# Audio Input Subsystem

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**Abstract**

This report documents the design of the Audio Input System, in the Crypto-Box Project. The small voltage generated by the Microphone is amplified and then passed through a comparator circuit to remove background noise voltages. A counter tracks the claps made and once an initial clap is detected, a logic circuit triggers a timer to begin counting. Once four claps are performed and nine seconds have passed, another logic gate circuit validates whether both requirements are met and the signal is sent to the Vibration Input Subsystem. This report describes the method in creating this system which has uses in security systems.

## I. Introduction

The Audio Input Subsystem aims to detect the distinct sound of a clap and should be able to track these claps on a seven-segment display while also enabling a timer to track the time for the entire systems operation. The subsystem needs to be able to detect a clap and ignore all background noises. Once the first clap is detected the timer should begin counting in seconds (up to 99 seconds). The subsystem needs to be able to track four claps within the time delay of nine seconds. Once the four claps are detected within the correct time-frame, progression to the Vibration Input System will be allowed.

### A. Report Outline

- Background
- Design
- Simulations
- Implementation and Measurements
- Discussion of results
- Conclusion

## II. Background

The microphone sensor used in this subsystem has a sensitivity of $-38 \pm 2\,\mathrm{dB}$ and has requires an operating voltage between 1V and 10V [1]. From the examined operating voltage, a power supply of $\pm 9V$ can be supplied to the system. The equation to get the average voltage produced by the microphone is given by [2]:

$$V = 10^{\frac{\mathrm{dB}}{20}} \tag{1}$$

Where: dB = -38dB.
The average voltage of 12mV produced by the microphone is too small to be used by other components and therefore needs to be amplified. Background noise voltages produced needs to be seen as a low input (up to 60dB is seen as noise) and a clap needs to be seen as a high input (above 70dB is seen as a high voltage). This can be done using a general comparator circuit or a Schmitt Trigger. Once the background noise is filtered out the signal can be sent to a counter IC allowing the clap number to be displayed on a 7-segment display. An astable 555 timer can then handle the timing system which counts up in seconds. Logic gates can verify whether the number of claps performed are correct and if the time delay of nine seconds is achieved.

## III. Design

Figure 1 shows a complete outline of the entire circuit for the Audio Input Subsystem.

### A. The Microphone

The microphone needs a minimum voltage of 4.5V to operate [1]. A power supply of $\pm 9V$ is supplied to the circuit so the positive pin of the microphone is connected to $+9V$ using a $2.2k\Omega$ resistor to prevent damage to the microphone. Due to the DC source added to the microphone from the $+9V$ supply, a capacitor of $10nF$ is added to the output of the microphone (positive pin) to eliminate this DC source as the added DC voltage can conceal the very small AC voltage produced by the microphone.

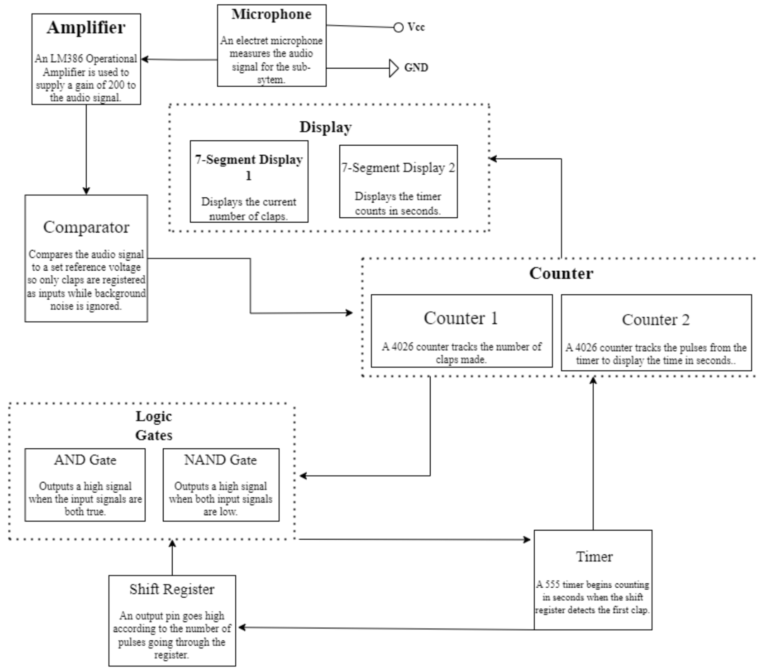


Fig. 1. A Block Diagram of the Audio Input Subsystem

### *B. Amplifying the Microphone Signal*

Initially the Operational Amplifier, LM741, was used but this particular IC is not reliable at amplifying very small voltages as the amplified voltage is clipped into the negative voltage region. A good Operational Amplifier IC to use for amplifying audio signals is the LM386 Operational Amplifier [3]. A maximum gain of 200 can be achieved [4] for this amplifier by connecting a large enough capacitor between the gain pins (Pin 1 and Pin 8). Connecting a resistor in parallel with the capacitor can further increase the gain. As a DC source is connected to the amplifier, a capacitor should once again be connected to the output of the amplifier to ensure the signal remains AC. The schematic for the microphones setup as well as the amplifier is shown in Figure 1.

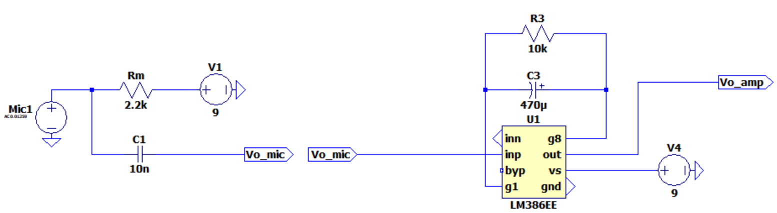


Fig. 2. A schematic of the Amplifying circuit and the configured microphone

### *C. Eliminating Noise*

Two approaches can be taken to eliminate noise voltage so only a clap is registered as an input: A Schmitt Trigger circuit or a standard Comparator Circuit.

1) An approach using a Schmitt Trigger
   - A Schmitt Trigger circuit: a unique comparator circuit which uses two reference voltages to prevent false triggers.

   To setup the Schmitt Trigger the upper threshold voltage (the voltage produced by the clap) and the lower threshold voltage (the voltage produced by background noise) needs to be determined. The equation to convert a sound measured using the microphone is given as [5]:

$$V = V_{ref} \times 10^{\frac{dB - dB_{ref}}{20}} \tag{2}$$

Where dB is the sound being measured, Vref is 12mV (reference voltage from the microphones sensitivity) and dBref is a reference determined from 1Pa which is the reference used in the datasheet [1] (1Pa $\approx 94dB$ [6]). From (2) the voltage produced by clap is approximately 0.79mV and the voltage from background noise is 0.23mV. With the gain from the amplifier the voltages become 0.2V and 0.05V. The reference voltage for the comparator is set to the average of these two value ($V_{ref} = 0.1V$) By examining the design of a non-inverting Schmitt Trigger the following equation is derived:

$$V_{UT} - V_{LT} = -V_L(\frac{R_1}{R_2}) + V_H(\frac{R_1}{R_2}) \tag{3}$$

Where $V_{UT} = 0.2V$, $V_{LT} = 0.05V$, $V_L = 0V$ (grounded) and $V_H = 9V$.
A ratio of $\frac{1}{60}$ is then derived to get the resistor values for the Schmitt Trigger. According to this ratio $R_1 = 100\Omega$ and $R_2 = 6k\Omega$. Figure 3 shows the schematic for the Schmitt Trigger circuit.

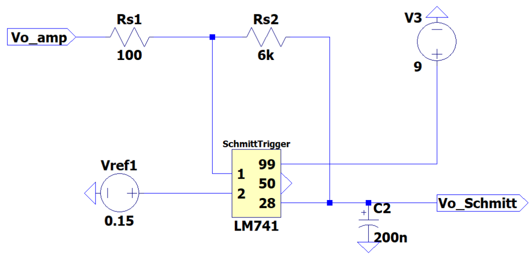


Fig. 3. A schematic of the Schmitt Trigger Circuit

2) An approach using a standard Comparator Circuit
A Comparator Circuit is a more simple approach as the input signal will be compared to a single reference voltage (reference voltage should be set between the voltages produced by background noise and the clap). This reference voltage can be set using a voltage divider as seen in the following equation:

$$V_{ref} = V_{cc} \times \frac{R_2}{R_1 + R_2} \tag{4}$$

Where $R_1$ is the resistor going to $V_{cc}$ which is the power supply of 9V and $R_2$ is the resistor going to the ground terminal of 0V.
The reference voltage should approximate to 0.1V hence resistor values of $R_1 \approx 20k\Omega$ and $R_2 = 220\Omega$ are used. A pull down resistor is added to the output of the comparator to stabilize the signal.

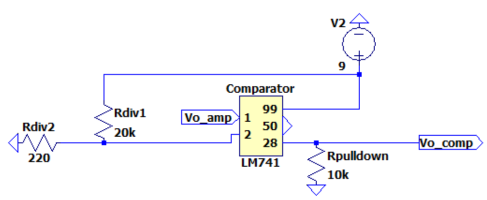


Fig. 4. A schematic of the Comparator Circuit

Both circuit options will be simulated in LTspice to determine which option is better suited to detecting the claps.

### *D. Counting the claps*

Claps are counted using a 4026 counter, which works in conjunction with a 7-segment display to visually show the increment every time a clap is detected. Bouncing of the input signal to the counter could occur hence the signal needs to be stabilized before being processed through the counter. This can be achieved by adding in smoothing capacitors. The value for the capacitor can be determined using the following equation:

$$V_{p-p} = \frac{V_{o(p)}}{fCR_L} \tag{5}$$

Where the peak voltage, $V_{o(p)} = 0.2V$, the peak to peak voltage of the signal wave, $V_{p-p} = 2 \times V_{o(p)} = 0.4V$, the frequency of the clap, $f = 1kHz$, corresponds to time step of $1ms$ used in the simulation and the load resistor is chosen to be $R_L = 10k\Omega$. This results in a smoothing capacitor with a capacitance of $50nF$. The capacitor is placed at the input to the counter.

### E. Enabling the timer after the first clap

- AND gate: Produces a high output only if both the inputs are high.
- NAND gate: Produces a high output only if both the inputs are low.
- OR gate: Produces a high output when at least one of the inputs are high.
- Sum-Of-Products form: A method in boolean algebra for designing a logic gate circuit in which AND products that produce a high output are summed together using an OR operation.

The timer can begin counting by incorporating logic gates. The number ”1” on the 4026 counter occurs when the segments $a, f, g, e$ and $d$ are off on the 7-segment display and segments $b$ and $c$ are on. The logic gates are chosen according to the truth table shown in Table 1.

Table 1: A Sum-Of-Products truth table showing required state of a 7-segment display for a produced signal to be high.

| a | b | c | d | e | f | g | Output | Minterm | Minterm name |
|---|---|---|---|---|---|---|---|---|---|
| 0 | 1 | 1 | 0 | 0 | 0 | 0 | 1 | $\bar{a}bc\overline{defg}$ | $m_1$ |

After the ”1” is detected using the logic gates, the timer is then triggered to start counting.

### F. The timer

- Astable Timer Configuration: Allows the timer to output a continuous series of pulses at an adjustable frequency [7].

An astable configuration for the timer is sourced online by [8]. The schematic for the timer is shown in Figure 5.

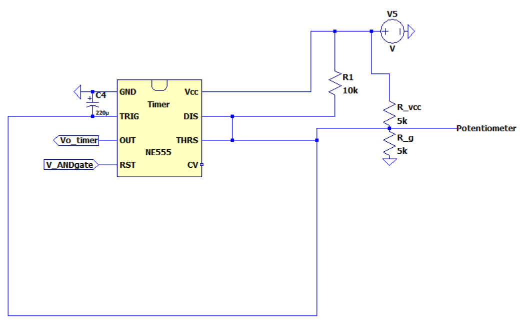


Fig. 5. A schematic of the Timer circuit

### G. Progressing to the Vibration Input System

Progression to the next subsystem (the Vibration Input System) will be allowed when the clap counter registers four claps and when nine seconds have passed. Detecting the correct claps can be done using logic gates similar to how the timer is started after the first clap. The number ”4” corresponds to the following specifications shown in Table 2 and the number ”9” corresponds to the specifications set in Table 3. Due to the large quantity of gates required for this approach, a similar approach using a shift register could be implemented for the time delay. The pin corresponding to nine pulses through the shift register will be high after nine seconds and this pin could then replace the output minterm, $m_3$ seen in Table 3. The complete schematic to get the final output signal according to Table 2 and Table 3 is given by Figure 6.

Table 2: A truth table showing required state of a 7-segment display (”4”) for a produced signal to be high.

| a | b | c | d | e | f | g | Output | Minterm | Minterm name |
|---|---|---|---|---|---|---|---|---|---|
| 0 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | $\bar{a}bc\overline{de}fg$ | $m_2$ |

Table 3: A truth table showing required state of a 7-segment display (”9”) for a produced signal to be high.

| a | b | c | d | e | f | g | Output | Minterm | Minterm name |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | $abcd\bar{e}fg$ | $m_3$ |

## IV. Simulations in LTspice

Transient analysis was performed on the Amplifying system and the Comparators to validate the circuit designs and ensure proper signal pulses are sent to the counter.
Figure 7 then compares how the amplified signal is processed through the two types of comparators (the standard comparator and the Schmitt Trigger).

The Comparator Circuit resistor values were changed to $R_1 = 1k\Omega$ and $R_2 = 1.1k\Omega$ to create a better square wave. From Figure 7 it can be seen that the standard Comparator correctly oscillates between a high and low state in the form of a square wave. The Schmitt Trigger however remains in a constant high state. Therefore the standard Comparator is used to eliminate noise voltage instead of the Schmitt Trigger.

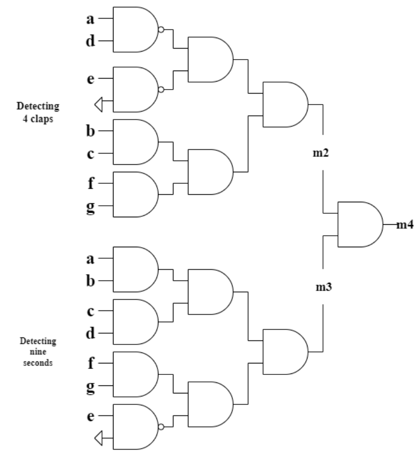


Fig. 6. A schematic of the logic circuit to obtain the final output signal

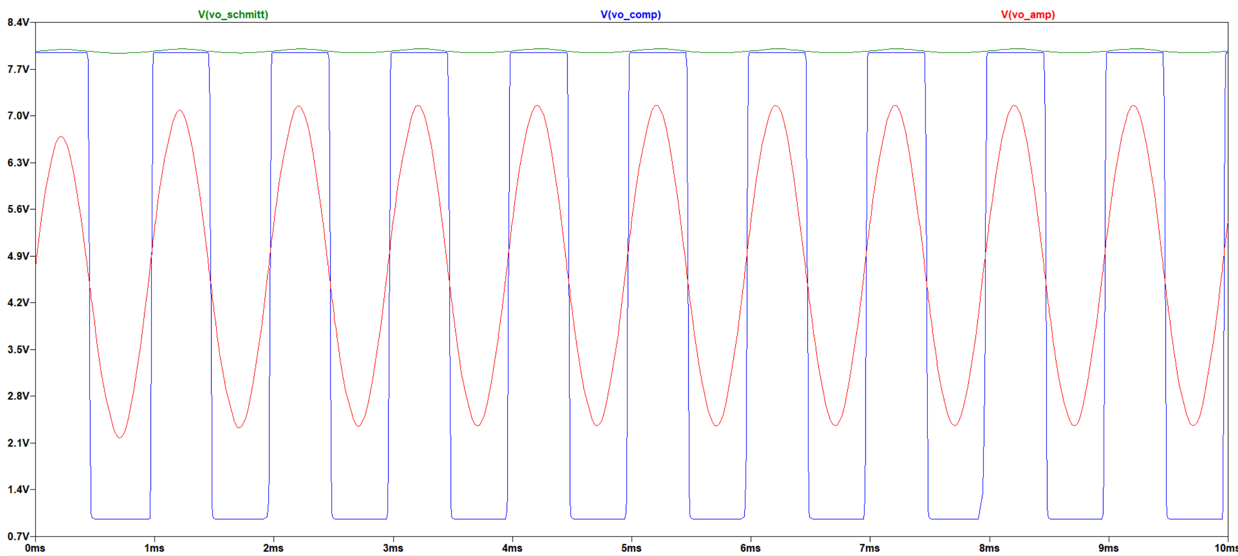


Fig. 7. A plot comparing how the standard Comparator ($V_{comp}$) and the Schmitt Trigger ($Vo_{Schmitt}$) process the amplified signal ($Vo_{amp}$)

## V. Implementation and Measurements

### A. Validating Simulation Results

Figure 8 shows a spike in voltage caused by a clap in comparison to the noise voltage which remains close to the origin. Table 4 shows the physically recorded voltages using a multi-meter at different stages of the circuit with the most significant differences being seen in the comparator signal.

Table 4: A table showing the average voltages produced by noise and claps at different points in the circuit

| | $V_{noise}$ (V) | $V_{clap}$ (V) |
|---|---|---|
| Microphone Signal | 0.008 | 0.008 |
| Amplified Signal | 4.2 | 4.3 |
| Comparator Signal | 1.8 | 2.1 |

## VI. Discussion of results

### A. System Results

The sub-system is able to accurately count claps performed at a specific frequency; however loud claps still cause spikes in the counts. Noise voltage is successfully ignored and not registered as an input to the counter. The timer begins counting immediately when the circuit turns on and the time is indicated using an LED instead of a 7-segment display due to a lack of

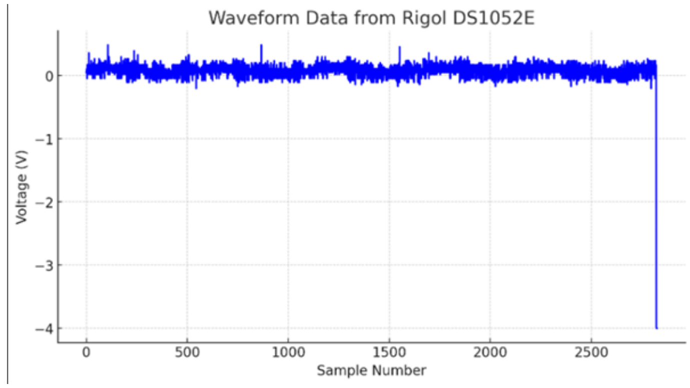


Fig. 8. A plot showing the spike in voltage from a clap

space. The four claps create a correct response indicated by an LED. A second LED indicating the time delay of nine seconds turns on using a shift register instead of a logic circuit. Progression to the Vibration Input Subsystem was not achieved as this system is still able to operate independently of the Audio Input Subsystem.

### B. Suggested Improvements

The method used in counting the claps resulted in loud claps causing spikes in the overall clap count. Smoothing capacitors in conjunction with a refined Schmitt Trigger circuit can ensure a stable signal to the counter irregardless of the clap frequency or loudness. The timer can be easily configured to count too 99 by incorporating another 555 timer as well as two 7-segment displays (with two 4026 counters). By configuring the second timer to generate a pulse every ten seconds, a count to ”99” can be achieved (an additional breadboard may be required due to large size requirement of these displays and timers).

Adding in the logic circuit to detect the initial clap, as well as including a transistor switch will allow the timer to start counting only after an initial clap is made. This will also require more space so additional breadboards may be required. Progression to the Vibration Input System can be achieved by utilizing a transistor switch which triggers once the correct signal from the Audio Input System is sent through to the Vibration Input Subsystem.

## VII. Conclusion

The Audio Input Subsystem successfully records claps made; however the timer does not have a display to show a count up to ”99”. The correct signals are obtained (four claps and a nine second delay) but successful progression to the next part of the Crypto-Box system was not achieved. The Audio Input Subsystem partly achieves its project aims and objectives but is not suitable for practical use in its current state; however with the mentioned improvements, the subsystem could become more suitable to real world applications.

## References


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