Application Report

SLOA273–May 2019

Medical Alarm Generator-an Economy Hardware Scheme

Sanjay Dixit

ABSTRACT

A hardware described below as outlined in the IEC 60601-1-8 standard enables the generation of audio alarm tones for medical alarm systems.

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Trademarks

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1 Introduction

Medical equipment such as patient monitors are typically provided with built-in alarms that get activated when measured patient parameters reach a critical value. The alarm alerts the healthcare professional who can then take the necessary action.

Currently, most solutions use an audio codec or are microcontroller based. There is, however, space for a robust hardware solution that provides an alarm independent of software.

A hardware circuit like the one described below and as outlined in the IEC 60601-1-8 standard enables the generation of audio alarm tones for medical alarm systems. These medical alarms, when designed in conjunction with a fully IEC 60601-1 compliant medical application, can be used in medical patient monitoring as well as electrocardiogram (ECG) systems.

The IEC 60601-1-8 Standard describes the waveforms that constitute medical alarms. For more information, see Section 2.

The standard describes tones as groups of pulses, each pulse containing multiple cycles of the frequency. Figure 1 shows the characteristic of each pulse. Each pulse has a certain rise time(t_r), width (t_d) and fall time (t_f). A spacing (t_s) exists between any two pulses. A group of pulses forms a burst. The time between two bursts is (t_b).

2 Timing

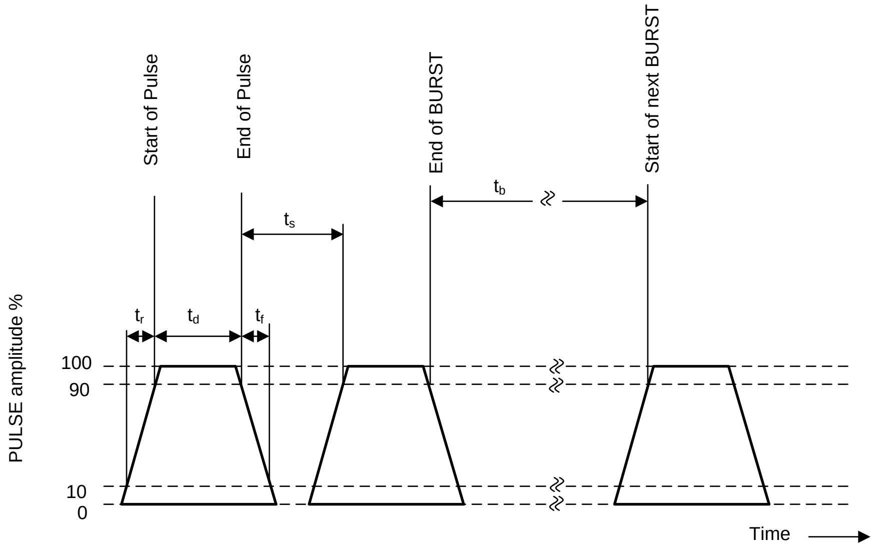

Figure 1. Burst Waveforms

A typical alarm has two burst of two pulses like 'Beep—Beep' ------------ 'Beep-Beep.' Each pulse is made of many cycles of a pulse frequency (F_p). The timing requirements of the wavforms per the IEC standard are listed in Table 1.

Table 1. Characteristics of the PULSE of Auditory Alarm Signals

Characteristic	Value
Pulse frequency (Fo)	150 Hz to 1000 Hz
Number of harmonic in the range 300 Hz to 4000 Hz	4
Pulse duration (td) Medium to low High	125 ms - 250 ms 75 ms to 200 ms
Rise time (tr)	10% td

[Figure 2](#) shows the three kinds of priority alarm signals.

- High: 10 pulses, which is two groups of five pulses separated by a time from 0.35 s – 1.3 s.
- Medium: 3
- Low: 2

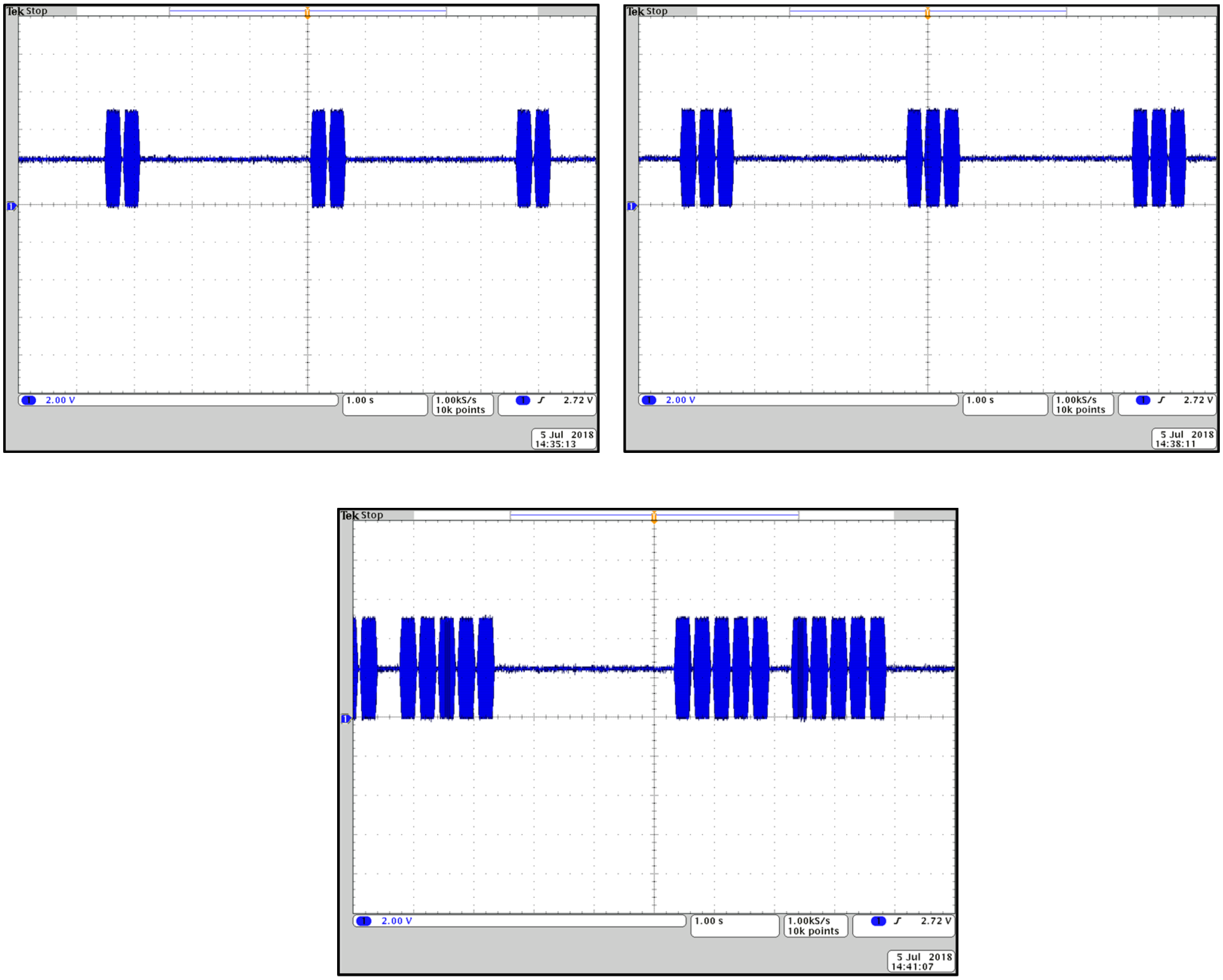

Figure 2. Three Types of Priority Alarm Signals

Table 2 describes the timing characteristics of the burst.

Table 2. Characteristics of the Burst of Auditory Alarm Signals

	High Priority	Medium	Low
1 & 2	x	y	y
2 & 3	x	y	
3 & 4	2x + t		
4 & 5	x		
5 & 6	0.35 s ti 1.30 s		
5 & 7	x		
7 & 8	x		
8 & 9	2x + t		
9 & 10	x		
Interburst	2.5 s to 15 s	2.5 s to 30.0 s	> 15 s
X=50 ms - 125 ms			
T = td			
Y = 125 ms - 250 ms			

3 Circuit Explanation

3.1 Circuit Description

The circuit has three control signals: LOW, MED, and HIGH. Connecting +5 V to any of the three signals activates any one of the three priority modes: high, medium and low. For more information, see Figure 5.

U2A is a Schmitt oscillator circuit, which is used to make the pulses. The high time is programmed by R2*C1 and the low time is programmed by R3*C1.

It is required to count 2, 3 or 5 of these pulses based on the selected mode. For this purpose a 74HCT4017 Johnson Counter U1 is used. This IC has a clock input and outputs from Q0-Q9. On the first clock, Q0 goes high. On the second clock, Q1 goes high and so on. An analog multiplexer U5 selects one of Q3, Q4 or Q6 and routes it to point x.

For example, if low is selected, Q3 is connected to point X. When power is applied, the oscillator starts routing clocks to the counter. After the third clock, Q3 on the counter goes high. This signal is routed through mulltiplexer U5, which activates transistor Q1. The action blocks any other clock pulses going into the counter. Three clocks have arrived at the input of the counter and, after that, the clocks have stopped. The first of the clocks is blocked by transistor Q2. U2B output has two clocks.

In a similar manner, if the control signal MED is asserted to 5 V, the U2B output has three clocks. If the control signal HIGH is selected, the U2B output has five clocks.

There is a delay circuit corresponding to D10, R4 and C2. After a delay corresponding to the R4*C2, the reset pin of U1 goes high. This resets all of the outputs of the counter to zero. Then, the counting starts again, which creates time t_b in Figure 1.

The high priority alarm signal discussed in Section 3 is comprised of 10 pulses, or two sets of 5 pulses. Between the fifth and sixth pulse, there is a time delay from 0.35 s - 1.3 s. This is done by means of a toggle flip flop made with U6A. The flip flop is activated by signal x, which is asserted each time the required pulse count happens. The output of the flip flop goes high every second time x asserts. This is used to connect resistor R5 across resistor R4, which determines the time delay. The action of this is to make a short time delay after 5 pulses and a long time delay after 10 pulses. Diode D9 blocks this action for the LOW and MED modes.

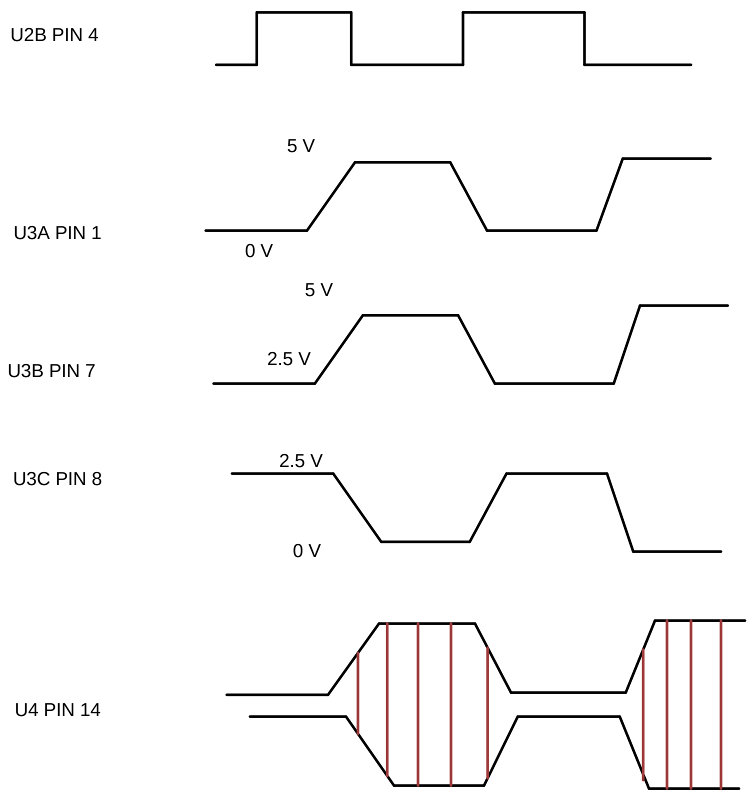

Figure 3. Tone Generation

Figure 4 shows the lower time delay after 10 pulses and the lower time delay after five pulses.

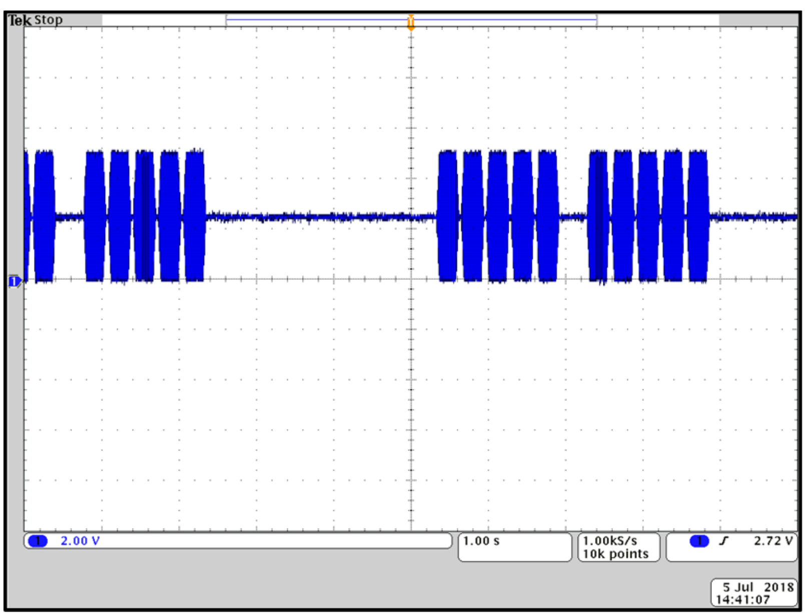

Figure 4. Lower Time Delay

The square wave at U2B pin 4 is passed through an integrator formed by U3A. This shapes the rising and falling edges of the waveform to create the waveform at U3A pin 1 shown in Figure 3. R12 and R11 level shift this waveform by 2.5 V creating waveform at U3B pin 7 at pin 6. U3C forms a unity gain differential amplifier and creates an inverted form of the waveform on the U3C pin 8 shown in Figure 5.

R12 and R11 level shift this waveform by 2.5 v creating a waveform at U3B pin 7. U3C forms a unity gain differential amplifier and creates an inverted form of the waveform on U3C Pin 8 as shown in Figure 3. The circuit around U2C forms a Schmitt oscillator circuit that generates a tone frequency. This is used to drive the analog multiplexer U4 in order to switch either U3B pin 7 or U3C Pin 8 to the output. The output of the multiplexer at U4 pin 14 is an amplitude modulated waveform.

The circuit around U2C forms a Schmitt oscillator circuit that generates a tone frequency. This is used to drive analog multiplexer U4 in order to switch either U3B pin 7 or U3C pin 8 to the output. The output of the multiplexer at U4 pin 14 is a amplitude modulated waveform as shown in Figure 3.

The signal at the output of the multiplexer is driven into a Class D audio amplifier TPA2005DI that can be used to drive an 8Ω speaker. This produces a medical tone.

An additional control signal SD can be used to shut down the system to stop producing any sound.

In some cases, the designer of the Medical Alarm may want to detect if the speaker attached to the circuit is actually producing the Desired Alarm tone. For the detailed description of a Coincidence detector circuit that can be used for this purpose, see the *Alarm Tone Generator Reference Design*.

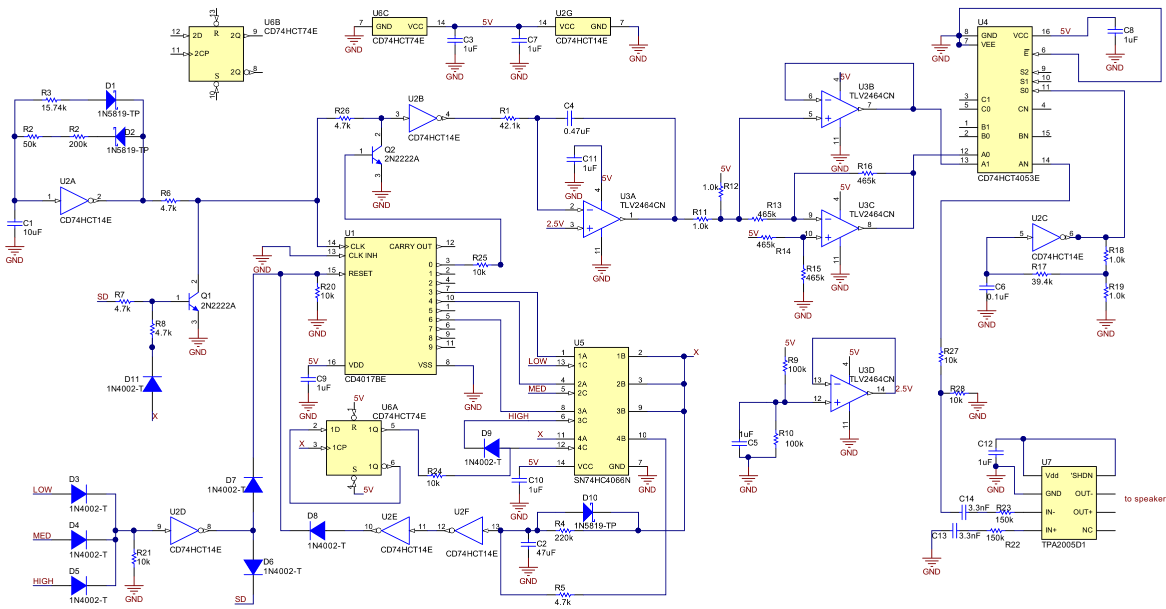

Figure 5. Schematic Medical Alarm

3.1.1 Typical Waveform for Medium Priority Alarm

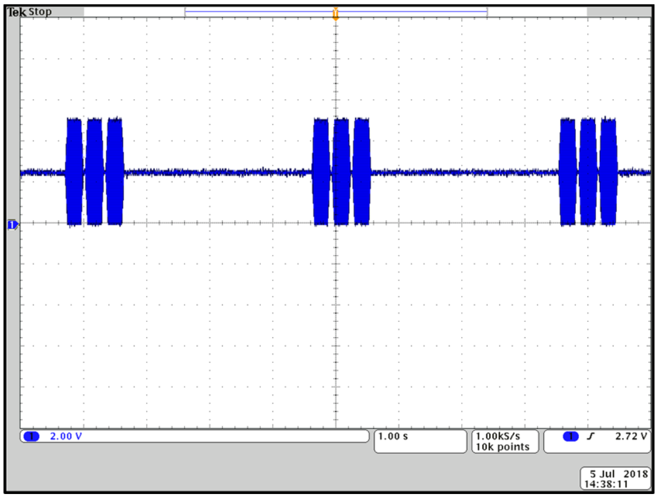

Figure 6. Three Bursts

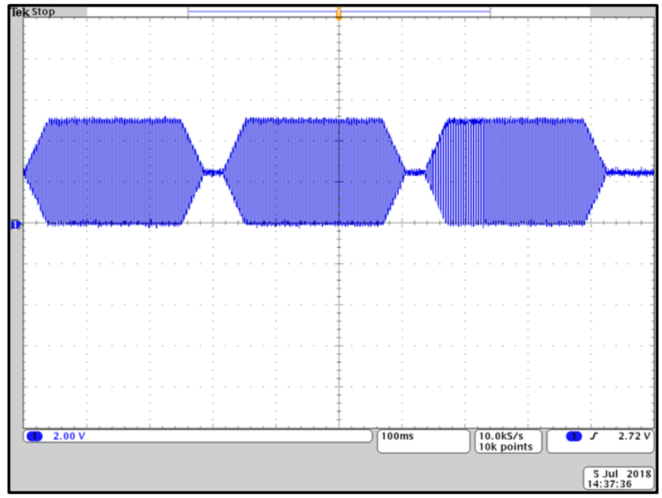

Figure 7. Zoomed in Single Burst

4 Summary

The circuit described above can be directly interfaced with a patient monitoring application to create alarms of high, medium and low priority.

5 References

- *Alarm Tone Generator Reference Design*