# EGB240 Electronic Design

## Assessment 1: PCB Alarm Circuit Design Portfolio

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### Executive Summary

This portfolio documents the design for a 2 Tone Alarm circuit, implemented on a printed circuit board (PCB). The design is constructed to the following specifications:

- Supplied from two AA batteries (nominal 3 V supply)
- Activated by slide switch (on-off)
- 2 kHz and 1 KHz tone with 1.45 Hz switching frequency (42% duty cycle)
- Total supply current is 24 mA
- PCB size is 71.12 X 44.27.
- LED and POT/Trimmer used as addons.

The alarm is constructed on a single sided PCB, to minimize cost, using through-hole componentry. The design uses exclusively Motorola 8-channel Analog Mux to maximize reliability, operating speed, performance, of the circuit in addition to simplifying error debugging process and the prototype designing phase.

### Contents

## 1. Circuit schematic

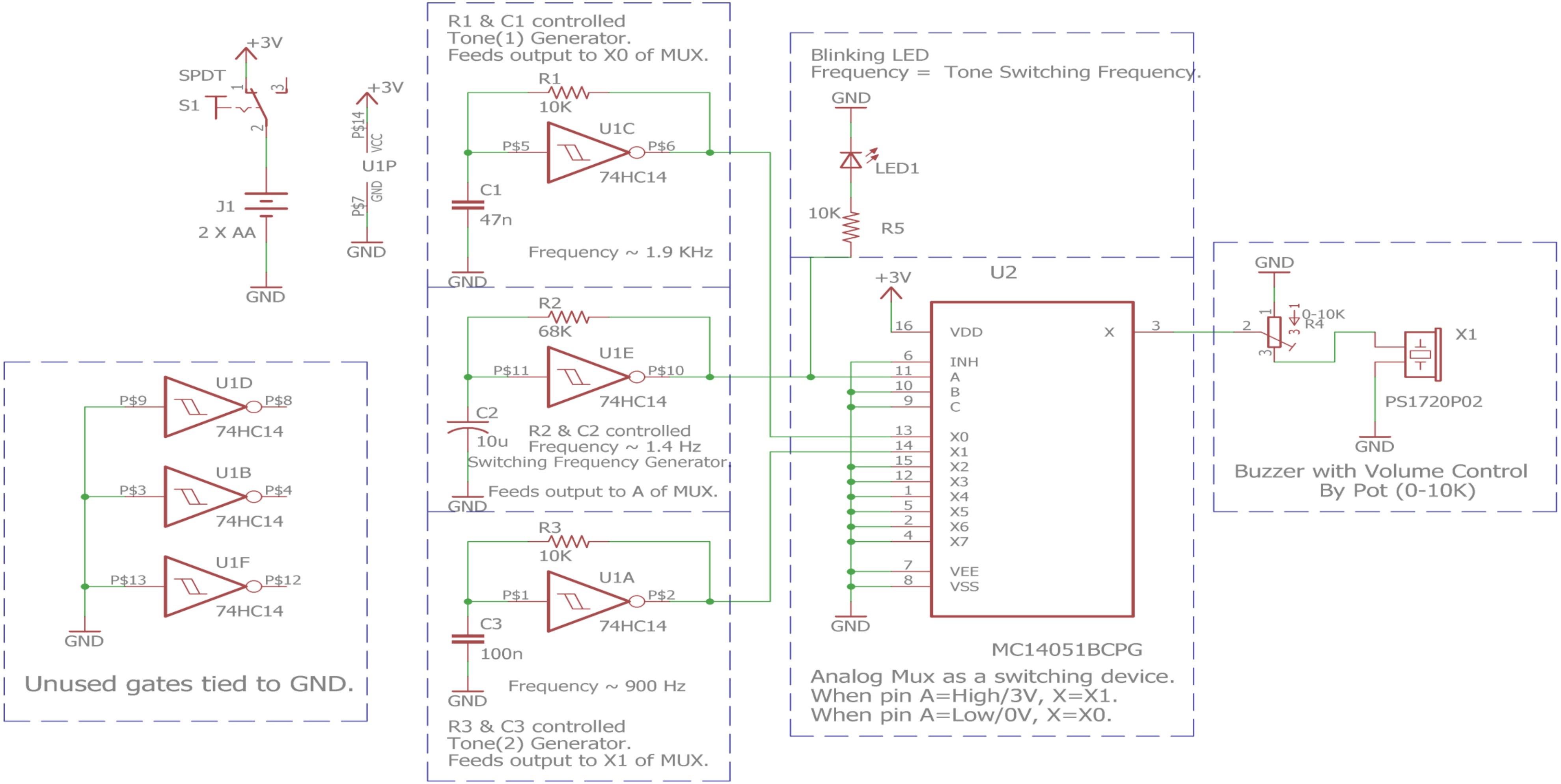



*Figure 1 – PCB alarm circuit schematic. Corresponds to PCB layout documented in Figure 2.*

## 2. Summary of design and operation

*My design of the 2 Tone Alarm Circuit, includes the use of three Schmitt Inverting Triggers, of the IC type 74HC14, a 8-channel Analog Multiplexer, of the IC type MC14051B, 3 resistor-capacitor pairs, a resistor-LED pair, a SPDT Switch and a POT / Trimmer-Buzzer pair.*

*The two tones are generated by two of the three Schmitt Triggers, in alliance with 2 of the 3 resistor-capacitor pairs. The choice of the resistor-capacitor pairs, produces two tones with 1.9KHz and 900Hz frequencies, which run parallel to the following design intent.*

***Tone Frequency Design Intent*** *– The peizo buzzer used in this design has the largest sound pressure or emits an audible sound of its maximum capacity, at around 2.6 KHz. But my design required me to generate a lower frequency sound of an optimal sound pressure / loudness. Surveys have proven that a loud alarm plays a massive role in acting as a catalyst to the panic amongst people engaged in tackling an emergency situation. The intent in the design of this prototype was to cut back on the volume, and to widen its reach as a unit of distance. Pruning the frequencies made this sound plausible. But on cutting down the frequencies to 439Hz and 892Hz respectively, experiments substantiated the successful increase in its reach but, the loudness was not favourable. Instead, picking frequencies around 1KHz and the nominal frequency of the buzzer, 2KHz, the buzzer manifested tones that were optimally loud and possessed a greater reach capacity, and hence made an obvious choice for my design.*

***Switching Frequency Design Intent*** *- Time period between 0.6s and 0.75s was preferred for the switching between the two tones. Selecting a resistor – capacitor pair of 68K and 10uF respectively, produces an average frequency of around 1.45Hz, ie, with a time period of 0.68s. Hence, the above value pair proved to be an instant pick.*

***Optional Component Addons*** *– Components like SPDT switch, LED and POT/Trimmer, act as an adjunct to the overall design. The LED with a resistor in series blinks in sync with the buzzer and has a frequency equal to that of the switching frequency generator (refer Fig. 1). The POT/Trimmer in series with the buzzer, regulates the current passing through the buzzer and acts as a buzzer volume control device. The loudness of the buzzer is now inversely proportional to the value of the resistance provided by the POT/Trimmer.*

### *Design Intent behind the use of a Multiplexer –*

*In analog circuit design, a multiplexer is a special type of analog switch that connects one signal selected from several inputs to a single output. The design makes use of a 8-channel analog multiplexer that acts as a digitally controlled analog switch. The particular model used in this design, is the MC14051B by Motorola, effectively implements an SP8T solid state switch.*

*In this design, the MUX assists the output load / buzzer in switching between the two tones, with a frequency equal to as that of the Switching Frequency Generator (refer Fig. 1).*

*It features a low ON impedance and very low OFF leakage current, thus a greater operating speed and performance. Other salient features of MC14051B are - Triple Diode Protection on Control Inputs, Switch Function is Break Before Make, Linearized Transfer Characteristics and Negligible / Low–noise. For more technical info, please refer to the following datasheet - [http://pdf.datasheetcatalog.com/datasheet/motorola/MC14053BCP.pdf](http://pdf.datasheetcatalog.com/datasheet/motorola/MC14053BCP.pdf)*

*Advantages over conventional techniques are that variable bandwidth is possible. General advantages include greater ability to operate at extreme values of temperature, encapsulation with a silicon oxide layer during manufacture which renders the layer as tough and resistant and thus giving the ability to operate at extremes of temperatures and other extreme environmental conditions, and also the elimination of soldered joints and need for fewer interconnections., thus more reliable.*

*Its use in the circuit erases off the reliability issue faced while implementing conventional components. These devices are specifically designed to handle faults caused by power-off conditions. When the power supplies are lost (through, for example, battery disconnection or power failure) or momentarily disconnected (rack system, for example), the current is limited to subnanoampere levels. Overvoltage conditions may occur due to systems with poorly designed power-supply sequencing or where hot-plug insertion is a requirement. Significant damage may result from these fault conditions, possibly rendering diodes malfunctioned. Moto MUX comes with an integrated protection, allowing me to eliminate external protection circuitry, reducing the number and cost of components in board designs. Savings are even more significant in applications with high channel count. Ultimately, using Moto MUX as switches with fault protection, overvoltage protection, immunity to latch-up, and a high ESD rating yields a robust product that meets industry regulations and enhances customer and end-user satisfaction.*

*Apart from all the technical justifications, there exists a **non-technical point of view** as well. Imagine QUT to be a miniature model of the world. Being involved in the world of business for a couple of years now, I can attest to the fact that investors, especially venture capitalists, look for an aspect that you own and that they can leverage in the competition market. And that aspect or an ingredient is the key component of the design which renders it unique and differentiable from all others and worthy enough to fetch itself a design patent. The patent will increase the chance of bagging an investment by a huge margin.*

## 3. PCB Layout

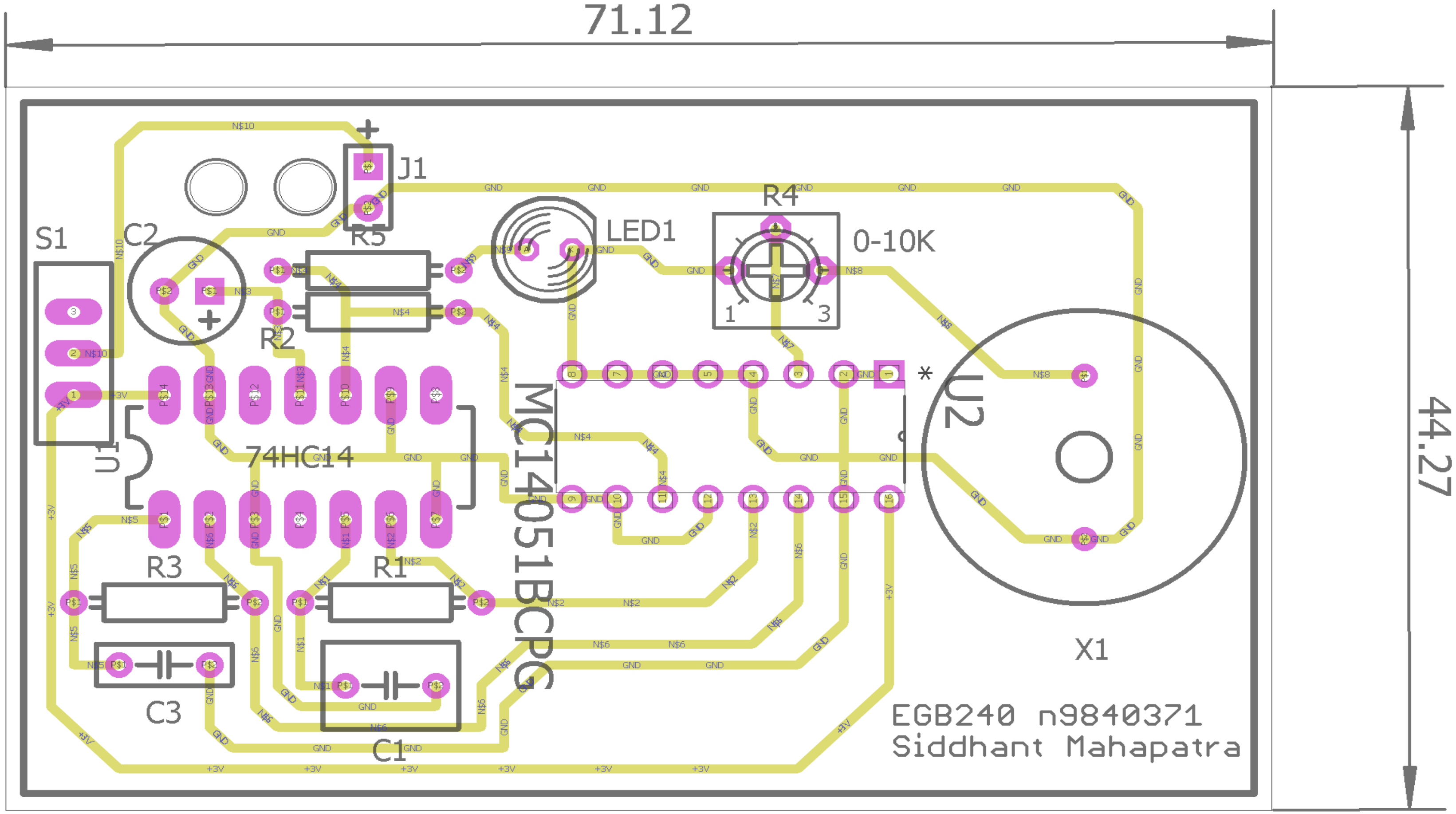



*Figure 2* –PCB layout of alarm circuit (component side-view) showing overall board dimensions.

## 4. Bill of materials

| Designator | Value | Description | Quantity | Footprint |
|---|---|---|---|---|
| *LED1* | | LED 5MM , Round | 1 | LED5MM |
| *R4* | 0-10K | Potentiometer 3362P Series, Range 0-10K, 1/4" Square Trimmer | 1 | 3362P |
| *C3* | 100n | Capacitor, Radial, Non-polarised, 5.0mm pitch, 7.5X2.5, MKT | 1 | CAP-MKT-7.5X2.5-P5.08 |
| *R1, R3, R5* | 10K | Resistor, Axial Horizontal, 0.25W, 0.4" pitch, 0.6mm lead diameter | 3 | AXIAL-P10.16 |
| *C2* | 10u | Capacitor, Radial, Polarised, 2.5mm pitch, 6.3mm diameter | 1 | CAP-RB-P2.54-D6.3 |
| *J1* | 2 X AA | Battery holder, 3V, 2xAA, flying leads,with strain relief holes | 1 | BATT-3V-SR |
| *C1* | 47n | Capacitor, Radial, Non-polarised , 7.5x5.0mm, 5.0mm pitch, MKT | 1 | CAP-MKT-7.5X5.0-P5.08 |
| *R2* | 68K | Resistor, Axial, 0.25W | 1 | AXIAL-P10.16 |
| *U1* | 74HC14 | Hex schmitt trigger INVERTER, DIP-14, IC | 1 | DIP-14 |
| *U1* | | IC socket, DIP-14 | 1 | |
| *U2* | | IC socket, DIP-16 | 1 | |
| *U2* | MC14051BCP | Analog Multiplexer - digitally–controlled analog switch, DIP-16, IC | 1 | DIP254P762X444-16 |
| *X1* | PS1720P02 | Piezoelectonic buzzer, 10mm pitch, 17mm OD, TDK PS1720P02 | 1 | PS1720P02 |
| *S1* | SPDT | Switch, SPDT, Slide, On-On, 0.1" pitch | 1 | SS-12 |

| Designator | Manufacturer | MPN | Supplier | SKU | MOQ | Price |
|---|---|---|---|---|---|---|
| *LED1* | Generic | LED 5MM , Round | Jaycar | ZD0150 | 1 | $0.30 |
| *R4* | Bourns | 3362P-1-103LF | Digikey | 3362P-103LF-ND | 1 | $1.02 |
| *C3* | Generic | Capacitor, Radial, Non-polarised, 5.0mm pitch, 7.5X2.5, MKT | Jaycar | RM7125 | 1 | $0.40 |
| *R1, R3, R5* | Multicomp | MCF 0.25W 10K | Element14 | 9339060 | 50 | $0.11 |
| *C2* | Generic | Capacitor, Radial, Polarised, 2.5mm pitch, 6.3mm diameter | WS (Ebay) | 489 446 207 3490 | 10 | $0.10 |
| *J1* | Generic | Battery holder, 3V, 2xAA, flying leads,with strain relief holes | Jaycar | PH-9202 | 1 | $0.95 |
| *C1* | Generic | Capacitor, Radial, Non-polarised , 7.5x5.0mm, 5.0mm pitch, MKT | Altronics | R3021B | 1 | $0.35 |
| *R2* | Multicomp | MCF 0.25W 68K | Element14 | 9339671 | 50 | $0.22 |
| *U1* | Texas Instruments | SN74HC14N | Jaycar | ZC-4821 | 1 | $1.15 |
| *U1* | Generic | IC socket, DIP-14 | Jaycar | PI-6501 | 1 | $0.35 |
| *U2* | Motorola | MC14051BCP | Quest Comp | MC14051BCP | 2 | $0.60 |
| *U2* | Generic | IC socket, DIP-16 | Jaycar | PI6502 | 1 | $0.40 |
| *X1* | TDK | PS1720P02 | Element14 | 1669968 | 1 | $0.95 |
| *S1* | NKK Switches | SS12SDP4 | Digikey | 360-2922-ND | 1 | $2.35 |

*Table 1–Bill of materials (BoM) for PCB alarm circuit design*.

## 5. Assembly Overlay

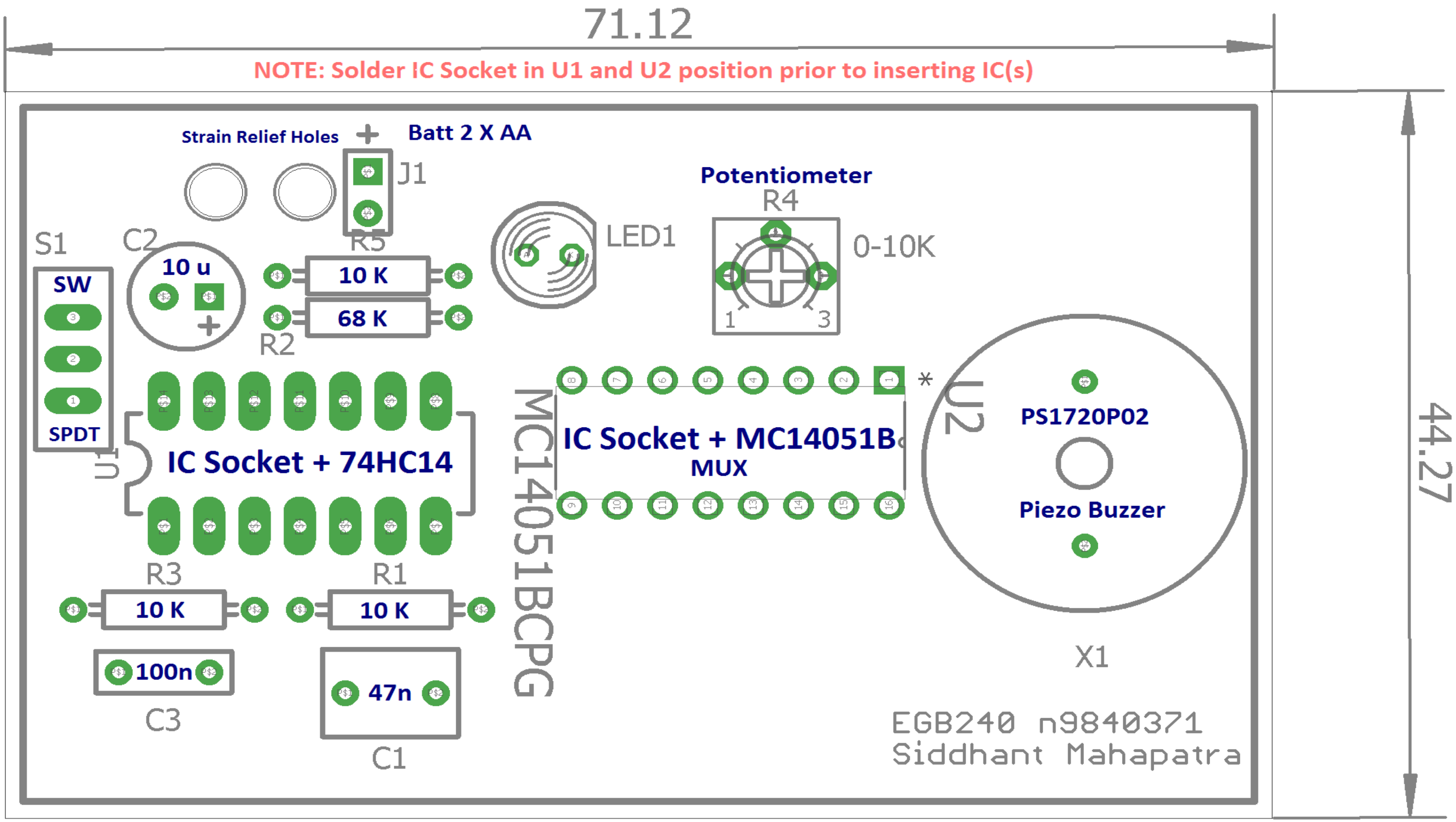
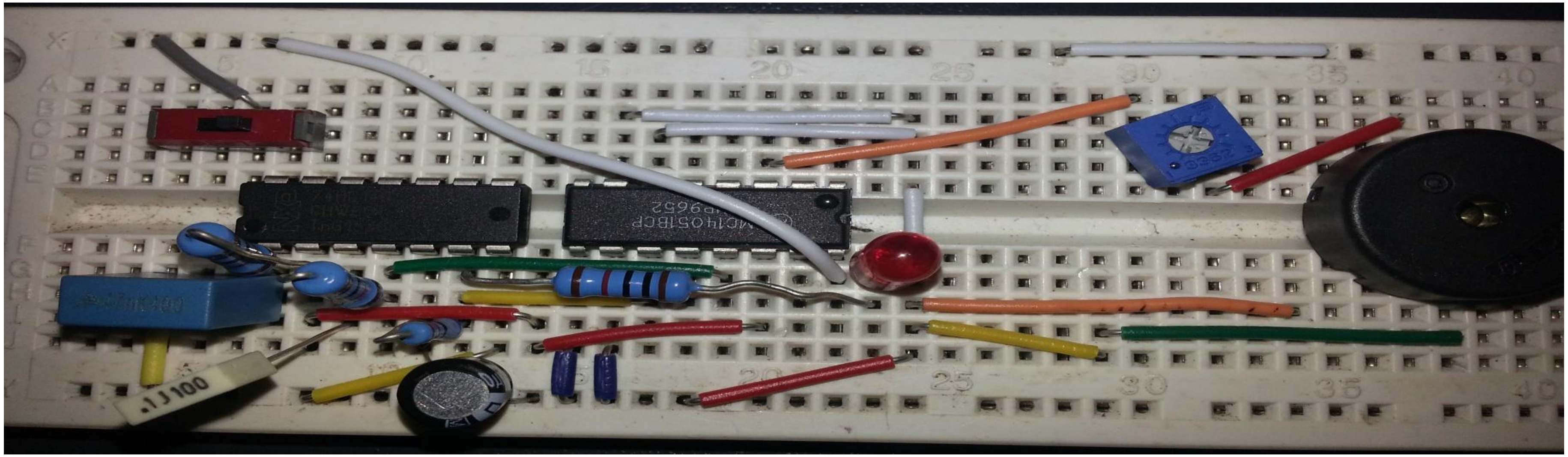
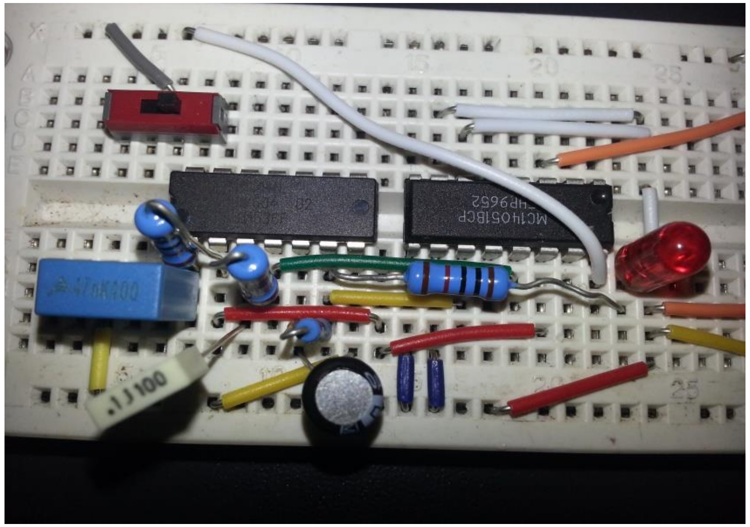
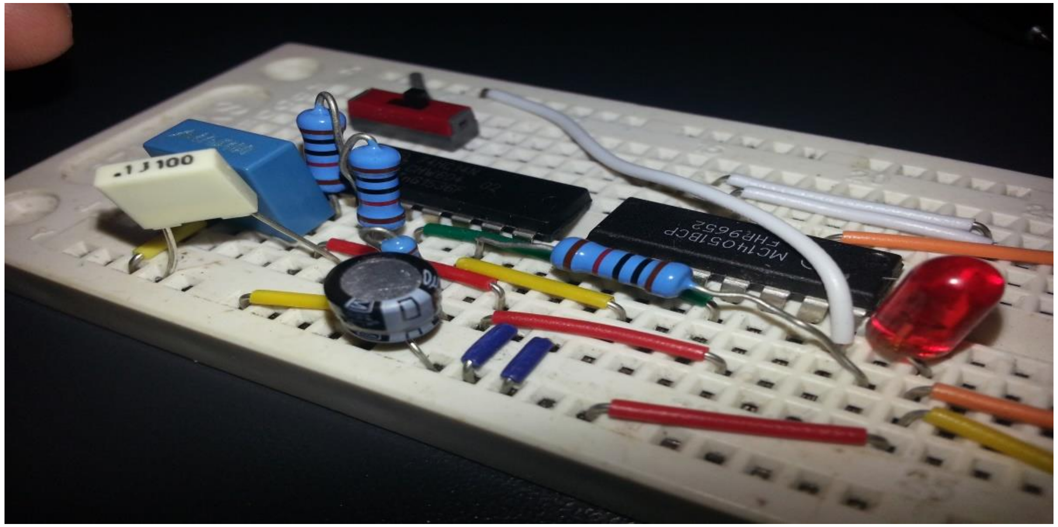



*Figure 3 – Assembly overlay and instructions for PCB alarm circuit assembly.*

## 6. **Photos of assembled prototype –** Visit https://youtu.be/LqCzupbXaes to watch it in action.



## 7. Simulation circuit

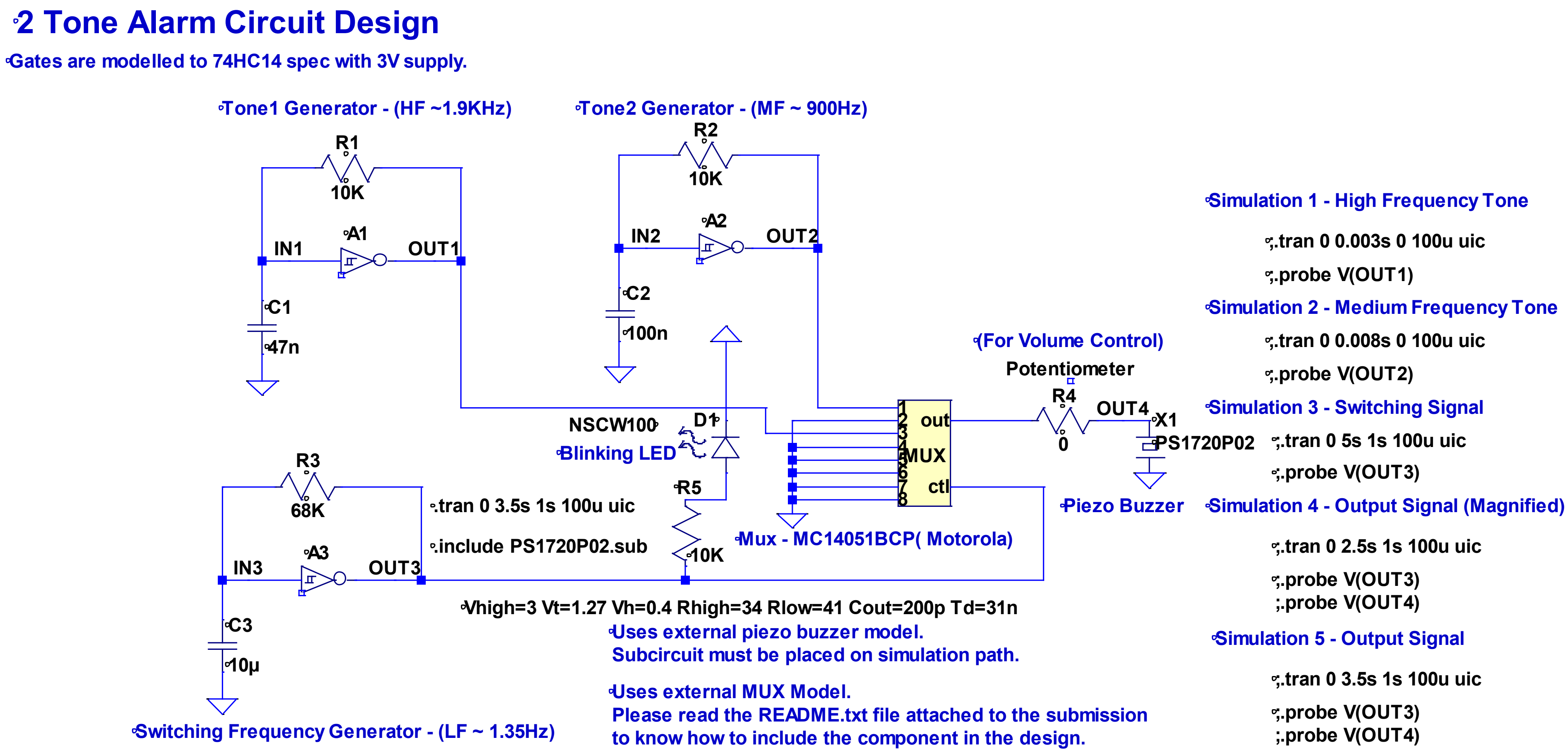



*Figure 4– LTspice circuit model used to simulate and validate circuit design. Model details are included in the netlist in Figure 7. Simulations 1, 2, 3, 4, 5 corroborates to the simulation results presented in Figures 6, 8, 10, 12,13 respectively.*

## Simulation model netlist (LTspice)

```
* C:\Users\Robosid\Documents\Alarm-LTSPICE\Draft1.asc
A1 IN1 0 0 0 0 OUT1 0 0 SCHMITT Vhigh=3 Vt=1.27 Vh=0.4 Rhigh=34 Rlow=41 Cout=200p Td=31n
C1 IN1 0 47n
R1 OUT1 IN1 10K
A2 IN2 0 0 0 0 OUT2 0 0 SCHMITT Vhigh=3 Vt=1.27 Vh=0.4 Rhigh=34 Rlow=41 Cout=200p Td=31n
C2 IN2 0 100n
R2 OUT2 IN2 10K
A3 IN3 0 0 0 0 OUT3 0 0 SCHMITT Vhigh=3 Vt=1.27 Vh=0.4 Rhigh=34 Rlow=41 Cout=200p Td=31n
C3 IN3 0 10µ
R3 OUT3 IN3 68K
XU1 OUT2 0 OUT1 0 0 0 0 0 OUT4 OUT3 MUX
XX1 OUT4 0 PS1720P02
D1 N002 0 NSCW100
R5 N002 OUT3 10K
.model D D
.lib C:\Users\Robosid\Documents\LTspiceXVII\lib\cmp\standard.dio
.tran 0 3.5s 1s 100u uic
.include PS1720P02.sub
* (For Volume Control)
* Tone1 Generator - (HF ~1.9KHz)
* Tone2 Generator - (MF ~ 900Hz)
* Switching Frequency Generator - (LF ~ 1.35Hz)
* Piezo Buzzer
* Mux - MC14051BCP( Motorola)
* Blinking LED
* 2 Tone Alarm Circuit Design
* Gates are modelled to 74HC14 spec with 3V supply.
* Uses external piezo buzzer model.\nSubcircuit must be placed on simulation path.
* Uses external MUX Model.\nPlease read the README.txt file attached to the submission\nto know how to include the component in the design.
;.tran 0 5s 1s 100u uic
;.probe V(OUT3)
* Simulation 3 - Switching Signal
;.tran 0 0.003s 0 100u uic
;.probe V(OUT1)
* Simulation 1 - High Frequency Tone
;.tran 0 0.008s 0 100u uic
;.probe V(OUT2)
* Simulation 2 - Medium Frequency Tone
;.tran 0 2.5s 1s 100u uic
;.probe V(OUT3)
;.probe V(OUT4)
* Simulation 4 - Output Signal (Magnified)
;.tran 0 3.5s 1s 100u uic
;.probe V(OUT3)
;.probe V(OUT4)
* Simulation 5 - Output Signal
.lib filt.sub
.backanno
.end
```

*Figure 5– LTspice netlist for the circuit model presented in Figure 6*

## 8. Simulation and Experimental results

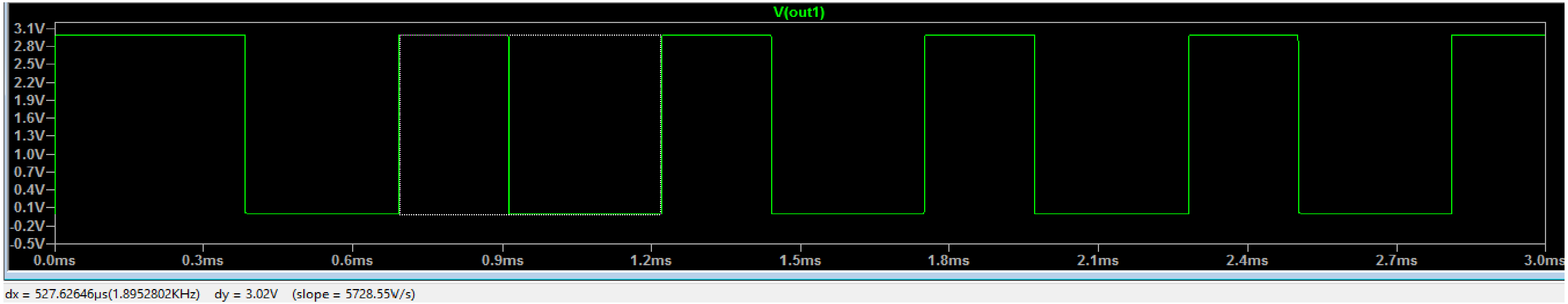



***Figure 6–Plot of Output voltage at the o/p node of Tone1 Generator for Simulation 1. Refer Fig 6. Shows 0-3V oscillation at tone frequency of 1.9KHz****(dx)*

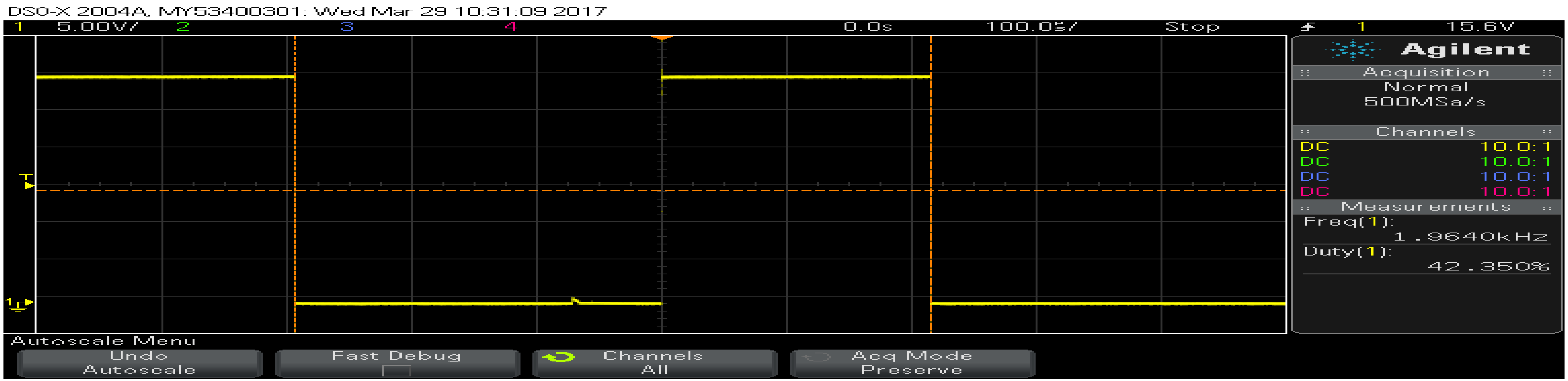



***Figure 7 – Oscilloscope capture showing voltage at o/p node of Tone1 Generator. Shows 0-3V oscillation at frequency of 1.96KHz with 42.25% DutyCycle.***

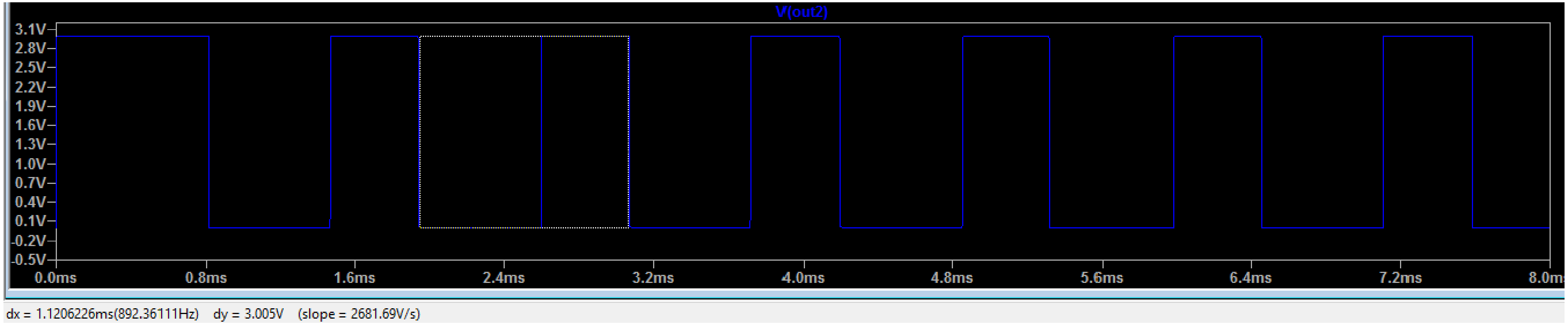



***Figure 8–Plot of Output voltage at the o/p node of Tone2 Generator for Simulation 2. Refer Fig 6. Shows 0-3V oscillation at tone frequency of 893Hz****(dx)*

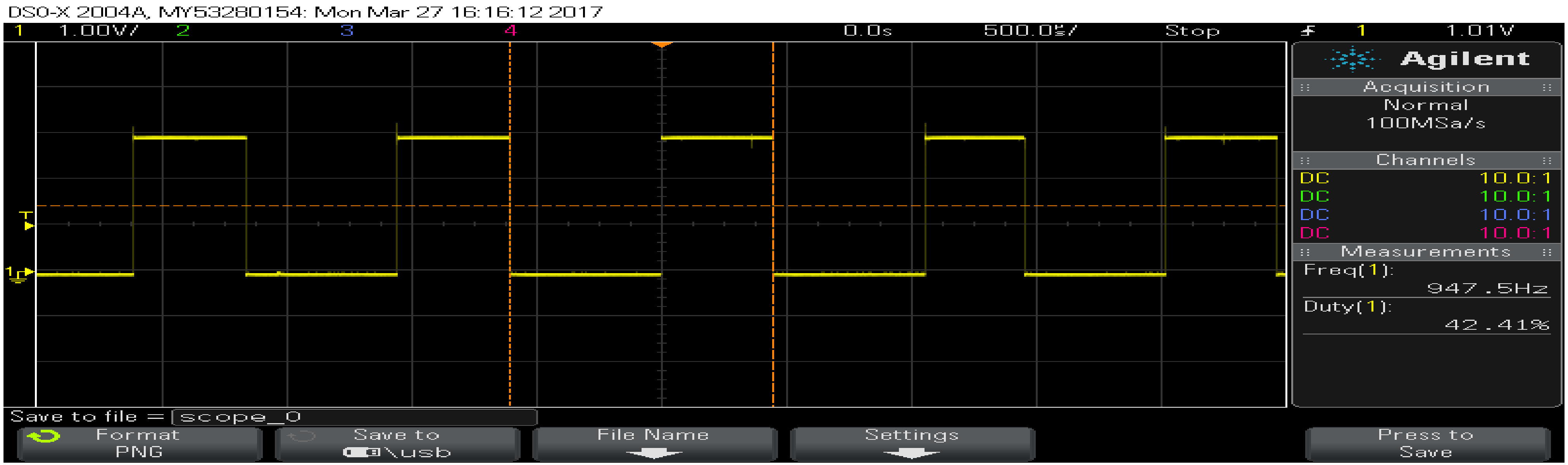



***Figure 9-Oscilloscope capture showing voltage at o/p node of Tone2 Generator. Shows 0-3V oscillation at frequency of 947.5 with 42.41% DutyCycle.***

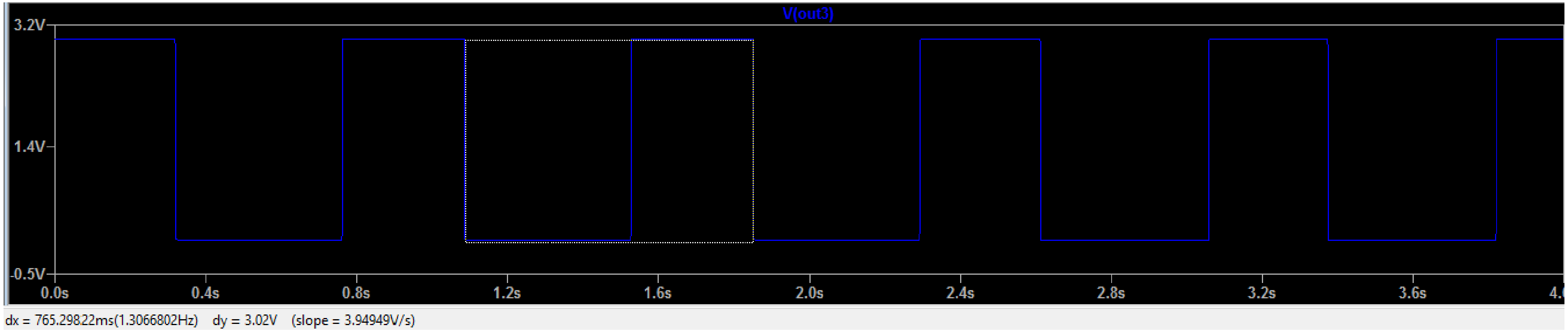



***Fig. 10–Plot of Output voltage of Switching Frequency Generator for Simulation 3. Refer Fig 6. Shows 0-3V oscillation at Switching frequency of 1.3Hz****(dx)*

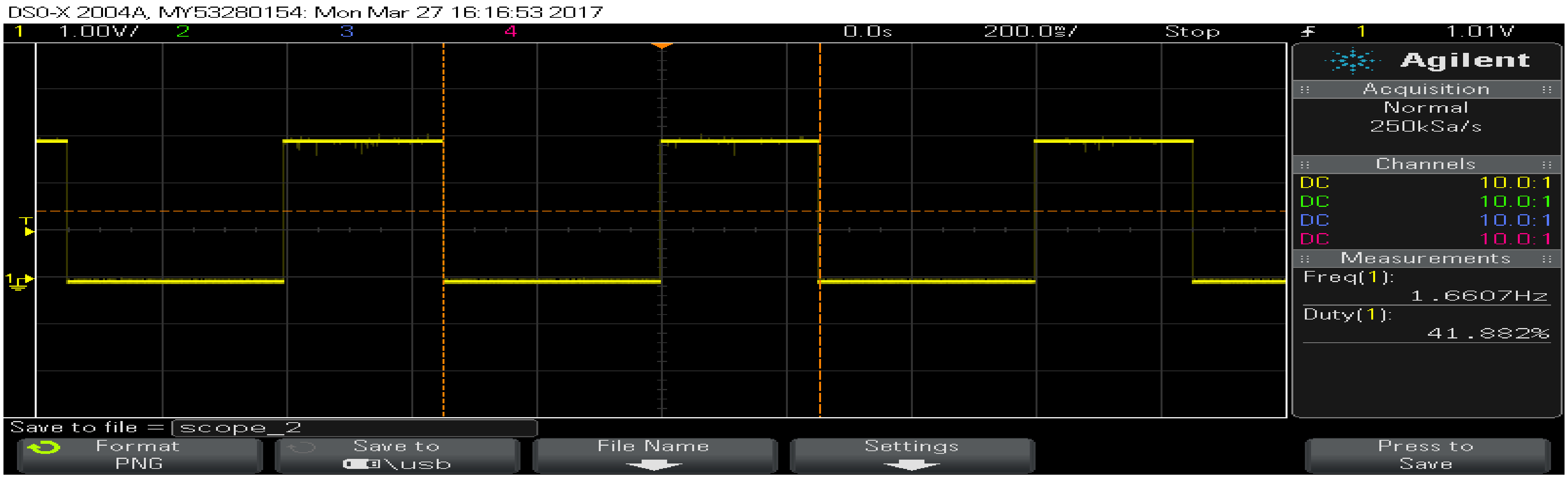



***Fig11-Oscilloscope capture showing 0-3V oscillation at o/p node of Switching Generator at frequency of 1.6Hz with 42%DutyCycle.Same as across Buzzer.***

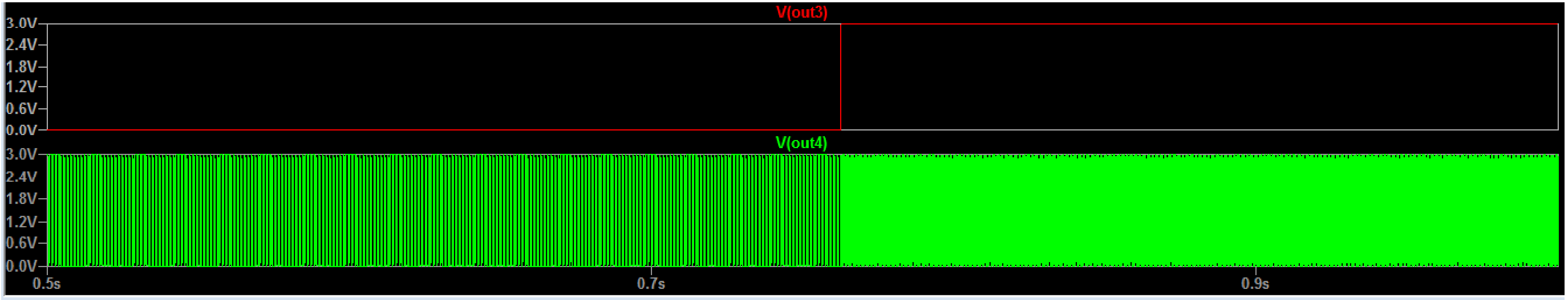



*Fig 12-Shows Magnified version of output voltage plot at the buzzer for Simulation 4 .The switching from one tone to the other, is consistent with the frequency of the Switching Generator, as expected.This show that when Voltage at OUT3 (Switching Generator) is low,the MUX connects the Buzzer to the output of Tone2 Generator and when it is HIGH,the MUX connects the Buzzer to the output of Tone1 Generator,the switching is in sync with OUT3*

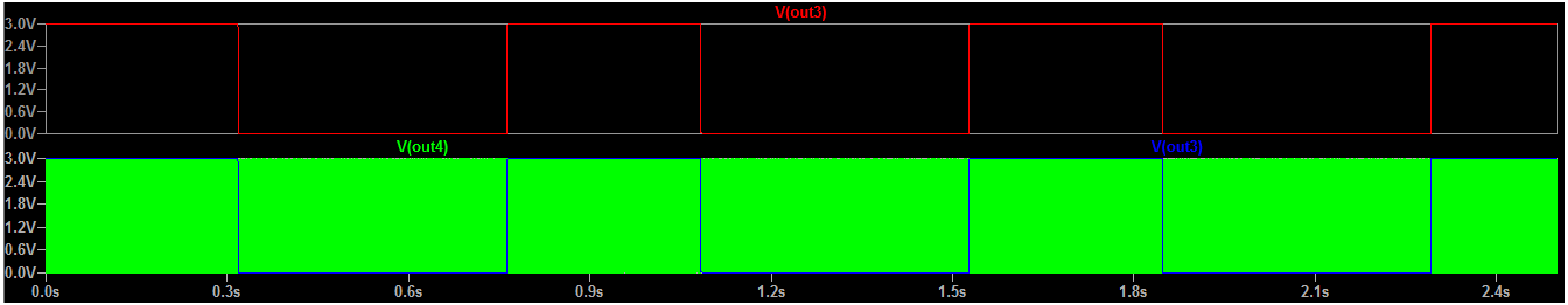



*Fig 13 – Shows the Zoomed out version of Fig14, the output voltage plot (OUT4) at the buzzer for Simulation . As expected, the switching from one tone to the other (OUT1 and OUT2), is in sync with the frequency of the Switching Generator(OUT3). Through the MUX, OUT3 is responsible for the switching and the Buzzer, as a result, produces alternating audible tone(s) of two different frequencies. Refer to Fig 6 and Fig 8 to Fig 14 and Simulation 5.*