Application Brief

Hardware-Based Smart DAC Medical Alarm Design

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Introduction

This application brief details an IEC60601-1-8 medical alarm design using the 10-bit, DAC53701 smart digital-to-analog converter (DAC), and shares primary alarm compliance testing data. The proposed design provides all the required components for a medical alarm subsystem and implements key features such as the primary alarm, visual alarm, and backup alarm (supplied by a supercapacitor). Figure 1 shows the IEC standard requirements that the design incorporates and the additional features implemented. The prototype board shown in Figure 1 stacks onto an MSP430 launchpad, allowing for the MSP430 microcontroller (MCU) to demonstrate control of the primary medical alarm.

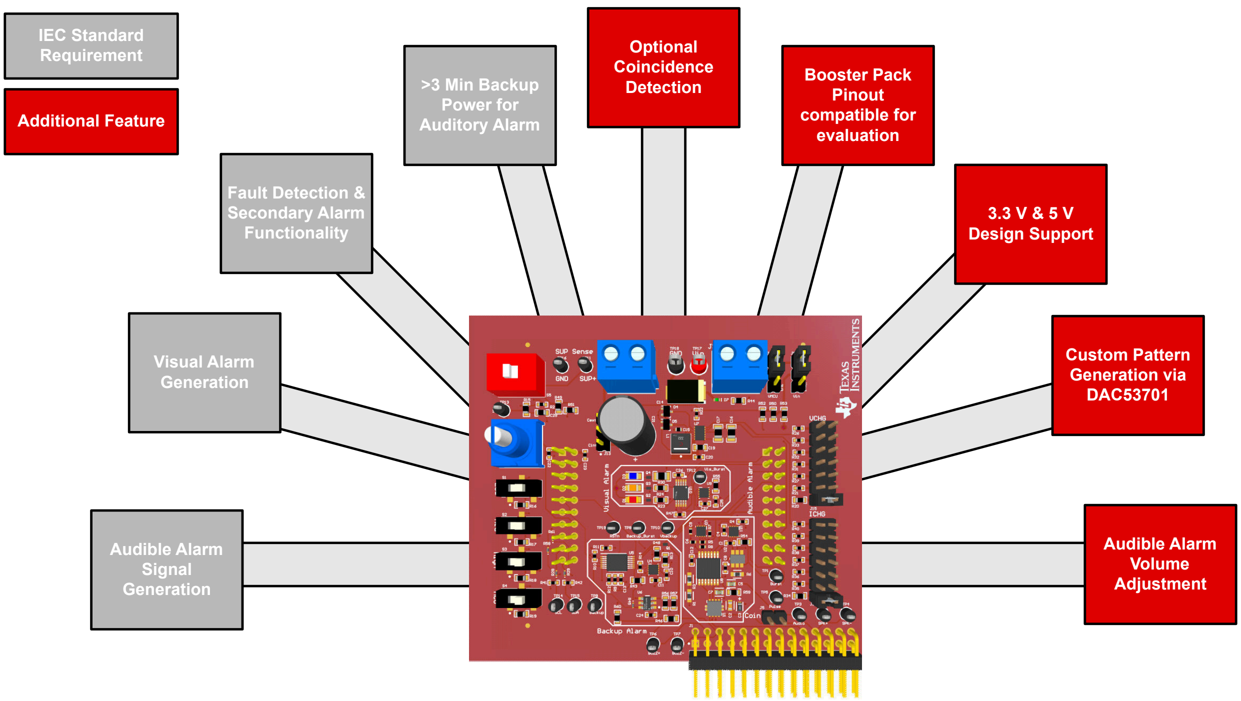

Figure 1. Medical Alarm Design using DAC53701 Smart DAC

Design

Figure 2 shows the block diagram for this design. The MCU triggers the primary alarm high, medium, or low state. The audio waveform is then generated by the DAC53701 devices, along with the buffering op-amp (OPA363). DAC 1 is used to create the alarm envelope and burst, while DAC 2 is used to create a waveform of the desired pulse frequency. The enable pin of the op-amp is repeatedly toggled on and off by the pulsed output of DAC 2. The input to this buffering op-amp is the DAC 1 envelope and burst. As the DAC 1 output passes through the op-amp, the DAC 2 toggling enable operation overlays the proper audio frequency. A digital potentiometer (digipot) is then used to scale the audio signal for volume control. Finally, the audio signal is sent to the audio amplifier to play on the speaker. For example, Figure 3 shows the high alarm state audio signal waveform.

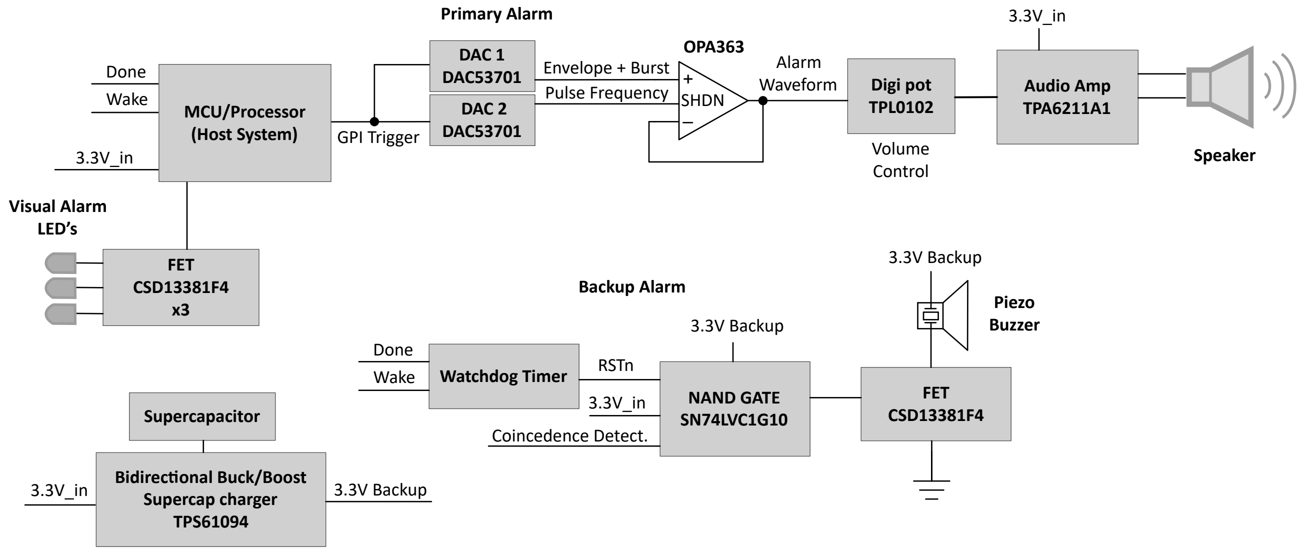

Figure 2. Block Diagram

Note that the DAC53701 is capable of producing the primary medical alarm even when the MCU is powered down or not present. The IEC compliant medical alarm tones are stored in the DAC53701's nonvolatile memory. The general purpose input (GPI) pin on the DAC53701 can be used to trigger the alarm without requiring an MCU.

Another important aspect of an alarm system is the backup alarm. This alarm is typically a buzzer that is powered by a supercapacitor or battery backup. The backup alarm is triggered by a variety of cases. The first case is when the MCU or processor stops responding. In this case the watchdog timer triggers the alarm. The second case is when there is a loss of power, leading to the backup alarm being powered from the supercapacitor backup circuit. The third case is when an external coincidence detection circuit monitoring for primary alarm speaker faults triggers the alarm. If any of these conditions are met, the NAND gate output engages the backup alarm. The alarm continues to play for more than 3 minutes, or until the alarm is disabled.

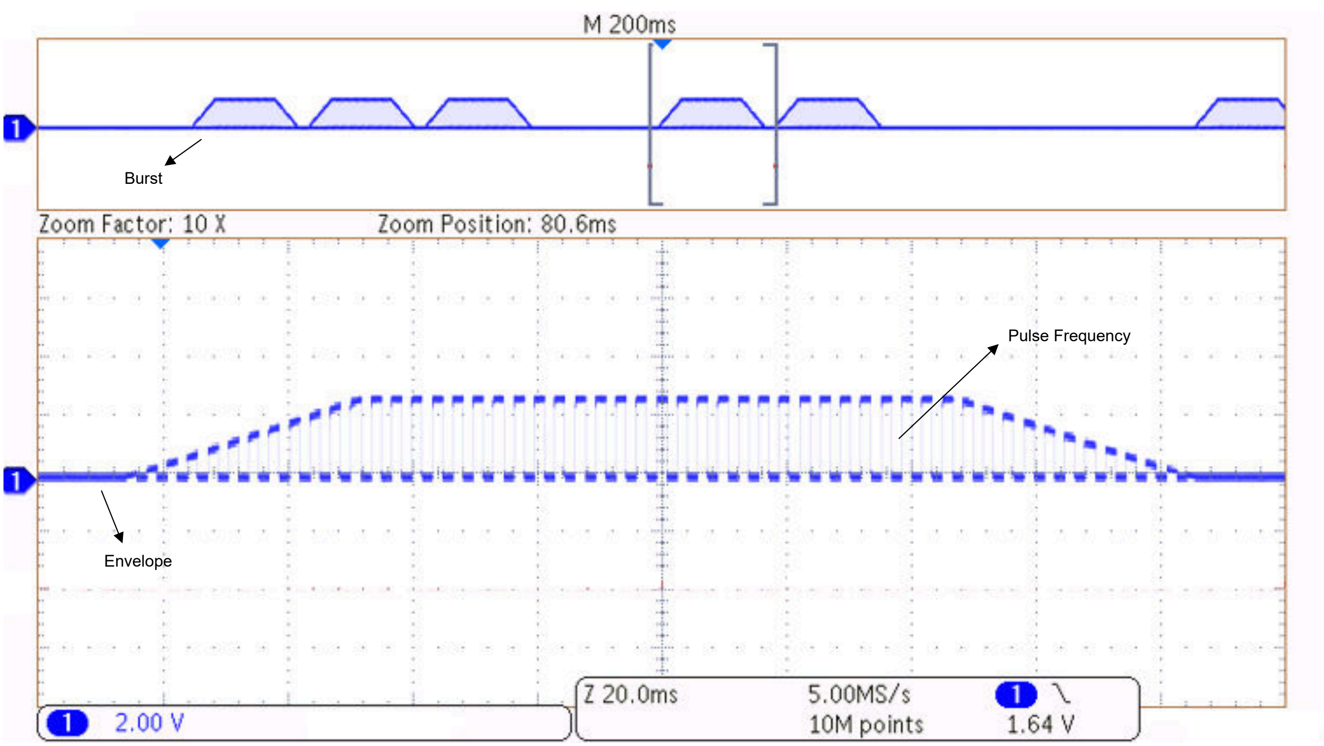

Figure 3. High Alarm State Waveform

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 must be ±15 dB from the amplitude of the fundamental frequency. These harmonics allow for enhanced spacial localization of the alarm sound. Following the IEC testing requirements this design was internally tested to meet these harmonic requirements using a variety of speakers and microphone measurement locations. Figure 4 shows an example of measured harmonic content for the high alarm state. More than 6 harmonics are measured within the required range for this high alarm state test.

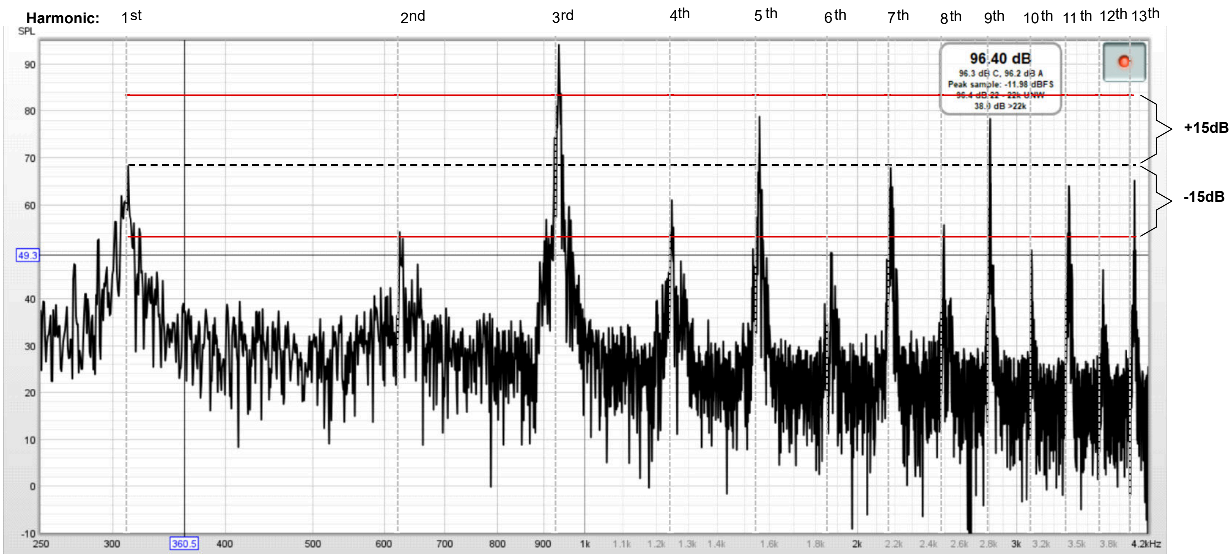

Figure 4. Harmonic Test High Alarm State

Conclusion

The design presented provides a full hardware based implementation of a medical alarm system including the primary alarm, backup alarm, and visual alarm. Features including a software free implementation and supercapacitor backup functionality make this design compelling for medical alarm systems.

References

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2. Texas Instruments, *Demystifying medical alarm design, part 2: Design inputs and existing techniques*, blog.
3. Texas Instruments, *Demystifying Medical Alarm Designs With Smart DACs*, application brief.
4. Texas Instruments, *MSPM0-Based Medical Alarm Design*, application brief.
5. Texas Instruments, *DACx3701 10-Bit and 8-Bit, Voltage-Output Smart DACs With Nonvolatile Memory and PMBus™ Compatible I2C Interface With GPI Control*, data sheet.
6. Texas Instruments, *TPS61094 60-nA Quiescent Current Boost Converter with Supercap Management*, data sheet.
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