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Clap and Whistle Detection for Electrical Appliance Control

Group No. D6

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Abstract

This work involves developing a circuit to detect sound signals i.e. claps and whistles for controlling electrical appliances e.g. room lights, fans, etc. This report discusses the basic approach to detect claps and whistles from other sounds. Output from the microphone is processed by using analog signal conditioning followed by a digital circuit, realized using a microcontroller. All the implemented circuits are discussed along with their circuit diagrams. Results after different stages are plotted and tabulated, wherever required.
The output from the microphone is simultaneously checked for whistles and claps. Whistles are nearly periodic signals and hence periodicity detection is performed for their determination. Envelopes of claps have the property of decaying to some fraction in a constant time. For the determination of claps, the time of their decay to $1/10^{th}$ of their peak magnitude is noted and if it falls in a pre-decided range, the detection of clap gets confirmed.

1. Introduction

Electrical appliances can be controlled by using various input mechanisms. Claps and whistles are used in this project to provide an input mechanism for their control. First stage of the work consists of detection of desired sound signals (i.e. claps and whistles) against other sounds and environmental noises on the basis of particular characteristics of claps and whistles. After detection, different logics can be developed to control any electrical appliance like fan or light. For real world application, this circuit is tested in various noisy environments to gauge the performance of the circuit.

2. Detection of Whistles and Claps

First stage of the project is detection of claps and whistles based on their frequency or time domain characteristics. Claps are detected by the properties of envelope traced by a sound signals. Whistles are nearly periodic hence periodicity detection can be used for them.

2.1 Detecting Claps

Experiments have shown that envelope of a clap signal decays to a fraction of its highest value, in a constant time. Therefore, a clap amplitude envelope can be differentiated from other sound signals by its property of decaying to a fraction of its highest value in a constant time. Table 1 shows the time of decaying of different clap signals to one tenth of their maximum value.

Table1: Time of decaying of different clap signals

USER	S. No.	Voltage of the peak (Volts)			Time of decaying to one tenth of the peak value(ms)		
		Range	Range	Mean	Range	Mean	Standard Deviation
USER 1	1.	2.3	3.0	0.868	10.8	11.1	2.32
	2.	3.1			11.2		
	3.	3.2			11.3		
	4.	2.8			11.0		
	5.	4.0			11.5		
	6.	4.2			11.5		
	7.	2.9			11.1		
	8.	1.5			10.6		
USER 2	1.	2.1	3.4	0.844	10.2	13.1	2.77
	2.	3.0			10.0		
	3.	3.4			12.9		
	4.	3.8			14.4		
	5.	4.2			15.2		
	6.	4.6			17.5		
	7.	3.7			14.2		
	8.	2.5			10.1		
USER 3	1.	2.3	3.7	0.805	9.6	12.9	2.1
	2.	3.2			11.2		
	3.	3.7			13.0		
	4.	4.0			14.1		
	5.	4.5			14.9.		
	6.	4.9			15.8		
	7.	4.1			14.5		
	8.	3.5			12.4		

2.2 Detecting Whistles

Whistles are periodic wave-forms of constant frequencies. Frequency may differ in the whistles generated by different sources but in one stretched whistle, the frequency remains nearly constant throughout. Therefore, periodicity of whistles is used to differentiate them from other sound signals.

3. System Design

The Hardware is described in three stages i.e. microphone, analog signal conditioning, and microcontroller. Output from the microphone is fed into analog circuit for processing. Digital pulses are generated at this stage, which are processed in the Microcontroller for final determination of the form of the input sound. Block Diagram of the circuit is shown in Figure 1.

3.1 Microphone

Microphone circuit consists of a microphone driver circuit followed by an amplifier. The output from the microphone is of the order of micro-volts to milli-volts depending on the level of sound and distance of the source from microphone. Signals from a considerable distance can not be identified because of their small amplitude at the microphone.

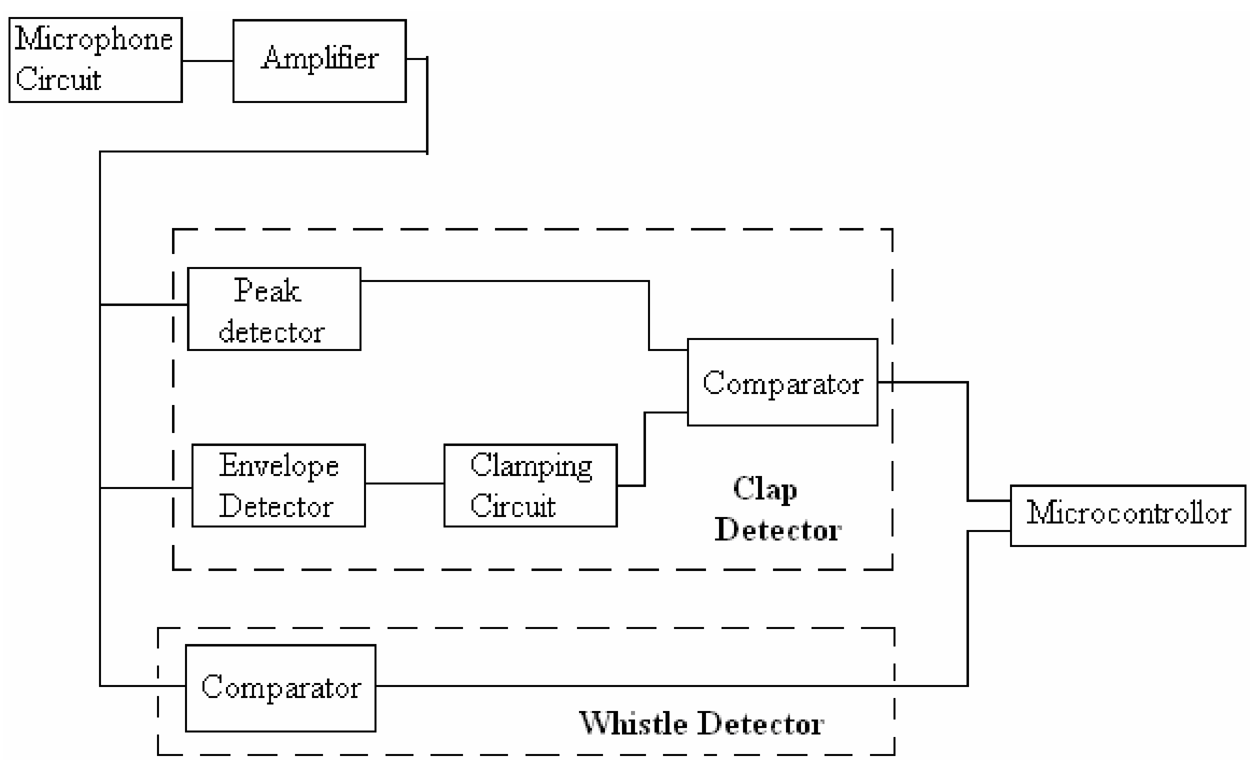


Figure 1: Block Diagram of the circuit

We need an amplifier with gain ≅50. Therefore, we have used an op-amp in inverting amplifier configuration with a gain of 56, as shown in Figure 2.

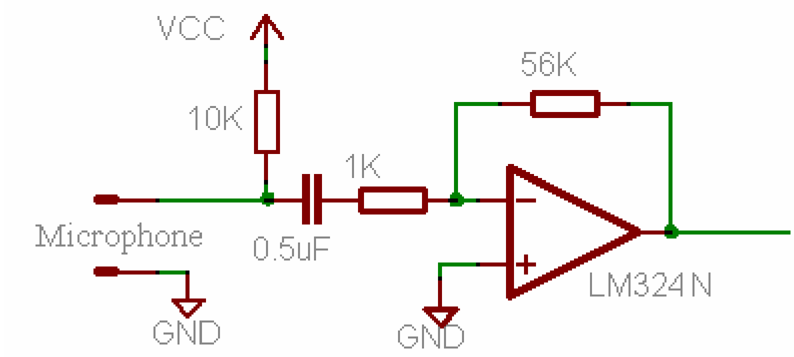


Figure 2: Microphone amplifier

3.2 Analog Circuits

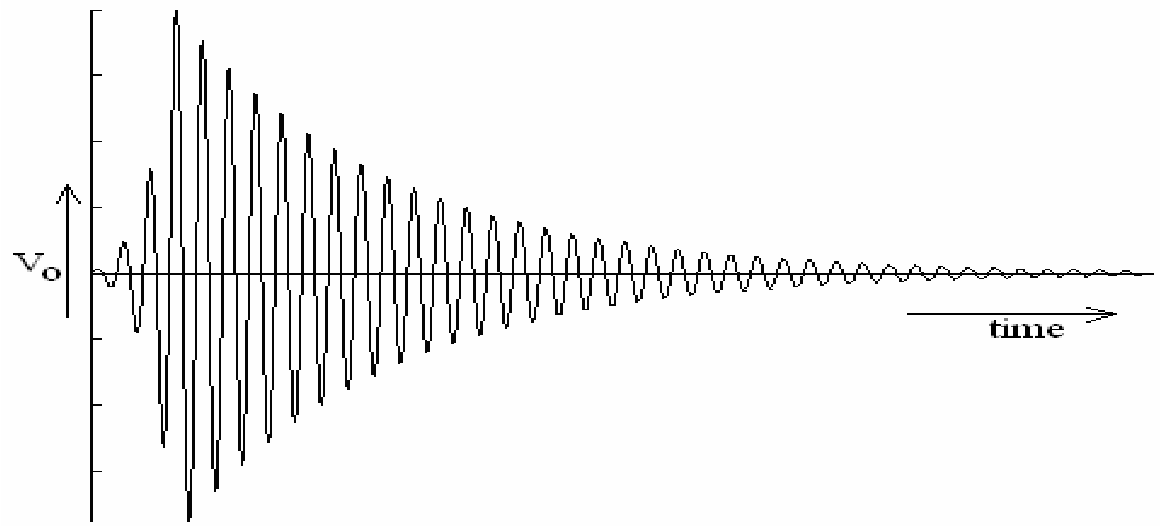
Clap detector in the block diagram shown above is used for the detection of claps, whistle detector block is used for the detection of whistles. Input to both clap detector and whistle detector is provided by one single microphone.

3.2.1 Clap Detector

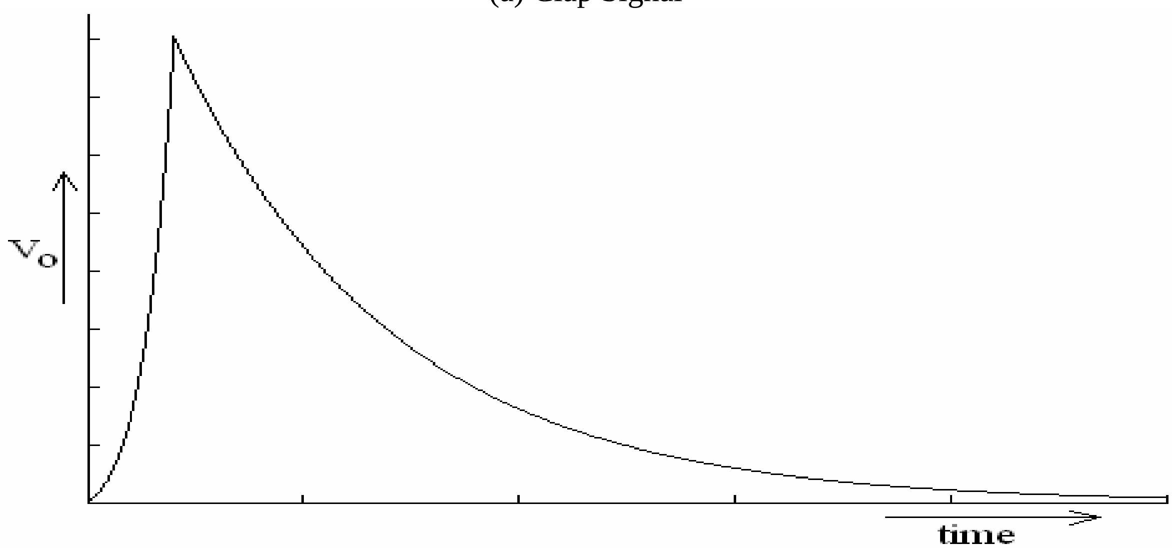
A typical clap signal is shown in Figure 3(a). As mentioned above, the aim of clap detector is to generate a pulse of duration in which, envelope of the sound signal decays to one tenth of its maximum amplitude.

3.2.1.1 Envelope detector

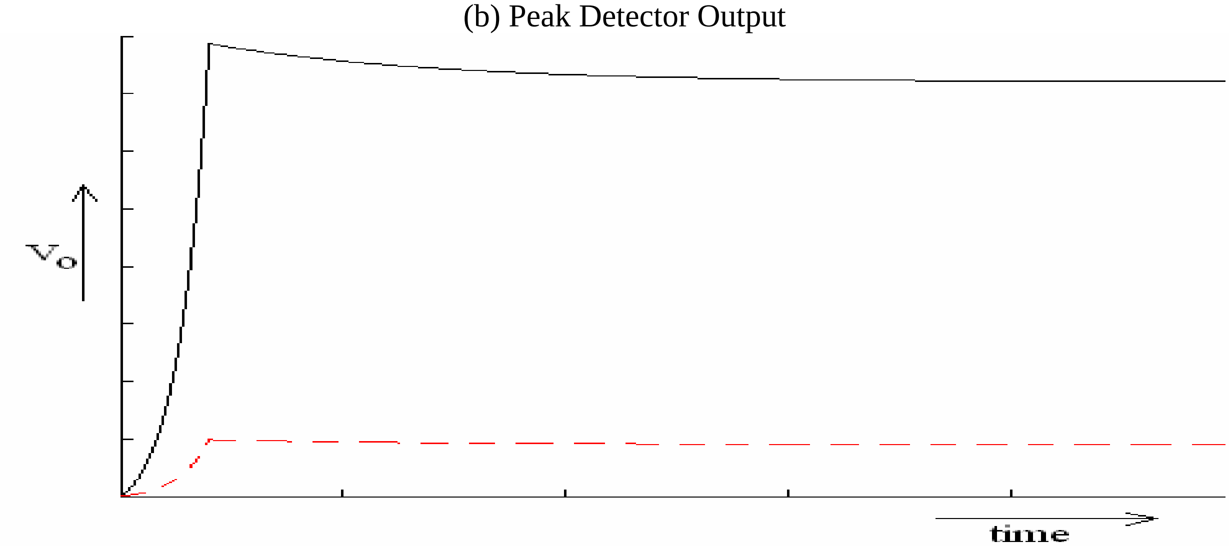
Envelope detector is a precision peak detector with a decay time much larger than the period of individual cycles but short enough to respond to envelope decay. When a positive voltage is fed to the non-inverting input, the output voltage of the op-amp forward biases the diode and charges up the capacitor. This charging last until the inverting and non-inverting inputs are at the same voltage, which is equal to the input voltage. When the non-inverting input voltage exceeds the voltage across the capacitor, the capacitor will charge up to the new peak value. Consequently, the capacitor voltage will always be equal to the greatest positive voltage applied to the non-inverting input. Once charged, the time that the peak detector holds this peak value depends on the resistance of the load that is connected to the circuit. To minimize this rate of discharge, a voltage follower is used to buffer the detector's output from any external load.



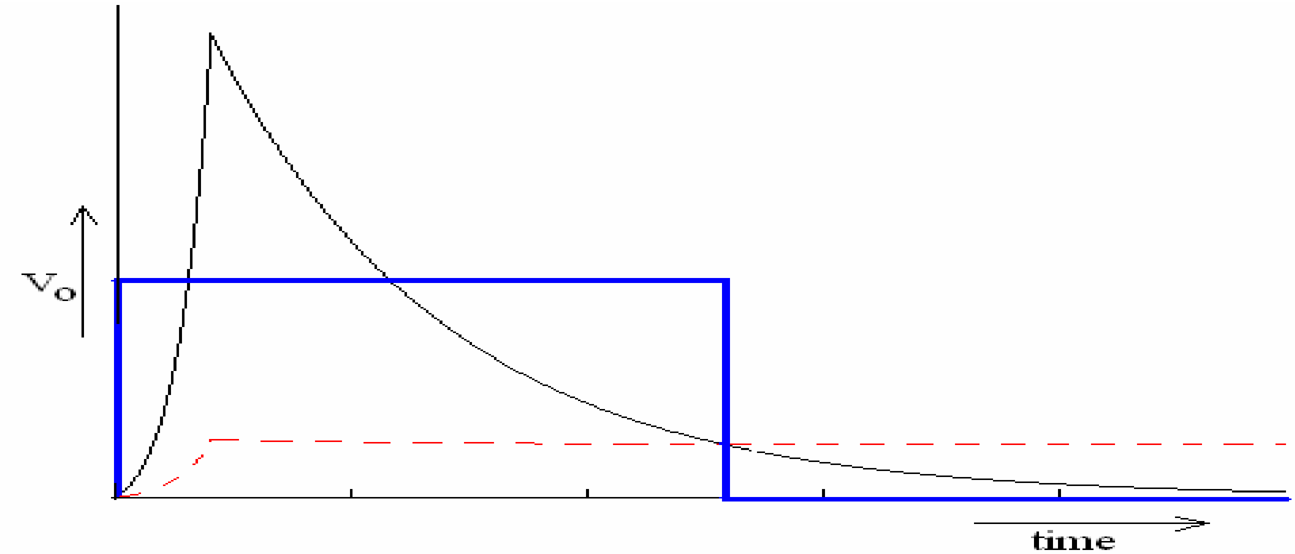
(a) Clap Signal



(b) Peak Detector Output



(c) Envelope Detector Output and Threshold



(d) Comparator Output with Threshold and Peak Detector Output

Figure 3: Clap Signal and outputs of different circuit elements

When the input's amplitude falls, the capacitor voltage is reduced by being discharged by a resistor. This charging and discharging of capacitor will give envelope of the input signal.

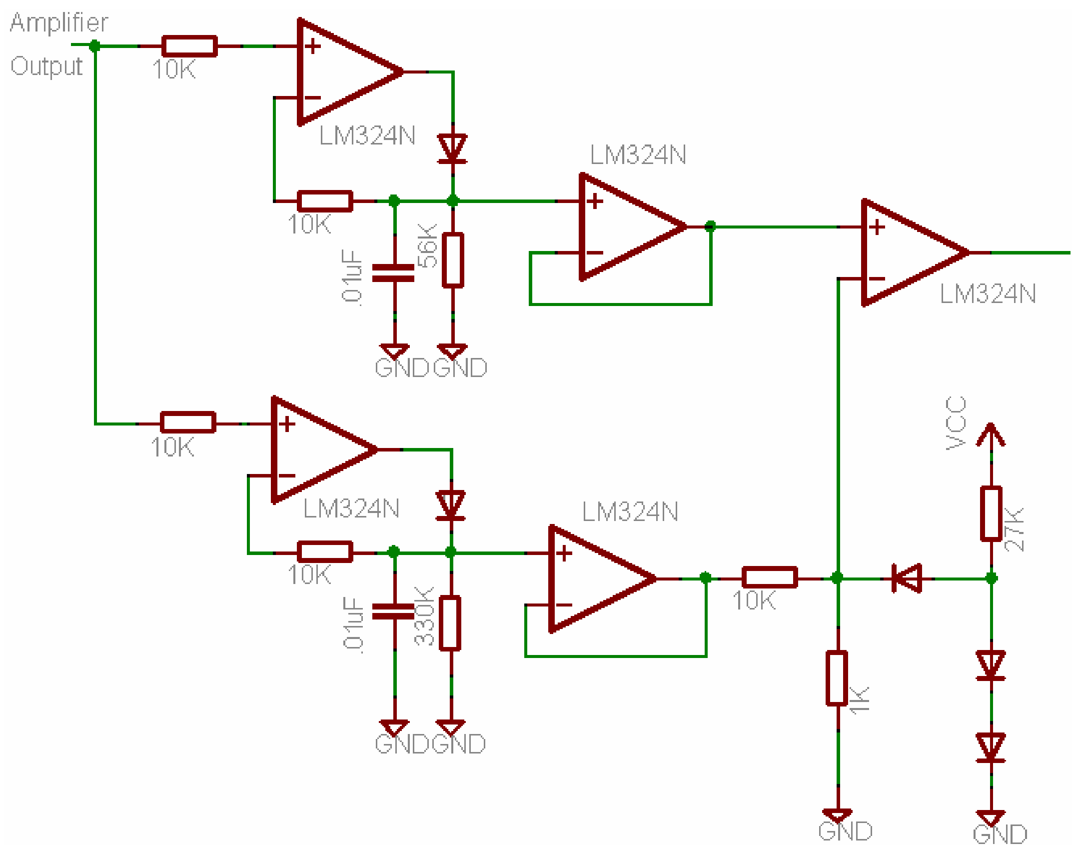


Figure 4: Envelope Detector, Peak Detector, Voltage Limiter, and Comparator

The circuit diagram of envelope detector circuit is shown in Figure 4. Output from this envelope detector on the clap input is shown in Figure 3(b).

3.2.1.2 Peak Detector

Peak of the clap is detected by a precision peak detector with a relatively large decay time, so that the peak is retained during the clap interval and the time taken for the envelope to decay to 1/10 of the peak can be detected. Circuit diagram of this peak detector is shown in Figure 4. Output from this envelope detector with the input as clap signal is shown in Figure 3(c).

3.2.1.3 Voltage limiter

Voltage limiter is used to maintain 10% of the peak detector output voltage at its output, so that the effect of noise can be minimized. Circuit diagram of the voltage limiter is shown in Figure 5. Output of the voltage limiter is plotted in Figure 3(c) in broken lines.

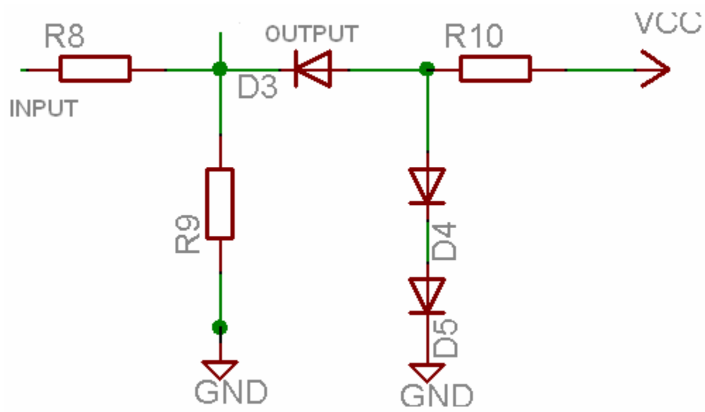


Figure 5: Voltage Limiter

3.2.1.4 Comparator

A comparator is a circuit that compares an input voltage with a reference voltage. The output of the comparator then indicates whether the input signal is either above or below the reference voltage. The output voltage saturates to the positive level when the input signal is less than the reference voltage Vref (applied to the positive terminal). When the input is higher than the reference the op-amp's output approaches the negative saturation. Output from the voltage limiter is applied at the inverting terminal of op amp and output from fast decaying envelope detector is applied to the positive terminal of op amp. Output, input, and reference voltages at the comparator are shown in Figure 3(d) in respectively bold, normal, and broken lines.

3.2.2 Whistle detector

Whistle detector of the circuit consists of the components for detection of whistles. As, mentioned above, whistles are pure sinusoids of different frequencies. A single analog circuit component (i.e. comparator) is implemented in whistle detector. V_{ref} for the comparator is set to be 0V and therefore the output from the comparator comes out to be a periodic square wave with the frequency same as that of the input sin wave.

3.3 Microcontroller

Output from the analog circuit is given as input to the microcontroller. Output from clap detector of the analog circuit is fed at pin P3.7 and that from whistle detector is fed on pin P3.5. Pin 3.5 is chosen because the event counting of timer 1 in Atmel-89C2051 occurs at this pin.

Duration of pulse from hardware in clap detector is compared with a pre-stored range. If the duration falls within the range, a counter for clap is increased. Numbers of falling zero crossings from hardware in whistle detector are counted in Timer1. Timer0 is set to count number of 50ms intervals. If the number of falling zeros in present 50ms interval is equal to that in previous 50 ms interval, the value of periodic events is increased by 1. Decisions pertaining to single/double clap and long/short whistles are taken in the output. The implemented algorithm is described below:

Algorithm:

1. *Start:*
   Initialize all registers and counter register.
2. *Start_timer:*
   timer0 and timer1 for 1.5 sec and counting events respectively.
3. *If(timer2 TH0 overflows)*
   Move TH1 in register
   If(value of register ==old value stored in another register)
   Periodic++
4. *Start_clap:*
   Count number of samples to get the width of pulse on P3.7.
   If(pulse is over)
   JMP to check_clap
   Else keep counting the period
5. *Check_clap:*
   If(1.5 sec over) go to output
   If(belong to range)
   clap++
   JMP start_clap
6. *Output:*
   Stop timer
   //Call whistle_chk
   If(periodic>=2)
   Call whistle
   Else
   If(clap ==1)

Output single clap

Else(clap==2)

Output double clap

JMP to Start

3.4 Power Supply

A 230V – 5V power supply using diode rectifiers and constant voltage regulators was designed to power up the circuit. The output of the power supply is +5 V – 0 V. The circuit diagram is as shown below.

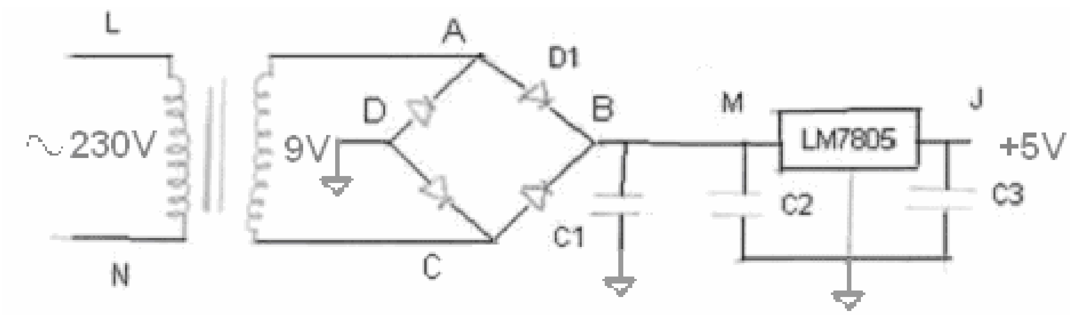


Figure 9: Power Supply

4 Complete Circuit Diagram

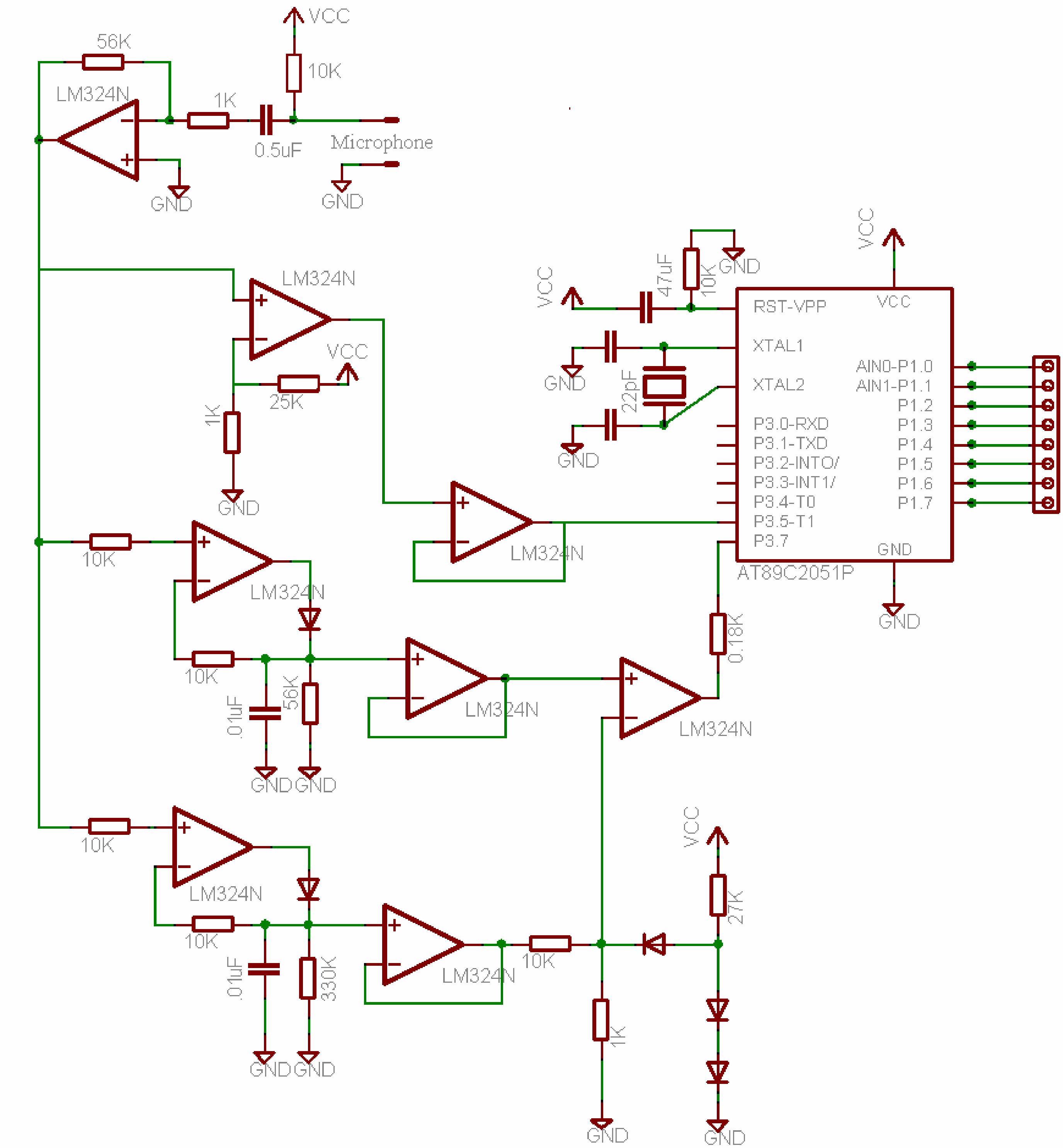


Figure 10: Circuit Diagram

5 Further Analyses

5.1 Web Search for Microphone

The circuit uses condenser microphone. Although they require an external power supply but the advantage of enhanced response scores over its disadvantage.

5.2. Environmental Noise testing

The circuit was tested in a 6m × 3m room in the presence of loud music of varying sound level and at varying distance from the music source. The performance of the circuit was good for low noise levels e.g. normal volume level of televisions in use at homes or offices. However at loud noise pertaining to the maximum television volume levels of speaker the performance was just satisfactory. The detection occurs successfully if the distance of a noise generating element, e.g. person talking, is greater than 10 cm. The detection is also successful if the clap occurs from a distance less than 2 m.

5.3. Analysis of Waveforms using SR785 Dynamic Signal Analyzer

The signal analyzer can be used for time as well as frequency domain analysis of a given signal. It also has an additional inbuilt functionality for correlation and auto-correlation. The signal analyzer was configured and the output from the audio amplifier was fed to the analyzer as the input signal.

5.3.1. Frequency Domain Analysis

The frequency domain analysis was carried on the frequency spectrum of the clap waveform. The frequency spectrum of the clap depends on its intensity. The spectrum of the clap was not found to be a band-limited signal hence the use of band pass filter does not produce any noticeable behaviors.

5.3.2. Time Domain Analysis

The earlier established fact of the constant ratio of the peak signal to time duration of the signal was also observed on the signal analyzer.

6. Conclusion

Claps and whistles are identified by the circuit from a distance of 2 to 3 meters. Tap has the same waveform as that of clap and therefore the circuit identifies tap as a clap. Simultaneous occurrence of both gives output of a whistle. Testing of circuit in varying noise decibel level and with varying distance suggest that circuit if possible should be put at maximum distance from noise generating element and should not be operated in high sound level environment.

7. References

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