Design Guide: TIDA-010997

Edge AI Sensor BoosterPack™ Reference Design

TEXAS INSTRUMENTS

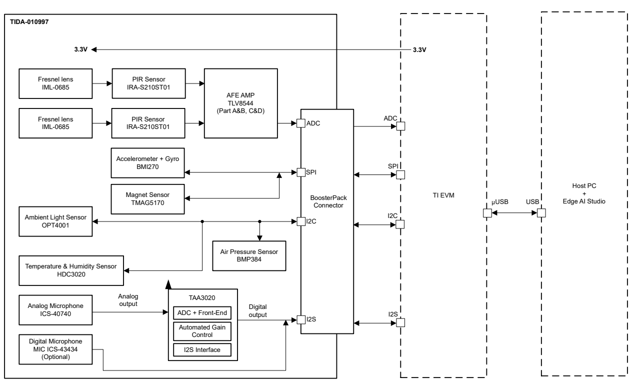
Description

This reference design introduces a plug-and-play time-series sensors BoosterPack™ that remains compatible with multiple TI Evaluation Modules (EVMs). The design offers direct access to different sensor types, enabling simple data collection for developing and evaluating Edge AI applications using CCStudio™ Edge AI Studio.

Resources

TIDA-010997	Design Folder
TAA3020	Product Folder
HDC3020	Product Folder
OPT4001	Product Folder
TMAG5170	Product Folder
TLV8544	Product Folder

Ask the TI E2E™ support experts

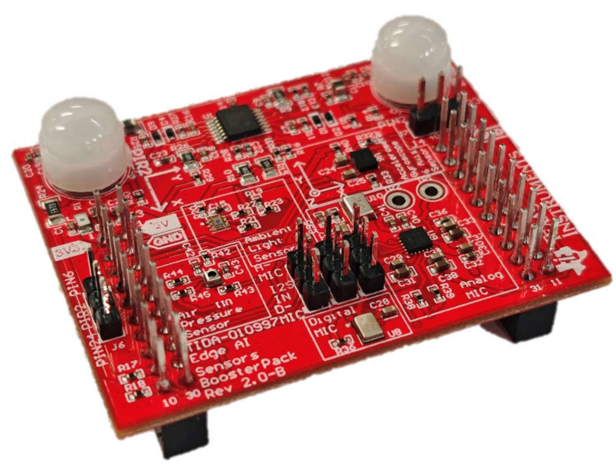


Features

- 2 × dual element PIR sensor and Fresnel lens (IRA-S210ST01 + IML-0685)
- Digital I^2S output bottom port microphone (ICS-43434)
- Ultra-low noise, differential analog microphone (ICS-40740)
- Digital humidity and temperature sensor (HDC3020)
- Low power 6-axis accelerometer + gyro sensor (BMI270)
- High-speed and high precision ambient light sensor (OPT4001)
- High-precision linear 3D Hall-effect sensor (TMAG5170)
- Digital pressure sensor (BMI384)

Applications

- Door and window sensor
- Electronic smart lock
- Glass break detector
- Motion detector
- Thermostat



1 System Description

Edge AI has rapidly become a baseline requirement across a wide range of industrial and automotive applications. Engineers increasingly expect embedded devices to locally interpret sensor data, reduce false alarms, and improve responsiveness. These devices must also enable predictive and context-aware behavior without constant cloud connectivity. This shift drives the need for accessible development platforms that allow engineers to quickly collect real-world data and deploy machine-learning models directly at the edge.

The Sensor BoosterPack™ addresses this need by providing a flexible hardware platform for time-series sensor evaluation and machine-learning development. The BoosterPack is supported by multiple TI evaluation modules (EVMs), enabling users to connect to different processing devices depending on performance, power, and connectivity requirements. Together, the hardware and software environment allow users to capture synchronized sensor data and rapidly deploy inference models.

To simplify development, the platform integrates with the Edge AI Studio software environment. Through a graphical user interface, users can collect datasets, label events, train machine-learning models, and evaluate performance. The platform generates software-ready outputs without requiring deep expertise in data science workflows. This enables fast prototyping of applications such as anomaly detection, activity classification, condition monitoring, acoustic event detection and more.

To maintain compatibility across different host processors, individual sensors can be enabled and disabled through onboard jumpers. This allows operation even when a selected EVM does not support a required communication interface (for example, disabling the digital microphone when an I2S interface becomes unavailable). All hardware design files, required software components, and development tools are described in the following chapters.

2 System Overview

2.1 Block Diagram

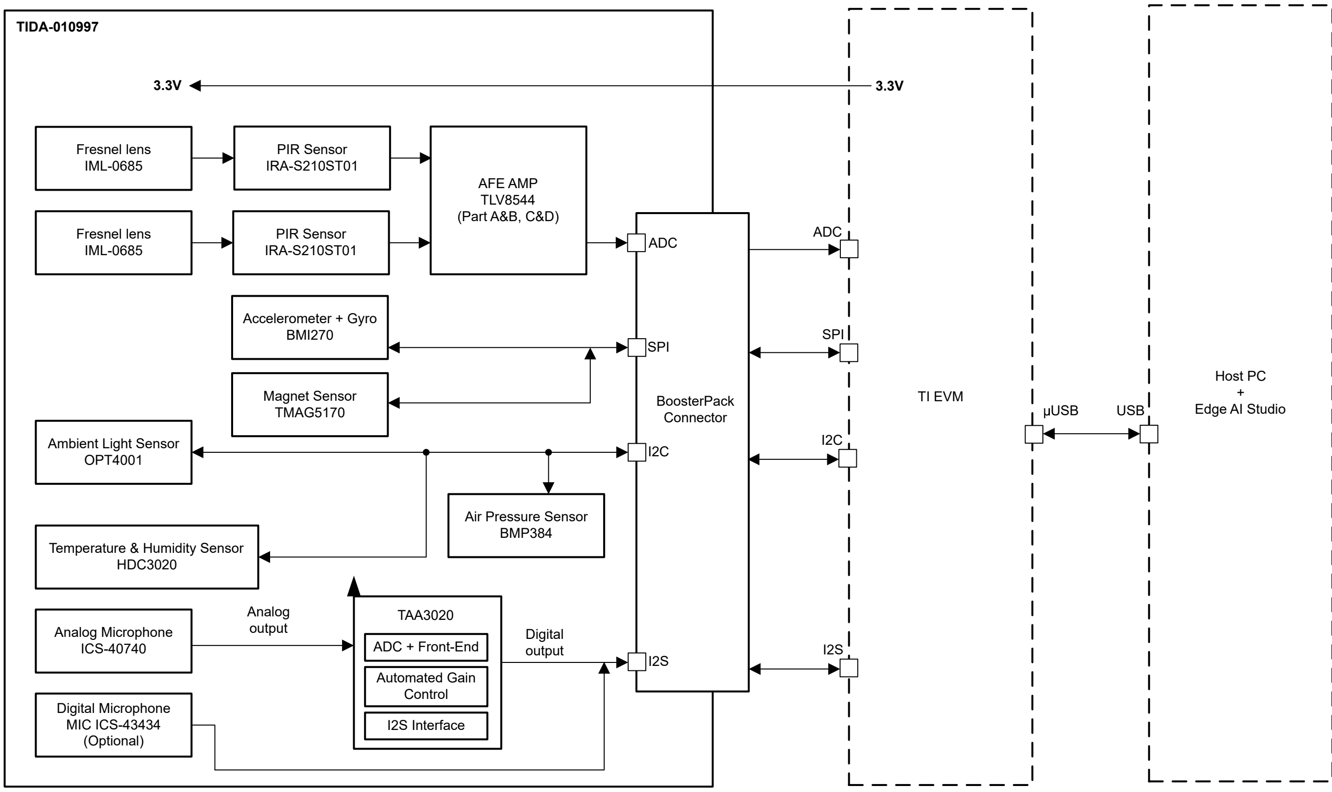


Figure 2-1. Block Diagram

2.2 Design Considerations

2.3 Highlighted Products

2.3.1 MSPM0G5187 Mixed-Signal Microcontrollers With Edge AI NPU

MSPM0G5187 microcontroller (MCU) is part of the MSP highly integrated, ultra-low-power 32-bit MCU family based on the enhanced Arm® Cortex®-M0+ 32-bit core platform, operating at up to 80MHz frequency. These MCUs offer a blend of cost optimization and design flexibility for applications requiring up to 128KB of flash memory in small packages or high pin-count packages (up to 64 pins).

The MSPM0G5187 series MCUs feature TinyEngine™ Neural-network Processing Unit (NPU) for enabling Artificial Intelligence (AI) and Machine Learning (ML) applications. The NPU provides a highly efficient core for deep convolutional neural networks (CNNs), supporting machine learning inference using pre-trained models. The core works in conjunction with the on-chip CPU to provide higher performance and lower power consumption for CNNs inference.

The NPU runs at 80MHz and operates autonomously from the main CPU in the device. The NPU provides a fully programmable hardware accelerator that can support arbitrary deep neural networks. Input activations can be 8 bit or 4 bit while weight parameters can be 8 bit, 4 bit, or 2 bit.

The supported layer types include the generic convolutional layer, pointwise layer, depthwise layer, pooling layers (maximum and average), and residual layers. Convolution kernel sizes can be configured and layers can include padding and strides. RELU activation receives support.

With capability for 640 Mega Operations Per Second (MOPS) to 2560MOPS, the NPU provides up to 10× NN inferencing cycle improvement when compared to a purely software-based implementation. For a seamless experience in data collection and model training, get started with the TI Edge AI Studio which can automatically generate source code for the MSPM0, eliminating the need to manually write code.

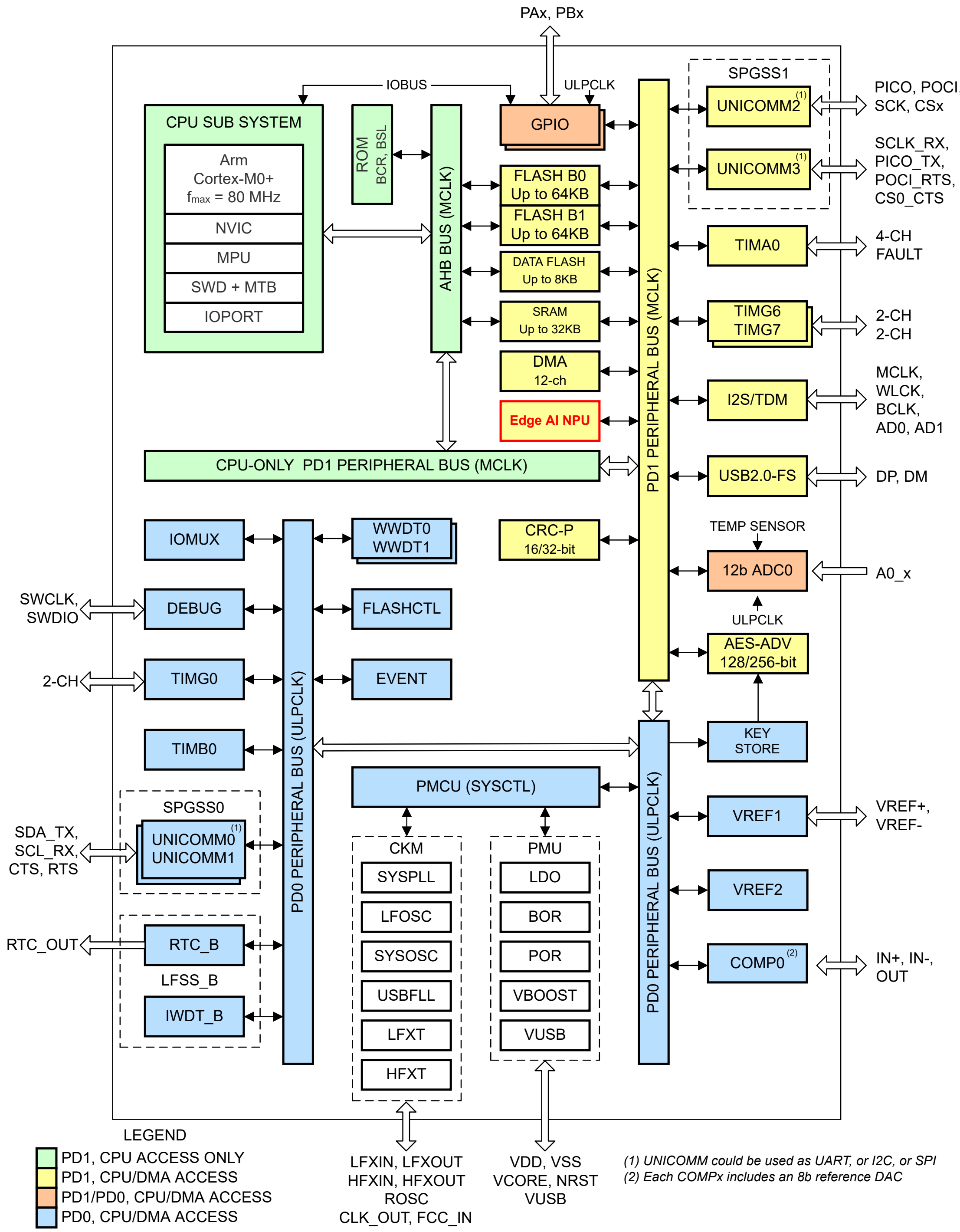


Figure 2-2. MSPM0G5187 Block Diagram

2.3.2 CC2755R10 SimpleLink™ Bluetooth® LE wireless MCU

The SimpleLink™ CC2755x wireless microcontrollers (MCUs) support Bluetooth® Low Energy 6.0 for automotive and industrial applications. These devices feature Arm® Cortex®-M33 processor (96MHz) with floating point unit (FPU), TrustZone®-M support, custom data path extension (CDE) for machine learning acceleration and Algorithm Processing Unit (APU) (96MHz). The APU is a mathematical accelerator for efficient vector and matrix operations, accelerating Bluetooth® Channel Sounding post-processing and supporting IFFT and advanced super-resolution algorithms such as MUltiple SIgnal Classification (MUSIC).

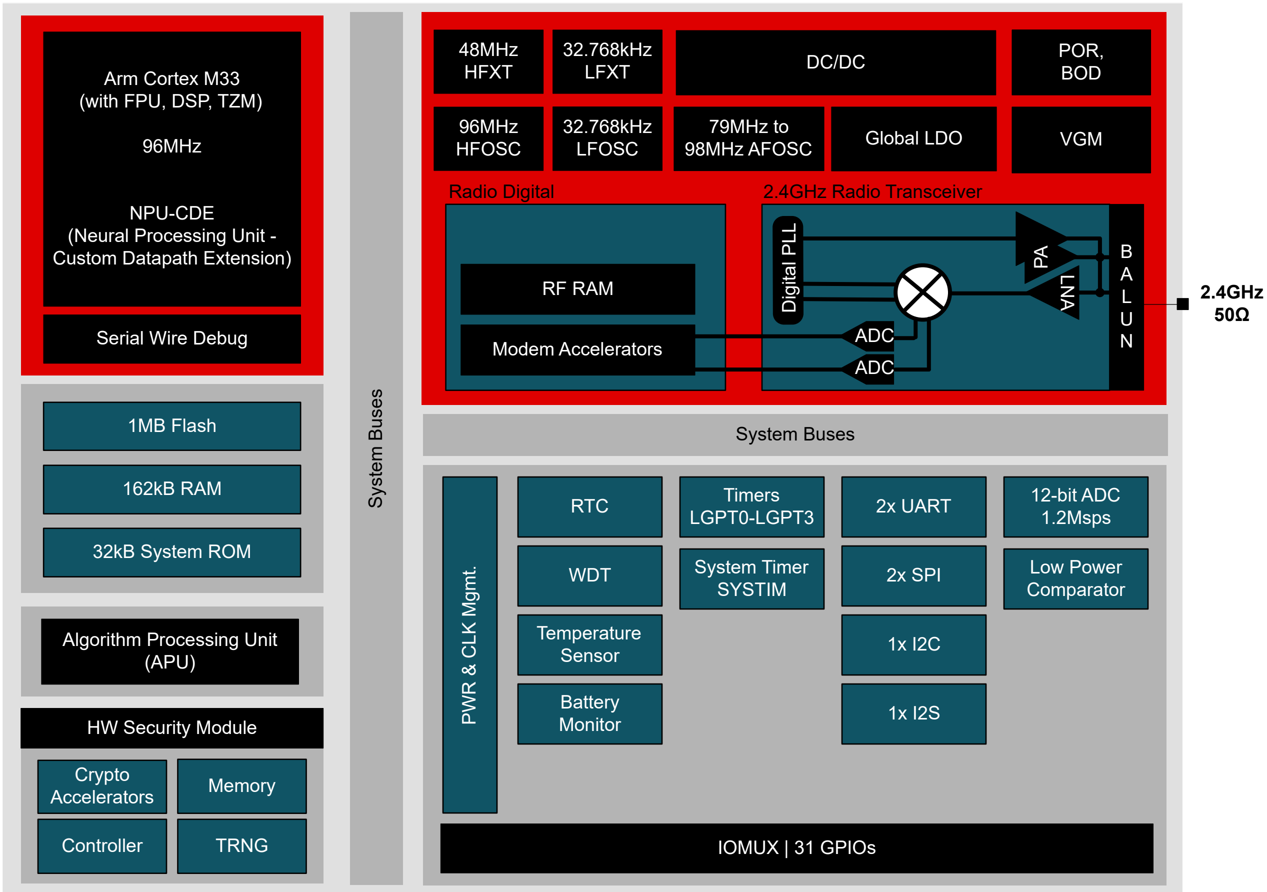


Figure 2-3. CC2755 Block Diagram

3 Hardware, Software, Testing Requirements, and Test Results

3.1 Hardware Requirements

The BoosterPack integrates both analog and digital sensors. Onboard jumpers allow customers to enable, disable, or reroute individual sensors depending on the target EVM configuration. This section outlines the key design considerations and explains the jumper functionality. Figure 3-1 shows how the BoosterPack is mounted on top of the EVM.

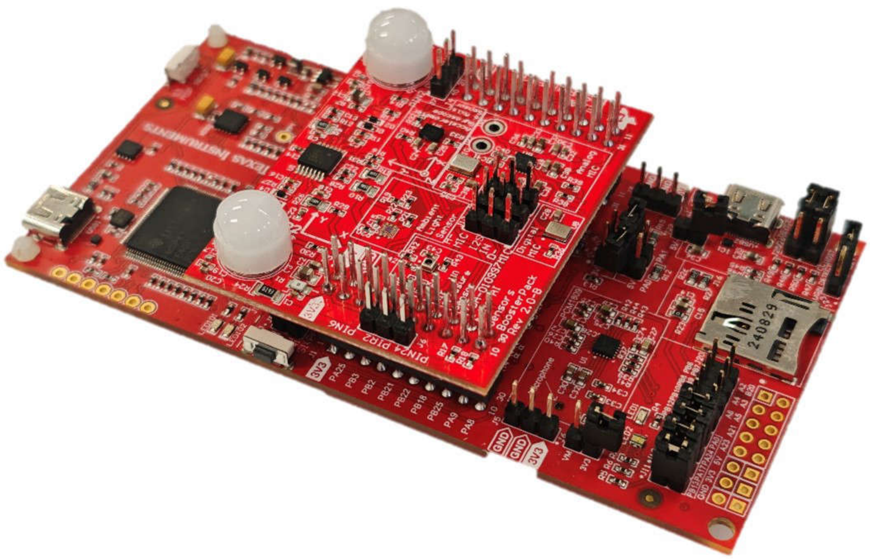


Figure 3-1. BoosterPack™ and EVM

The following jumpers provide this functionality:

- J7 routes PIR1 to the onboard ADC channel, either to PIN2 or PIN23
- J6 routes PIR2 to the onboard ADC channel, either to PIN6 or PIN24
- J8, J9, and J10 switch the audio I2S bus between the digital microphone (ICS-43434) and the analog microphone + external codec (ICS-40740 + TAA3020)

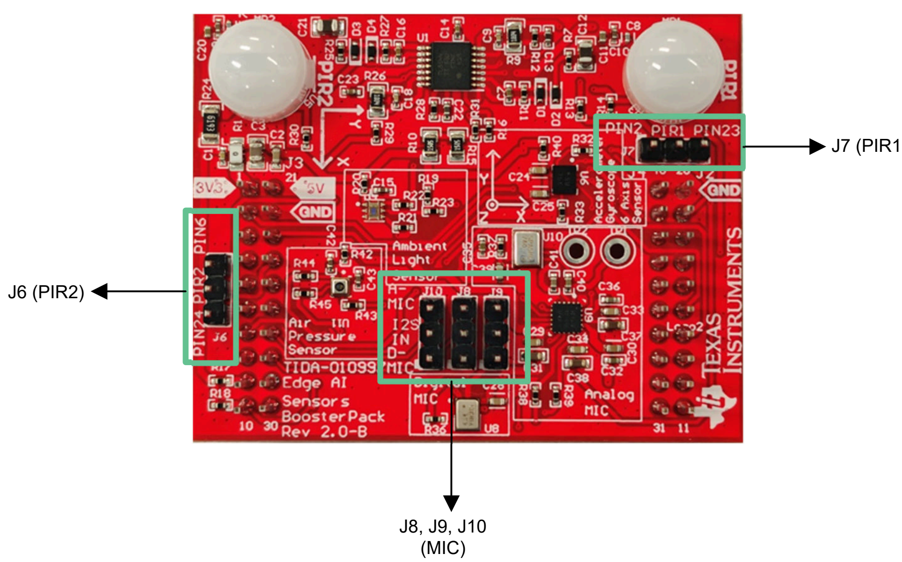


Figure 3-2. Jumper Configurations

Figure 3-3 and Figure 3-4 show the complete pin map of the BoosterPack. Full schematics file are available in the TIDA-010997 design folder.

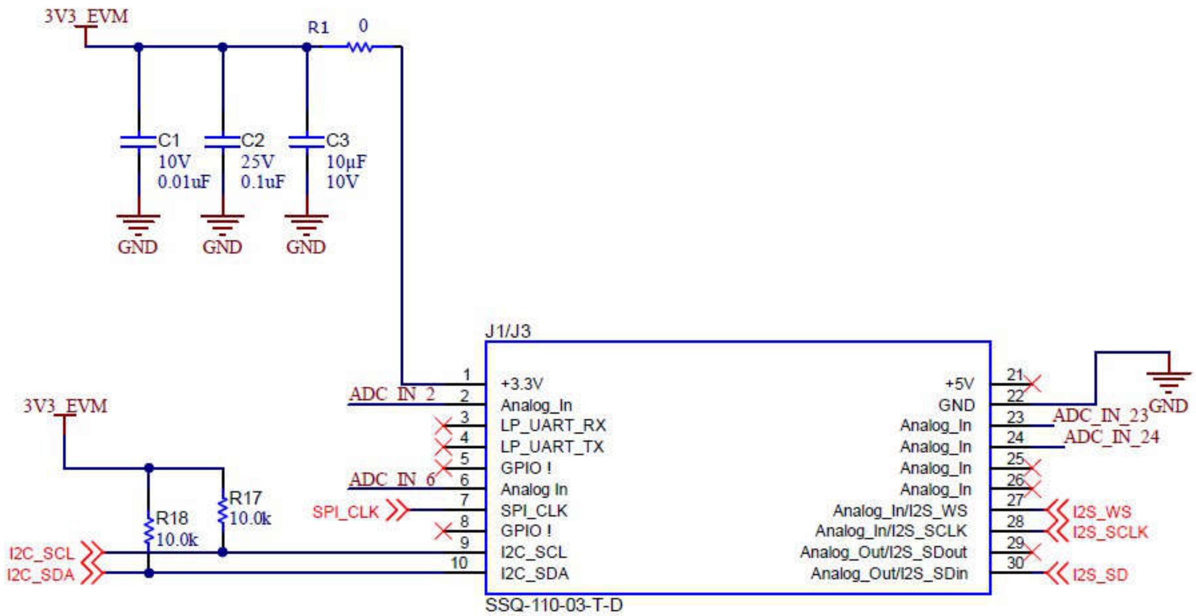


Figure 3-3. BoosterPack™ Pin Map 1

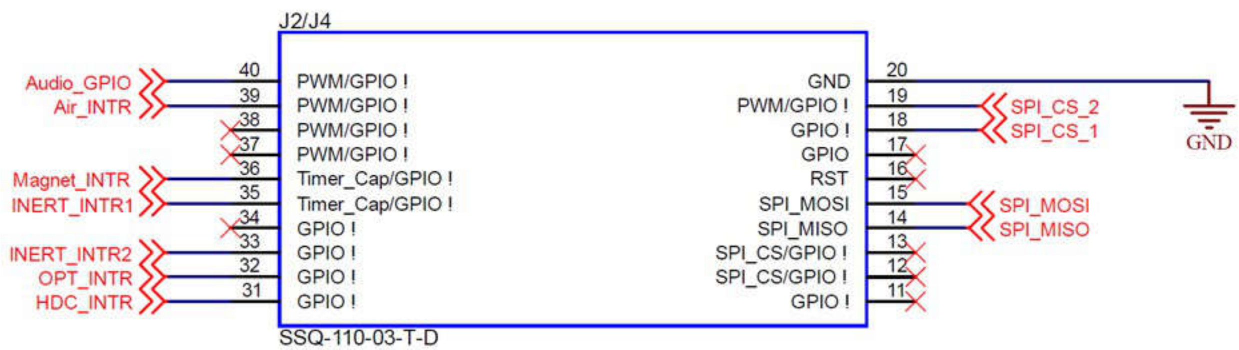


Figure 3-4. BoosterPack™ Pin Map 2

3.1.1 PIR Analog Signal Chain

The signal chains used for PIR1 and PIR2 are identical. The following description takes PIR1 as an example; the same logic applies to PIR2. As Figure 3-5 shows, there are two stages to implement the amplified filter function.

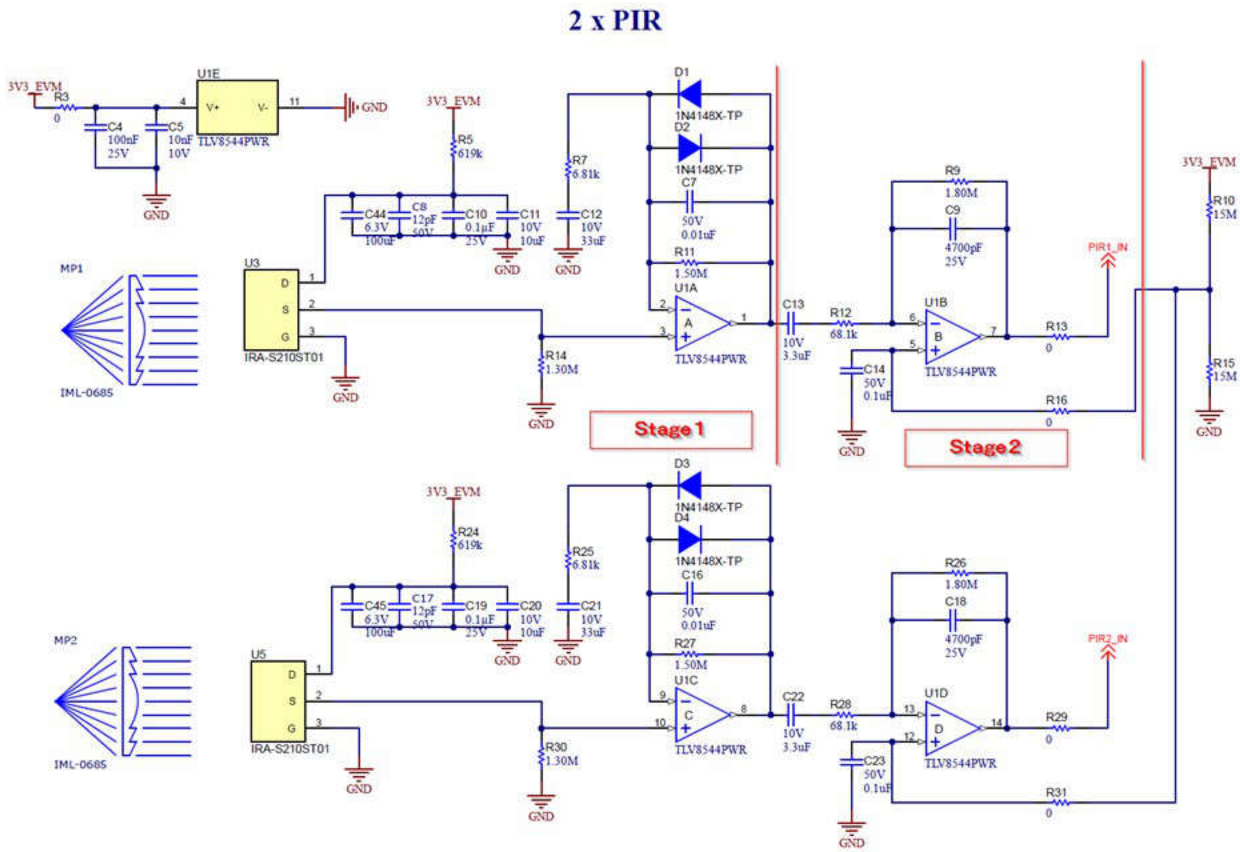


Figure 3-5. PIR Signal Chain

The first stage of the filter is arranged as a non-inverting gain stage. This provides a high-impedance load to the sensor so the bias point remains fixed. The gain and cutoff frequencies are calculated as follows:

$$f_{\mathrm{Low}_1} = \frac{1}{2\pi \times R_7 \times C_{12}} = \frac{1}{2\pi \times 6.81\mathrm{k\Omega} \times 33\mu\mathrm{F}} = 0.71\mathrm{Hz} \tag{1}$$

$$f_{\mathrm{High}_1} = \frac{1}{2\pi \times R_{11} \times C_7} = \frac{1}{2\pi \times 1.5\mathrm{M\Omega} \times 0.01\mu\mathrm{F}} = 10.6\mathrm{Hz} \tag{2}$$

$$|G_1| = 1 + \frac{R_{11}}{R_7} = 1 + \frac{1.5\mathrm{M\Omega}}{6.81\mathrm{k\Omega}} = 221.26 \tag{3}$$

The second stage is AC coupled to the first stage, being arranged as an inverting gain stage. This allows the DC bias to be set to Vcc/2 easily by connecting the center point of the string to the non-inverting input of the op amp in this filter stage. Equation 4 through Equation 6 show the gain and cutoff frequencies for this stage.

$$f_{\mathrm{Low}_2} = \frac{1}{2\pi \times R_{12} \times C_{13}} = \frac{1}{2\pi \times 68.1\mathrm{k\Omega} \times 3.3\mu\mathrm{F}} = 0.71\mathrm{Hz} \tag{4}$$

$$f_{\mathrm{High}_2} = \frac{1}{2\pi \times R_9 \times C_9} = \frac{1}{2\pi \times 1.8\mathrm{M\Omega} \times 4700\mathrm{pF}} = 18.8\mathrm{Hz} \tag{5}$$

$$|G_2| = \left|-\frac{R_9}{R_{12}}\right| = \left|-\frac{1.8\mathrm{M\Omega}}{68.1\mathrm{k\Omega}}\right| = 26.4 \tag{6}$$

The default parameters for this reference design are selected based on actual experimental tests, where a signal range of a human moving from 3.5–9.5 meters, provides appropriate amplitude. PIR1 and PIR2 share the same default gain. Users can adjust resistors and capacitors according to the actual detection distance to modify the gain and filter frequency. Use the following to achieve one long-range and one short-range channel, for example.

- Keep PIR1 unchanged for 3.5–9.5m detection.
- Reduce the filter gain of PIR2, making PIR2 an excellent choice for distances within 3.5m.

3.2 Software Requirements

Section 3.3 outlines the steps required to enable data capture from all sensors on the BoosterPack and the MSPM0G5187. Before proceeding, make sure that the onboard jumpers are configured according to the hardware requirements in Section 3.1.

To enable the sensors, first flash the *tida_010997_data_capture* code example from the latest MSPM0 SDK. The example includes predefined sensor configurations, which the user can either keep as default or modify as needed.

Figure 3-6 shows the sensor configuration, which can be manually adjusted as needed:

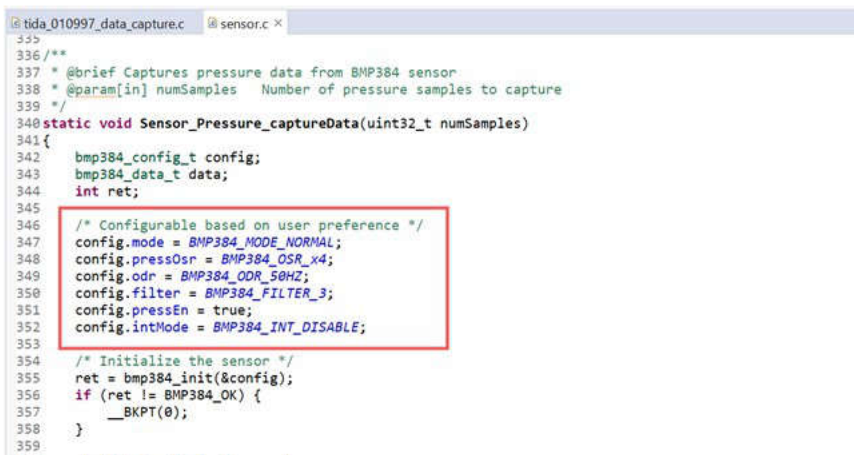


Figure 3-6. Sensor Configuration

After flashing the device, open Edge AI Studio and launch the Model Composer tool - either by installing the desktop version or using the cloud-based version.

3.3 Test Setup

Figure 3-7 illustrates the complete test configuration. The MSPM0 EVM is physically connected to the Sensors BoosterPack, serving as the main processing and control unit. The EVM provides power, communication interfaces, and data handling for each of the onboard time-series sensors. The MSPM0 EVM is interfaced with the Edge AI Studio platform, which enables real-time data collection.

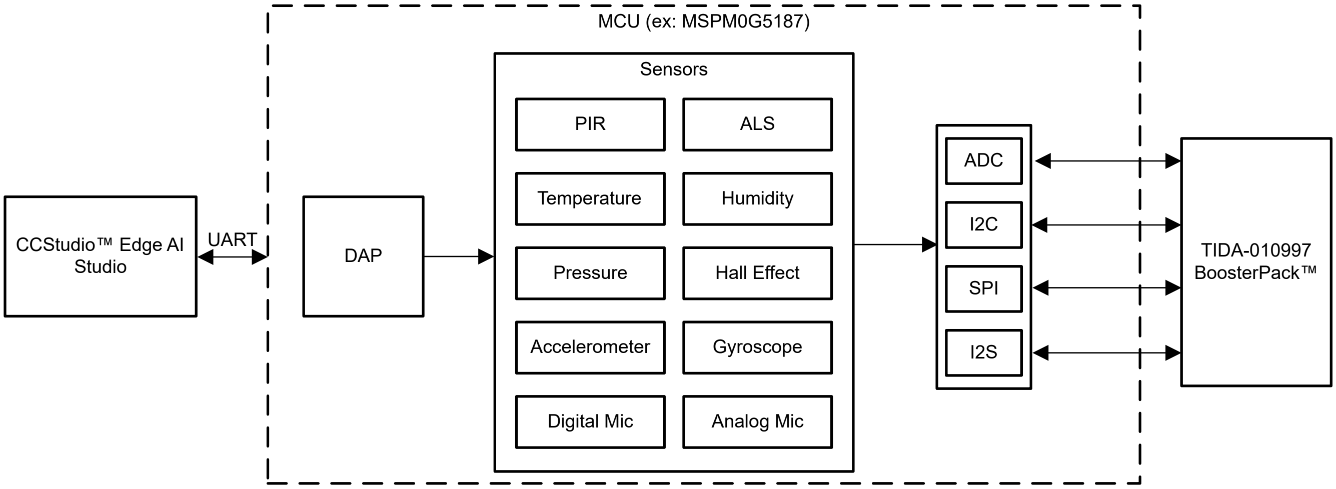


Figure 3-7. Software Flow

3.3.1 Data Collection

The following steps describe how to collect sensor data using the BoosterPack together with Edge AI Studio. These instructions are demonstrated using the MSPM0G5187 EVM as the reference platform. However, other TI EVMs can also support sensors from the BoosterPack, and compatibility is continuously being expanded.

Detailed documentation for data collection with MSP devices is available from the *tida_010997_data_capture* ReadMe file.

1. Hardware Setup:
   a. Connect the BoosterPack to the LP-MSPM0G5187 LaunchPad™ Development Kit
   b. Make sure jumper J7 on the BoosterPack is set to 1:2
   c. Build and flash the *tida_010997_data_capture* example from the MSPM0 SDK to the MSPM0G5187
2. Data Collection:
   a. Launch the CCStudio™ Edge AI Studio on your host PC
   b. Create a Time-series Classification project and navigate to the *Capture* tab
   c. Make sure the correct COM port is selected and baud rate is configured to *115200bps*
   d. Verify the status bar displays *Hardware connected*
   e. Select the appropriate sensor, set the sample count and sample label, and select *Start Capture*
   f. Data is saved in CSV format

3.4 Test Results

3.4.1 Passive Infrared Sensor (PIR)

- By default:
  1. ADC pin is configured for PIR1
  2. Sampling rate at 31.25Hz

See the Multi-class motion detection for PIR based building security with >98% accuracy content on TI's Edge AI technology landing page. The architecture is built using this sensor BoosterPack, and accompanying software is available to TI customers free of charge on Edge AI Studio.

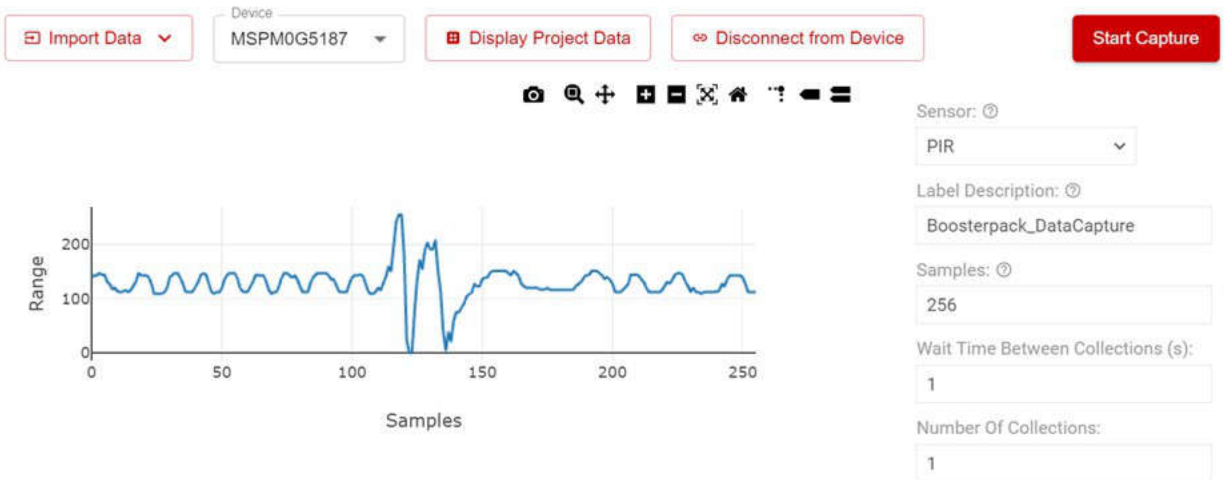


Figure 3-8. PIR Data Capture

3.4.2 HDC3020 – Temperature and Humidity Sensor (I2C)

1. Default Configuration:
   a. Mode: Auto Measurement (continuous)
   b. Low Power Mode: LPM_0 (lowest noise, 12.5ms conversion)
   c. Measurement Rate: 10Hz
2. User Configurable:
   a. Measurement mode (trigger-on-demand or auto)
   b. Low power mode (LPM_0 to LPM_3)
   c. Measurement rate (0.5Hz, 1Hz, 2Hz, 4Hz, 10Hz)
   d. Sensor selection (temperature only, humidity only, or both)
3. Not Enabled and Not Configurable:
   a. Heater control
   b. Alert or threshold interrupts
   c. Offset calibration
   d. MIN and MAX tracking
   e. Status register readback

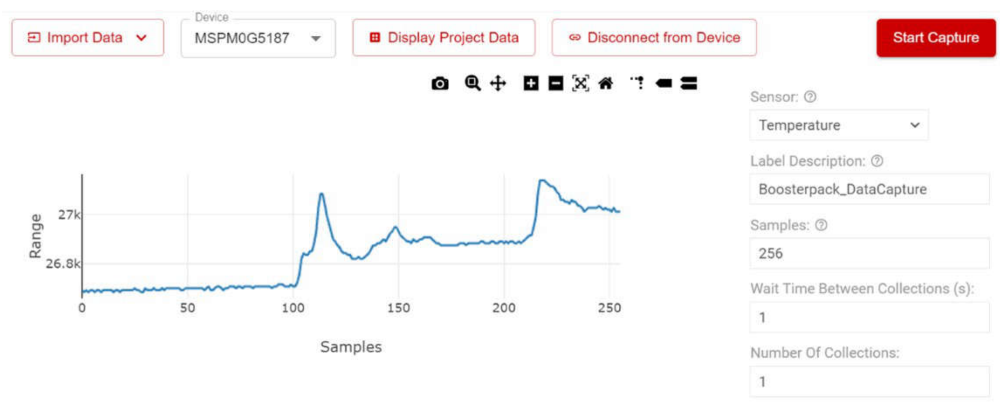


Figure 3-9. Temperature Data Capture

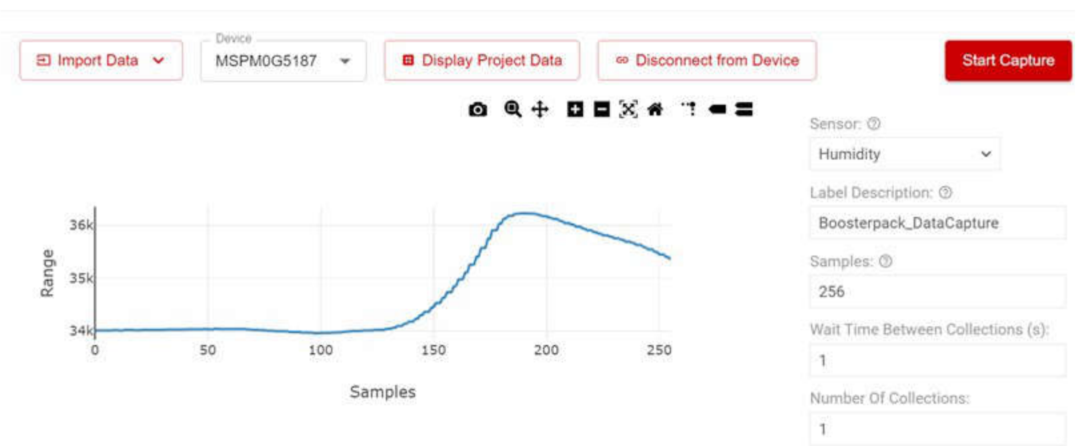


Figure 3-10. Humidity Data Capture

3.4.3 BMP384 – Barometric Pressure Sensor (I2C)

1. Default Configuration:
   a. Mode: Normal (continuous)
   b. Pressure Oversampling: ×4
   c. Output Data Rate: 50Hz
   d. IIR Filter: Coefficient 3
   e. Interrupt: Disabled
2. User Configurable:
   a. Power mode (sleep, forced, normal)
   b. Pressure oversampling (×1 to ×32)
   c. Output data rate (0.0015Hz to 200Hz)
   d. IIR filter coefficient (off, 1, 3, 7, 15, 31, 63, 127)
   e. Interrupt mode (disabled, data ready, FIFO watermark, FIFO full)
3. Not Enabled and Not Configurable:
   a. Temperature measurement (only pressure is returned)
   b. Temperature oversampling
   c. FIFO functionality
   d. Altitude calculation
   e. Pressure compensation and calibration

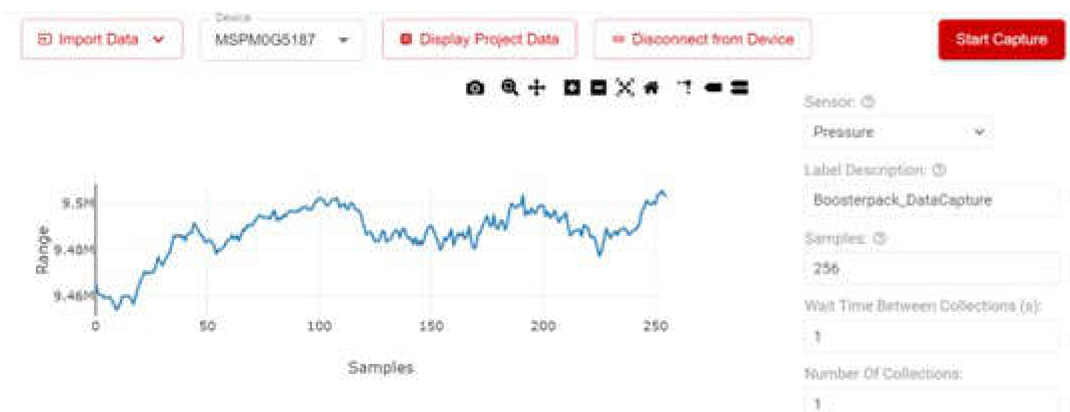


Figure 3-11. Pressure Data Capture

3.4.4 OPT4001 – Ambient Light Sensor (I2C)

1. Default Configuration:
   a. Mode: Continuous
   b. Conversion Time: 100ms
   c. Range: Auto
2. User Configurable:
   a. Operating mode (shutdown, one-shot, continuous)
   b. Conversion time (600µs to 800ms, 12 options)
   c. Range (fixed ranges 0–8, or auto)
   d. Latch mode (transparent, window)
   e. Interrupt configuration and polarity
   f. Quick wake enable
3. Not Enabled and Not Configurable:
   a. LUX calculation (returns raw exponent and mantissa only)
   b. Threshold interrupt levels
   c. Fault count configuration
   d. FIFO readback

Figure 3-12. Ambient Light Data Capture

3.4.5 BMI270 – 6-Axis IMU (SPI)

1. Default Configuration - Accelerometer:
   a. Power Mode: Normal
   b. Range: ±8g
   c. Output Data Rate: 100Hz
   d. Bandwidth: Normal
   e. Filter Performance: High
2. Default Configuration - Gyroscope:
   a. Power Mode: Normal
   b. Range: ±2000dps
   c. Output Data Rate: 100Hz
   d. Bandwidth: Normal
   e. Filter Performance: High
   f. Noise Performance: Normal

3. User Configurable:
    a. Power mode (suspend, low-power, normal, performance)
    b. Sensor enable (accelerometer only, gyro only, both)
    c. Accelerometer range (±2g, 4g, 8g, 16g)
    d. Gyroscope range (±125 to 2000dps)
    e. Output data rate (0.78Hz to 3200Hz)
    f. Bandwidth mode (OSR4, OSR2, normal, CIC)
    g. Filter and noise performance modes
    h. Interrupt type and pin selection
4. Not Enabled and Not Configurable:
    a. FIFO operation
    b. Motion and no-motion detection
    c. Step counter and detector
    d. Wrist gesture recognition
    e. Activity recognition
    f. Internal temperature sensor
    g. Self-test and offset calibration

Figure 3-13. Accelerometer Data Capture

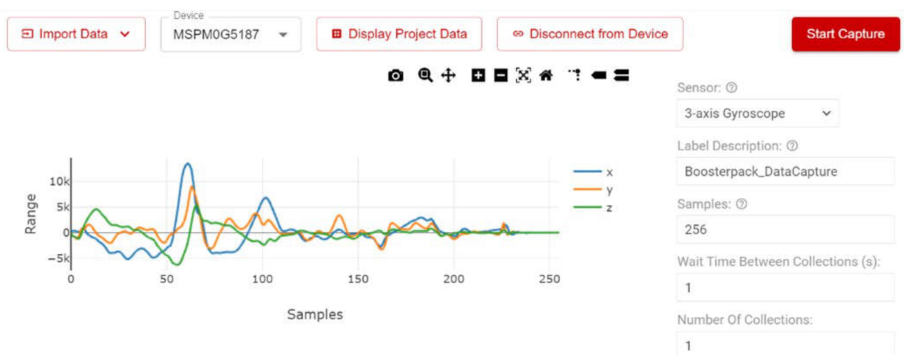


Figure 3-14. Gyro Data Capture

3.4.6 MAG5170 – 3D Hall-Effect Sensor (SPI)

1. Default Configuration:
    a. Operating Mode: Active Measure (continuous)
    b. Magnetic Range: ±50mT
    c. Channels: X, Y, and Z enabled
    d. Conversion Averaging: 4 samples
    e. CRC: Disabled
2. User Configurable:
    a. Operating mode (configuration, standby, active, trigger, sleep)
    b. Magnetic range (±25mT, 50mT, 100mT)
    c. Channel enable (X, Y, Z individually or combined)
    d. Conversion averaging (1 to 32 samples)
    e. CRC enable, CRC disable
3. Not Enabled or Not Configurable:
    a. Per-axis range configuration (all axes use same range)
    b. Temperature measurement
    c. Angle calculation (CORDIC)
    d. Threshold alerts
    e. Magnetic gain, offset trim
    f. Data rate configuration

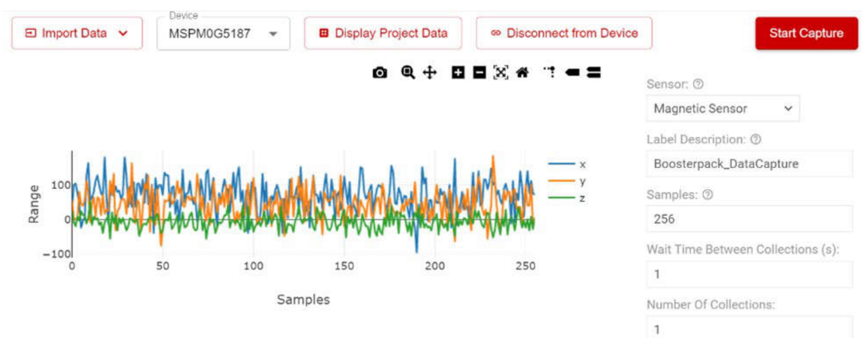


Figure 3-15. Hall Effect Data Capture

3.4.7 ICS43434 – Digital Microphone (I2S)

- Sampling Rate: 62.5kHz

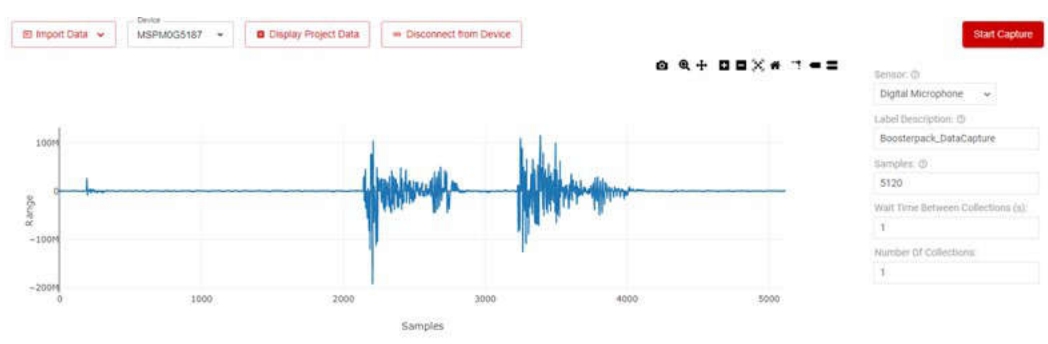


Figure 3-16. Microphone Data Capture

4 Design and Documentation Support

4.1 Design Files

4.1.1 Schematics

To download the schematics, see the design files at TIDA-010997.

4.1.2 BOM

To download the bill of materials (BOM), see the design files at TIDA-010997.

4.2 Tools and Software

Tools

CCStudio™ Edge AI Studio CCStudio™ Edge AI Studio is a collection of graphical and command line tools designed to accelerate edge AI development on TI microcontrollers and processors.

Software

MSPM0 SDK The MSPM0 SDK provides the ultimate collection of software, tools and documentation to accelerate the development of applications for the MSPM0 MCU platform under a single software package.

4.3 Documentation Support

1. Texas Instruments, *Edge AI PIR Motion Detection using CC27xx*, Code Example
2. Texas Instruments, *TIDA-010997 Data Capture using MSPM0G5187*, Code Example

4.4 Support Resources

TI E2E™ support forums are an engineer's go-to source for fast, verified answers and design help — straight from the experts. Search existing answers or ask your own question to get the quick design help you need.

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