Application Brief
MSPM0-Based Medical Alarm Design

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Introduction

Medical alarm systems are a required subsystem for most medical devices, especially those used in an intensive care unit (ICU). For patient safety, these medical devices must comply with the requirements established by the International Electrotechnical Commission (IEC). The IEC60601-1-8 standard details the necessary alarm related elements for these systems including a primary alarm, a redundantly powered backup alarm, and a visual alarm indicator. This design provides an IEC60601-1-8 medical alarm utilizing the MSPM0G150x microcontroller (MCU) to offer primary alarm, backup alarm, and visual alarm functionality. Figure 1 depicts the design block diagram.

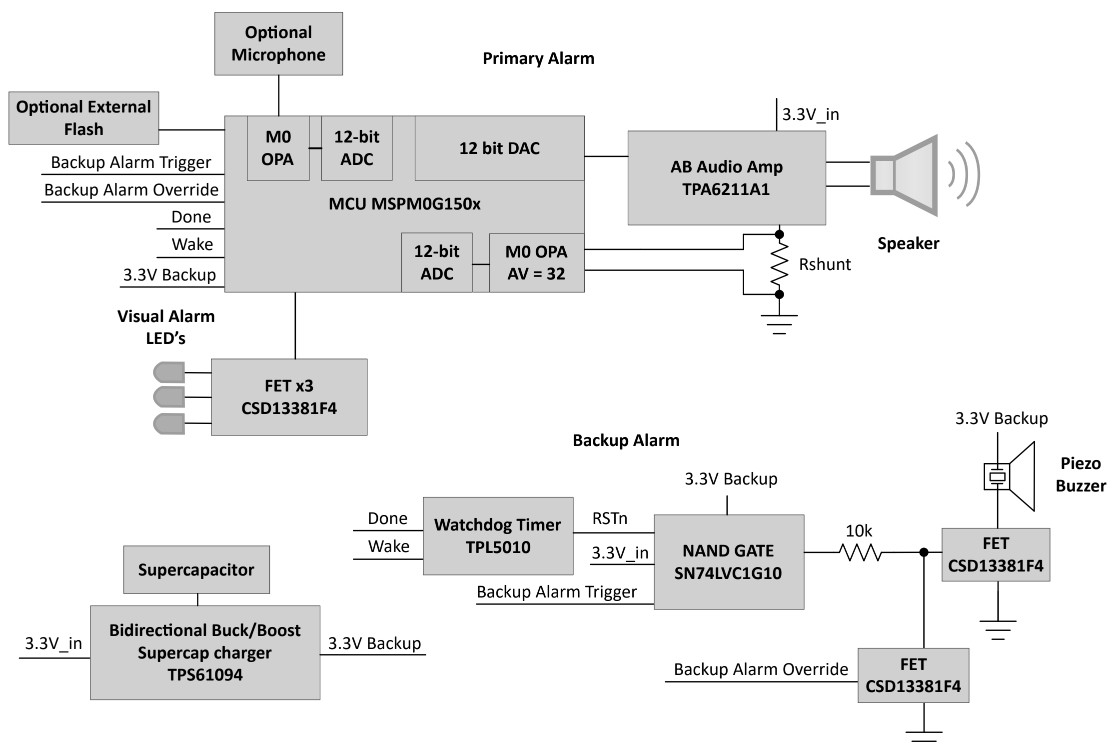

Figure 1. Design Block Diagram

Design: Key Features

- Capability to play any standard or custom alarms
- 12-bit, adjustable frequency (capable of 48kHz+) high fidelity audio.
- 128kB internal flash and external flash options.

Design: Primary Alarm

Using the 12-bit DAC, the MSPM0G150x MCU can generate fully custom medical alarm waveforms, which allows designers to use their existing unique audio alarm content or the alarm audio provided by the IEC standards committee. The integrated analog op-amps on the MSPM0 MCU allow for current measurement of the audio amplifier to detect faults and the option for ambient noise detection with a microphone. The MCU can be used in a standalone mode or can be controlled by a host processor or controller. In addition, the MCU has an integrated real time clock (RTC), which allows for timestamping, system uptime monitoring, and system event scheduling.

During normal operation an alarm or custom audio file can be triggered by the MSPM0 MCU or external host. The MCU then reads the audio sequence from internal or external flash and outputs the alarm to the integrated 12-bit DAC. The DAC output audio waveform is sent to the TPA6211A1 audio amplifier to be played by the speaker. The 12-bit DAC can output the audio waveform at selectable frequencies (for example 48kHz). If only the internal flash is used and a high frequency audio output is desired, individual tones can be extracted from the audio file. Delay spacing can be programmed into the MCU to reduce the size of the audio file. This allows for a clear high, medium, and low alarm signal to fit into the MCU's internal flash. Alternatively, the external flash option provides more storage space, allowing for a simple upload and play approach for audio files.

Design: Visual Alarm and Backup Alarm

In this design, the visual alarm is created by the MCU's general purpose input/output (GPIO) pins toggling the visual alarm LED's. The backup alarm is accomplished by using a supercapacitor with the associated TPS61094 supercapacitor charger, an optional TPL5010 external watchdog timer (to detect MCU failure), and a SN74LVC1G10 NAND gate to trigger the piezo alarm if an MCU or power failure mode occurs. During this state, the low power MSPM0 MCU is able to control the system and terminate the backup alarm from user input or after the required three minute timeframe.

Test Results: Primary Alarm

The DAC output waveform for the high alarm state is shown in Figure 2. Key waveform characteristics including the fundamental frequency, rise time, fall time, pulse spacing, and more were measured internally to meet the IEC60601-1-8 requirements.

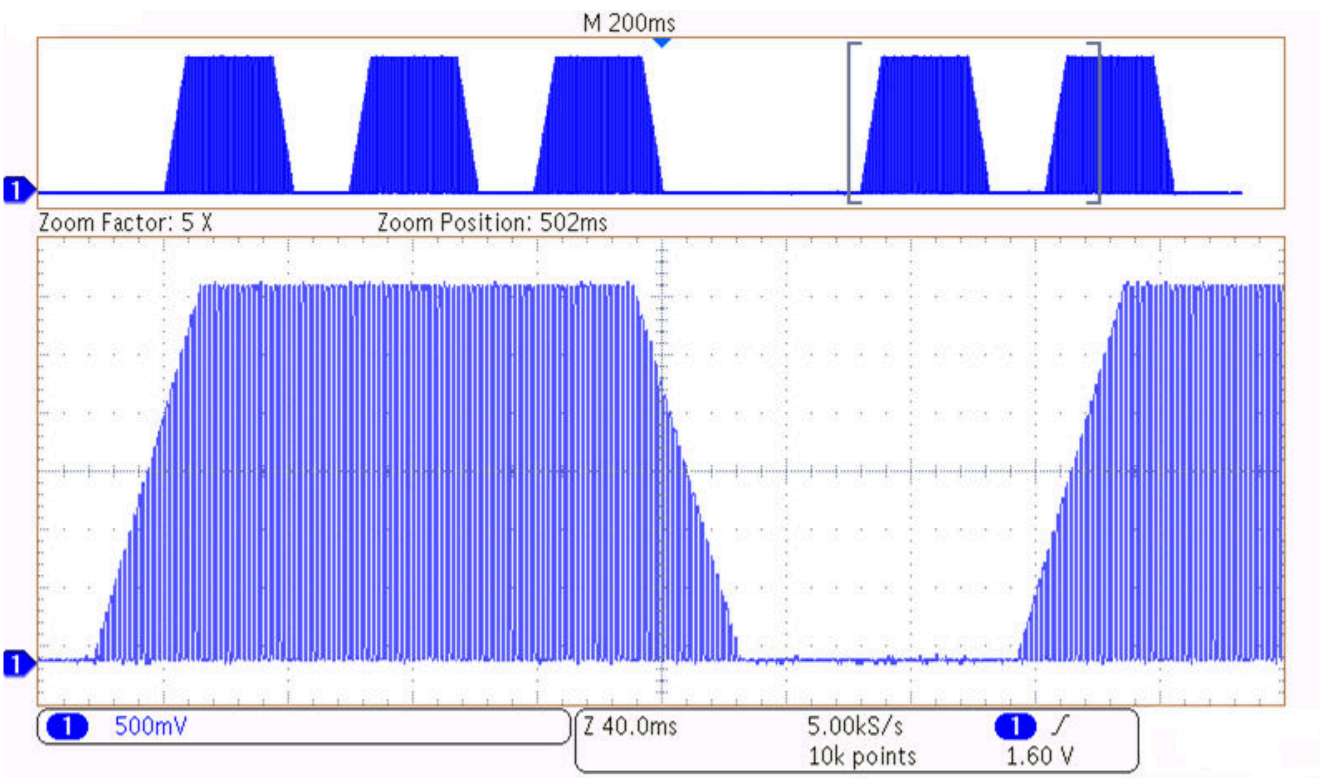

Figure 2. High Alarm State Waveform

Test Results: Coincidence detection

The coincidence detection circuit was also tested by measuring the MSPM0G150x internal op-amp output. The pulses shown in Figure 3 show the high alarm state waveform through the measurement of the TPA6211A1 current consumption. If the speaker is faulty (for example, disconnected), the current waveform dramatically reduces. The waveform itself can also be analyzed by the MCU to detect if the proper audio waveform is being played. For additional feedback from the environment (such as ambient noise or acoustic feedback from the primary alarm), a microphone can be added as an input to the MCU.

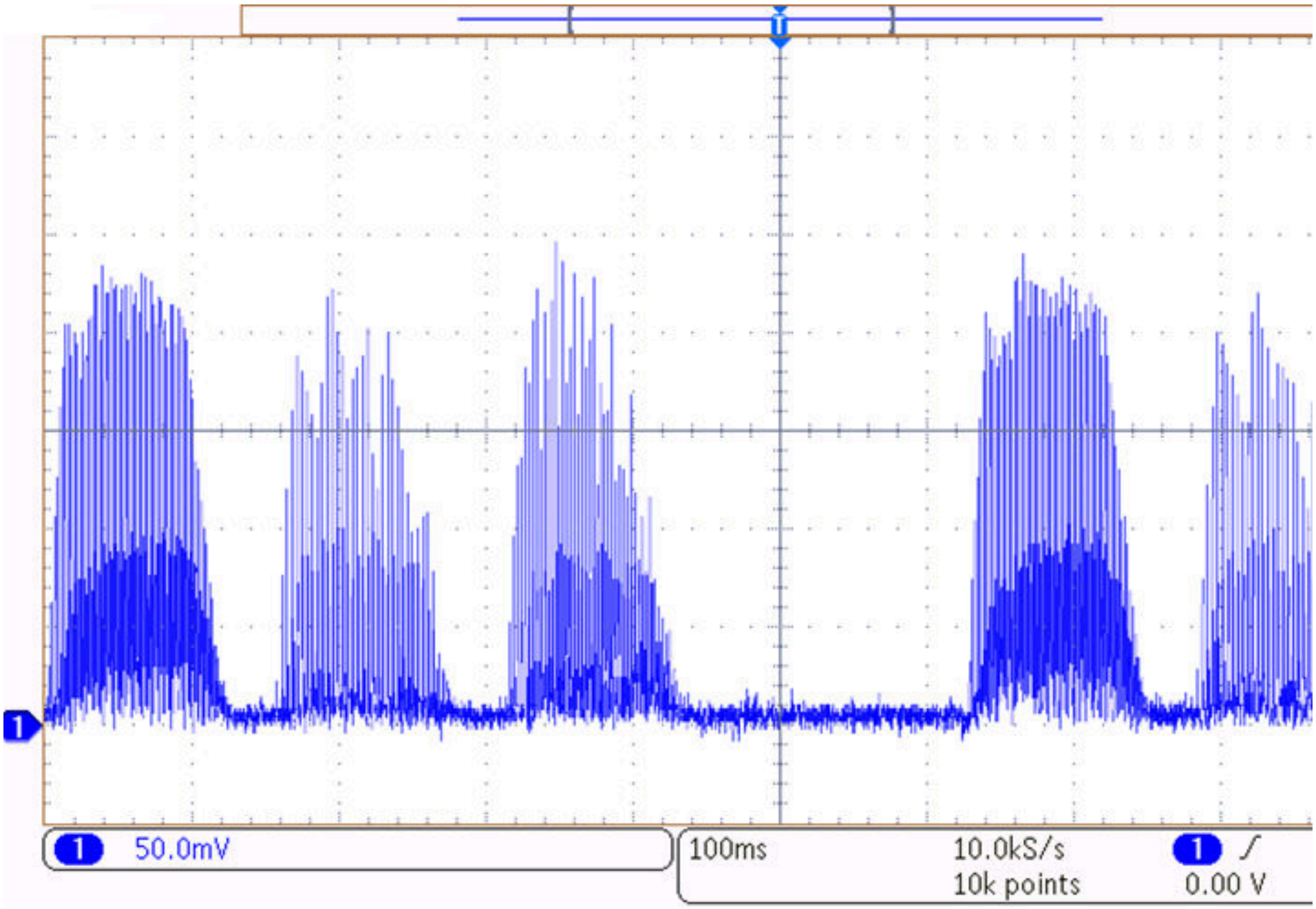

Figure 3. Coincidence Detection Waveform

Test Results: Primary Alarm Compliance Testing

To meet the IEC6060-1-8 requirements, the primary medical alarm must follow specific harmonic requirements. Specifically, at least 4 harmonics need to be +/- 15 dB from the amplitude of the fundamental frequency. These harmonics allow for enhanced spacial localization of the alarm sound. Figure 4 shows an example of measured harmonic content for the high alarm state. The figure shows that six harmonics are measured within the required range for this high alarm state test.

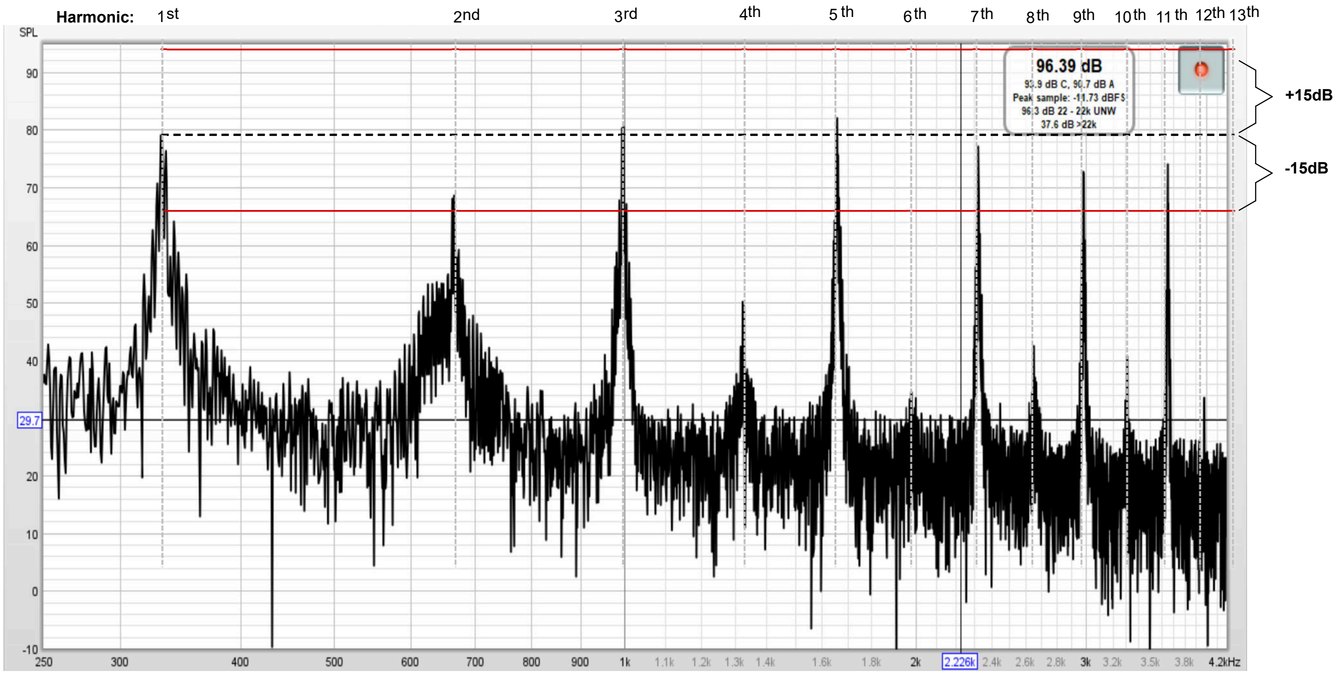

Figure 4. Harmonic Test High Alarm State

Conclusion

The design presented provides a full MCU based implementation of a medical alarm system including the primary alarm, backup alarm, and visual alarm. Features such as high fidelity custom alarms, alarm fault detection, and super capacitor backup functionality make this design compelling for medical alarm systems.

References

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