Indian Institute of Technology Bombay
Department of Electrical Engineering

Clap Detector

Group: MON-PCP-2-2

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April 8, 2022

Contents

1 Project Objectives

- To analyse and understand clap waveforms and their distinguishing attributes.
- To design and build a circuit which detects clap signals through a microphone.
- To write a control code to control appliances based on the sequence of detected claps.

2 Design Approach

2.1 Detection Strategy

The detection strategy is based on the observation that claps have a distinct property of envelope which can be used to distinguish them from other environmental sounds. The time it takes for a clap to decay from fraction f_1 of peak value to fraction f_2 of peak value remains within a specific range. Hence the task simply reduces to finding

1. Fractions f_1 and f_2
2. The specific range of decay time
3. A way to generate envelope of clap
4. Logic to check whether the decay time lies with the specific range

We analysed various types of claps and other sounds to find 1 and 2. For 3, we designed and built circuits. Finally, for 4, we used a microcontroller, to code the logic.

2.2 Clap Waveform analysis

We analyse waveforms of various claps and calculate the major frequency components in the waveform by measuring the time period of cycles.

We observe that in the beginning of the clap, high frequency components in the range 5 to 10 kHz exist as shown in Figure 2.1. We see that these high frequency components decay quickly and frequencies in the range 2 to 3 kHz remain as shown in Figure 2.2.

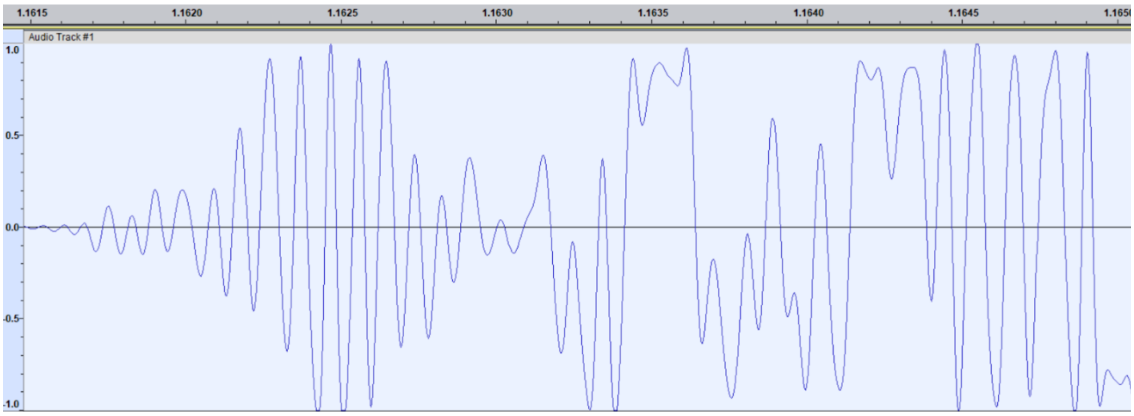

Figure 2.1

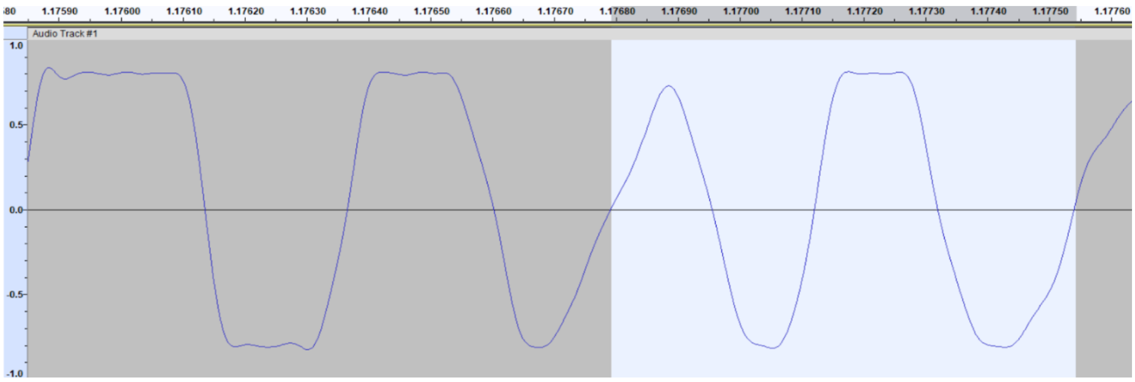

Figure 2.2

The fractions f_1 and f_2 are decided after testing the final circuit with different combinations. We chose $f_1 = 0.5$ and $f_2 = 0.25$ as the values since these produced consistent time difference values for many claps.

2.3 Block Diagram

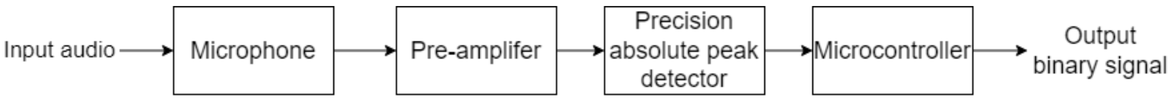

Figure 2.3

The audio signal from the user is captured by the electret microphone. This audio signal is amplified using a pre-amplifier circuit to bring the voltage to line level. This is followed by a precision absolute peak detector which, gives the envelope of the absolute amplified signal.

This envelope is input to an analog pin of a microcontroller to read the voltage values of the signal. The microcontroller decides whether an input audio signal is a clap or not on the basis of the decay time, duration and peak of the envelope waveform. The final output is a binary signal which will toggle the LED on or off if the input audio is a clap. The various subsytems are explained in detail below.

3 Implementation

3.1 Pre-amplifier

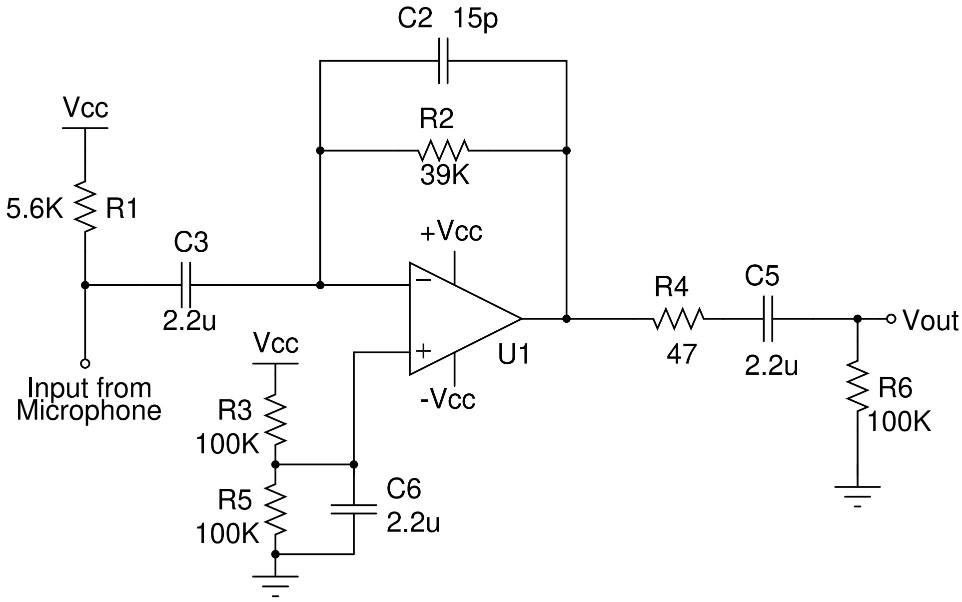

Figure 3.1: Pre-amplifier Circuit

3.1.1 Working

The circuit diagram for the pre-amplifier for the electret microphone is shown in Figure 4.1. An opamp is used as a transimpedance amplifier to convert the output current from the electret microphone to signal level voltage. The current into the microphone consists of two components that are dc and ac. The dc component is used to bias the JFET in the microphone The impedance of capacitor C3 is kept small compared to resistor R1 to keep the ac component of the current to flow through it and the dc component through R1. The output of the opamp is given by equation

3.1 where V_B is the bias applied at the non-inverting input of the opamp for a wider output swing.

$$V_{OA} = I_{ac} \times R_2 + V_B \tag{3.1}$$

The ac coupling at the output of the opamp prevents any dc voltage to pass through and hence we get a amplified signal.

3.1.2 Component Selection

The value of R1 can be calculated from the bias required by the internal JFET in the microphone. The value of R1 is calculated using equation 3.2. The current of 0.5 mA is the current consumption of the microphone.

$$R_1 = \frac{V_{CC} - V_{MIC}}{I_S} = \frac{5-2}{0.5mA} = 6\ k\Omega \tag{3.2}$$

To keep impedance of C3 less than R1 and since the combination of R1 and C3 acts as a high pass filter we take care that the cut-off frequency of this filter allows frequencies of audio signals to pass through, C3 is chosen as shown below in equation 3.3.

$$C_3 = \frac{1}{2\pi R_1 f_c} = \frac{1}{2\pi(5.6k\Omega)(10Hz)} = 2.8\mu F \tag{3.3}$$

Since the sensitivity if the electret micrphone is not known to us, the resistor R2 is chosen by checking whether the required output voltage of the pre-amplifier circuit is in the range 1 to 1.5 V. We observe that for a resistance of 39 kΩ, this is true. The AC-coupling network at the output of the opamp acts a high pass filter

3.2 Precision absolute peak detector

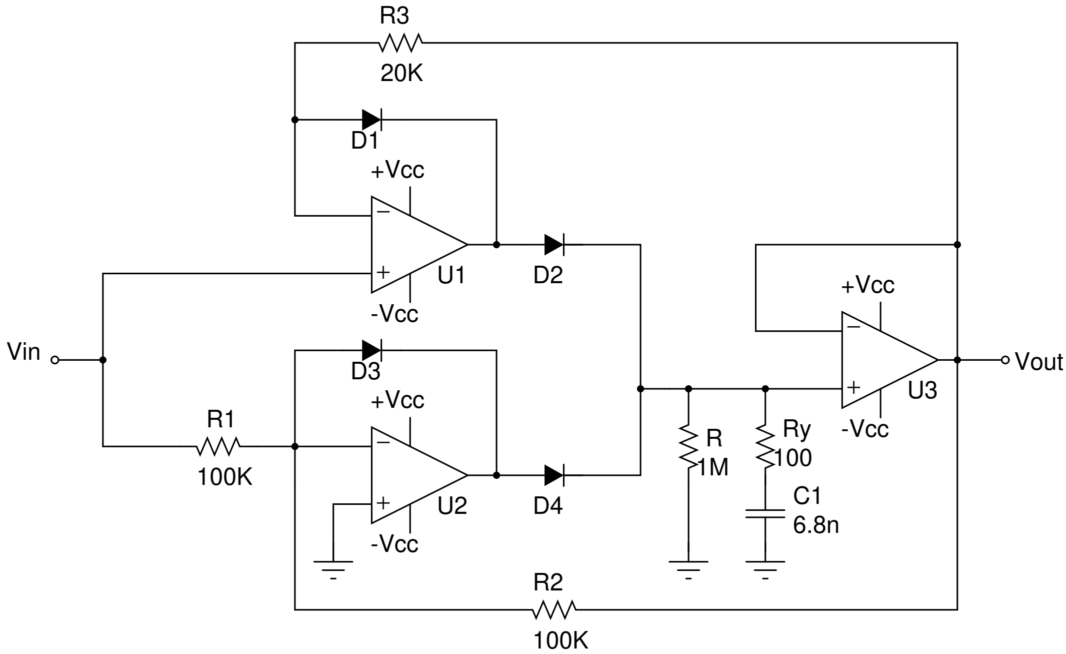

Figure 3.2: Precision Peak Detector Circuit

3.2.1 Working

Figure 4.2 describes the circuit diagram of an absolute precision peak detector. The output of this circuit is the envelope of the input signal. The peak detector is absolute in the sense that it can detect both, positive and negative peaks.

The peak detector circuit can be broken down into a combination of positive peak detector and negative peak detector. The upper half of the circuit diagram in Fig. 4.2 i.e. the sub-circuit consisting of op-amp U1, op-amp U3,holding capacitor C1, discharge resistor R and the feedback path which has resistor R3 constitutes the positive peak detector. While the lower half of the circuit diagram i.e consisting of op-amp U2, op-amp U3, holding capacitor C1, discharge resistor R and the feedback path which has resistor R2 constitutes the negative peak detector. When the input signal has a positive peak, the positive peak detector would be active and output would be a positive envelope. On the other hand, when the input signal has a negative peak, the negative peak detector would be active and since U2 is operating in inverting configuration, the output would be an inverted envelope which is a positive envelope.

The need for a unity follower, after the holding capacitor, is to reduce peak-hold error by providing the feedback current to the inverting terminals of op-amps U1 and U3, which would, otherwise, be provided by C1. Resistors are put in the feedback loops to reduce the feedback currents.

3.2.2 Component Selection

Note that the feedback current(I_f) is given by-

$$I_f = \frac{V_1 - V_{out}}{R_x} \tag{3.4}$$

where V_1 is the voltage at the inverting terminal of op-amps U1 and U2, R_x is the value of resistor in the feedback loop. Hence for a 5V difference, choosing $R_x = 20\text{K}\Omega$ and $R_x = 100\text{K}\Omega$ for the positive and negative peak detector feedback loops respectively, gives I_f as 0.25 mA and 0.05 mA respectively. One of the major

3.3 Microcontroller

We use the Arduino UNO microcontroller in our project. The output signal from the peak detector is fed into an analog pin of arduino. This value is read and the logic showcased in the flowchart in Figure 4.3 is used to detect whether the sound was a clap or not. The variables f1 and f2 used in the flowchart correspond to fractions less than 1. The time difference in the envelope to achieve these fractions of the peak serves as the basis of clap detection in our method. We also set a threshold voltage (V_{th}) which does not allow any background noises of low amplitudes to be considered as a clap. Finally to reduce false positives, the user is required to produce two quick consecutive claps instead of one, to turn on or off the LED.

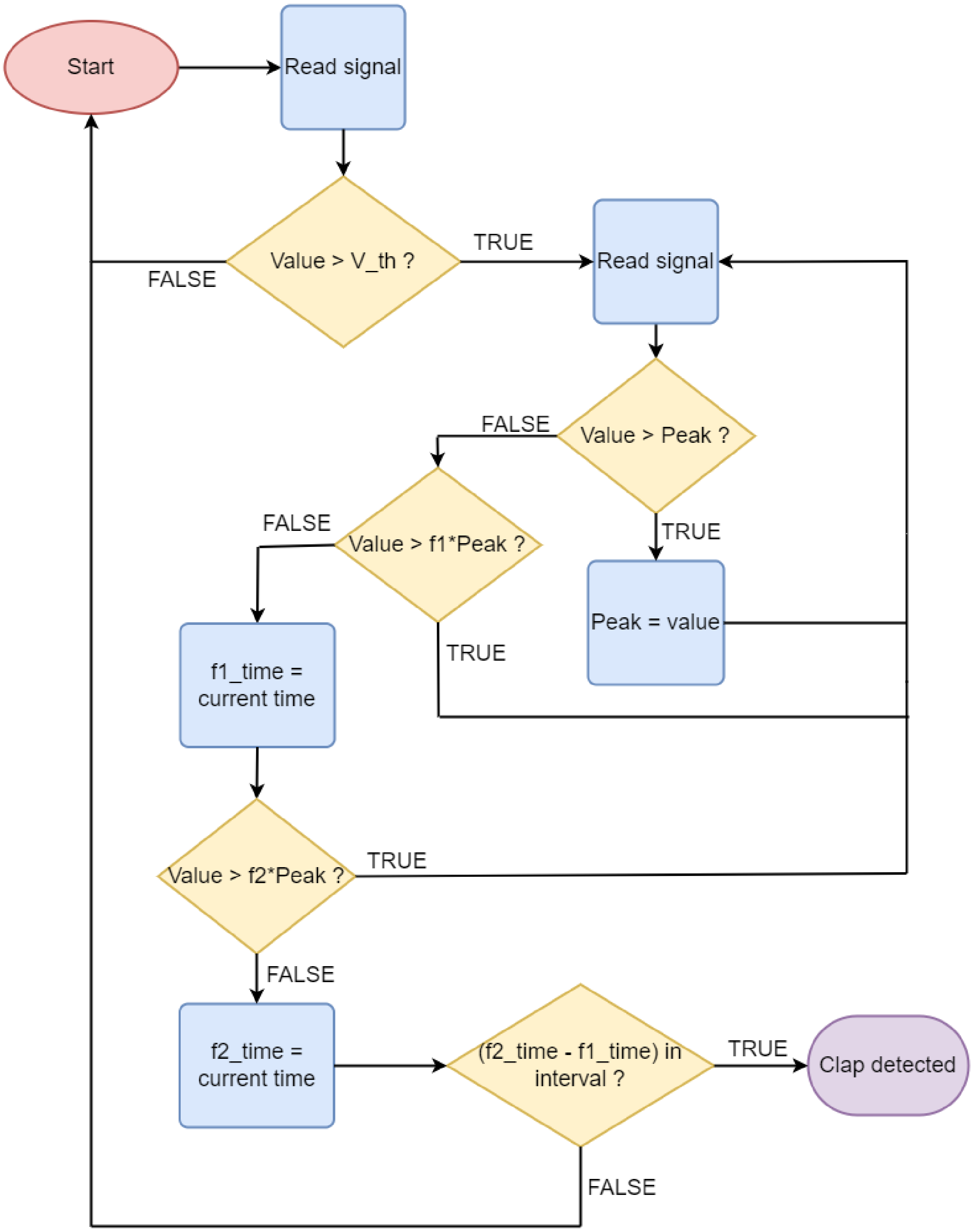

Figure 3.3: Flowchart for Clap detection

3.4 Power Supply

We need to supply +3.5 V and -1.5 V to the positive and negative V_{CC} terminals of the op-amps to ensure

4 Test Results

5 Bill of materials

Table 1: Major components

Component	Quantity	Approximate cost	Availability in lab
Electret microphone	1	₹50/-	✓
LM324 Quad OPAMP DIL-14	2	₹40/-	✓
Arduino UNO	1	₹650/-	✓

6 Appendix

6.1 PCB layout

We implemented the schematic of our circuit design on EAGLE software to get the layout for PCB design.

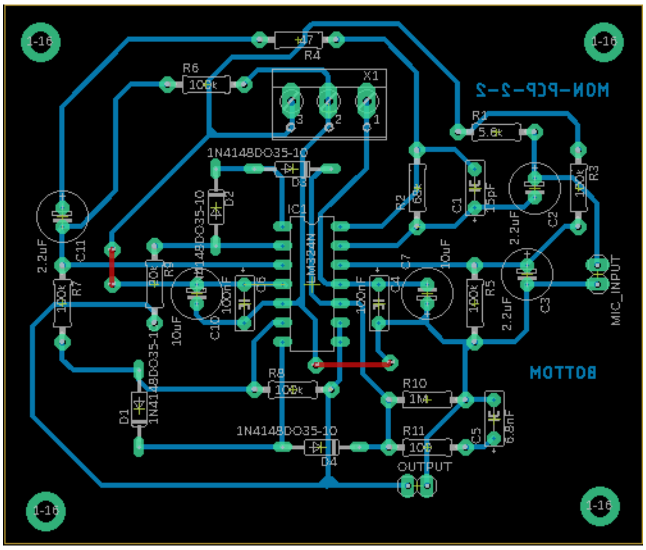

Figure 6.1: PCB layout