Application Note AN2186

Acoustic Glass Break Detector

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Associated Part Family: CY8C22xxx, CY8C24xxx, CY8C27xxx
PSoC Designer Version: 4.1
Associated Application Notes: AN2099

Abstract

This Application Note describes a low-cost, 3-band acoustic glass break detector. Digital signal processing provides high sensitivity and sufficient resistance to false alarms.

Introduction

There are a variety of ways to implement glass break recognition. One possible method is to detect the vibration made by breaking glass. This technology may be realized using a piezo-film sensor for impact detection. Another method is to detect the sound of breaking glass. The simplest of such detectors are responsive to sound level spike in the 4-5 kHz frequency band. The main disadvantage of the acoustic method is the high probability of false alarms caused by loud music, tinkling of bells, or other sounds. To increase false alarm immunity, two or more frequency bands are treated and information relating to amplitude and timing of the separated channels is analyzed.

It is possible to make dual technology detectors where one part detects a very low frequency sound pressure wave created by the flexing of glass before breakage and another part is sensitive to high frequencies of the shattered glass. The most advanced detectors are based on neuronets and pattern recognition. However, these detectors require powerful digital signal processors to implement complex algorithms.

The PSoC™ solution for a framed-glass break detector presented in this Application Note is based on timing and amplitude analysis of sound at three frequencies: 35 Hz, 300 Hz, and 5000 Hz. All signal treatments are performed in the software. This allows tuning flexibility and adaptation to different glass types.

Detecting Algorithm

A typical waveform for the sound of breaking glass is shown in Figure 1.

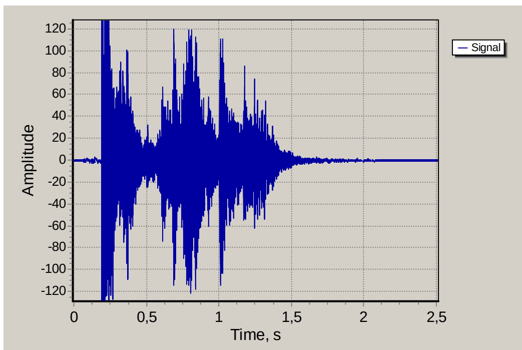

Figure 1. Waveform for Breaking Glass

The initial spike created by the shock waves that flow outward after impact is easily seen.

To recognize the sound of breaking glass and to distinguish it from another source, three band pass filters (BPFs) are applied and their timing and output amplitudes are analyzed.

The first filter is a low-pass filter (LPF) with a 35 Hz cutoff frequency. Its role is to detect the initial shock wave. The second filter is a band-pass filter with a 5 kHz central frequency and a Q-factor of 5. This filter responds to the sound of shattering glass. The third filter is a 300 Hz BPF and serves to eliminate false alarms. Figure 2 shows the filters' outputs when a test signal is applied.

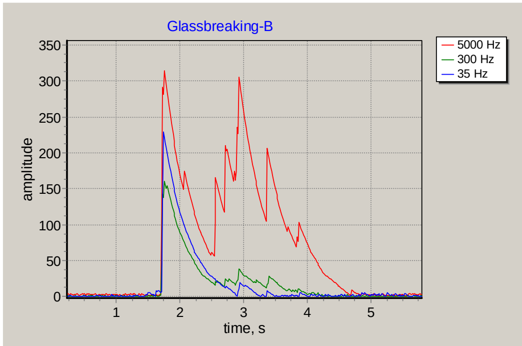

Figure 2. Filter Output (Glassbreaking-B.wav)

Another test signal response is shown in Figure 3.

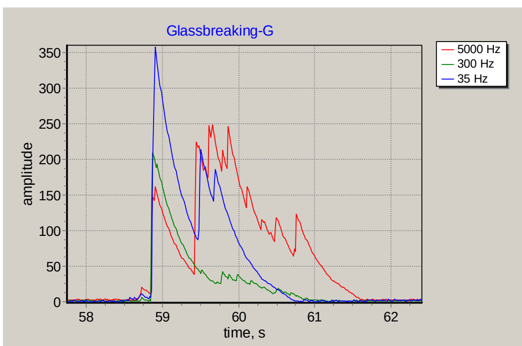

Figure 3. Filter Output (Glassbreaking-G.wav)

For comparison, output caused by a rock music signal is shown in Figure 4.

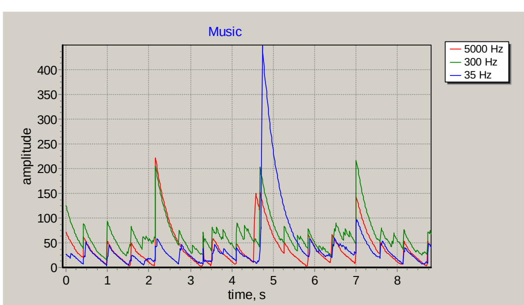

Figure 4. Filter Output (Music)

A comparative analysis of the presented waveforms allows one to make the following conclusions:

- Peculiarities in the sound of breaking glass are present in the amplitude spike for all filters' outputs and,
- Music differs from the sound of breaking glass in the amplitude of the middle-frequency filter output.

Therefore, the algorithm shown in Figure 5 may be employed to detect the sound of breaking glass.

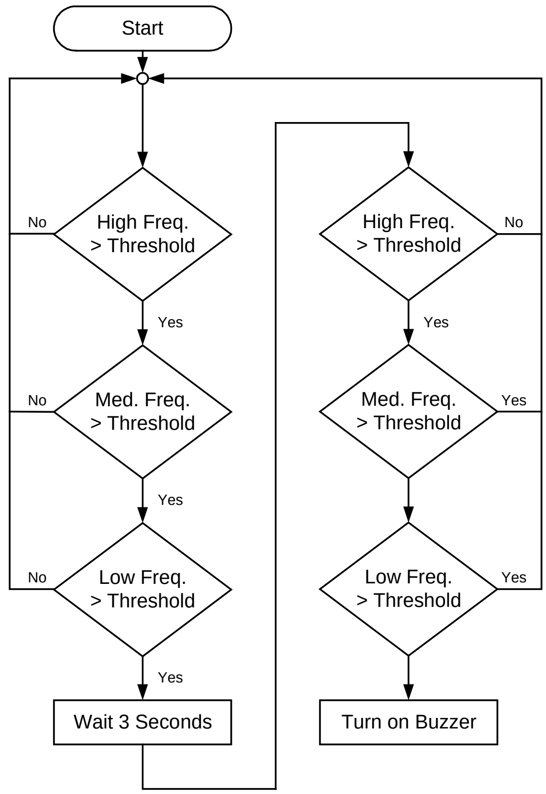

Figure 5. Sound Break Detection Algorithm

PSoC Implementation

A high-level device block diagram is shown in Figure 6.

The acoustic signal is received by the microphone and amplified by the programmable gain amplifier (PGA). The signal is digitized using an 8-bit delta-sigma analog-to-digital converter (ADC). All subsequent signal processing occurs in the software.

Such uncomplicated hardware architecture allows implementation of the simplest and least expensive 8-pin PSoC, the CY8C22xxx series. Using the more complex CY8C24xxx or CY8C27xxx PSoC family devices yields additional features such as wide range sensitivity adjustment and communication with a computer for tuning purposes.

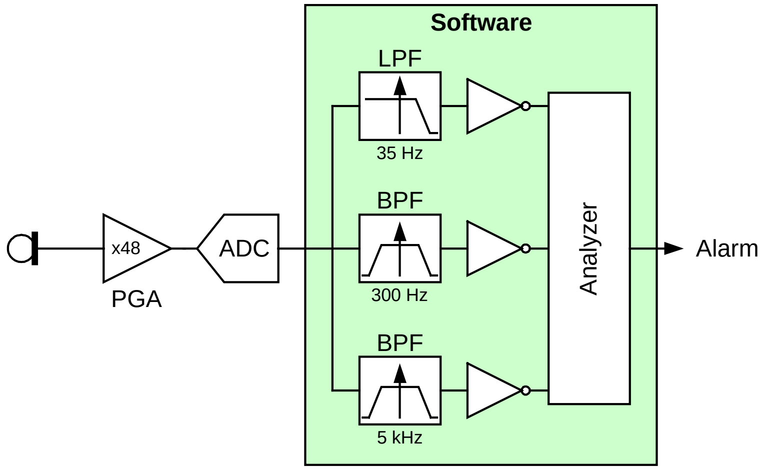

Figure 6. High-Level Device Block Diagram

Figure 7 shows user module placement for the CY8C22113 implementation.

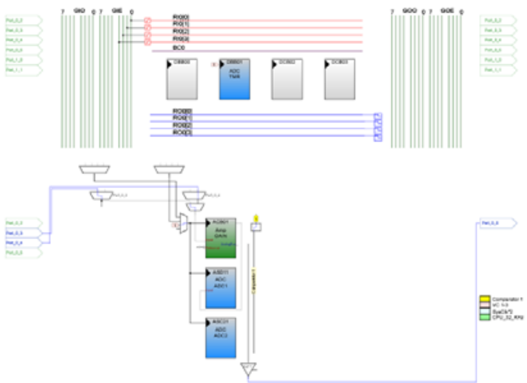

Figure 7. User Module Placement for CY8C22113

Figure 8 shows the PSoC CY8C22113 interface schematic. Pin 1 (P0[5]) is the analog ground output. The TestMux routes the analog ground signal on P0[5]. Pin 3 (P0[1]) is the open drain alarm output. P0[1] powers the LED D1 in the test circuit.

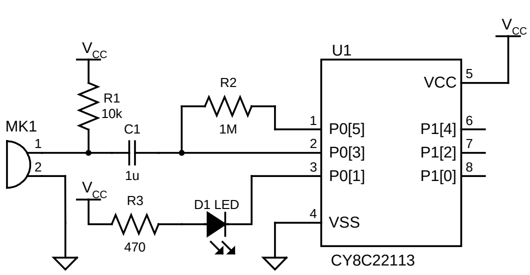

Figure 8. Interface Schematic

To perform various tests with different sounds and visualize device output on the computer, the CY8C27xxx PSoC family may be used. Three user modules are added: two PGAs and a serial transmitter, TX8. One PGA is used to extend the gain range, the other to deliver the amplified signal to a test point external to pin P0[4]. The output of TX8 is connected to P2[7] and may be passed to a computer COM port through an RS232 line driver. The user module configuration is shown in Figure 9.

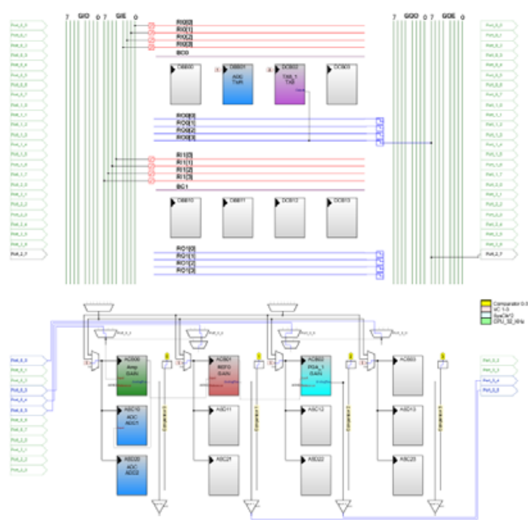

Figure 9. User Module Placement for CY8C27443

Software

The following tasks are completed in the software:

- Perform 3-channel digital filtration,
- Rectify filter outputs, emulating a peak detector,
- Compare calculated amplitudes with predefined and calculated real-time threshold levels,
- Perform timing analyses and decision making about alarm turn on.

The 5 kHz IIR band pass filter is defined by:

$$y_n = \frac{1}{4}(x_n - x_{n-2}) - \frac{3}{4}y_{n-2} \qquad \textbf{(1)}$$

y is output and x is input.

The filter described in Equation (1) has a frequency response function with a maximum of 2 at one-fourth the sampling frequency and a Q-factor of approximately 5. In our case, the ADC sample rate is chosen to be 18750 Hz, $\left(\frac{24\,MHz}{5 \cdot 256}\right)$, so the filter is tuned to a frequency or approximately 4.7 kHz.

It is important that coefficients in Equation (1) avoid multiplication and division operations. Addition and arithmetical shift operations are sufficient.

The 300 Hz BPF is also defined by Equation (1). However, it is necessary to reduce the input data sample rate. This is accomplished using another LPF and a decimator. A simple equation is used:

$$x_n = \frac{1}{16}\sum_{i=1}^{16} x_i \qquad \textbf{(2)}$$

In other words, input data to the 300 Hz BPF is an average of the 16 ADC samples.

The LPF is defined by:

$$y_n = \frac{1}{2}(x_n + 2x_{n-1} + x_{n-1}) - \frac{1}{8}y_{n-2} \qquad \textbf{(3)}$$

This filter has a cut-off frequency approximately 0.23 times the input sample rate. The gain is 1.78. Input data is measured as the average of the 128 ADC samples to achieve the 35 Hz band.

The averaged values are passed through a first order IIR high pass filter (HPF) with a cut-off frequency of approximately 0.36 Hz to generate offset canceling. This additional filter is based on Application Note AN2099 “Single-Pole IIR Filters. To Infinity And Beyond!”

Rectification is the next stage of signal treatment. A simple peak amplitude detector is simulated as shown in Figure 10.

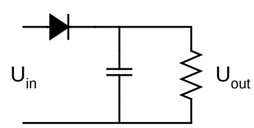

Figure 10. Simple Peak Amplitude Detector

This circuit is emulated by the following:

$$U_{out}[n] = \max\left(U_{out}[n-1]\cdot\left(1-\frac{1}{32}\right), U_{in}[n]\right) \qquad \textbf{(4)}$$

Equation (4) is equivalent to the amplitude detector with a characteristic time of 0.5s.

Rectifier outputs are compared to threshold levels. These levels are defined by the analysis in Figures 2, 3 and 4. The threshold for the 5 kHz channel is set to 150 and the other channels' threshold levels are calculated dynamically as a quarter of the current 5 kHz amplitude.

The timing analysis of filters' outputs is shown on Figure 11.

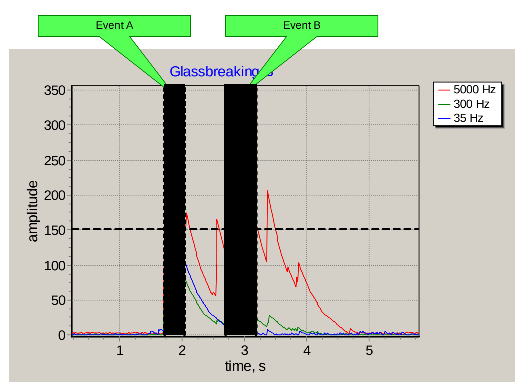

Figure 11. Timing Analysis

There are two events that must be detected to ascertain glass breakage. The first event, marked as “Event A,” is that all channel output amplitudes exceed their threshold levels.

The second event, marked as “Event B,” occurs when high frequencies are above their threshold and middle frequencies are less then their corresponding threshold values. Event A is considered valid only if its duration is less then 1s. Event B must be longer than 0.25s in duration. Timeout for all events is set to 3s.

The CY8C27xxx implementation permits that all channel output amplitudes be transmitted through the TX8 User Module to a computer’s COM port. The source code for a Borland Delphi amplitude visualization application is included with the associated project. Note that this code uses freeware components. Go to TurboPower Async Professional for details.

Broken glass test sounds are also included. It is possible to pass these sounds from a computer sound card’s linear output directly to C1 without a microphone. See Figure 8.

Conclusion

This Application Note presents a simple acoustic glass break detector design. The design demonstrates the basic principles of glass breakage sound recognition. Development of the end user devices may require additional adjustment of threshold levels and timing analysis parameters, depending on glass types, microphones used, or other parameters. Industrial glass break detector testers may be used for additional adjustments.

About the Author

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