

A Robust Glass-Breakage Detector Using the MSP430

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MSP430 Applications

ABSTRACT

This application report describes the working and operation of a modified version of the hardware and software described in the application report *A Simple Glass-Breakage Detector Using the MSP430 (SLAA351)*. This modified version is more robust, with comparable current consumption values to the simple glass-breakage detector. Hardware and software changes are made to the previous design to improve accuracy when detecting a valid glass breakage. The robust glass-breakage detector includes an extra thud detection stage before actual glass-breakage detection. This avoids false triggering of the glass-breakage detector for sound events with signal spectrum similar to a glass-break sound. Hardware and software modifications made to the existing MSP430F2274 glass-breakage detector are shown in this application report.

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1 Introduction

A simple glass-breakage detector picks up acoustic signals and analyzes their peak content, number of zero crossings, and frequency composition to detect a glass breakage.[1] Upon valid detection, an onboard buzzer is turned on for indication. However, at times, sounds similar to a glass breakage can trigger the buzzer alarm. These sounds are called glass-breakage failure sounds, as they mimic the acoustic composition of a glass breakage and trigger a false alarm. False glass-breakage indications can be eliminated by improving the algorithm used to detect a glass breakage. In this application report, an extra detection procedure called thud detection is discussed and implemented. A thud is associated with an initial impact between the striking object and the glass surface. It is followed by the formation and propagation of cracks in the glass. After this initial portion, the glass fragments continue to resonate and strike other glass fragments as they hit the floor and surroundings. Thud is a large-amplitude low-frequency signal that occurs during the initial portion of any glass-breakage sound. Although its frequency depends on the striking object and the type of glass, it most often falls in the frequency range of 200 Hz to 300 Hz. This information is used in the application to improve the robustness of a glass-breakage detector.

This robust glass-breakage detector first looks for a thud, a low-frequency component, and then looks for high-frequency components that constitute a glass-breakage signal. This detection arrangement helps the detector distinguish between actual glass-break sounds from the failure sounds that previously caused false alarms. The latter portion follows the exact same glass-breakage detection analysis used in the simple glass-breakage detector application. The entire hardware setup, software flow, and range testing of the application are discussed in subsequent sections. The complete details of this reference design using the MSP430F2274 are provided in the form of a zip file accompanying this application report.

2 Hardware Description

This section includes the hardware description of the robust glass-breakage detector board using the MSP430F2274.

2.1 Device Specifications

The MSP430F2274 is a 16-bit microcontroller from the 2xx family of the ultra-low-power MSP430 family of devices from Texas Instruments.[2] The supply voltage for this microcontroller ranges from 1.8 V to 3.6 V. The MCU is capable of operating at frequencies up to 16 MHz. It also has an internal very-low-power low-frequency oscillator (VLO) that operates at 12 kHz at room temperature. It has two 16-bit timers (Timer_A and Timer_B), each with three capture/compare registers. An integrated 10-bit analog-to-digital converter (ADC10) supports conversion rates of up to 200 ksps. The ADC10 can be configured to work with on-chip operational amplifiers (OA0 and OA1) for analog signal conditioning. The current consumption of 0.7 μ A during standby mode (LPM3) and 250 μ A during active mode makes it an excellent choice for battery-powered applications.

In this application, the MSP430F2274 device operates in either one of the two different detection modes, thud detection or glass-breakage detection, after activity detection. [Figure 1](#) shows the setup for the robust glass-breakage detector using this device.

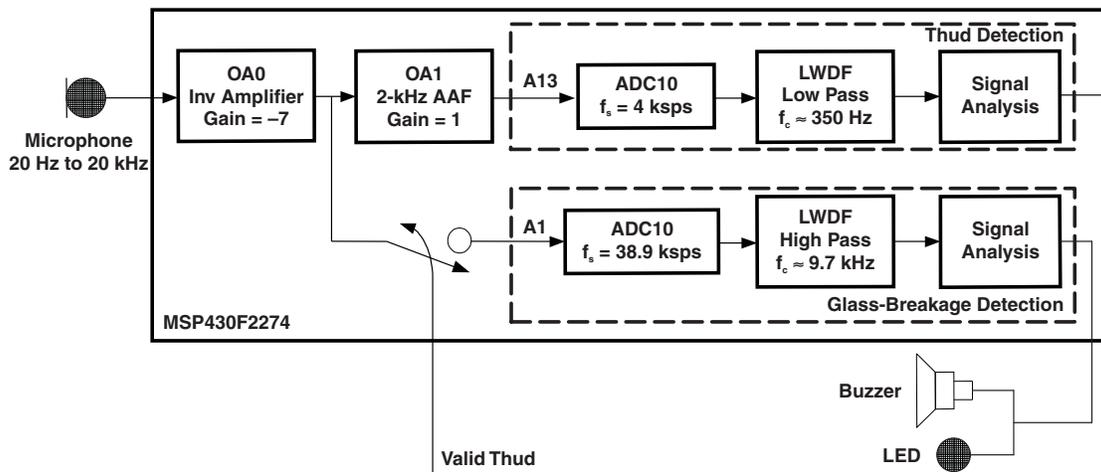


Figure 1. Setup for Robust Glass-Breakage Detector Using MSP430F2274

Figure 1 gives a graphical representation of the signal chains for two different detection modes: thud detection and glass-breakage detection. Activity detection is, however, not explicitly shown in this figure, but it is discussed in detail in Section 3. During activity detection mode, the device checks for any activity (signal with significant amplitude) at the external microphone every 2.5 ms. The signal chain for this mode is external microphone → inverting gain amplifier OA0 → ADC10 (channel A1, single-channel single-conversion mode). Once an activity is detected, the device enters thud detection, in which the analog signal at the microphone is amplified and passed through a 2-kHz antialiasing analog low-pass filter using OA1.

This amplified and filtered signal is then sampled at the rate of 4 kpsps by the ADC10 (channel A13), and signal processing and analysis is performed to detect a valid thud. Only upon confirming a valid thud, the glass-breakage detection signal chain is enabled. The amplified signal at the output of OA0 is sampled and accumulated by the ADC10 (channel A1) at a sampling rate of 38.9 kpsps. Signal processing and analyses are done to verify the occurrence of a glass breakage. Detection of glass breakage is accompanied by the buzzer and LED turning on. Minimal changes were made to the simple glass-breakage detector hardware to implement the robust version.[1] Most of the hardware features, including the operational amplifiers, power supply, microphone, LED and buzzer alert, interface to CC1100/2500, internal VLO, and JTAG interface remain the same as the simple glass-breakage detector.

2.2 Operational Amplifiers (OA0 and OA1)

The MSP430F2274 has two software-configurable operational amplifiers, OA0 and OA1. The first operational amplifier (OA0) is used as an inverting amplifier with a gain of 7. OA0 uses the internal resistor ladder settings to provide this gain. The output of OA0 is internally connected to channel A1 of ADC10 for further processing. The second operational amplifier (OA1) is configured as a unity-gain low-pass filter, which is used as an anti-aliasing filter (AAF) during thud detection. The output of OA1 is internally connected to channel A13 of ADC10 for further processing. The filter is a second-order Butterworth type, realized using the Sallen-Key architecture. The filter has a 3-dB cutoff frequency of 2 kHz. A reference voltage of $DV_{CC}/2$ is provided for both the operational amplifiers, and all the signals passing through them are raised to this reference voltage level.

2.3 Current Consumption

The board is sourced by two 1.5-V AAA batteries. As discussed previously, the robust glass-breakage detector operates in different detection modes such as activity detection, thud detection, and glass-breakage detection. Different sets of peripherals are active with the CPU running at different clock frequencies during various modes of operation. Graphical representation of the current consumption profile of this board during each mode is shown in the following sections.

2.3.1 Activity Detection

Figure 2 shows the current consumption profile during activity detection. The device wakes up every 2.5 ms and goes into Active Mode for 20 μ s and checks for activity. This active mode is represented as Active Mode 1 (AM1) in the current profile. When there is no activity detected at the external microphone, the device goes back to standby mode or low-power mode 3 (LPM3). During AM1, the CPU clock is set to 12 MHz. Periodic wake-up from standby mode is achieved by using the Timer_A with its clock TACLK set to the VLO running at \sim 12 kHz at room temperature.

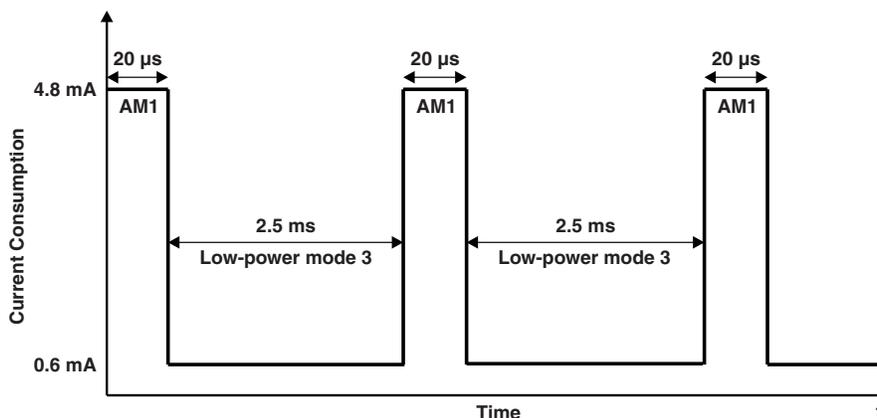


Figure 2. Current Consumption Profile During Activity Detection

2.3.2 Thud Detection

Figure 3 shows the current consumption profile when there is significant activity detected at the external microphone. The device goes into AM1 for 18 μ s and is configured to operate in thud detection mode. The CPU now runs at 8 MHz, and the device enters active mode. This active mode is represented as Active Mode 2 (AM2) in the current profile. In this mode, the MSP430 is configured to sample at a rate of \sim 4 ksp/s. This sampling frequency is achieved by configuring the Timer_B with its clock TBCLK set to sub-main clock (SMCLK) that runs at 8 MHz. Signal analysis is done on every sample for a period of 32 ms. If a valid thud is not detected, the device goes back to AM1 for 12 μ s, during which the device is reinitialized and configured to return to activity detection mode with periodic wake-up of 2.5 ms. At the occurrence of a valid thud, the device proceeds to the next stage, described as glass-breakage detection (see Section 2.3.3).

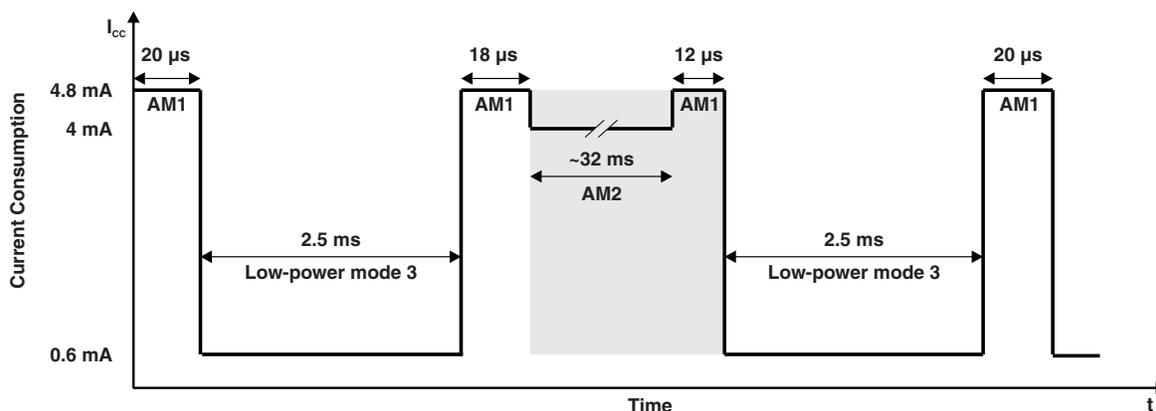


Figure 3. Current Consumption Profile During Thud Detection

2.3.3 Glass-Breakage Detection

When a valid thud is detected, the device is initialized to execute the glass-breakage detection algorithm. Figure 4 shows the current consumption profile when a valid thud is confirmed with the device proceeding to glass-breakage detection mode. During glass-breakage detection, the CPU clock is configured to run at 12 MHz, and the device enters active mode with a sampling rate of ~38.9 ksp/s. This active mode is represented as Active Mode 3 (AM3) in the current profile. Signal analysis is done on every sample for a period of 60 ms. If a valid glass breakage is not detected, the device goes back to AM1 for 4.6 μ s, during which the device is reinitialized and configured to return to activity detection mode with periodic wake-up of 2.5 ms. At the occurrence of a valid glass breakage, the device proceeds to the next stage described as glass-breakage detected (see Section 2.3.4).

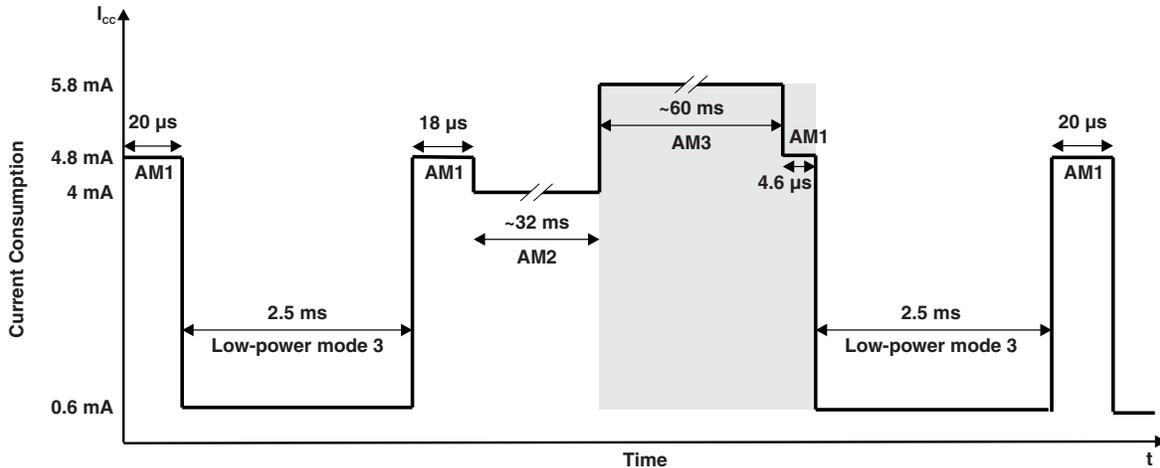


Figure 4. Current Consumption Profile During Glass-Breakage Detection

2.3.4 Glass-Breakage Detected

Figure 5 shows the current consumption profile when a glass breakage is detected. Upon confirming a glass breakage, the device enters active mode. This active mode is represented as Active Mode 4 (AM4) in the current profile. During AM4, an LED and buzzer are ON for a period of three seconds. After this time, the device goes back to AM1 for 4.6 μ s, during which it is reinitialized and configured to return to activity detection mode with periodic wake-up of 2.5 ms.

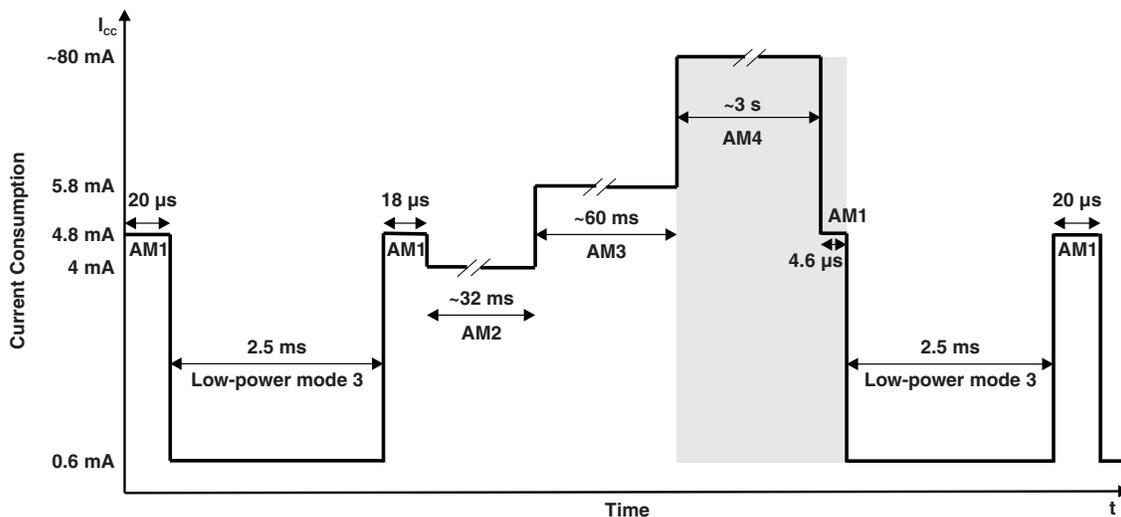


Figure 5. Current Consumption Profile Upon Confirming a Glass Breakage

Table 1 gives a list of all the peripherals and clocks that are on during various modes of operation. These peripherals are significant contributors to the overall current consumption during each stage.

Table 1. Significant Current and Timing Considerations

Condition/Mode	Peripherals ON	Clocks	Current	ON Time
LPM3	Timer_A ON (up-mode)	MCLK = DCO = OFF SMCLK = DCO = OFF ACLK = VLO ≈ 12 kHz TACLK = ACLK = VLO	0.6 μA	2.5 ms
Activity detection/AM1 (Active Mode 1)	P4.0 = 1 (microphone ON), P2.4 = 1 (V _{CC} /2 offset ON), OA0 ON (gain amplifier)	MCLK = DCO = 12 MHz SMCLK = DCO = 12 MHz ACLK = VLO ~ 12 kHz	4.8 mA	20 μs
Thud detection/AM2 (Active Mode 2)	P4.0 = 1 (microphone ON), P2.4 = 1 (V _{CC} /2 offset ON), OA0 ON (gain amplifier) OA1 ON (2-kHz AAF) Timer_B ON (up-mode)	MCLK = DCO = 8 MHz SMCLK = DCO = 8 MHz ACLK = VLO ≈ 12 kHz TBCLK = SMCLK = 8 MHz	4 mA	32 ms ⁽¹⁾
Glass-breakage detection/AM3 (Active Mode 3)	P4.0 = 1 microphone ON), P2.4 = 1 (V _{CC} /2 offset ON), OA0 ON (gain amplifier) ADC10 ON (continuous conversion)	MCLK = DCO = 12 MHz SMCLK = DCO = 12 MHz ACLK = VLO ≈ 12 kHz	5.8 mA	60 ms ⁽²⁾
Glass-breakage detected/AM4 (Active Mode 4)	P1.0 = 1 (LED ON), P3.7 = 1 (buzzer ON)	MCLK = DCO = 12 MHz SMCLK = DCO = 12 MHz ACLK = VLO ≈ 12 kHz	80 mA	3 s

- (1) Device goes into AM2 (Timer_B ISR) for 51.2 μs once every 250 μs and waits in LPM0 for the rest of the time. Sampling frequency = $(250 \mu\text{s})^{-1} = 4 \text{ ksp/s}$; 128 samples accumulated; $128 \text{ samples} \times (4 \text{ ksp/s})^{-1} = 32 \text{ ms}$.
- (2) Device goes into AM3 (ADC10 ISR) for 22 μs once every ~25.7 μs and waits in LPM0 for the rest of the time. Sampling frequency = $(25.7 \mu\text{s})^{-1} = 38.9 \text{ ksp/s}$; 2336 samples accumulated; $2336 \text{ samples} \times (38.9 \text{ ksp/s})^{-1} \approx 60 \text{ ms}$.

3 Software Description

This section describes the software modules used in the glass-breakage detector using the MSP430F2274. Figure 6 shows a very high-level program flow of the application. When there is no activity detected at the external microphone, the device enters activity detection. If significant activity is detected at the microphone, the device enters thud detection. Upon confirming a valid thud, the device enters glass-breakage detection, else the device goes back to activity detection. After the glass breakage analysis, if a glass breakage is detected, the buzzer and LED are turned ON for approximately three seconds, and the device returns to activity detection. If a glass breakage is not confirmed, the device simply returns to activity detection mode.

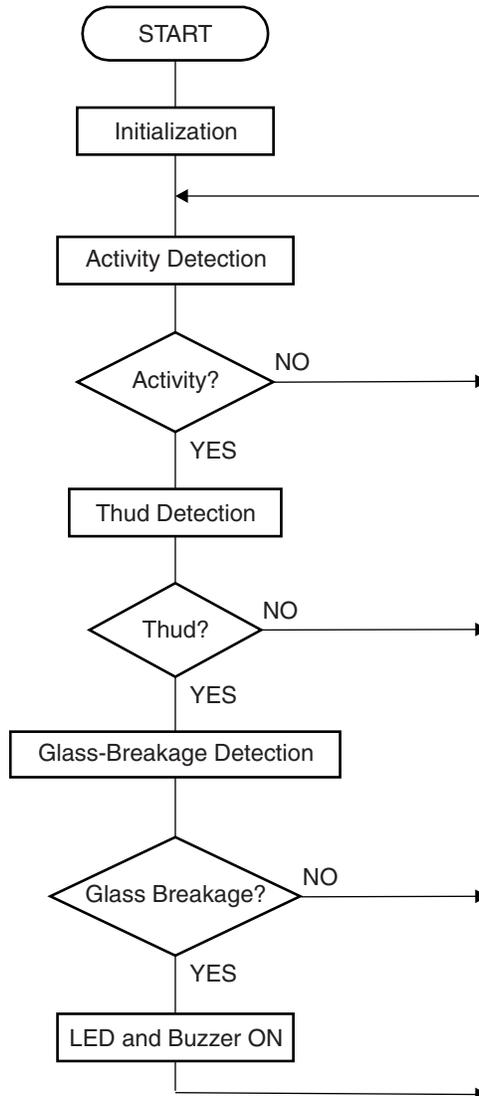


Figure 6. High-Level Program Flowchart

3.1 Initialization Routine

The software execution for the initialization of the robust glass-breakage detector board is shown in Figure 7. This section of the main program initializes the system and all the peripherals required for the activity detection mode. The CPU clock is configured to run at 12 MHz in this mode. The inverting gain amplifier OA0 and 2-kHz unity-gain AAF OA1 are configured with their corresponding analog enable bits

set. Both OA0 and OA1 are only configured in this section. OA0 is turned on every 2.5 ms in the activity detection mode and both OA0 and OA1 are turned on during the thud detection mode. ADC10 is configured to sample in single-channel single-conversion mode. Channel A1, which is internally connected to the output of gain amplifier OA0, is set as input to ADC10. Timer_A is initialized to wake the device every 2.5 ms and check for activity at the external microphone.

Once all the peripheral initializations are complete, the device enters the low-power mode selection part of the code. The Activity flag decides which low-power mode the device should enter. In activity detection mode, the Activity flag is set to zero and the device always enters LPM3 between successive Timer_A interrupts. Activity flag is set only when an activity is detected at the external microphone.

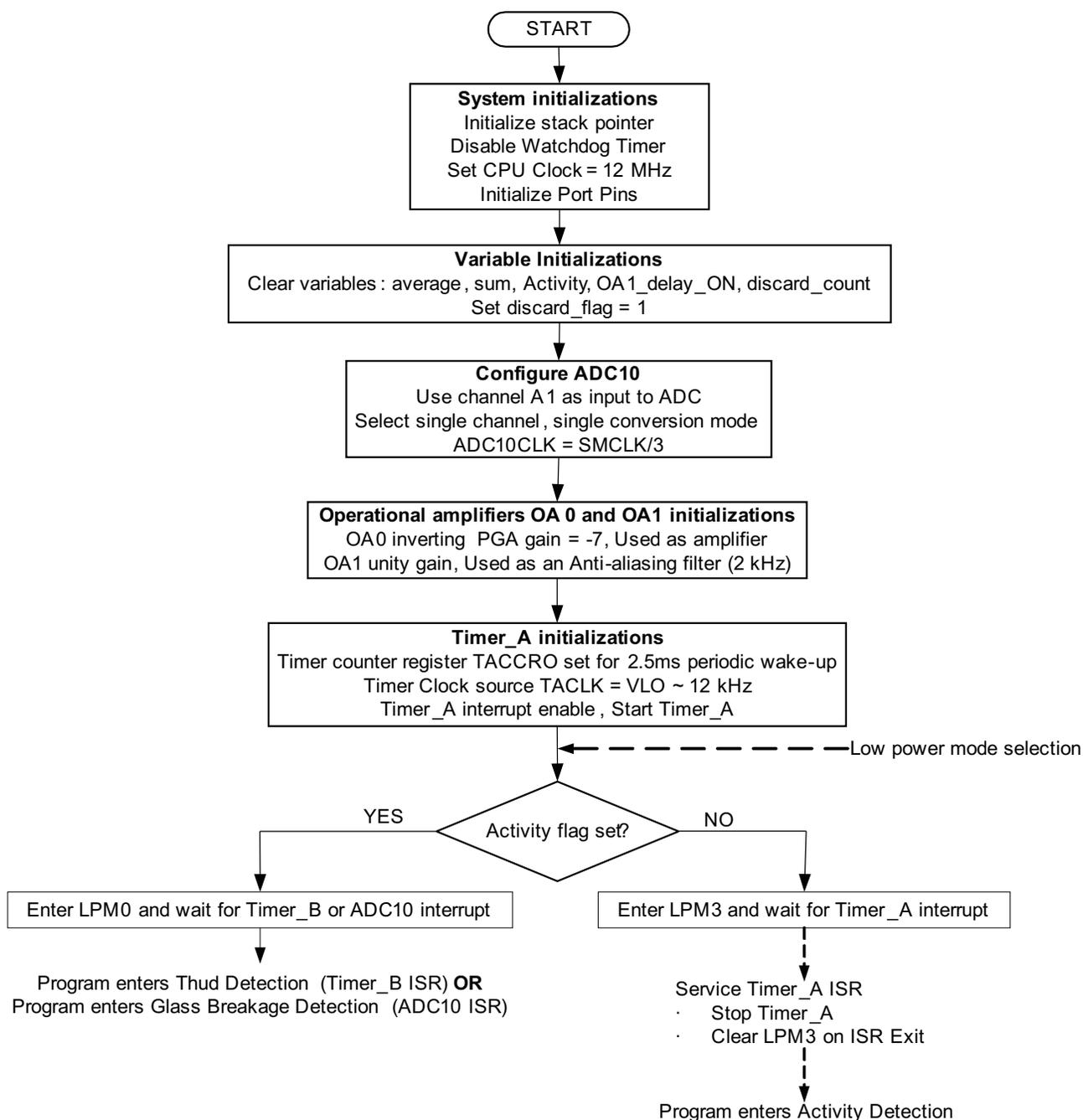


Figure 7. Device Initialization Flowchart

3.2 Activity Detection

During the activity detection mode, the device wakes up every 2.5 ms and checks for any activity detected at the external microphone. The Timer_A peripheral provides this 2.5 ms wake-up for the device. TACLK is sourced from ACLK = VLO \approx 12 kHz (at room temperature) and, therefore, the device always enters LPM3 when in activity detection mode.

3.2.1 Timer_A ISR

Timer_A wakes the device up every 2.5 ms to check for activity. In activity detection mode, the OA1_delay_ON flag is set to zero, as the 2-kHz AAF OA1 is not turned on. Inside the Timer_A ISR, the Timer_A is stopped, and device clears low-power mode bits in the status register and exits the ISR.

3.2.2 Activity Detection in Main Function

Upon exiting the Timer_A ISR with its low-power mode bits cleared, the device executes code in the main function. For detecting activity, the external microphone, the inverting gain amplifier OA0, and the offset voltage of $DV_{CC}/2$ (reference to the OA0 positive input) are enabled. ADC10 is enabled and single conversion of the sample at channel A1 is performed. The conversion result is subtracted by 500 (which is approximately equal to $DV_{CC}/2$) to remove the reference value of OA0 from the digitized sample. This converts the measurement to bipolar format. The resulting value is compared to the low- and high-level thresholds (LOW_LVL and HIGH_LVL, respectively). These thresholds help distinguish spurious noise inputs from valid activity. In the absence of any activity, all the peripherals are switched off, Timer_A is reenabled, and the device runs in LPM3 mode.

On the other hand, if an activity is detected, the software executes the initialization for thud detection and, thus, configures the device to enter thud detection mode.

The microphone, offset, OA0, ADC10 are turned on and off every 2.5 ms to ensure low current consumption, as these peripherals consume considerable current.

Sample Discard

When the device is initially turned on, the first few samples that are sampled by the ADC10 are invalid, as the analog signal chain is still settling. Therefore, these initial ADC10 conversion results are discarded and this discard process happens only in the beginning, when the device is turned on for the first time.

Discard_flag is initially set and the variable discard_count keeps track of the number of samples that need to be discarded. Once the discard_count exceeds a predefined number, Discard_flag is reset, and all the ADC10 samples thereafter are compared with LOW_LVL and HIGH_LVL for a valid activity.

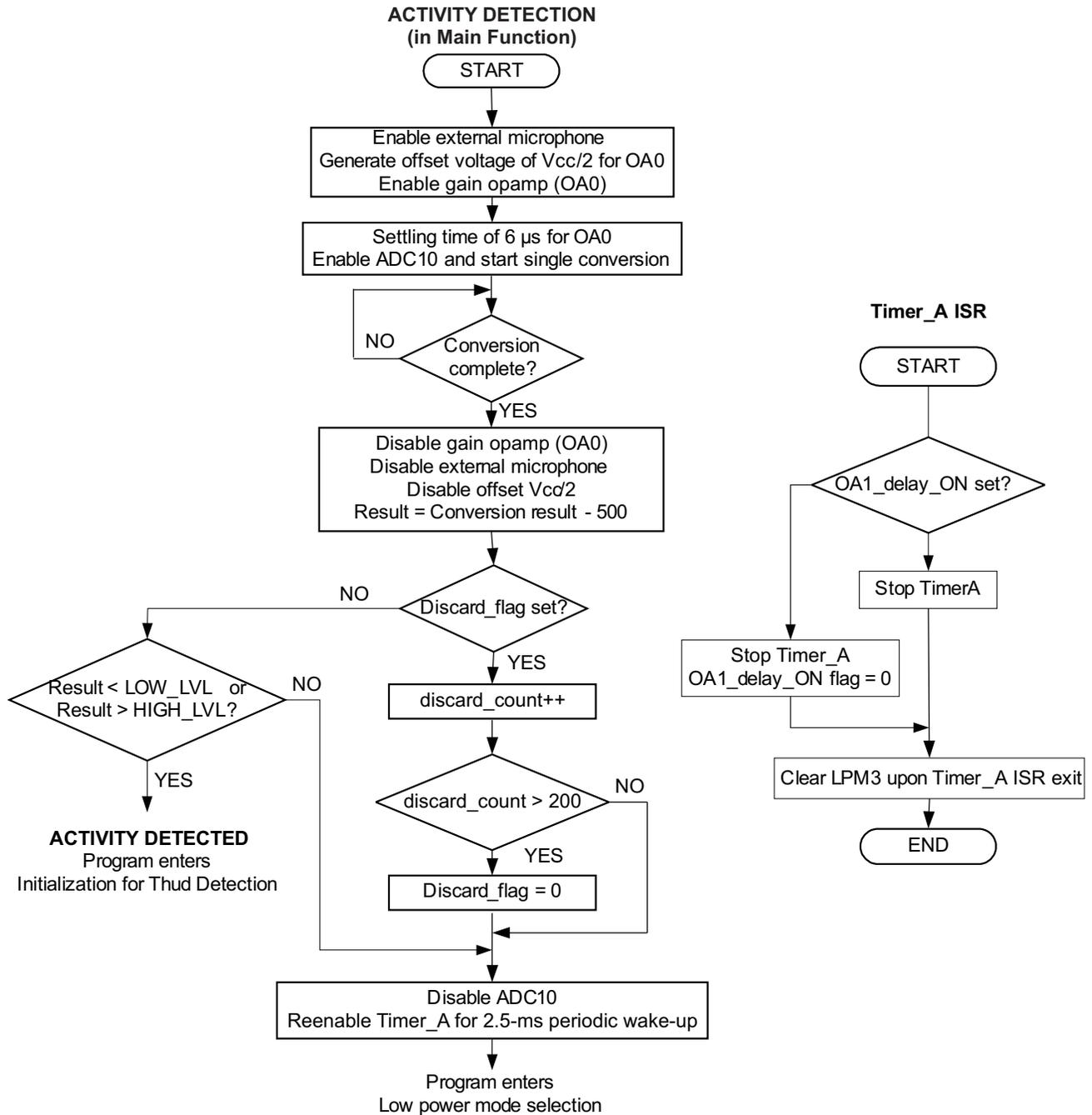


Figure 8. Activity Detection Program Flowchart

3.3 Thud Detection

If activity is detected, the device is configured and initialized for thud detection in the main function and enters thud detection mode. [Figure 10](#) shows the Initialization and working of the device in thud detection mode.

3.3.1 Initialization for Thud Detection in Main Function

In thud detection mode, the CPU clock is set to 8 MHz. The analog signal chain for thud detection is external microphone → inverting gain amplifier OA0 → 2-kHz AAF OA1 → ADC10 (channel A13). Therefore, this part of the code initializes all these peripherals. The external microphone and $DV_{CC}/2$ voltage offset for op-amp reference are enabled. Both the operational amplifiers in MSP430F2274 are enabled and the OA1_delay_ON flag is set. OA1, which is used as an anti-aliasing low-pass filter with 2-kHz cut-off, has a longer settling time compared to OA0. Timer_A is used to provide this delay. Timer_A counter (TACCR0) is loaded with a value that generates a device wake-up after ~3.2 ms. This time is sufficient for the 2-kHz AAF to settle. TACLK is still sourced from ACLK = VLO, so the device enters LPM3 and waits for an interrupt from Timer_A.

In the Timer_A ISR, as the OA1_delay_ON flag is set, the Timer_A is stopped and the flag is reset. Upon exiting the ISR, the LPM3 bits are cleared and, therefore, the software execution continues the initialization for thud detection in the main function.

The activity flag is now set and ADC10 is configured to sample channel A13 (which is internally connected to the output of 2-kHz AAF OA1) in single channel single conversion mode. Timer_B is then configured for a sampling frequency of 4 kHz with its clock TBCLK = SMCLK = 8 MHz. Under this condition, the device waits in LPM0 mode between successive Timer_B interrupts.

3.3.2 Thud Detection (Timer_B ISR)

As the output of 2-kHz low-pass filter is to be sampled, according to Nyquist criterion, the sampling frequency should be at least 4 kHz. Timer_B is used to wake the device up every 250 μ s, and the ADC10 samples channel A13 during this interval, achieving a sampling rate of 4 kHz. 128 samples are processed at the rate of 4 kHz for a period of 32 ms.

In Timer_B ISR, ADC10 is enabled and single conversion of the sample at channel A13 is performed. The reference value of OA0 and OA1 ($\sim DV_{CC}/2$) is subtracted from the conversion result. This converts the digitized samples to bipolar format. Signal analysis is performed on each of these digitized values. Signal analysis includes passing the sample through a low-pass filter with a cutoff frequency of ~350 Hz. A low-pass lattice-wave digital filter (LWDF) is used to do this filtering, which is well suited for microcontrollers without a hardware multiplier.[3] The LWDF exhibits excellent stability properties over non-linear conditions and has a good dynamic range in its coefficients. The LWDF gives one output sample every sample period and this output is accumulated in the variable sum.

Sample_count keeps track of the number of samples accumulated. If Sample_count is less than 128, the control comes out of the Timer_B ISR and waits in LPM0 until the next Timer_B interrupt. After processing 128 samples totaling to a period of 32 ms, Timer_B is disabled, and the average (sum/128) of the accumulated values is computed. This average is compared to the thud threshold (THUD_LVL) to confirm a valid thud. If no valid thud is confirmed, the device is reinitialized to enter activity detection mode with CPU clock = 12 MHz, all peripherals turned OFF, and Timer_A reconfigured for 2.5-ms periodic wake-up. The device finally enters LPM3 mode on Timer_B ISR exit.

However, if a valid thud is detected, the software executes the initialization for glass-breakage detection discussed in [Section 3.4](#).

3.3.3 Low-Pass Filtering for Thud Detection

As mentioned in [Section 3.3.2](#), a thud is a low-frequency component approximately 300 Hz. It is also important to note that, in any glass-breakage signal, the thud component occurs during an impact, which is always at the beginning. These properties have been exploited to achieve robust thud detection. To determine the occurrence of a valid thud, only the first few samples of the incoming signal are filtered, using a digital low-pass filter with a cut-off frequency of 350 Hz. The corresponding output samples of the filter are accumulated, averaged, and compared to a prefixed threshold. The glass-breakage detection algorithm is initialized only if the average exceeds this threshold. [Figure 9](#) shows a typical glass-breakage signal frequency response, showing the thud component.

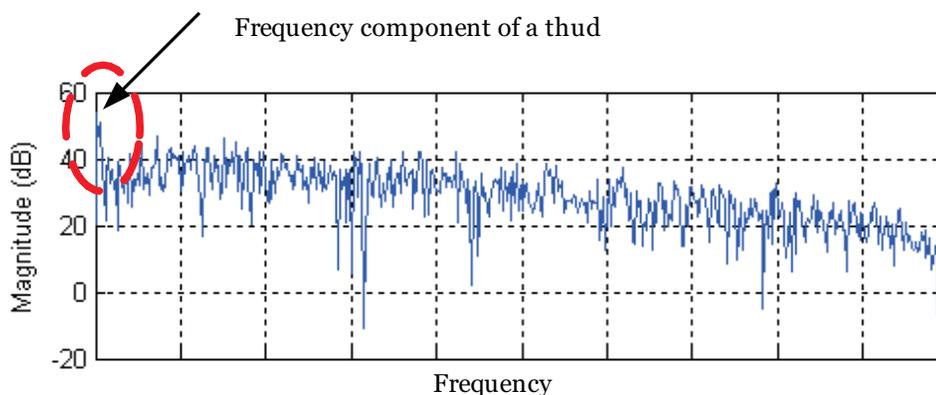


Figure 9. Frequency Response of Sample Glass-Breakage Signal

The low-pass filter realized for this narrow bandwidth is of order 7 and has the LWDF type of structure. The alpha coefficients for this filter are $\alpha_0 = 0.212738$, $\alpha_1 = 0.27612304$, $\alpha_2 = 0.0718994$, $\alpha_3 = 0.12081909$, $\alpha_4 = 0.12710571$, $\alpha_5 = 0.030487$, and $\alpha_6 = 0.15614648$. This low-pass filter is active only during thud detection and consumes 253 CPU cycles for its operation.

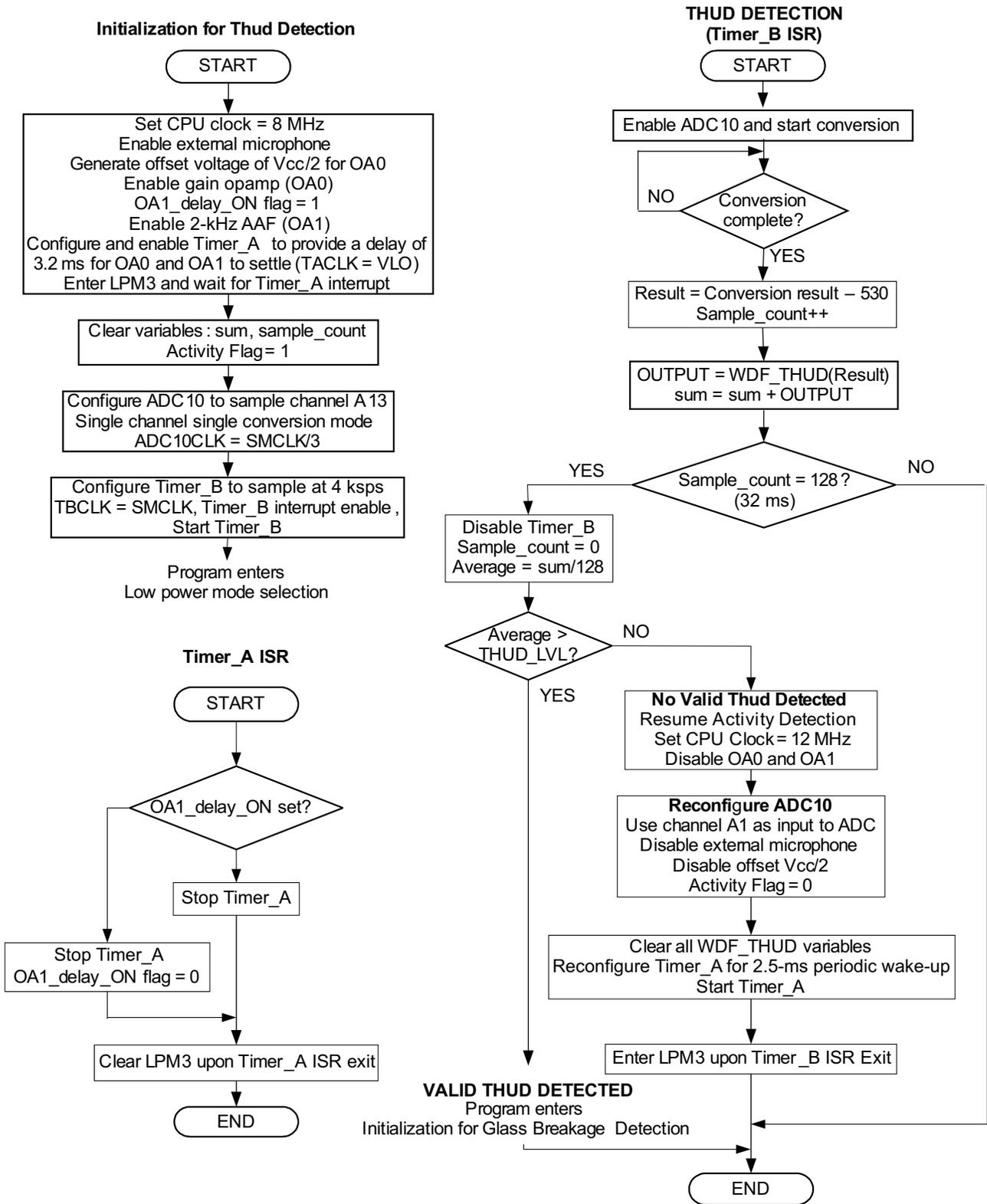


Figure 10. Thud Detection Program Flowchart

3.4 Glass-Breakage Detection

If a valid thud is detected, the device is configured and initialized for glass-breakage detection in the Timer_B ISR and enters glass-breakage detection mode. [Figure 11](#) shows the initialization and working of the device in glass-breakage detection mode.

3.4.1 Initialization for Glass-Breakage Detection in Timer_B ISR

In glass-breakage detection mode, the CPU clock is set to 12 MHz. The analog signal chain in this mode is external microphone → inverting gain amplifier OA0 → ADC10 (channel A1). The external microphone, voltage offset ($DV_{CC}/2$), inverting gain amplifier OA0 and the 2-kHz AAF OA1 are on during thud detection. All these peripherals, except the 2-kHz AAF OA1, continue to be on during glass-breakage detection.

The microphone that is used in this application, Panasonic WM-61A, has a frequency response between 20 Hz and 20 kHz. The MSP430F2274 has two operational amplifiers, OA0 and OA1. In the simple glass-breakage detection application, OA0 was used as an inverting gain amplifier and OA1 as a 19.2-kHz AAF for glass-breakage detection. An option was provided for the user to select operation with or without the AAF. This was possible, because the microphone rejected frequency components greater than 20 kHz at its output. Thus, for glass-breakage detection, the signal detected at the external microphone must be sampled at a rate of ~40 ksp/s.

ADC10 is configured to sample in single-channel continuous-conversion mode. The output of the inverting gain amplifier, OA0, is sampled by the ADC10 at channel A1. The sampling rate is maintained at 38.9 ksp/s, similar to the simple glass-breakage detector application. ADC10 is enabled and continuous conversion is started. Device enters LPM0 mode between successive ADC10 sampling.

3.4.2 Glass-Breakage Detection (ADC10 ISR)

The complete glass-breakage detection signal analysis is done in the ADC10 ISR. Each digitized sample is converted to a bipolar value by subtracting the reference voltage value of the operational amplifiers. [Figure 11](#) shows the program flow inside the ADC10 ISR. The signal analysis is split into two parts: signal analysis one and signal analysis two. Signal analysis one is performed on every sample and is completed before the arrival of the next sample. 2336 samples are processed at the rate of 38.9 kHz totaling to a period of 60 ms. Sample_count keeps track of the number of samples that have been sampled by the ADC10. For real time operation, the entire processing must be complete before the arrival of the next sample. The number of available CPU cycles between successive sampling instants is approximately 300.

Once 2336 samples have been processed, signal analysis two is performed on the data that has passed through signal analysis one. The duration of 60 ms is not based on any requirement of the algorithm but chosen as a convenient number for efficient processing. During signal analysis two, all the peripherals such as the external microphone, offset voltage $DV_{CC}/2$, OA0, OA1, and ADC10 are switched off.

During signal analysis two, it is determined if a glass breakage actually occurred or not. After this stage of signal processing, the device is reconfigured to resume activity detection mode. ADC10 is reconfigured to sample channel A1 in single-channel single-conversion mode, Timer_A is reconfigured for 2.5-ms periodic wake-up, and the device enters LPM3 mode on ADC10 ISR exit.

Signal analysis one and signal analysis two routines form a major part of this ISR and have been described in greater detail in the application report *A Simple Glass-Breakage Detector Using the MSP430* ([SLAA351](#)). For convenience, the flow charts have been reproduced in the following sections, with slight changes in names.

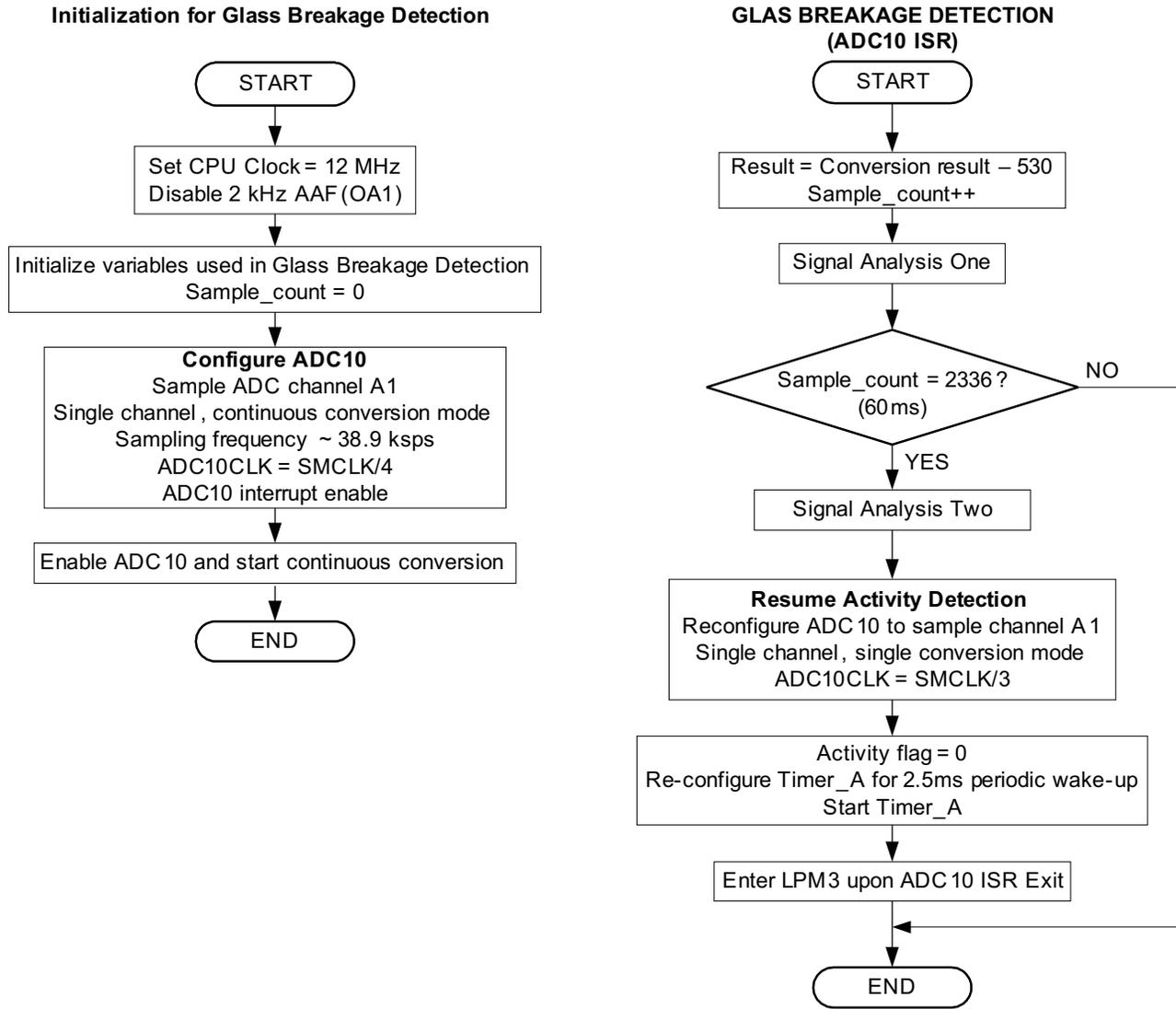


Figure 11. Glass-Breakage Detection Program Flowchart

3.5 Glass-Breakage Detection Signal Analysis

This portion of the software implements the methodologies used to detect a glass breakage.

3.5.1 Signal Analysis One

The first stage of processing is done on every sample once a thud has been detected. The summary of operations for this processing is shown in Figure 12.

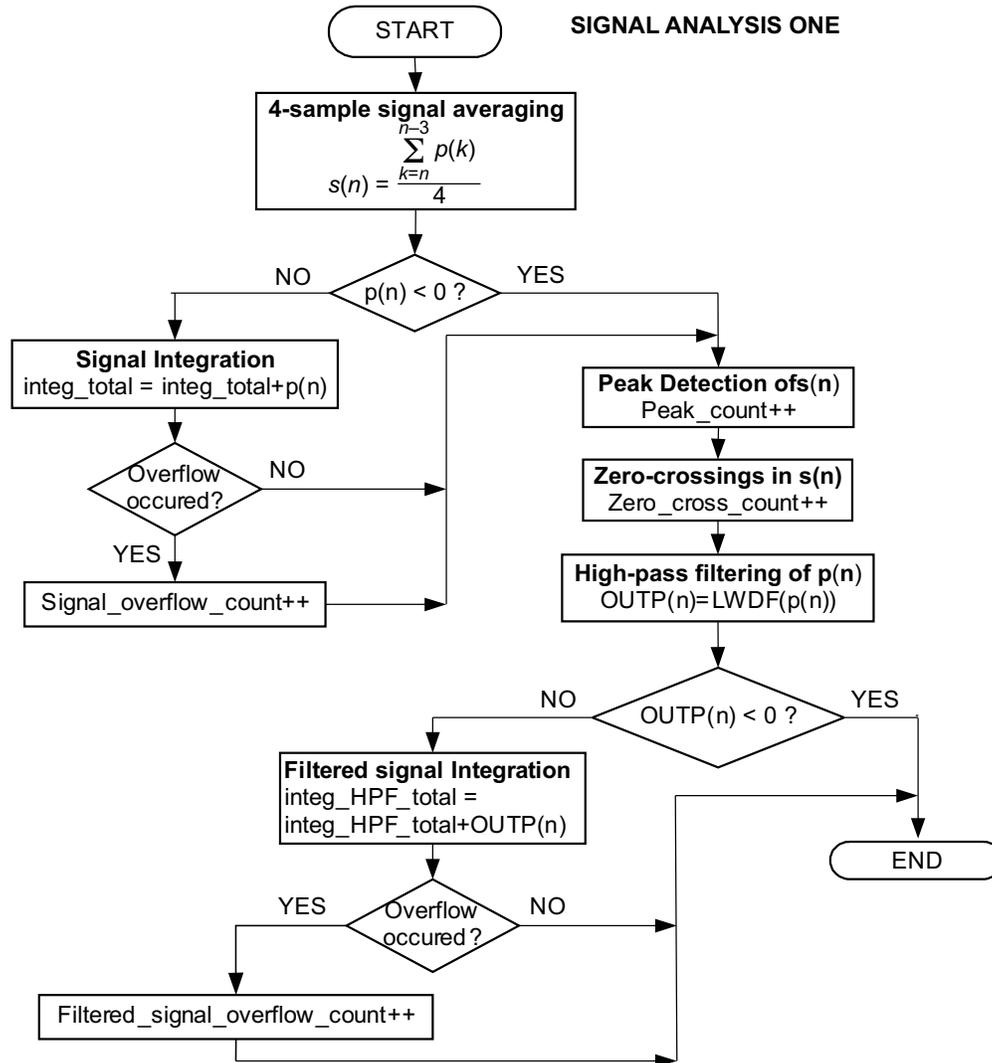


Figure 12. Signal Analysis One Flowchart

3.5.2 Signal Analysis Two

The second stage of processing does not require a real-time operation. It is done only after 60 ms of the input signal has been processed by the signal analysis one algorithm. The summary of operations is shown in Figure 13. This section of signal analysis also confirms if a glass breakage actually occurred or not.

Glass-Breakage Detect

The simple glass-breakage detector application report ([SLAA351](#)) discusses the computation of frequency composition ratio, peak, and zero-crossing count in detail. False flags are set if these computed values fall outside of the characteristic range of a glass breakage.

If none of the false flags are set, then a glass-breakage detect is issued. This immediately enables the buzzer and the LED for indication. The buzzer and LED are turned on for a period of three seconds and then turned off.

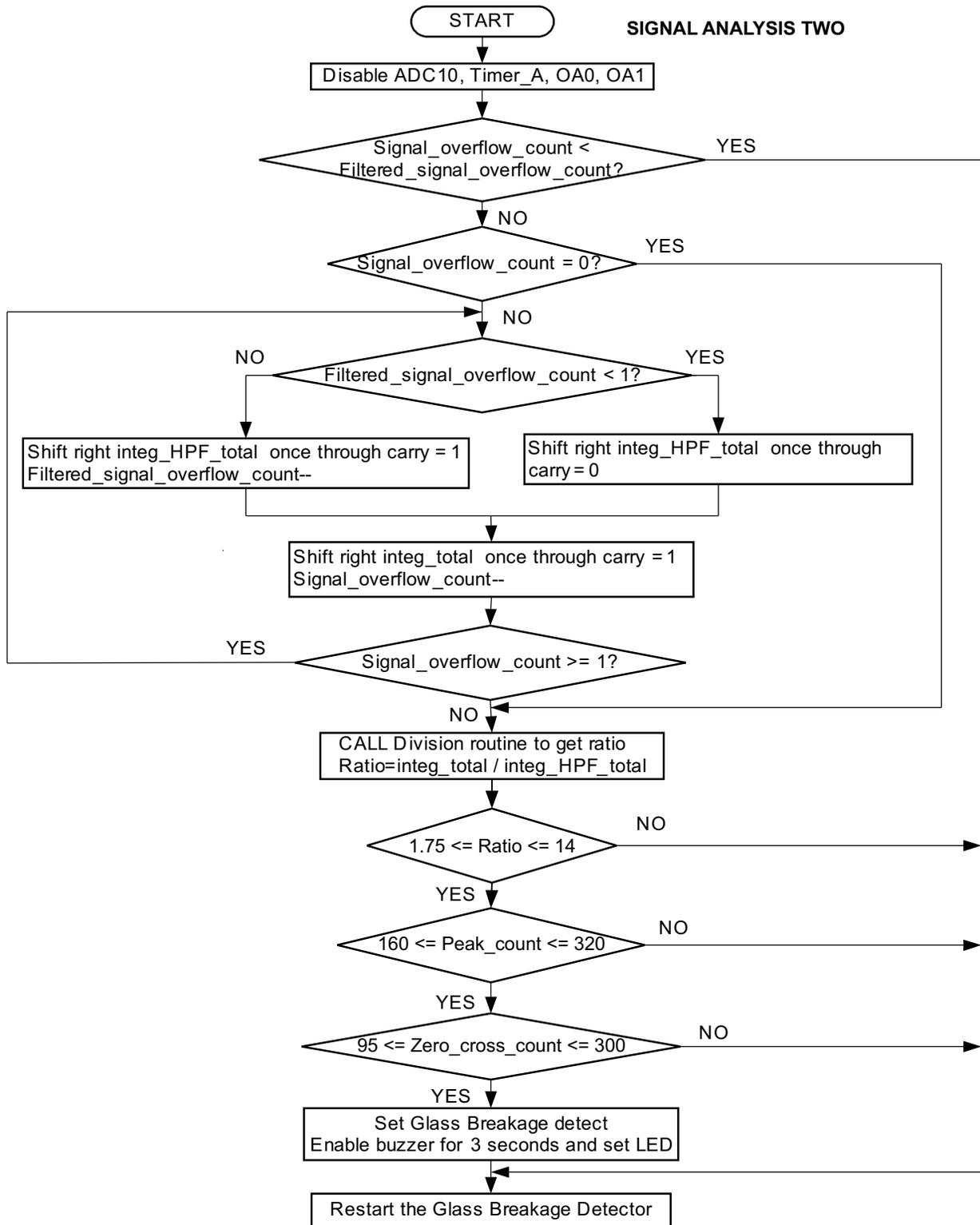


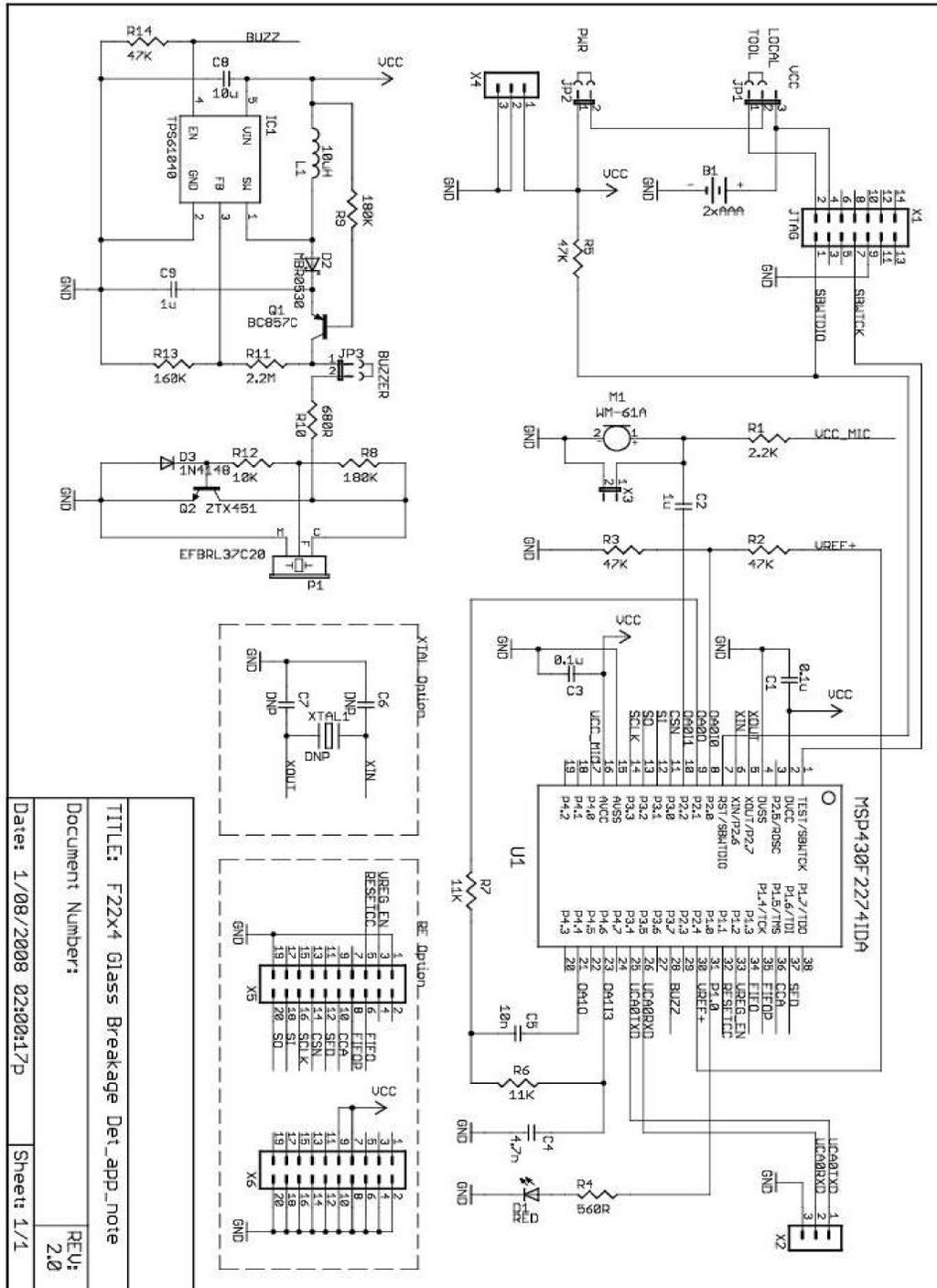
Figure 13. Signal Analysis Two Flowchart

4 References

1. Robin Kammel, Kripasagar Venkat, *A Simple Glass-Breakage Detector Using the MSP430* ([SLAA351](#))
2. MSP430x22x2, MSP430x22x4 data sheet ([SLAS504](#))
3. Kripasagar Venkat, *Wave Digital Filtering Using the MSP430* ([SLAA331](#))

Appendix A Hardware Schematic

A zip file accompanying this document has all the necessary files to reproduce the hardware and software designs.



Appendix B Range Testing

This appendix discusses the test setup and range testing of the robust glass-breakage detector. The test setup is similar to the measurement arrangement of the simple glass-breakage detector.[1] [Figure B-1](#), [Figure B-2](#), and [Figure B-3](#) show the different views of test setup. The range of operation of the robust glass-breakage detector depends on various thresholds used in the application. The thresholds LOW_LVL and HIGH_LVL help distinguish a significant activity from spurious noise during activity detection, and the THUD_LVL threshold helps detect a valid thud during thud detection. These prefixed threshold values vary with the types of glass, and it is left to the end user to set these thresholds appropriately. In this application, typical glass-breakage sounds were used to set these thresholds. (These glass-breakage sound files were obtained from a sound effects vendor via the website www.sounddogs.com.) Tests were performed with increased sound levels, compared to the original sound files, to ensure all sound files have nearly the same sound pressure level. Range of operation of the robust glass-breakage detector can be increased by varying these thresholds. With threshold values of LOW_LVL = -65, HIGH_LVL = 130, THUD_LVL = 30 with the test setup shown in the following figures, the range of operation of the detector is approximately 8 feet.

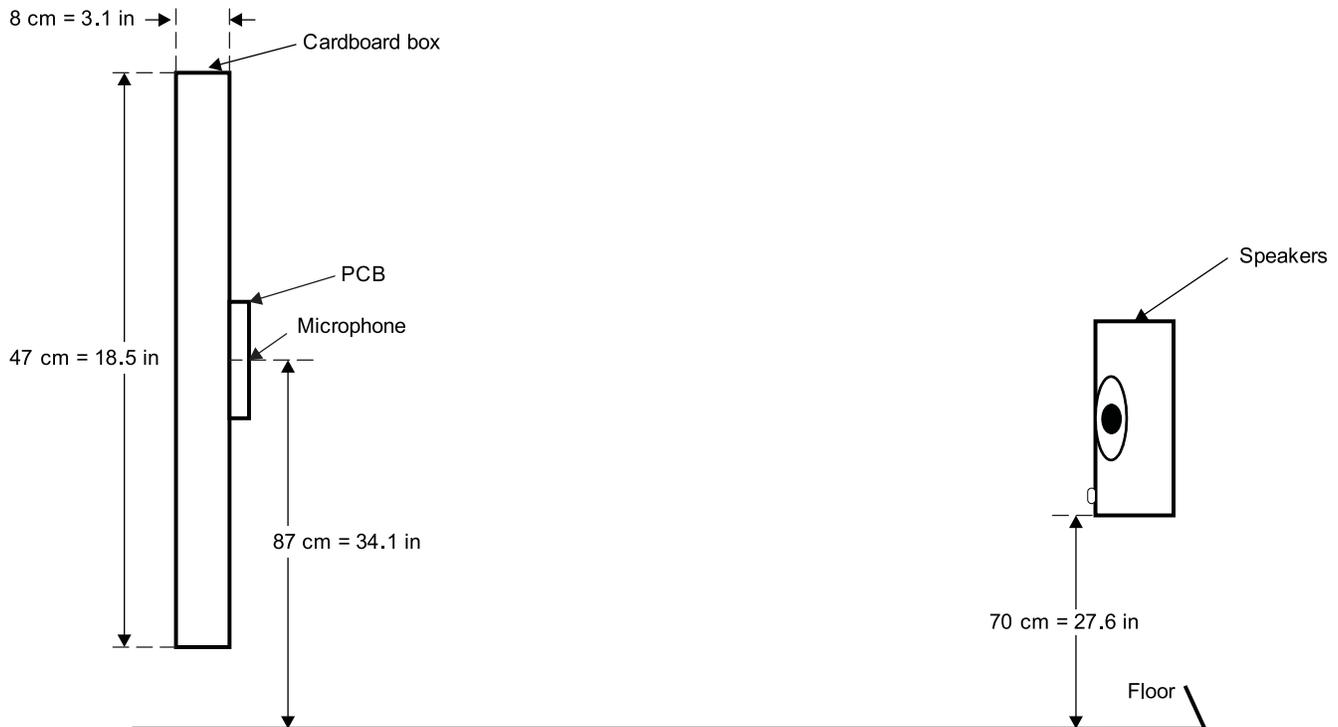


Figure B-1. Test Setup (Side View)

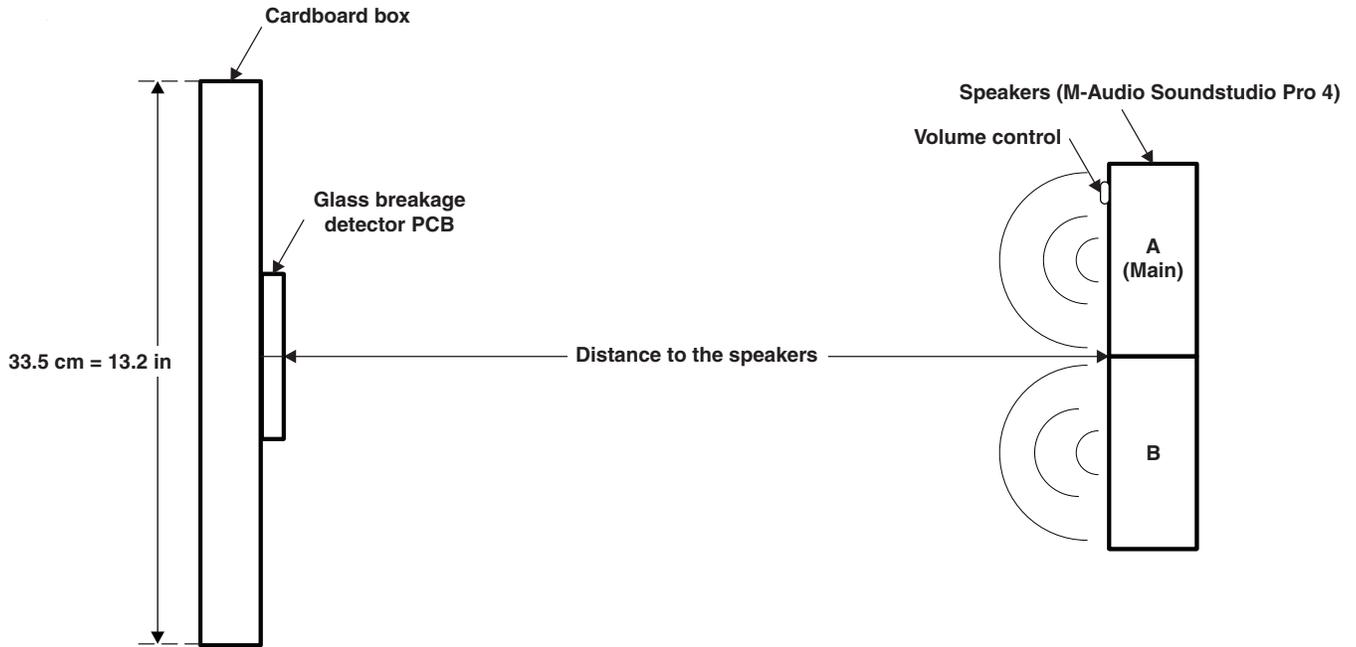


Figure B-2. Test Setup (Top View)

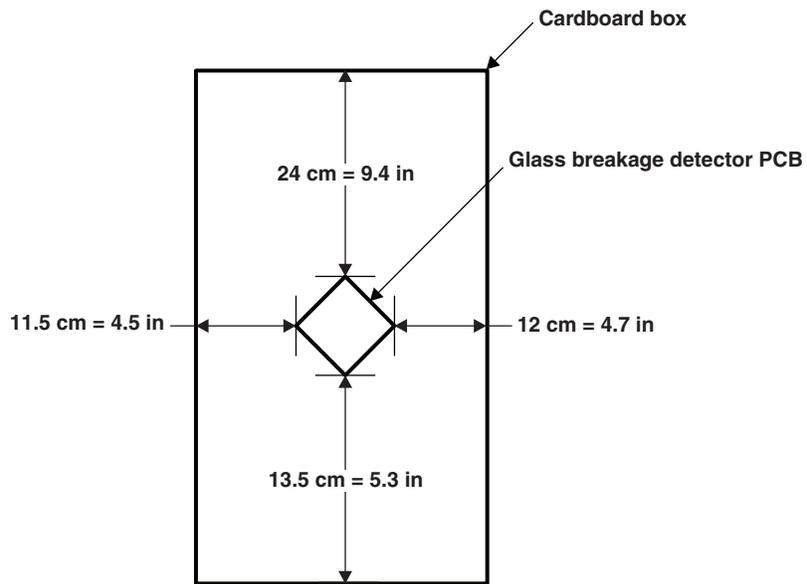


Figure B-3. Test Setup (Front View)

Appendix C Tips to Modify Existing Application

This appendix lists a few tips that the user can implement to modify the existing code to suit their application.

Modifying the Range

The present hardware works well for a range of up to 8 feet. If the range needs to be increased, the user can easily modify the predefined thresholds `LOW_LVL` and `HIGH_LVL`. These thresholds are inversely related to distance, and appropriate values can be obtained only by performing tests over different ranges with corresponding changes to these values.

Thud Detection

Thud detection depends entirely on the value chosen for the threshold `THUD_LVL`. Glass-breakage detection is initialized only if this threshold is met. This threshold also depends on the distance of the glass-breakage detector from the sound source. Similar to the previous case this threshold is inversely proportional to the distance, and correct values can be arrived at only by conducting sufficient number of tests with sample sound events with and without thud.

Supply Voltage

The present application at times has its CPU running at 12 MHz and is powered by two 1.5-V AAA batteries. It is an absolute requirement that the voltage level at the supply rails be at least 3 V, conforming to the device data sheet. Failure to meet this requirement can lead to unpredictable CPU behavior. If the application needs to be modified to a higher speed to meet design and sampling requirements, care should be taken to adhere to the CPU frequency versus voltage requirement provided in the device data sheet.

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