addresses this issue by providing low-power, high-accuracy keyword detection at the edge. It consists of the AIS240A "SpectroMic" IC paired with a microcontroller unit (MCU), which is also shown with a block diagram in Figure 1. The AIS240A "SpectroMic" integrates an analog MEMS microphone with programmable gain and voice activity detection, together with a hardware spectral engine for feature extraction. The MCU runs an AI model on the spectral features to spot keywords.

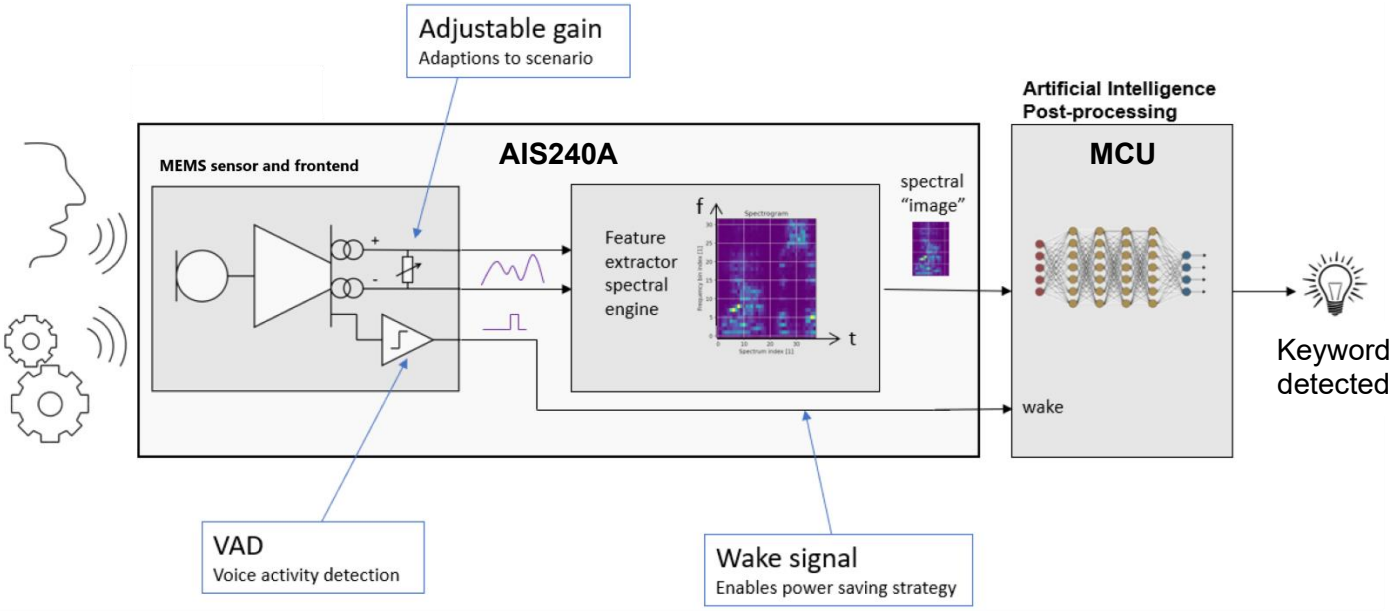

Figure 1: Keyword Spotting solution block diagram

For Demo purposes the AIS210A-AIS2001-EVB01 Evaluation Kit can be ordered online under AIS210A-AIS2001-EVB01 AIStorm, Inc | Audio Products | DigiKey. Dedicated firmware and software can be downloaded on request.

Contact AIStorm under Contact Us – AIStorm for further documentation and software resources.

1.1 Scope of the Document

This document provides instructions on how to install and run AIStorm's Keyword Spotting solution on the SpectoMic EV Kit. A description of the installation process is given, as well as a description of the firmware implemented on the Raspberry Pi Pico MCU. The document provides the information in the following order:

- Overview of the SpectroMic EV Kit hardware
- Using the standalone Keyword Spotting solution with the SpectroMic EV Kit
- Description of SpectroMic Application software
- Information on available firmware for this board

1.2 Features

- Acoustic activity detection with adjustable threshold level and frequency characteristic
- Wide gain adjustment range with internal programmable resistors, and/or external resistors
- SPI interface
- 2 Interrupts to wake microcontroller, one optional from VAD and one when spectral data ready
- Raspberry Pico 2 for configuration, running standalone applications or feature data transmission to host device
- USB powered
- Can run battery powered for standalone applications
- Two on-board multicolor LEDs for visualization

2 Getting Started

In order to use SpectroMic Board, the following hardware and software is required:

- SpectroMic EV Kit Ver.: 1.0 (see Figure 2)
- USB 2.0 Micro-B cable to connect the Board to a host device
- PC running Windows 10/11
- AIStorm's SpectroMic GUI Software

2.1 Hardware overview

The Board is shown in Figure 2. Its dimensions are 66 mm by 28 mm.

Figure 2: SpectroMic EV Kit Ver.:1.0 top and bottom view

2.2 AIS240A "SpectroMic" Package

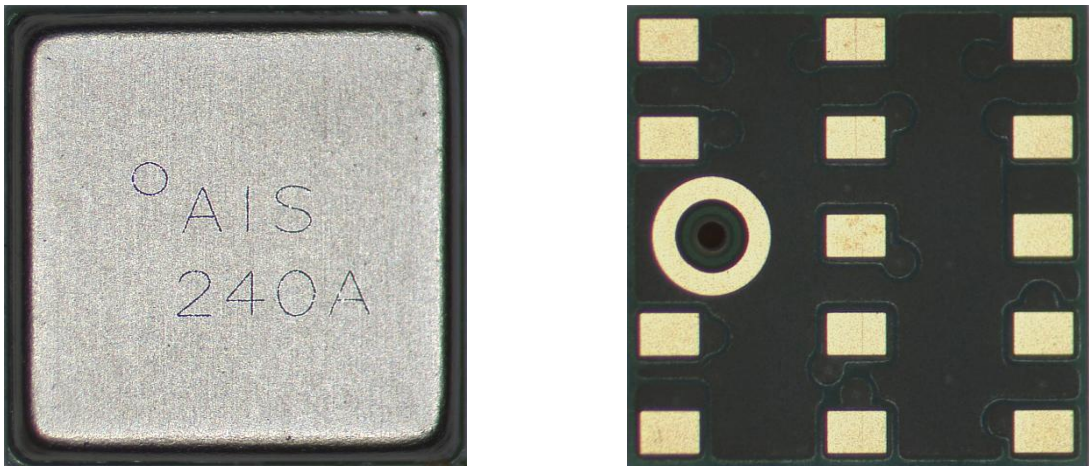

Figure 3: AIS240A package top (left) and bottom (right) view

2.3 Block Diagram

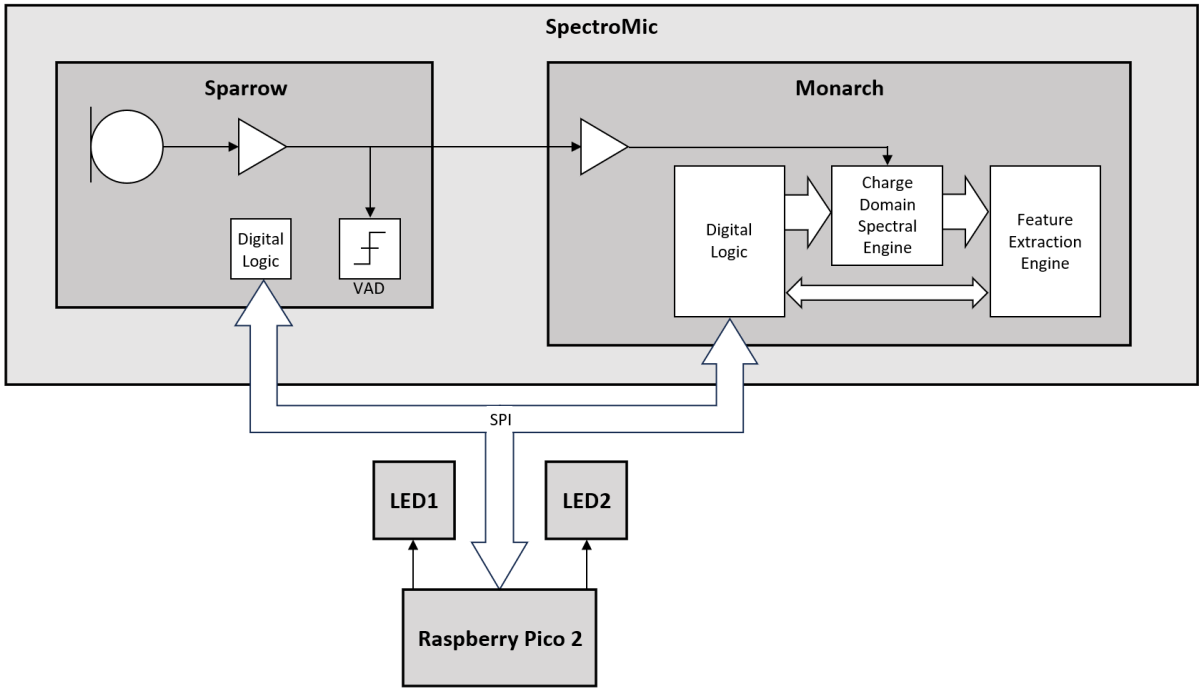

Figure 4: Block diagram of SpectroMic EV Kit

2.4 Application Circuit

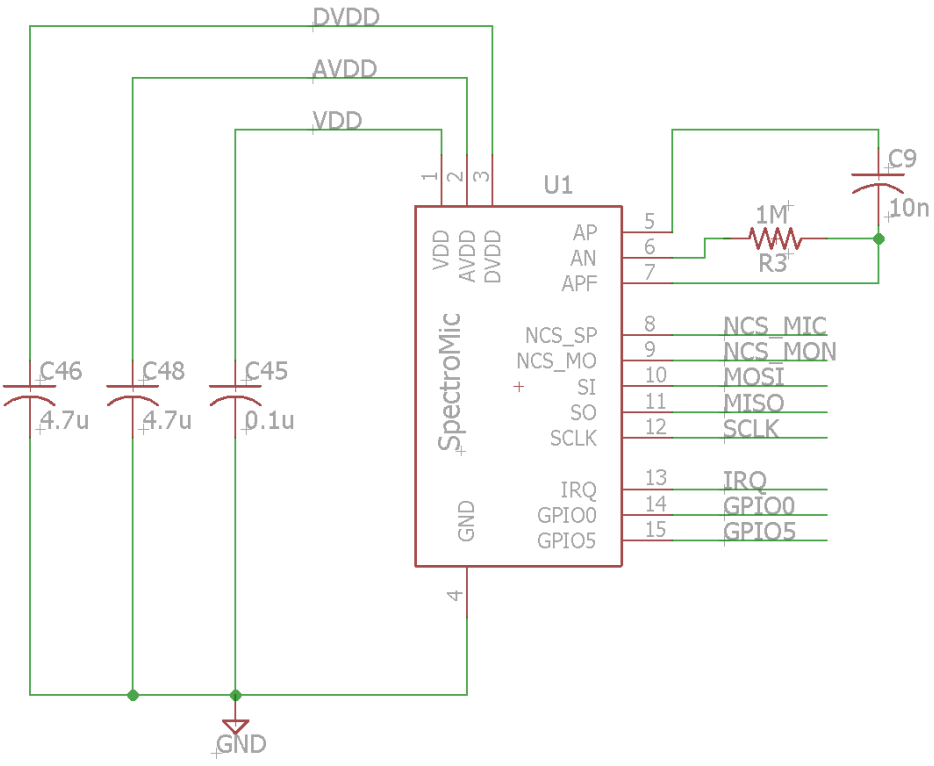

Figure 5: SpectroMic application circuit

3 Keyword Spotting with the SpectroMic EV Kit

The Keyword Spotting solution continuously monitors the microphone output in real time and detects predefined keywords based on the trained model. Essentially, the system extracts features from the analog microphone audio output using the built-in hardware spectral engine and then analyzes this data live to spot a set of keywords using a trained model.

The used model is trained on a popular and well-established dataset known as the Google Speech Commands set. This dataset includes short spoken words designed for command recognition tasks. Our model specifically targets a core subset of ten words: yes, no, up, down, left, right, on, off, stop, go. These keywords cover a wide range of common control actions, making them ideal for real-world voice-controlled interfaces. This model takes up less than 23 Kilobyte of memory and has an inference time of under 260 milliseconds on the Raspberry Pi Pico2 MCU.

An example for the SpectroMic inference pipeline is shown in Figure 6. There, a visual time-frequency representation (Mel spectrogram) is extracted from speech input and processed by the compact proprietary model. Then the network outputs a predicted command label along with its confidence score - in this case, the keyword 'right' is predicted with a confidence score of 99%.

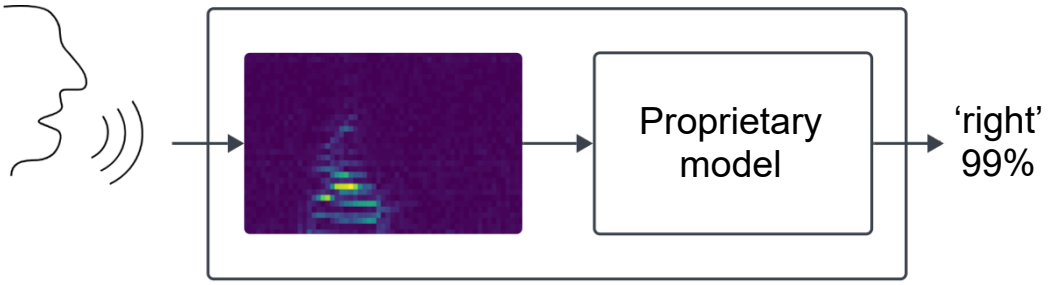

Figure 6: SpectroMic inference pipeline

The Keyword Spotting solution runs as a fully standalone application per default. When the EV Kit is powered, LED1 shows the VAD ready by cyan color. When the VAD triggers on sound activity, it lights up green to signal this. The neighboring LED2 shows keyword spotting results by color, as defined in Table 1. If a person says the keyword 'right' for example, LED2 will light up in yellow color.

Additionally, the SpectroMic Application software can be used to monitor the live spectrogram, enable/disable different system modes, run external models and change system settings. This is explained in more detail in Chapter 4.

Table 1: LED2 color result map

Keyword	LED Color
silence	Black
unknown	Dim Gray
up	White
down	Red
go	Green
stop	Blue
right	Yellow
left	Cyan
yes	Magenta
no	Orange
on	Purple
off	Lime Green

4 Software

4.1 Installation of the SpectroMic Application

1. If you don't have the SpectroMicApplication.exe saved locally, the folder containing all required software and firmware files can be downloaded on request
2. Inside the folder you can find the executable SpectroMicApplication.exe

4.2 Software Features

- Monitor Live-Spectrogram (extracted features from Monarch)
- Load external AI models and run them inside the software to test on Live-Spectrogram data
- Access and control Monarch and Sparrow registers (The register maps of Monarch and Sparrow can be found in the respective Datasheet)
- Switch operating modes, e.g. Voice Activity Detection (VAD)
- Equalize the gains for all 32 frequency bins

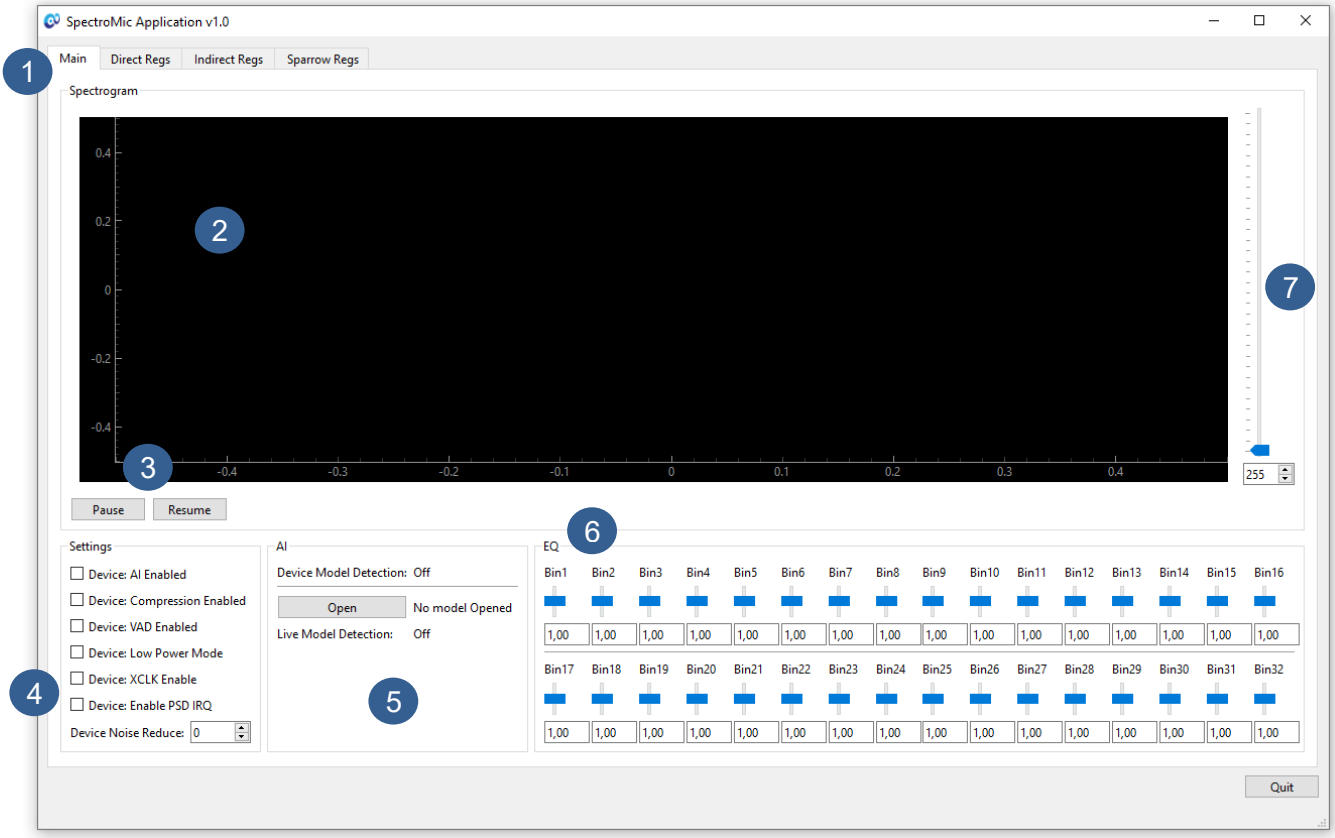

Figure 7: Main Control Panel at start-up

4.3 GUI Main Tab at start-up

Here is an explanation of the marked control elements from Figure 7:

1. Choose between accessing Main tab, the Direct- and Indirect Register Map controls of Monarch, and the Sparrow Register Map controls
2. Live-Spectrogram visualization (time on horizontal axis, 32 frequency bins on vertical axis)
3. Pause/Resume the Live-Spectrogram visualization
4. Check box for settings and operating modes
5. AI section for monitoring results and loading models
6. Equalize gains for all 32 frequency bins individually
7. Slider to adjust scaling of the Live-Spectrogram colormap

4.4 Run Live-Spectrogram

Depending on the firmware version, the Live-Spectrogram does not run automatically on start-up. In this case to run the Live-Spectrogram, under Settings in the main control panel enable the following settings:

1. Device: XCLK Enable
2. Device: Enable PSD IRQ

These two enabled check boxes and a Live-Spectrogram example are both shown in Figure 8:

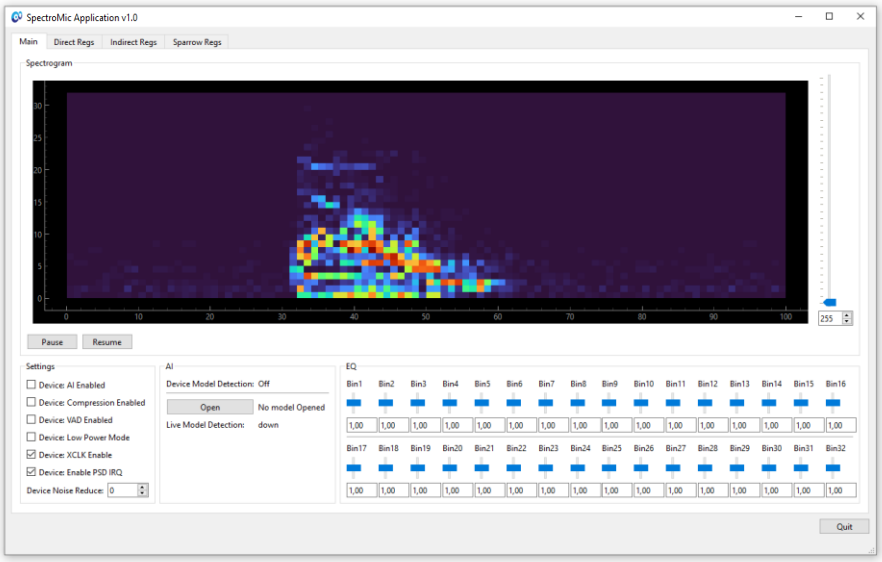

Figure 8: Live-Spectrogram of the spoken word "down"

The Live-Spectrogram in Figure 8 displays 32 frequency bins on the vertical axis for each of the 100 intervals on the horizontal axis. Each time interval is 16ms long which results in an overall displayed time of 1.6 seconds. Each data point in the Live-Spectrogram has a value between 0 and 65535.

4.5 Register Tabs

Inside the three GUI tabs Direct Regs, Indirect Regs and Sparrow Regs the Monarch and Sparrow register maps can be manually accessed. Detailed information about the contents of these register maps can be found in the respective Datasheet. Please see the most recent Raspberry firmware about the correct register settings. Whenever register values are to be changed, make sure to open the according Registers-tab in the GUI first press “Read All” in Monarch Register tabs or “Read” in in the Sparrow Register tab to update the GUI from the device. After that the values can be changed and written using the “Write”-button.

4.6 Running an external AI Model

At start-up, the SpectroMic Application loads a default AI model to spot 10 Keywords from a dataset. It runs fully on the host device and its current live results are displayed in the “AI” section under “Live Model Detection: “. This is also shown in Figure 8, where the spoken word “down” is detected.
With the Open button in the same section a suitable external model (.onnx-file) can be opened, to load an external AI model. This will also fully run on the host device.
With enabling the “Device: AI Enabled” checkbox in the “Settings” section, an AI model can be run on the firmware of the Raspberry Pico 2 MCU independently of the above-mentioned AI models.

5 Firmware

- The latest firmware can be downloaded on request
- To flash new firmware (uf2-file) onto the on-board Raspberry Pico 2, please check the Raspberry homepage.

Table 2: Firmware overview

Firmware Version	Description
000-AIS240A-EVB01	Google Speech Commands set; All features are disabled at startup and have to be enabled manually using the SpectroMic Application software.
001-AIS240A-EVB01	Google Speech Commands set; VAD and keyword spotting features enabled at startup; Setup changes are possible manually using the SpectroMic Application software.

6 List of Abbreviations

Table 3: List of Abbreviations

Name	Description
AI	Artificial Intelligence
EQ	Equalizer
GUI	Graphical User Interface
IC	Integrated Circuit
LED	Light-Emitting Diode
MCM	Multi-Chip Module
MCU	Microcontroller Unit
PSD	Power Spectral Density
VAD	Voice Activity Detection

7 Revision History

Table 4: Revision History

Revision	Date	Description	Author
1.0	2025-06-11	Document release	Maximilian Heindel

8 List of Figures

9 List of Tables

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