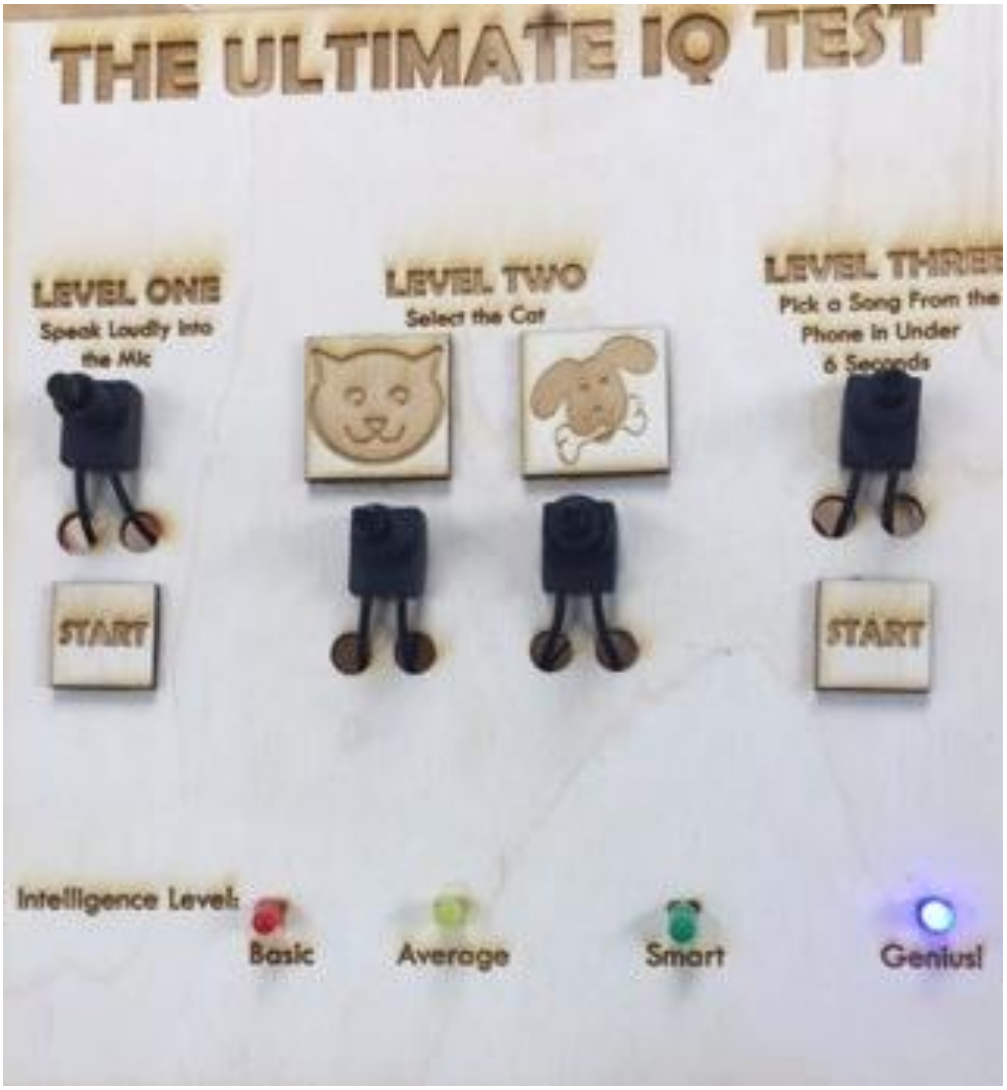
“The Ultimate IQ Test” Project



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June 18, 2017

BMME 350: Electronics

Note: This project integrated three separate circuits into a final product. Each circuit will receive its own subsection within each section.

INTRODUCTION

"The Ultimate IQ Test" project aims to integrate three different circuits into one user-friendly interface. The goal of the user is to pass each "level" in order to get a high intelligence rating, indicated by a lit LED. "Failing" a level will result in red LED illumination.

Purpose and Description

Circuit One

The purpose of circuit one is to illuminate a yellow LED when the Electret microphone is spoken into after the switch ("Start" button) is closed. This circuit will demonstrate a basic knowledge of RC high pass filters, operational amplifiers, and voltage dividers.

Circuit Two

The purpose of circuit two is to have two separate switches activate two separate LEDs. One switch ("Cat" button) will illuminate a green LED, while the other ("Dog" button) will illuminate a red LED. The goal of the player is to select the cat to win. This circuit will demonstrate a rudimentary knowledge of switches and voltage divider circuits.

Circuit Three

The purpose of circuit three is to produce one of two outputs from a single input, catalyzed by switch ("Start" button) activation. The input is music from by an iPhone's auxiliary port. One output is red LED illumination, while the other is blue LED illumination. The two are mutually exclusive. The goal of the user is to—after closing the switch—disable the red LED by playing a song which illuminates the blue LED. This circuit will demonstrate a working knowledge of op-amps, peak detectors, voltage dividers, and 555 timers.

METHOD

Circuit One

Materials

- One white 15x7.5cm breadboard
- One black 4.5x3.5x0.85cm breadboard
- Wooden laser cut interface
- One switch (button)
- Breadboard wires
- Various insulated wires
- Yellow LED

- Electret microphone
- One 5kΩ resistor
- One 1kΩ resistor
- Two 100kΩ resistors
- One 330Ω resistor
- Laboratory 4 channel power supply
- LM324N Operational amplifier
- Three power supply leads
- One .1μF Capacitor
- Gorilla Glue
- One Multimeter

Set Up

The wooden interface was designed using Adobe Illustrator and laser cut in the UNC BEAM Lab (fig 2).

The schematic used for circuit one is depicted in fig 1 below. There are several things to note: The electret microphone was placed on a separate, smaller breadboard in front of the wooden interface for convenience of the user. The wiring remained the same. Further, there was no symbol for a microphone in Multisim, so the 5Ω resistor represents the mic. The legs of the switch were soldered to insulated wires and fed through holes in the wooden interface and subsequently inserted into the breadboard in their respective positions pictured below. The body of the switch was glued to the interface. Insulated wires were also soldered to the legs of the LED; a red wire to the positive lead and a black wire to the negative lead. The LED leads were then fed through holes in the wooden interface to the white breadboard. +9V were supplied to the positive input (pin 4) of the op-amp, while –9V were supplied to the negative input (pin 11). The -9V potential was obtained by placing channels one and two in series mode (both at 9V) and connecting a red lead from the ground of channel two and to the negative input of the op-amp. Only one ground wire (from channel one) was required, as the two channels were placed in series.

The circuit was tested, and a multimeter was used to measure the microphone and op-amp output voltages (see “Results”).

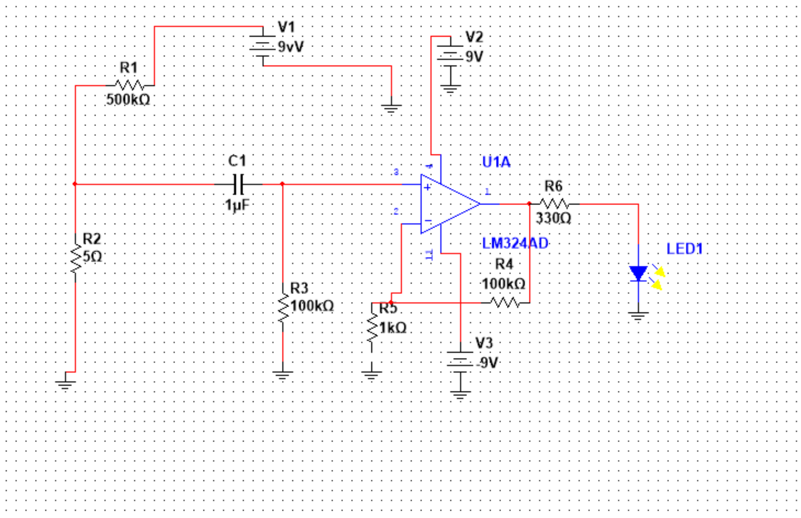

Figure 1 digital rendering of circuit one. Done in Multisim.

Figure 2 laser cut wooden interface to which the LEDs and switches were mounted.

Signals Changed

The signals changed included input voltage (from "on" to "off"), pressing of the button (closing the switch), and audio input from the mic.

Signals Observed

The signals observed included: Yellow LED illumination.

Phenomenon to Look for

There should be no signals observed from only switching on the input voltage, as the other independent variables have to be "on" in order for desired results to be obtained. Upon closing the switch, there should be no visual output without audio input. Upon applying audio input, the yellow LED should flicker in sync with the beat of the input. Input must be on and switch must be closed to observe any visual effect.

Circuit Two

Materials

- One white 15x7.5cm breadboard
- One red 4.5x3.5x0.85cm breadboard
- Wooden laser cut interface
- Two switches (buttons)
- Breadboard wires
- Various insulated wires
- Red LED
- Green LED
- Electret microphone
- Two 330Ω resistors
- Laboratory 4 channel power supply
- One power supply lead
- One Multimeter

Set Up

The setup used for circuit one is depicted in fig 3 below. Switch one represents the "Cat" button, while switch two represents the "Dog" button (fig 3). The buttons and LEDs were mounted to the interface in the manner described for circuit one. The 3.2V from the supply was directly connected to switches one and two via the breadboard.

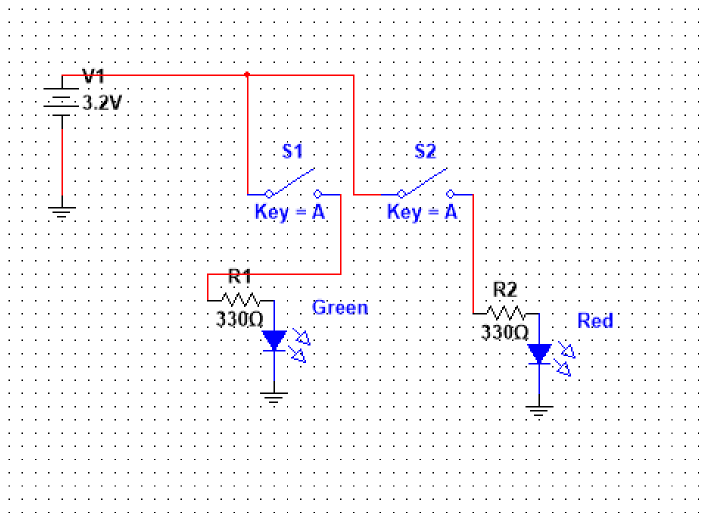

Figure 3 Theoretical digital rendering of circuit two. Done in Multisim.

Signals Changed

The signals changed included input voltage (from "on" to "off"), and pressing of the button (closing the switch).

Signals Observed

The signals observed included: Red LED illumination and/or green LED illumination.

Phenomenon to Look for

There should be no signals observed from only switching on the input voltage, as the other independent variables have to be "on" in order for desired results to be obtained. Upon closing the switch, the (pushing down the "Cat" button) green LED should light up. Upon pushing down the "Dog" button, the red LED should light up, indicating the player has lost the game. Input must be on and switch must be closed to observe any visual effect.

Circuit Three

Materials

- One white 15x7.5cm breadboard
- One blue 4.5x3.5x0.85cm breadboard
- Wooden laser cut interface
- One switch (button)
- Breadboard wires
- Various insulated wires
- Blue LED

- One 470Ω resistor
- One 47kΩ resistor
- One 1.1kΩ resistor
- Three 10 kΩ resistors
- One 20kΩ resistor
- One 330Ω resistor
- One 100µF capacitor
- One 10µF capacitor
- Laboratory 4 channel power supply
- LM324N Operational amplifier
- One TL082IP Operational Amplifier
- One 555 Timer
- Auxiliary Cord
- Gorilla Glue
- Sound emitting device with auxiliary port (iPhone)
- One 8Ω Speaker
- One Multimeter
- One Oscilloscope

Set Up

The red and blue LEDs and button were mounted to the breadboard in the same fashion described in the circuit one set up description.

The first step in assembling circuit three was to obtain an auxiliary cord. The cord was then stripped. A red insulated wire was soldered to the positive wire within the aux cord, while a black insulated wire was soldered to the negative lead. Both leads were then wrapped in electrical tape and inserted into the breadboard. The aux ground wires were attached with alligator clips to the ground strip of the larger breadboard.

Next, a red insulated wire was soldered to the positive terminal of the 8Ω speaker, a black insulated wire to the negative terminal. The positive/negative leads from the speaker and aux cord were aligned in the same vertical column on the large breadboard, allowing the signal to flow from the phone to the speaker and back, producing sound. The oscilloscope was used to measure the iPhone’s output voltage (see “Results”).

A breadboard wire was then connected from the vertical column containing the positive leads to the positive input terminal of the non-inverting amplifier pictured in fig 4 below. The theoretical gain of the amplifier (see fig 14) was two. The +-10V to the op-amp were obtained in the manner described in the circuit one set up description. An oscilloscope was used to measure the non-inverting op-amp's output signal (see "Results").

A breadboard wire was then connected from the output of the non-inverting operational amplifier to the input of the peak detector, represented by fig 4 below. The output of the peak detector on the other side of the diode was connected via the breadboard to the gate of the p-channel MOSFET used in the 555 timer. An oscilloscope was used to measure peak detector's output signal (see "Results"). Inspiration for the design of the peak detector was obtained through Circuit Lab (Robbins), and altered to serve the purpose of this project.

The 555 timer was fed a positive voltage of +7.3V. The schematic of the 555 timer is pictured below. The 10kΩ resistor at the output was connected to the source of a p-channel MOSFET. The drain of the MOSFET was connected to a 330Ω resistor in series with the red LED.

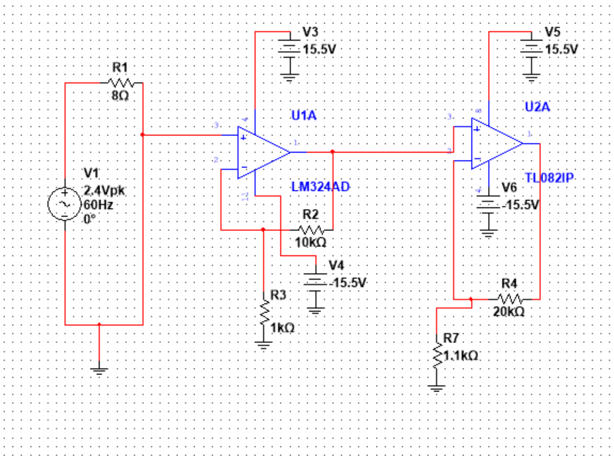

Figure 4 Theoretical digital rendering of circuit three. Done in Multisim.

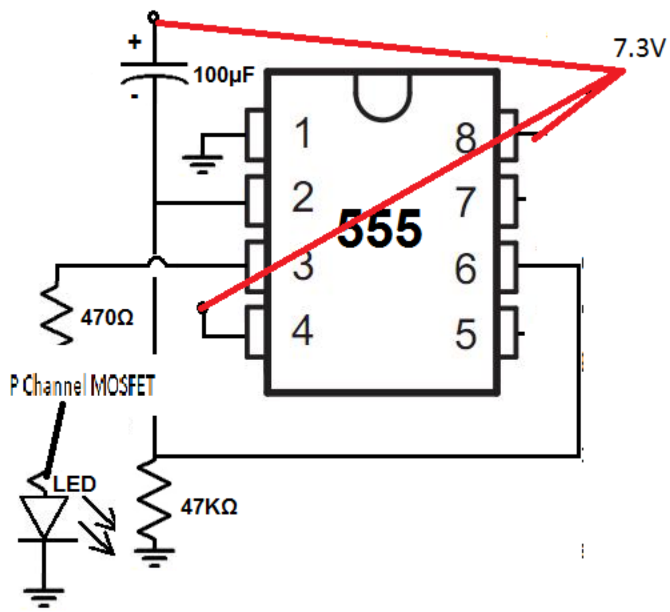

Figure 5 Theoretical digital rendering of circuit three's 555 Timer. Done in MS Paint. 555 Timer schematic obtained from Learning About Electronics ("How to Build a Delay Before Turn On Circuit with a 555 Timer")

Signals Changed

The signals changed included input voltage (from "on" to "off"), pressing of the button (closing the switch), and audio input from the auxiliary cord (from "on" to "off").

Signals Observed

The signals observed included: Red LED illumination or blue LED illumination.

Phenomenon to Look for

There should be no signals observed from only switching on the input voltage, as the other independent variables have to be "on" in order for desired results to be obtained. Upon closing the switch, the 555 timer is activated, causing red LED illumination if there is no audio input. Upon applying audio input, the blue LED should shine brightly and disable the red LED. Input must be on and switch must be closed to observe any visual effect.

RESULTS

Circuit One

Output Plots and Tables

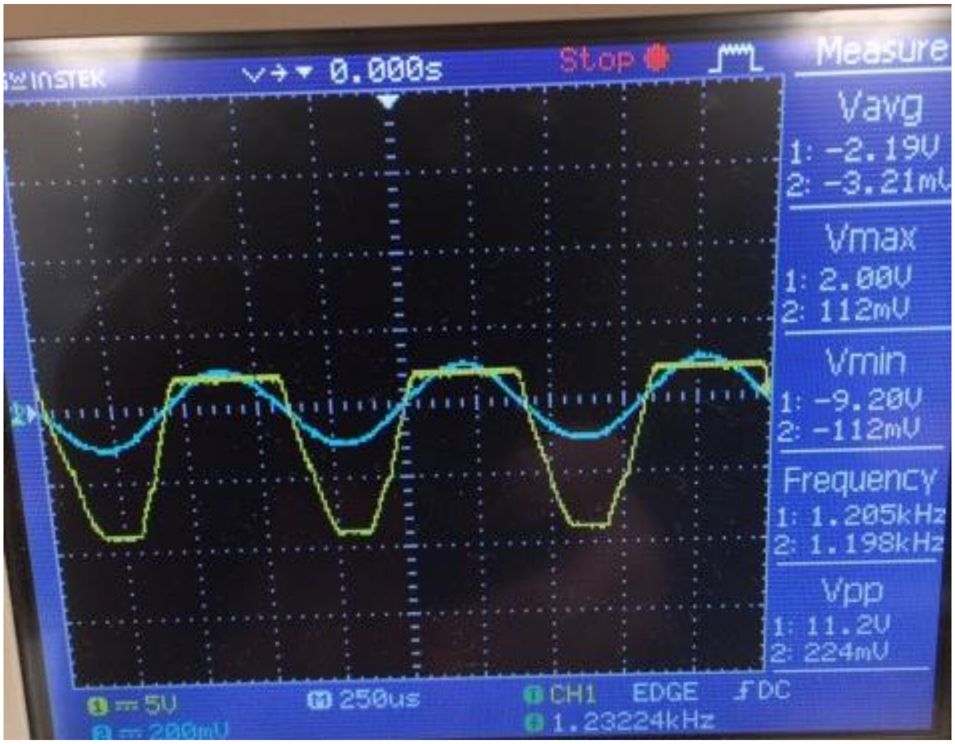

Fig 6 The yellow wave was the output of the operational amplifier, while the blue wave was the output of the microphone after being passed through the capacitor. Values were measured using an oscilloscope.

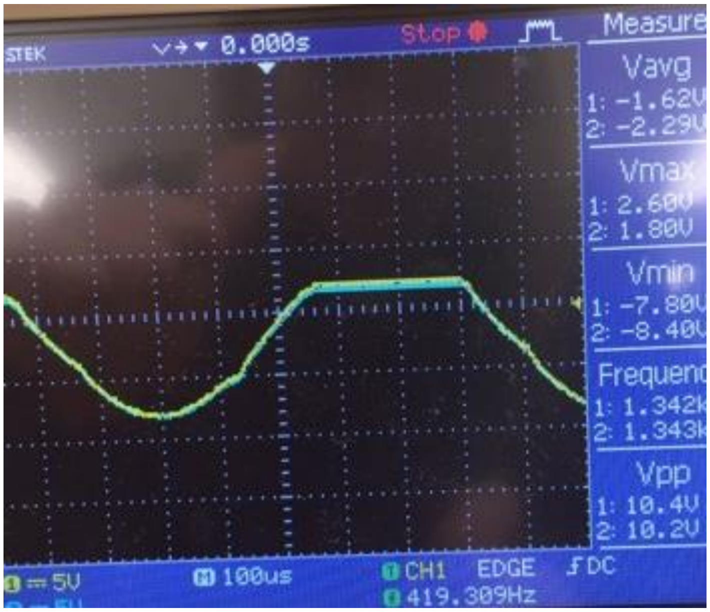

Fig 7 The yellow wave was the output of the operational amplifier, while the blue wave was the output of the yellow LED. Values were measured using an oscilloscope.

Data Trends

As seen in fig 6, the output of the operational amplifier is considerably higher than the input from the microphone exiting through the capacitor (before any voltage has been dropped). Vmax for the op-amp output is measured at 9V while Vmin is measured at -9.2V, outputting a frequency of 1.205kHz. For the mic output, Vmax was 112mV while Vmin was -112mV, operating at a frequency of 1.198kHz. The input/output frequencies were very close.

Fig 7 shows that the output from the op-amp matches the voltage across the yellow LED fairly well. When the op-amp is at Vmax (2.60V), the diode is at Vmax (1.80V). While the op-amp is at Vmin (-7.80V), the yellow diode is at a higher in magnitude -8.40V. The frequencies match extremely well (1.342kHz, 1.343kHz).

Circuit Two

Output Plots and Tables

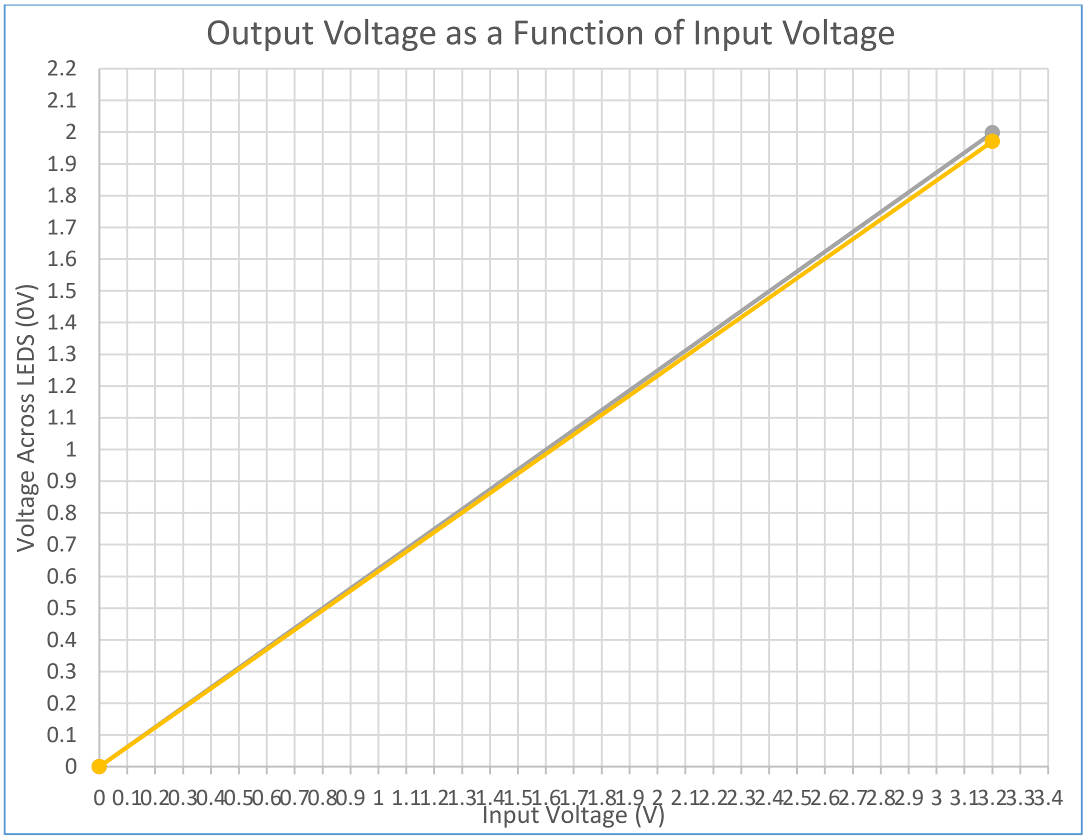

Figure 8 The yellow line represents output voltage of the green LED with both power source on and switch closed while the grey line represents the output of the red LED with both power source on and switch closed. Values were measured using a multimeter.

Table 1 Actual resistor values compared to their theoretical values. Refer to fig 3 for labeling of R1 and R2. Values were measured using a multimeter.

Resistor Number	Theoretical Value (Ω)	Actual Value (Ω)
R1	330	298
R2	330	299

Data Trends

Circuit two was a relatively simple circuit with simple trends. In accordance with fig 8, there was a direct linear correlation between input voltage and output voltage.

Table 1 demonstrates that the actual resistor values are lower than their theoretical value.

Circuit Three

555 Timer Output Plots and Tables

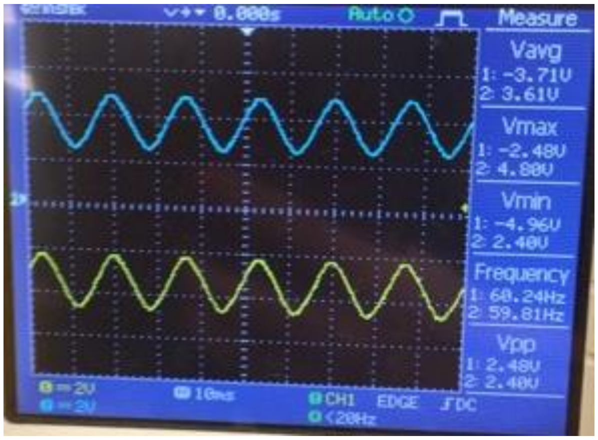

Figure 9 Channel two is the output from the DC power source before LED activation. Channel one is the voltage across the LED (output LOW).

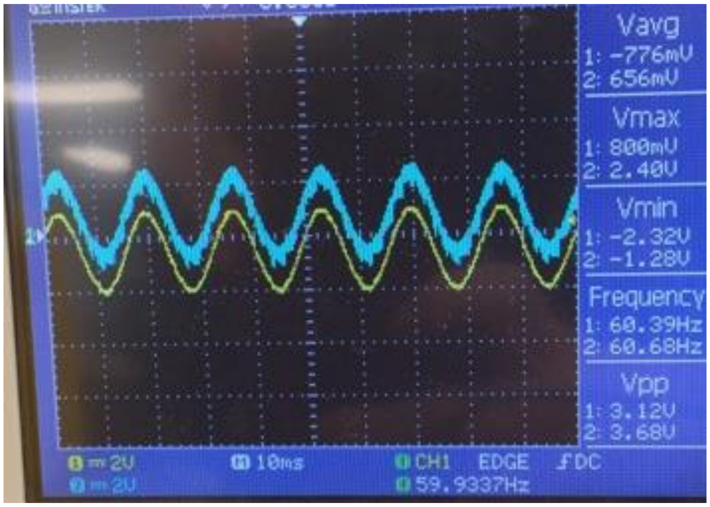

Figure 10 Channel two is the output from the DC power source. Channel one is the voltage across the LED after 6 second activation (output HIGH).

555 Timer Data Trends

Before the 6 second LED activation, the peak to peak voltage of the power source output (2.48V) matched the peak to peak voltage across the LED very well (2.40V), shown in fig 9. The source's output reaches a max value of 4.80V at this time, while its minimum value reached 2.40V. The LED's maximum value was -2.48V, while its minimum was -4.96.

After 6 seconds, the LED was activated as planned. The ensuing output is depicted in fig 10. The LED's voltage rose and reached its maximum value (800mV). At the same time, the input voltage decreased with a new maximum value of (2.40V). The peak to peak voltage also decreased to 2.12V(LED) and 3.68V (source).

The frequency of both matched ~60Hz.

Non-Inverting Amplifier Output Plots and Tables

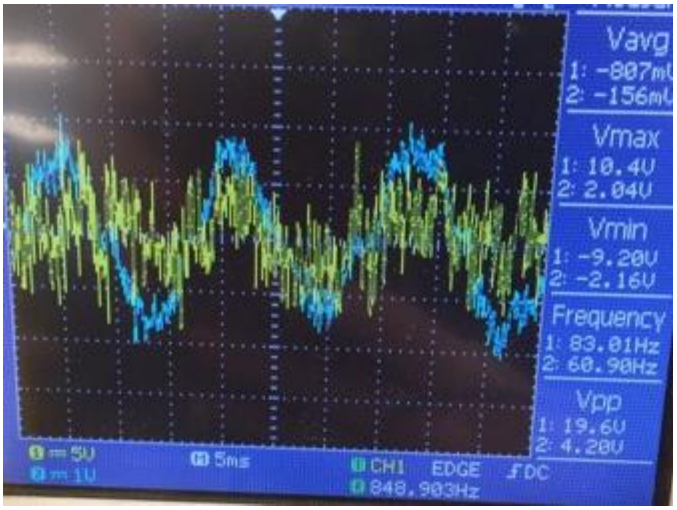

Figure 11 Channel one was the output of the non-inverting amplifier with auxiliary cord input. Channel two was the output of the auxiliary cord while music was playing.

Non Inverting Amplifier Data Trends

The op-amp amplified the signal from an input Vmax of 2.04V to an output Vmax of 10.4V. Vmin of the input was -2.16V, which is close in magnitude to the maximum input. Vmin of the output signal was -9.20, also close in magnitude to its Vmax. The output had a frequency of 83.01Hz while the input had a lower frequency of 60.90Hz. The shape of the waveforms w4ere in sync for such a variable signal.

Peak Detector Output Plots and Tables

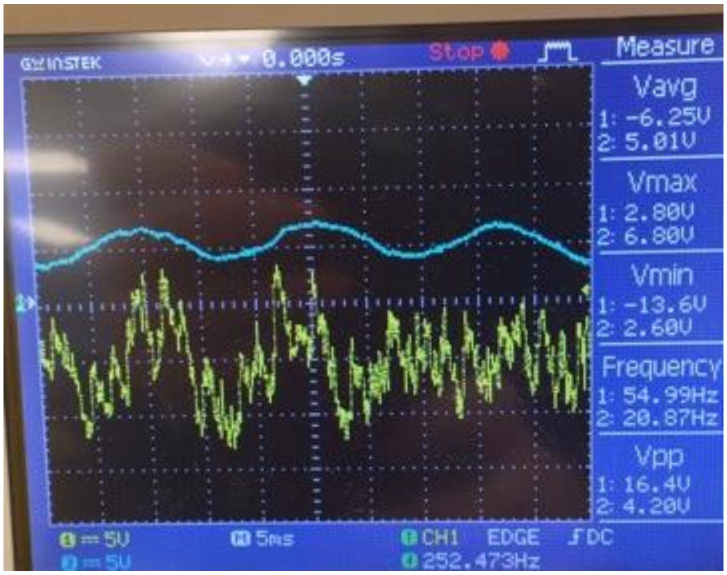

Figure 12 Depiction of input from operational amplifier (channel 1) compared to the output of the peak detector (channel 2).

Peak Detector Data Trends

Fig 12 the output of the peak detector is a much cleaner, amplified (positive amplification only) waveform. The input of the peak detector (output of the non-inverting op-amp) is jagged and has a Vmax of 2.80V in comparison with the 6.80V output from the peak detector. Vmin for the op-amp is -13.6V. The peak detector blocks this negative voltage, so it has a minimum of 2.6V and never goes negative. When the input waveform peaks, as does the output. The input has a higher frequency (54.99Hz) compared to the output (20.87Hz).

DISCUSSION

Circuit one

Theory Background

The electret microphone, powered by the 9V potential, takes audio input and feeds it into the circuit. This audio input is then fed into a RC high pass filter. A high pass filter was used because it eliminates the 9V DC input and any faint background noises, allowing for only audio inputs directed at the mic to be amplified. This fits the goal of the circuit; for the LED to illuminate when the mic is spoken into and not at other times. A high pass RC was used instead of a high pass LC circuit because inductors can act unpredictably under variable AC inputs (such as the audio input), outputting large voltage spikes which could feed unanticipated voltages into the op-amp and subsequently to the LED, which could exceed the LED's maximum voltage input.

A high gain (100) non-inverting amplifier was used to amplify the mic's very small voltage output (fig 6). The op-amp's measured output was then fed to a voltage divider circuit designed to provide an optimal input voltage to illuminate the LED—with a 1.8-2.2 maximum forward voltage (CYSLT). The 330 Ω resistor value was chosen via the equation depicted in fig 13 below. Vin was the maximum output voltage of the op-amp (see “Results” section).

$$R_{LED} = \frac{V_{in} - V_f}{I_{LED}}$$

Figure 13 Equation for determining appropriate resistor for LED voltage divider circuit (Donnelly, “Optoelectronics”).

Expected vs. Actual Results Explanation

In reference to the theory explanation above, circuit one operated closely to the its expected function. The operational amplifier successfully amplified the microphone input (“Results”), albeit at a slightly lower gain: The power rail limited the output voltage and thus gain of the system in comparison to theoretical yield. It is now clear that the op-amp could not possibly amplify to the theoretical gain of 100 in the given conditions: its output is limited by its Vcc and Vee (±9V). This was not considered until now. Subsequently, a much smaller resistor value could have been used.

$$Gain, G = \frac{V_{out}}{V_{in}}.$$

Figure 14 The formula for the gain of a non-inverting amplifier circuit (Donnelly, 2017).

The voltage across the yellow LED was a function of op-amp output, as expected (see “Results” section). The potential across the LED fluctuated between positive and negative maxima/minima. This explains the flickering visual effect of the LED: When the input goes negative, the forward-biasing LED does not illuminate. It also makes sense that Vmax(2.60) of the op-amp is higher than Vmax (1.8V) of the diode: The output from the op-amp is fed through a resistor before entering the diode, which would understandably yield a smaller voltage drop across the diode. The max input to the diode is appropriate (CYSLT). The frequency of the diode’s output matches the frequency of the op-amp’s output: 1.342kHz. This is as expected, as resistors do not change the frequency of an input signal.

Summary

Circuit one was a simple high pass filter set up fed into an op-amp. The LED behaved appropriately to the input; flickering on with ample sound and turning off when no sound a negative voltage from the op-amp was inputted.

If more time was permitted, I would have liked to feed the output of the op-amp into a peak detector so the LED would stay lit once spoken into so the user could see whether they won or not—it was hard to look at the board and speak into the mic simultaneously. This would aid in ease of use of the project.

Circuit Two

Theory Background

Circuit two was a relatively simple circuit designed mainly for aesthetic purposes for the game. The other two circuits increase the level of difficulty of the overall design.

Circuit two works through voltage dividers and switching. The 330Ω resistors were determined by the equation in fig 13 in order to supply an appropriate voltage to the LEDs.

Expected vs. Actual Results Explanation

In reference to the theory explanation above, circuit two operated very closely to the its expected function. The voltage drops across the LEDs were slightly smaller than expected (see "Results"), but this can be accounted for by the uncertainties (±10%) of the resistor values used. Therefore, the observed voltage drops are within the tolerance level for what was expected.

For the sake of the LED lifetime (CYSLT), I would have used a larger resistor value for the red LED. The red LED requires less current than the green LED. I amped up the current to the circuit (3.2V) because the green LED was not as bright as I had hoped. In retrospect I should have increased the resistor from 330Ω.

Summary

Circuit two successfully illuminated a red and green LED with switch activation and a power supply. The simple circuit served its purpose to provide loner user interaction.

If more time were available, I would have complicated the circuit a little more by making the LEDs disable one another, because if both the cat and dog were pressed both LEDs would light up, so the user would win and lose at the same time.

Circuit Three

Theory Background

The design behind circuit three was obtained from Learning About Electronics ("How to Build a Delay Before Turn On Circuit with a 555 Timer"). Research was then conducted to integrate the circuit presented on the site into this project in order to accomplish the desired visual effect. The original design was edited to fit the purpose of the circuit by adding a MOSFET before the voltage divider LED setup. A different voltage value was also used to override any leakage voltage (due to the capacitor) from the output of the Peak Detector when off.

Circuit three contained three main parts: non-inverting operational amplifier, 555 Timer circuit, and a peak detector.

Audio input was first fed from the output to the LM324 non-inverting op-amp which had a gain of 10. This op-amp was used because the input from the auxiliary cord was minute (see "Results" section).

The output of the LM324 was connected to the input of the peak detector. A peak detector was used because I wanted a steady DC current to flow through the blue LED to eliminate flickering, and the peak detector provided this. The diode was used so negative input from the LM324 would be blocked from entering the RC circuit connected to the output of the TL082. The 10µF capacitor in conjunction with the load resistor ensured that the capacitor slowly drained solely through the blue LED (via leakage current), which produced an essentially steady current to yield constant illumination.

The 555 Timer was used because I wanted a 6 second delay before the red LED was illuminated, giving the user time to disable the red LED. The 555 Timer setup works as follows: The input voltage (+7.5V) initially flows from the input to the capacitor to the trigger (pin 2), setting it to high. The trigger is active low, so no current is flowing (thus no voltage) to the red LED in the 6 seconds it takes for the capacitor to fully charge. Once the capacitor has charged, it blocks current and thus voltage to the trigger, setting it to low at which point current flows from the output, pin 3, to the source of the P-channel MOSFET. The output of the peak detector is connected to the gate of the MOSFET so that, at 0V (when sound is off), the MOSFET will be switched on because of the negative Vgs, and the red LED will be illuminated. If sound is on, the gate will have a potential higher than that of the MOSFET source because of the peak detector's large gain. This will turn off the MOSFET, disabling the LED. This achieves the purpose of the game: To give the user time to win.

Expected vs. Actual Results Explanation

In reference to the theory explanation above, circuit two behaved closely to what was expected.

The non-inverting operational amplifier theoretically applied a gain of 10 to the input signal. This was not the case: a gain of about 5 was observed. It is speculated that the op-amp did not behave ideally because of the variable signal supplied by the auxiliary cord. As noted in "Results", both the inputs and outputs varied widely with frequency spikes and dips from the music being played. This is the reason a gain of 3 was supplied to the peak detector: Ample voltage had to be emitted in order to shut down the MOSFET.

The peak detector worked close to what was expected. The peak detector smoothed the volatile op-amp output relatively well. As predicted, the peak detector's output never went negative. This resulting waveform never outputted a negative voltage. As referenced in the theory section above, the diode successfully prevented negative input. The output of the peak detector was not a completely smooth DC circuit (it fluctuated by about 4V pkpk). Ideally, the continually positive input via the diode would completely prevent the capacitor from ever discharging; the capacitor is being fed a DC current and would charge to its maximum value. However, there is leakage current leaving to the the load resistor and entering the LED.

The 555 Timer had some discrepancies in comparison to expected behavior. For example, the input to the circuit should have been the constant 7.3V supplied by the power source. This was not the case. As mentioned in the "Results" section, the max input voltage was 4.80V, lower than expected. Unlike in the theoretical model, I supplied the entire circuit with the same 7.3V source. I should have had two separate inputs to prevent voltage division. The circuit upon which I based my 555 Timer had two inputs. As expected, once the input to pin 2 (trigger) went low, the red LED peaked in voltage and illuminated constantly. The buzzer also sounded, indicating loss.

Summary

Circuit three emitted the desired effect, albeit with some strange behavior from the 555 Timer. The input/output values should have been higher, yet they yielded lower values than expected. The peak detector and non-inverting operational amplifier served their purpose.

If more time were allotted I would have perfected my timer to function exactly how I wanted it to (to adhere to theory).

LITERATURE CITED

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