Term Project
The Noise Detector

Ataberk ÖKLÜ
METU – EEE | 2305142

Student 1 : Ataberk ÖKLÜ 2305142
Student 2 : ------------------
Assistant : Murat Bayraktar

Date : 24.12.19
Group : Friday Morning

İçindekiler

Student 1 : Ataberk ÖKLÜ 2305142
Student 2 : -------------------
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Abstract

We have analyzed the process that consists of problem-solving and designing in this report. We wanted to relate noise level with blinking duration of an LED. Firstly, we elaborated the "Noise Detector" project and understood the input of the circuit. After forming a proper background for solving the problem, we have proposed a solution and analyzed it.

Introduction

In this project, we handle ambiance noise around the circuit and try to give a reasonable and understandable output to the user. Our input data is an analog signal coming from an electret microphone. We aimed that after some operations, the circuit will blink led with a premeasured amount of time. We consider four levels of noise. Each level is presented as LEDs. These thresholds are carefully designed with real data. We categorize sound levels as following:

1) 0 Level: General Ambience (0% Duty Cycle, 1Hz PWM)
2) 1 Level: Low-Level Noise (20% Duty Cycle, 1Hz PWM, Threshold: 3.2V)
3) 2 level: Medium Level Noise (50% Duty Cycle, 1Hz PWM, Threshold: 5.2V)
4) 3 Level: High-Level Noise (80% Duty Cycle, 1Hz PWM, Threshold: 8.4V)

How to handle with Input Signal

Driving an Electret Microphone

In order to obtain meaningful data from this kind of capacitive microphones, first, we ought to operate it properly, which means directly connecting this to the circuit will not work. Since this electret microphones work in principle of varying capacitance value, we should drive it as shown in Figure 2, the black cable indicating ground is connected to the common ground whereas red wire is connected as in the figure.

Figure 1 - Small Condenser Microphone

Understanding Input Signal

Our input signal is produced by a condenser microphone. This device provides us an analog signal indicating the noise simultaneously. However, we observed the signal to have a small amplitude, like in millivolts. Moreover, there exists a DC offset related to driving voltage and serially connected C1 (in Figure 2) capacitor. We can either change this C1 capacitance or differentiate the input signal in order to reduce this DC offset. We have chosen C1 to be 220nF, which is considerably small, resulting in low amplitude of the signal. Therefore, we used very short cables, kept the signal line far away from the power line, and prevented constructing loops that might have effects on to circuit due to electromagnetic noise.

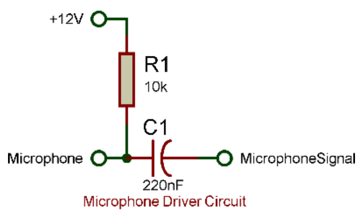

Figure 2 - Microphone Driving Circuit

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Amplifying

Since the input signal is small in amplitude, as the first step, we should amplify the input signal with an “Inverting Operational Amplifier with Negative Feedback” (Figure 3) with a noticeable gain. We magnified the signal 3.300 times via two stages. At the end of the amplifying, we obtained an analog signal with a range of 0 – 11 V.

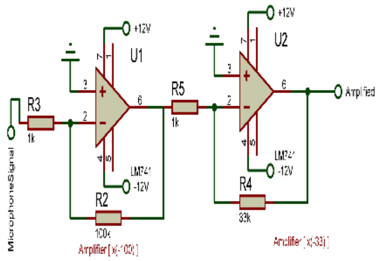

Figure 3 - Amplifying Process

Filtering

After this amplification with significant gain, there is considerable noise in the signal. Therefore, before continuing the process, we filtered the signal by using “Low-Pass RC Filter”, as shown in Figure 4. By calculation, this RC circuit results in an upper boundary around 5 kHz for frequencies. This filter provides us a more sensible and observable ambiance noise. However, this process causes a minor voltage drop. On the other hand, we could use different RC combination that we used in Experiment 7 – Preliminary Work – 2B (parallel connected R and C).

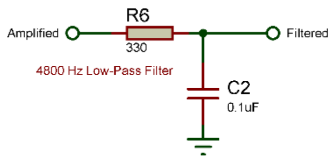

Figure 4 – RC Filter (5kHz)

Converting to absolute

At this point, we have an analog signal from -12V to 12V. If we assume that noisiness is related to the amplitude of the signal, then we should convert this signal to the absolute value of itself. By using the circuit shown in Figure 5, we obtain a comparable magnitude. We can do this process by using either bridge rectifier or Op-Amps. We have chosen Op-Amps for this process to prevent voltage drops and delays due to diodes. This combination worked very well; however, we can replace 1N4001 with 1N4148, which is a fast-reacting diode.

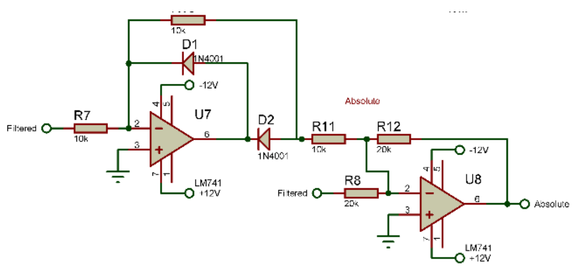

Figure 5 - Converting to Absolute Signal Process

Obtaining a meaningful noise level signal

After getting the non-negative amplitude of the amplified input signal, we want to see a more stable signal rather than a fluctuating one. Hence, we again used the RC filter (Figure 4) with higher impedance, and to compensate for the voltage drop; we used two-stage amplifiers (Figure 3) with five times gain. For the last touch, we third time filtered with a much higher impedance shown in Figure 6. After all these steps, finally, we obtain a meaningful noise level signal. Let this signal be “*Comparable Signal*”.

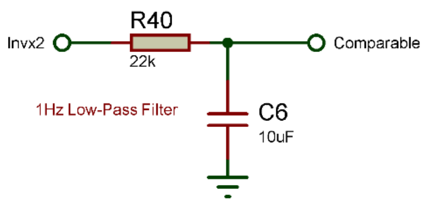

Figure 6 - RC Filter (1Hz)

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How to achieve obtaining a PWM signal with 1 Hz

PWM signal is a square waveform whose duty cycle can be adjusted. In order to create a PWM signal with a desired duty cycle, we can use a triangle wave and a comparator Op-Amp. The idea is that the compared voltage value divides the triangle wave into two parts, which are on (+12V) and off (-12V but should be 0V for PWM). To realize this idea, we should first obtain a square wave.

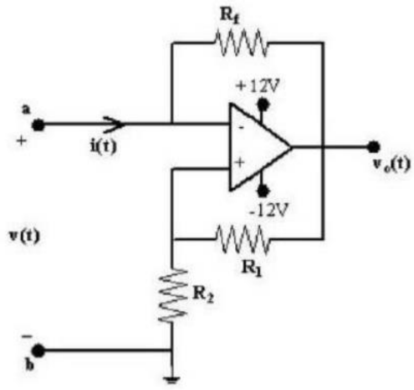

Figure 7 - Square Wave Generator

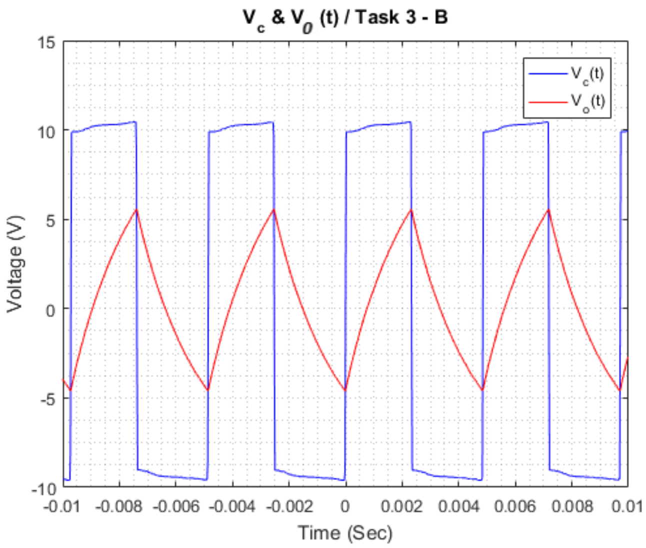

Figure 8 - Square Wave Generator Experimental Results

Square Wave

We need this square wave to obtain the desired triangle wave. In Experiment 6 – Task 3, we received square wave by the circuit shown in Figure 7. However, we should adjust the capacitor and resistor values so that we can see 1 Hz Square Wave. The capacitor is acting like a triangle wave, as indicated by the experiment result in Figure 8.

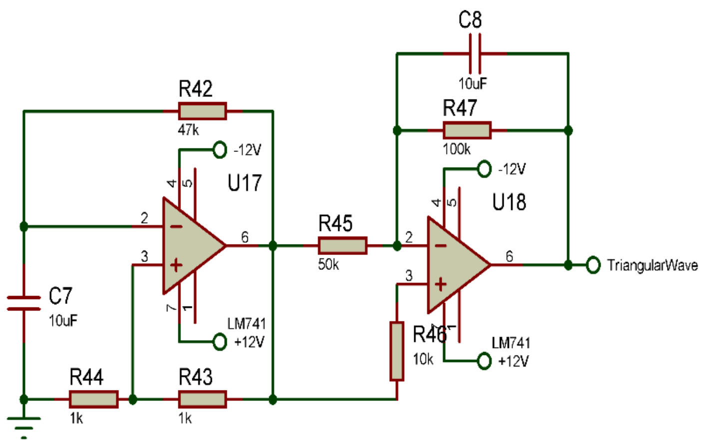

Figure 9 - Triangle Wave Generator with an integrator with gain two

Triangle Wave

At this point, we can either use buffer to get Vc as a triangle wave or use an integrator to obtain a triangle wave by square wave.

Nevertheless, integrating the square wave is more precise. Therefore, we build a circuit to generate a triangle wave with gain two by this method with properly calculated values. Calculations are specified later.

Finally, we have a 1 Hz triangle wave to generate PWM signals with desired duty cycles.

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Extract Information from "*Comparable Signal*"

We have discussed manipulations we made on the input signal to get a meaningful noise level signal. However, this only is the beginning. We need to know when and how long the noise exists and its intensity. This information is in the "*Comparable Signal*" and ready to be extracted and interpreted. Then, how do we extract them?

Noise Level

The first information required is at which noise level we are. In order to figure out what level of noise existing around the circuit, we need to compare this signal with reasonable thresholds. As we indicated in the introduction part, we have selected our limit for levels as 3.2V, 5.2V, and 8.4V, respectively. By comparing the "*Comparable Signal*" with these thresholds, we can understand how loud the noise is.

Duration of Noise

The other information useful for us is how long this noise lasts. We use this information in the PWM generation to determine how long we continue producing the proper PWM signal. When we use comparison, as explained in the "Noise Level" part, we also get a signal indication of how long the noise is exceeding this specific threshold.

To sum up this part, we basically should compare the "Comparable Signal" with stated thresholds. So, we build the circuit in Figure 10 to get proper threshold values by voltage dividing, but we did not use buffer because the input impedance of Op-Amp is much higher than that of the voltage divider. Hence, we can neglect the marginal effect of impedance. Eventually, we are ready to extract data from the signal. By using comparator Op-Amp as shown in Figure 11, we obtain both the level and duration of the noise.

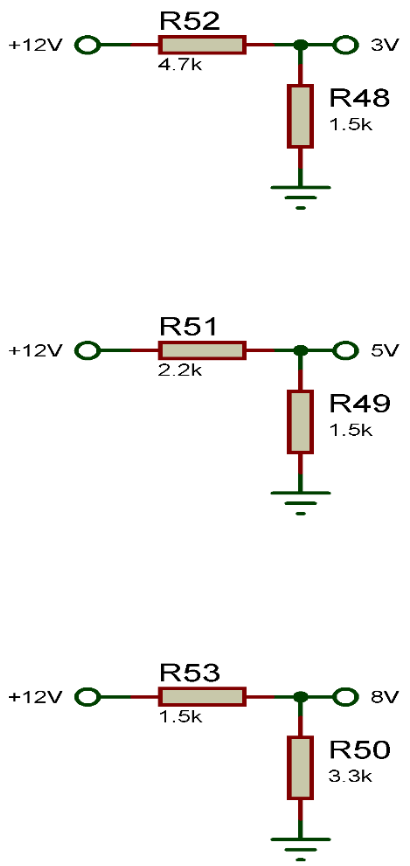

Figure 10 - Thresholds are obtained by voltage division and buffer Op-Amp

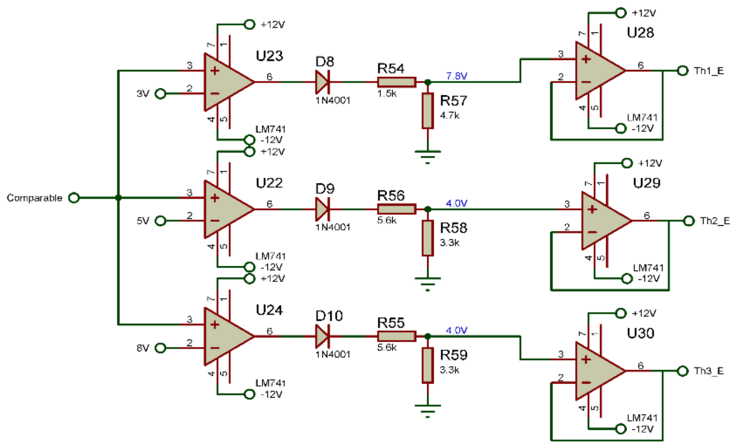

Figure 11 - Comparing the "Comparable Signal" in order to interpret its information

Diodes enable us to receive only positive values for the next voltage dividing and buffer that we are going to use to produce PWM signals with desired duty cycles. These voltage divisions and buffers will be elaborated later.

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Form a Solution

At this stage, we have all the information about noise and how to use explained sub-circuits. Now, we must gather all to construct a solution for requirements. The final output should be a 1Hz PWM signal that has various duty cycle ratios. This implies that the final output should be produced solely one device, to prevent interference between multi signals. Since we want 1 Hz PWM signal, we should use our triangle wave and comparison. We know that this comparison of the triangle wave with different constant voltages results in a square wave that has a constant ratio of activity (+Vcc and -Vcc may be related to on/off states, which is duty cycle). This comparison-constant voltage should be determined for each noise level. We have chosen these constants for each noise level to be approximately 4V, 0V, and -4V, respectively.

Design of the decision unit

Noise level activity takes a role in determining the current comparison voltage at that time. Thus, we need to relate the noise level with this process. We want a signal that satisfies the following cases:

- When in silence, should give us higher voltage that the peak voltage of our triangle, in order to obtain non-positive voltage in output.
- When in Low-Level Noise, should give us 4V, in order to produce a 1Hz PWM with a 20% duty cycle.
- When in Medium Level Noise, should give us 0V, in order to produce a 1Hz PWM with a 50% duty cycle.
- When in High-Level Noise, should give us -4V, in order to produce a 1Hz PWM with an 80% duty cycle.

As a design suggestion, we use an adder Op-Amp as shown in Figure 12.

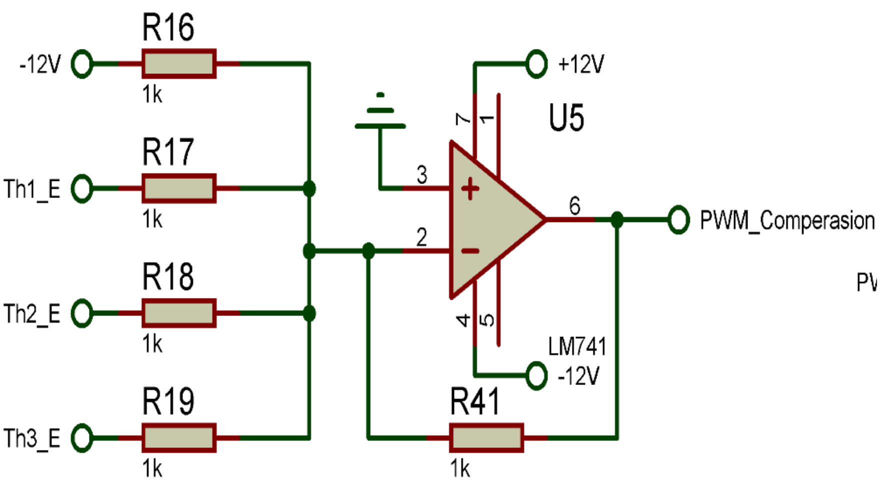

Figure 12 - Design for desired output that satisfies our cases by using "Adder Op-Amp"

Here it comes, why we used diodes, voltage division and buffer after getting the enable signals for each level in Figure 11. The voltage division is to obtain correct comparison constants for the desired output that is explained previously. Diodes enable us to have 0V for non-activated noise levels. Finally, buffers are for preventing these comparison-constants from being affected by the impedance of serially connected resistors. We used -12V power line for the adder because, in silence, we want a higher voltage output than the peak voltage of the triangle wave. For each level is activated output voltage is going to decrease to the minimum value of -4V for the high-level noise. This design satisfies our requirements and produces a 1Hz output with different ratio of activity, which is defined as $\frac{Total\ time\ of\ +Vcc}{Total\ Time\ (+Vcc\ \&\ -Vcc)}$.

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Driving the LED

Our circuit should indicate the level of noise via LED, which is a meaningful data for the user. Therefore, we need to drive the LED by defined PWM signals. So far, we managed to obtain a PWM-like signal whose only difference is that instead of 0V (GND) it has -Vcc voltage. Thus, we designed the circuit in Figure 13 in order to make LED behave as if a PWM signal drives it. The diode allows us to avoid -Vcc voltage, whereas the resistor limits the current flowing to protect the LED. Eventually, LED receives the signal as a PWM signal with a proper duty cycle.

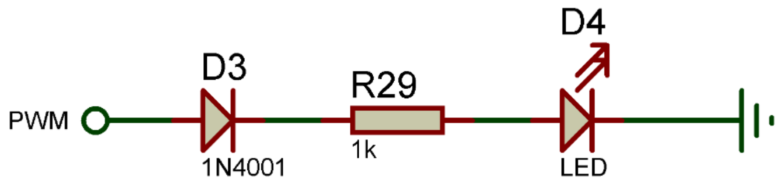

Figure 13 - Final Output - Blinking LED

Conclusion

To sum up, we started with an analog input coming from the electret microphone and modified it to be useful information for us. Operational Amplifiers are the basis of this project. We have used both our knowledge from experiments or lectures and also problem-solving ability to design proper behaving sub-circuits. We manage to generate a PWM signal that has the intended frequency and duty cycle for each level of noise. We have improved our skills and understanding of signals.

Appendix I

Total time spent on/during

- Pre-Design Report : 12 hours (average time spent on your initial research and report writing)
- Pre-Report : 28 hours (average time during the design and report writing)
- Final Report : 14 hours
- Project Implementation : 12 hours (average time spent building/debugging your design)

Appendix II: Power Consumption

Overall circuit consumption:

Voltage	**Current**	***Power***
+12 V	0.028 – 0.034 A	*0.336 – 0.408 W*
-12 V	0.018 – 0.024 A	*0.216 – 0.288 W*
	Total	***0.552 – 0.696 W***

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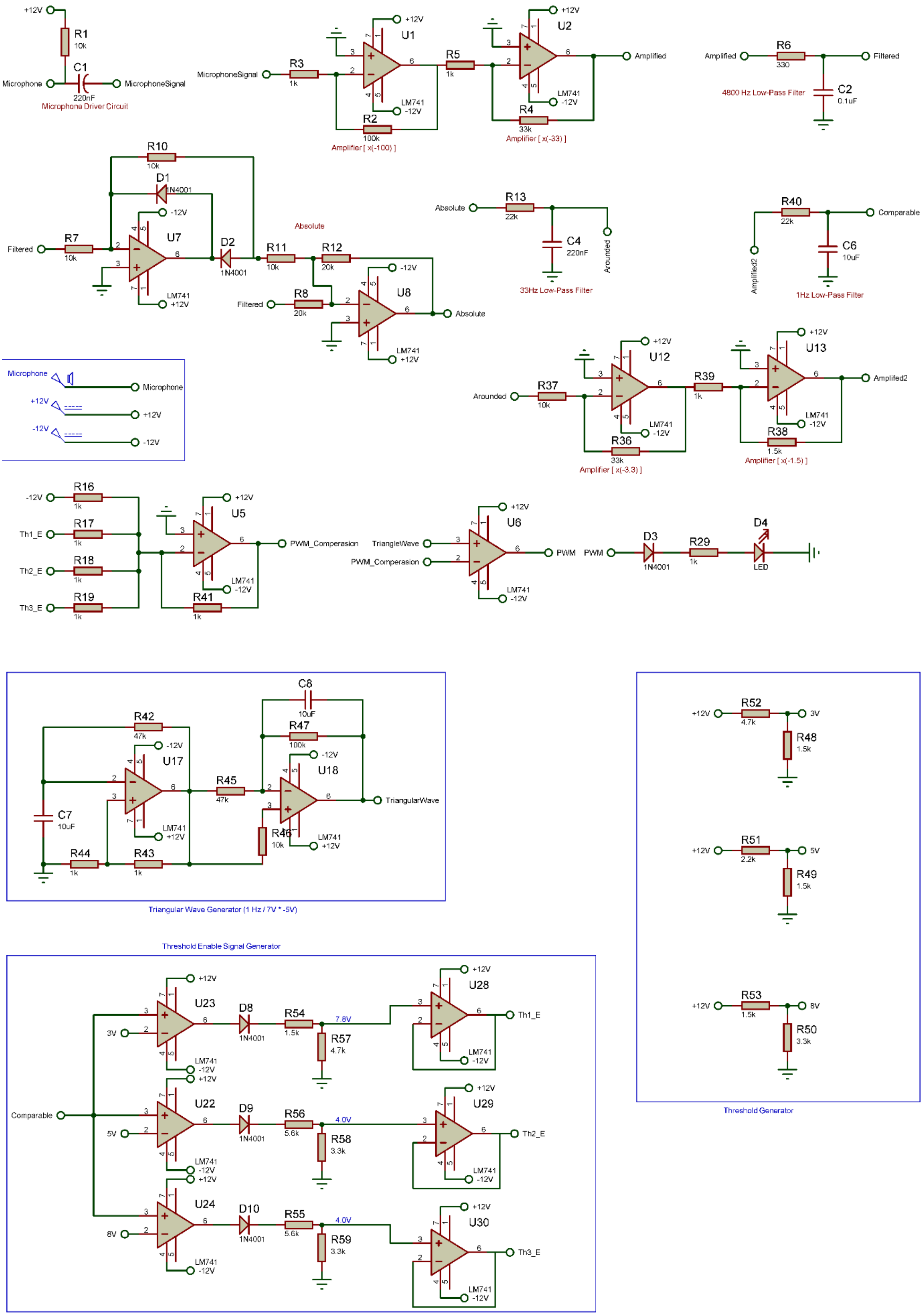
Appendix III: Overall Circuit Block Diagram



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Appendix IV: Basic Formulas

Two-Stage Inverting Amplifier

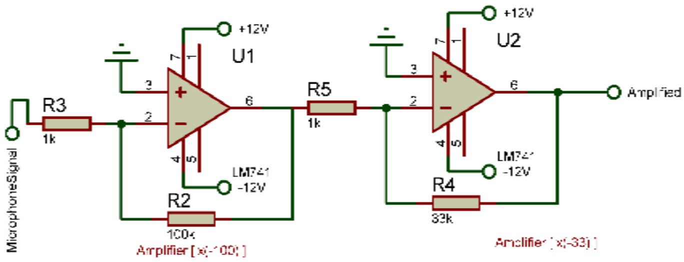


Figure 14 - Two Stage Inverting Amplifier

$$V_{out} = \left(\frac{R4}{R5} \times \frac{R2}{R3}\right) \times V_{in}$$

RC Low-Pass Filter

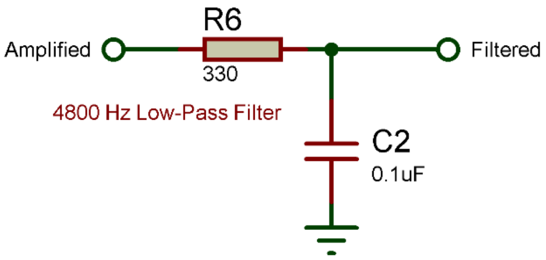


Figure 15 - RC Low-Pass Filter

$$f_c = {}^{1}/_{2\pi RC}$$

Square Wave & Triangle Wave Generator

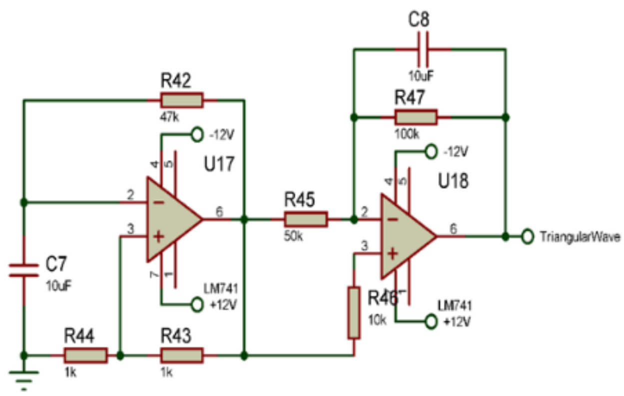


Figure 16 - Two Stage Inverting Amplifier

$$f_c = {}^{1}/_{2RC}$$

Adder Op-Amp

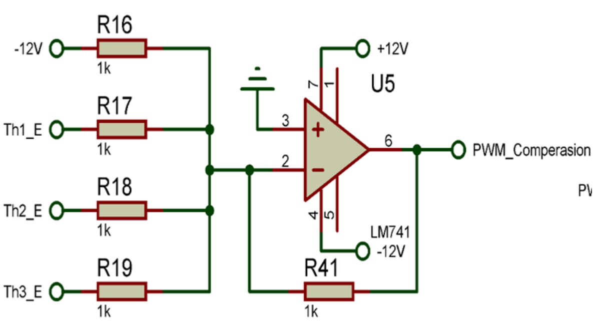
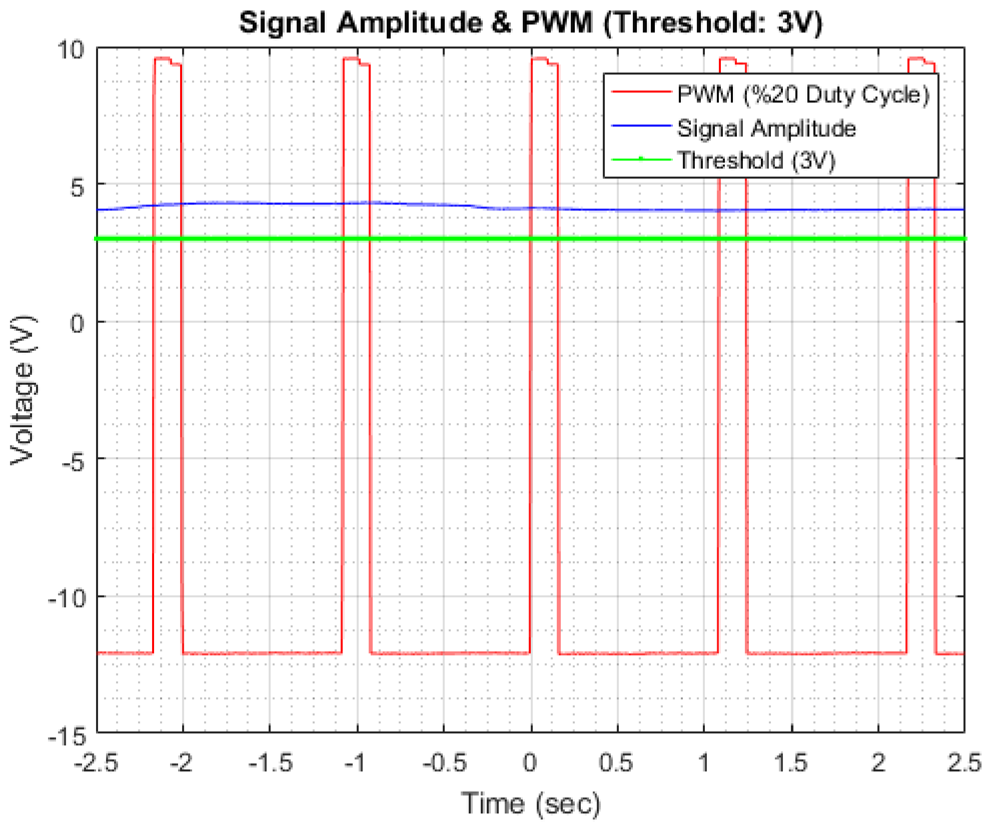
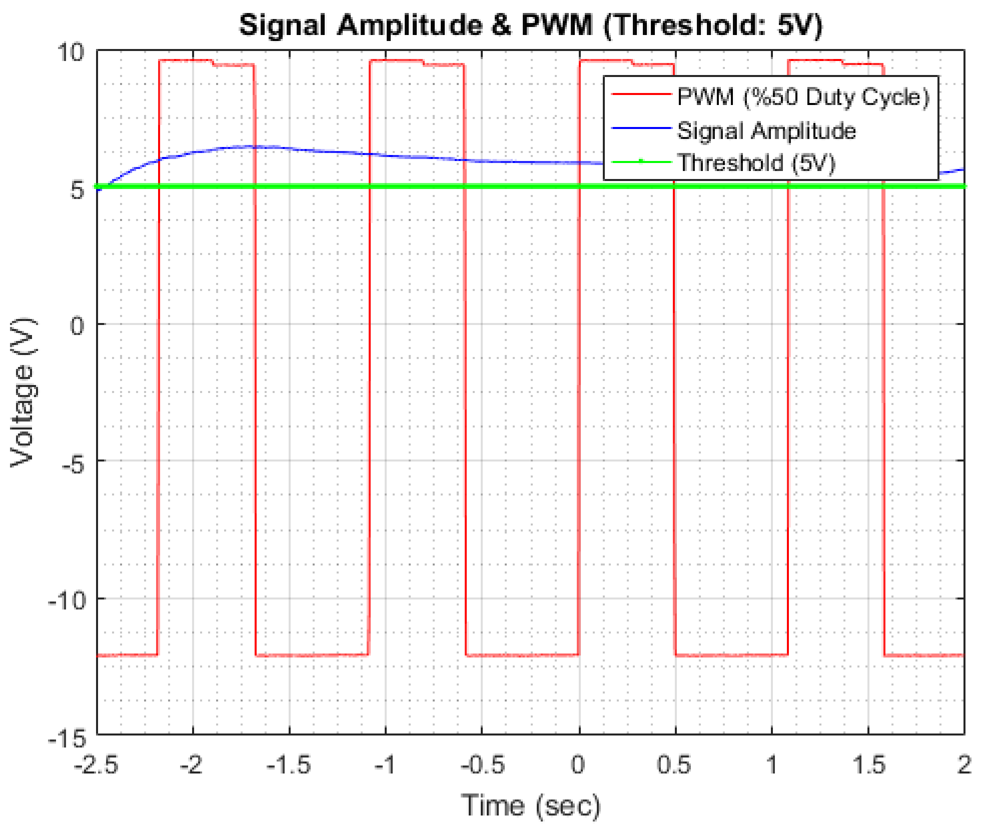


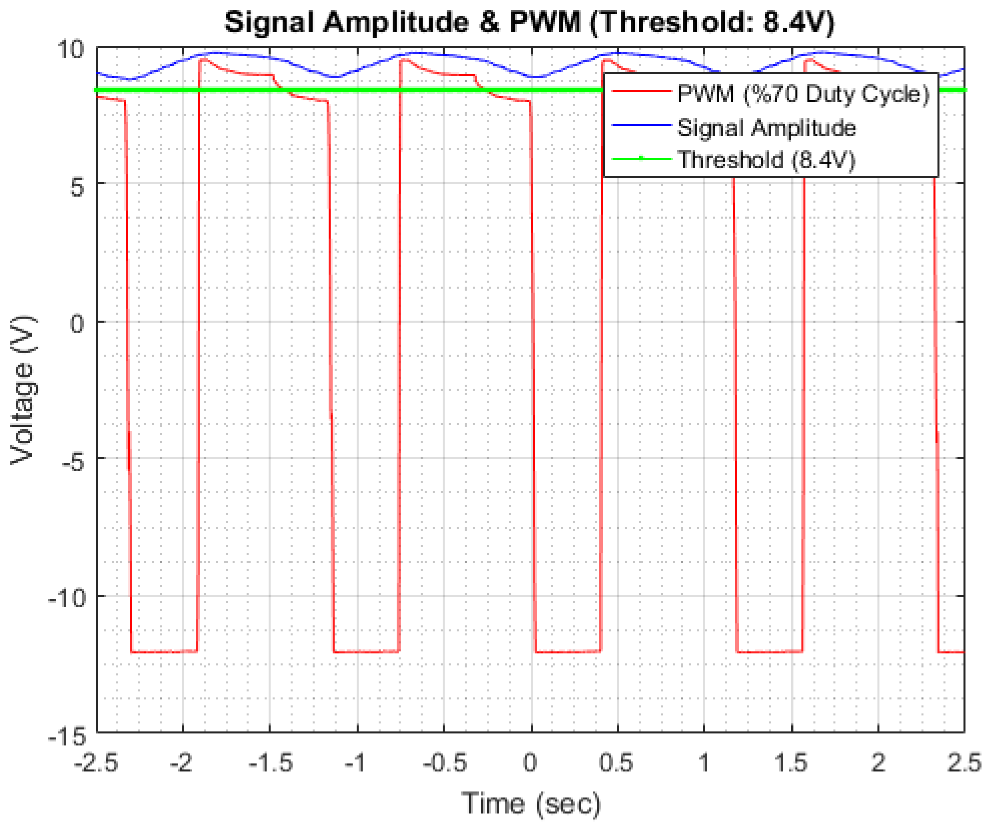
Figure 17 - Adder Op-Amp

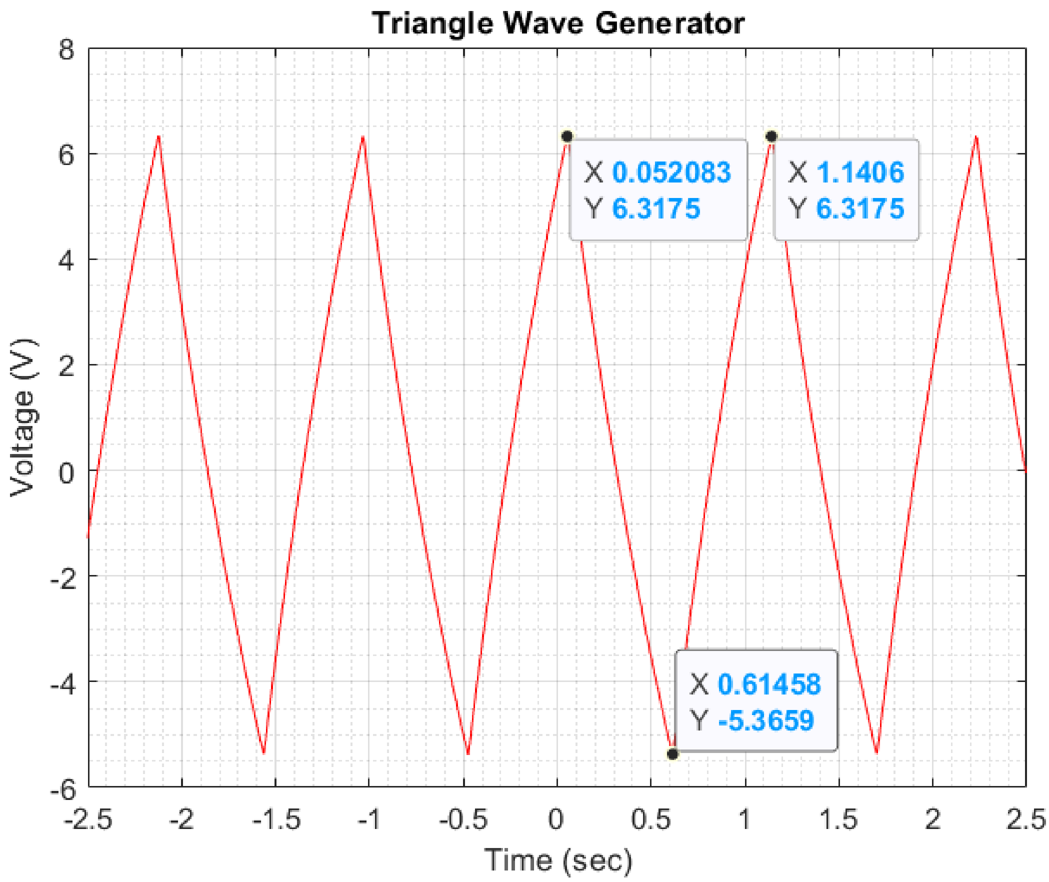
$$V_{out} = -\frac{1}{R41}(R16 \times V_1 + R17 \times V_2 + R18 \times V_3 + R19 \times V_4\ )$$

Appendix V: Simulations & Experimental Results

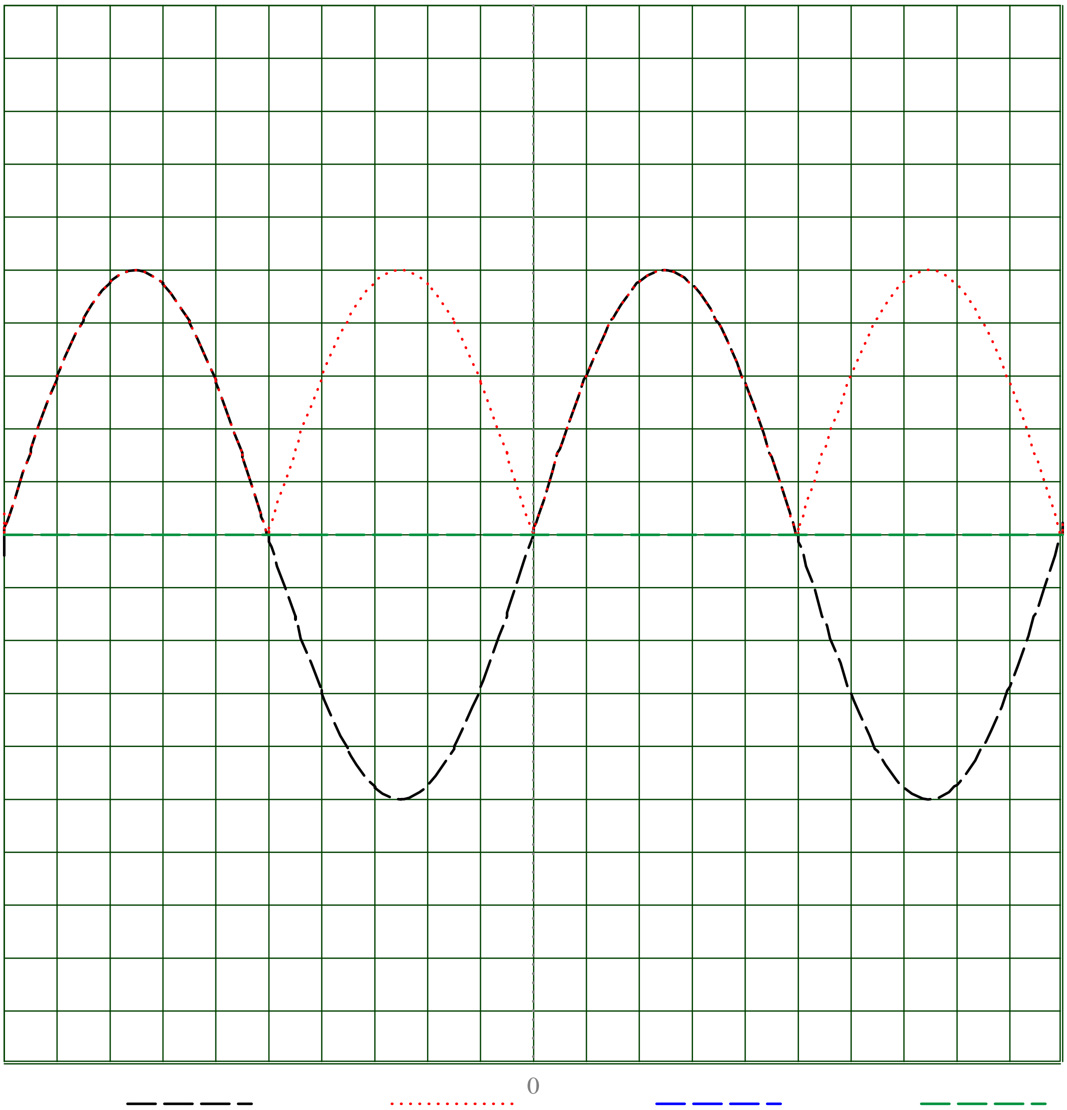





Signal Amplitude & PWM (Threshold: 8.4V)
PWM (%70 Duty Cycle)
Signal Amplitude
Threshold (8.4V)
Voltage (V)
Time (sec)
10
5
0
-5
-10
-15
-2.5
-2
-1.5
-1
-0.5
0
0.5
1
1.5
2
2.5


Triangle Wave Generator
X 0.052083
Y 6.3175
X 1.1406
Y 6.3175
X 0.61458
Y -5.3659
Voltage (V)
Time (sec)
8
6
4
2
0
-2
-4
-6
-2.5
-2
-1.5
-1
-0.5
0
0.5
1
1.5
2
2.5

Absolute Circuit Simulation



	INPUT	Absolute	OFF	GND
V/Div	1.00 V	1.00 V	1.00 V	2.00 V
Offset	0.00 V	0.00 V	0.00 V	0.00 V
Invert	Normal	Normal	Normal	Normal
Coupling	DC	DC	Off	Ground

	Horizontal
Source	Trace
Position	1.00 S
S/Div	100.00 mS

	Trigger
Source	Channel A
Level	0.00 V
Coupling	DC
Edge	Rising
Mode	Auto

Bill Of Materials for Noice_detector

Design Title	Noice_detector
Author	
Document Number	
Revision	
Design Created	22 Kasım 2019 Cuma
Design Last Modified	6 Aralık 2019 Cuma
Total Parts In Design	101

8 Capacitors

Quantity	References	Value	Unit Cost
2	C1,C4	220nF	₺0,15
1	C2	0.1uF	₺0,15
5	C3,C5-C8	10uF	₺0,15
Sub-totals:			₺1,20

59 Resistors

Quantity	References	Value	Unit Cost
7	R1,R7,R10-R11,R23,R37,R46	10k	₺0,03
3	R2,R24,R47	100k	₺0,03
12	R3,R5,R14-R19,R29,R39,R43-R44	1k	₺0,03
2	R4,R36	33k	₺0,03
1	R6	330	₺0,03
2	R8,R12	20k	₺0,03
4	R9,R22,R42,R45	47k	₺0,03
2	R13,R40	22k	₺0,03
9	R20,R31,R33-R34,R38,R48-R49,R53-R54	1.5k	₺0,03
4	R21,R30,R52,R57	4.7k	₺0,03
6	R25-R26,R35,R50,R58-R59	3.3k	₺0,03
4	R27-R28,R55-R56	5.6k	₺0,03
2	R32,R51	2.2k	₺0,03
1	R41	1k	
Sub-totals:			₺1,74

24 Integrated Circuits

Quantity	References	Value	Unit Cost
23	U1-U4,U6-U13,U17-U18,U22-U30	LM741	₺0,30
1	U14	741	
Sub-totals:			₺6,90

10 Diodes

Quantity	References	Value	Unit Cost
8	D1-D2,D5-D10	1N4001	₺0,10
1	D3	DIODE	
1	D4	LED	₺0,17
Sub-totals:			₺0,97

Totals:	₺10,81

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