ENPH 259 - John van der Kuur
Exp. 6 (Final Project)/6c Servo Motor/Final Lab Project

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on

Dec 04, 2017 @08:47 PM PST

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Final Lab Project

SIGNED by John van der Kuur Dec 04, 2017 @08:47 PM PST

• John van der Kuur • Nov 08, 2017 @02:10 PM PST

Partner: Jeremy Wiens

• John van der Kuur • Nov 20, 2017 @06:50 PM PST

1 Objectives

• John van der Kuur • Nov 20, 2017 @06:58 PM PST

Using devices which have been previously investigated in ENPH 259 (Op Amps, counters, and transistors) combined with some new ones (LEDs, photo-transistors, buffers, and resistor ladder networks), create a circuit which can set and control the speed of an electric motor.

• John van der Kuur • Nov 20, 2017 @06:58 PM PST

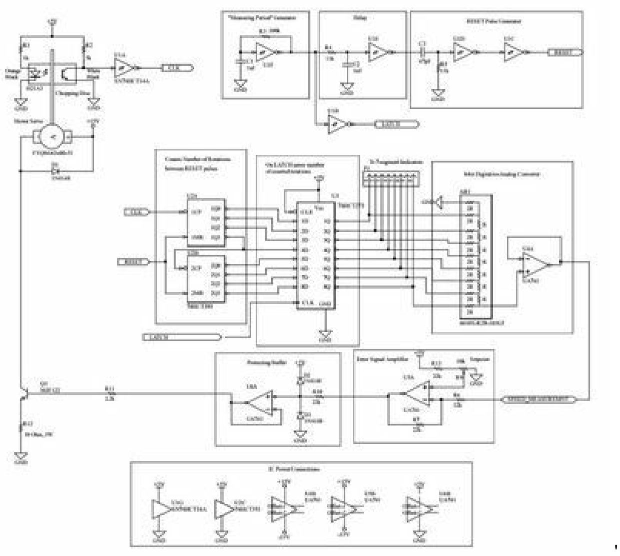
2 Introduction

• John van der Kuur • Nov 20, 2017 @07:15 PM PST

A servo control loop circuit utilizes feedback to actively control different quantitative properties, e.g. (temperature or speed). These devices are used everywhere in our everyday lives. In this lab, we are building a circuit which uses the input current to control the motor speed which changes the revolutions per minute of the motor. The figure below shows the entire circuit which will be created.

The motor works by measuring the amount of times a slit in a disc (which is attached to the motor) passes over a photo-transistor. Every time the slit passes over the photo-transistor, some light generates a current and creates a clock pulse. A counter then counts how many clock pulses there are before a Reset pulse and stores that value with an 8-bit D-Latch. The digital D-Latch signal is converted to a analog signal using an R - 2R ladder network. This analog output is then compared to a voltage representing a set point for the motor speed. The difference between the two values is then re-transmitted to the motor and controlled using a power transistor.

• John van der Kuur • Nov 20, 2017 @07:00 PM PST



Full_System_Circuit.JPG(92 KB) - download

• John van der Kuur • Nov 20, 2017 @07:20 PM PST

There are 5 components which must be constructed for this circuit:

1. Latch and Reset Generator
2. Counter and D-Latch
3. 8-bit DAC (Digital to analog converter)
4. Motor Sensor and Motor Driver
5. Error Signal Amplifier/buffer

We are making sure to keep this circuit Neat and Tidy since this will save hours of trouble shooting. We will also plan out where each of the components will go on the breadboard to save space and make sure we don't run into problems later. When each component is built, the operation of the component must be reported on to understand what it is doing and if it is doing it properly.

• John van der Kuur • Nov 08, 2017 @02:12 PM PST

3 Components

• John van der Kuur • Nov 08, 2017 @02:12 PM PST

3.1 Latch and Reset generator

• John van der Kuur • Nov 08, 2017 @02:54 PM PST

Measuring Hysterisis: 3.1.1

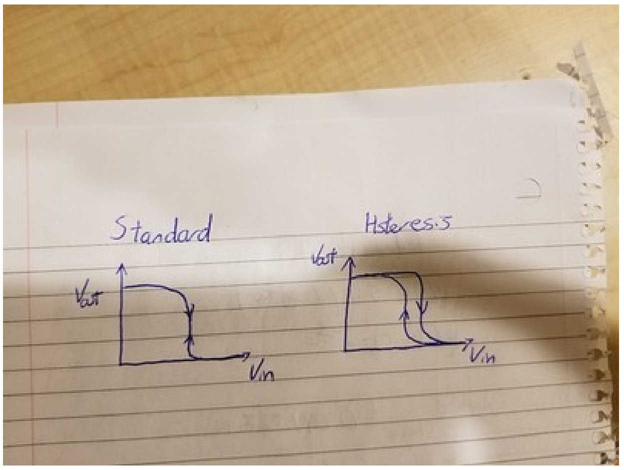
• John van der Kuur • Nov 20, 2017 @06:01 PM PST

The first thing we needed to do was measure the Hysteresis for a Schmitt-Trigger Inverter which is one of the components we'll be using for our circuit. The effects of a hysteresis on an inverter is shown below:

When the input voltage changes from Low → High, the Output is changed at a Voltage of 2.72 +/- 0.08 V

Similarly, when the voltage changes from High → Low, the output voltage is changed at a voltage of 1.76 +/- 0.08 V

• John van der Kuur • Nov 20, 2017 @06:02 PM PST



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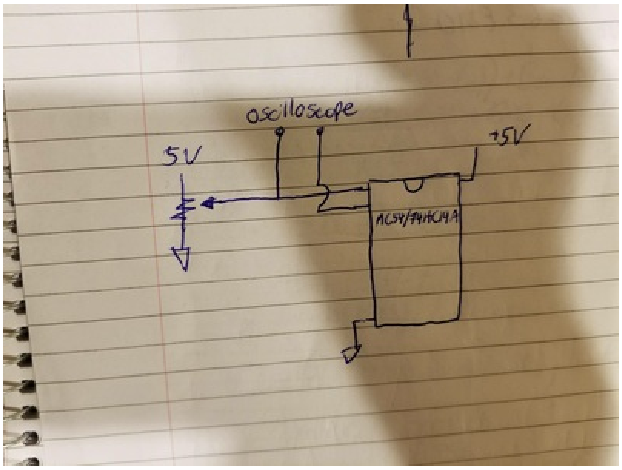
• John van der Kuur • Nov 20, 2017 @06:10 PM PST

Construct The circuit shown below to test the Hysteresis of a Schmitt-Trigger Inverter:

- Attach the +5V source to the breadboard
- Place the Inverter-Package over the bridge on the breadboard
- Ground the GND pin and apply 5V to V_{cc} according to the MC54/74HC14A while paying attention to the orientation of the device
- Use the on-board potentiometer and apply +5V to the right pin of the potentiometer and ground the left pin
- Run the output of the potentiometer into the input of one of the inverters from the device and into the Oscilloscope using a BNC cable
- Attach the output of the inverter into the Oscilloscope using a BNC cable
- Simultaneously measure the input and outputs and take note at what input voltages the output voltages switch at.

• John van der Kuur • Nov 20, 2017 @06:10 PM PST



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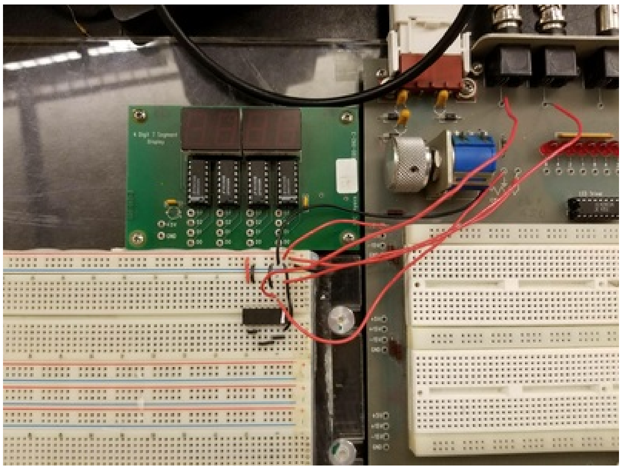
• John van der Kuur • Nov 20, 2017 @06:11 PM PST



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• John van der Kuur • Nov 08, 2017 @03:06 PM PST

Why is this useful?

The Schmitt-trigger can negate noise compared to a regular inverter because it has a buffer zone of around 1V (for this device). So even if the input voltage has some fluctuations, it doesn't impact the output voltage of high or low as long as it is within the 1V buffer zone. Similarly, if a input takes a long time to charge to it's maximum value or takes a long time to discharge to it's minimum value, the Schmitt inverter will compensate for this by dropping the voltage to Low after the discharge voltage decreases to 1.76V or by immediately increasing the output voltage after the charging voltage reaches 2.72 V.

• John van der Kuur • Nov 20, 2017 @06:12 PM PST

3.1.2 Measuring the Period

• John van der Kuur • Nov 20, 2017 @06:22 PM PST

The next step is to create the "Measuring Period" Generator component of the system.

Construct the system according to the diagram below:

- Ensure that the V_{cc} is connected to +5V and GND is grounded.
- Ground one end of a capacitor and attach the other end into the input of an inverter
- Run a feedback resistor from the output of the inverter into the input of the same resistor
- Measure both the input and outputs of the inverter with the Oscilloscope with BNC cables

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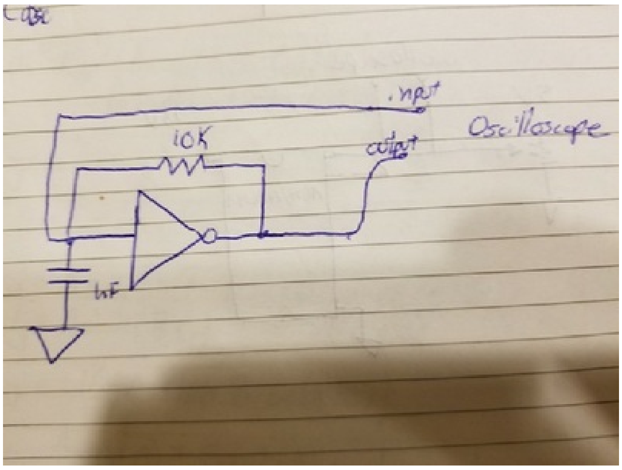

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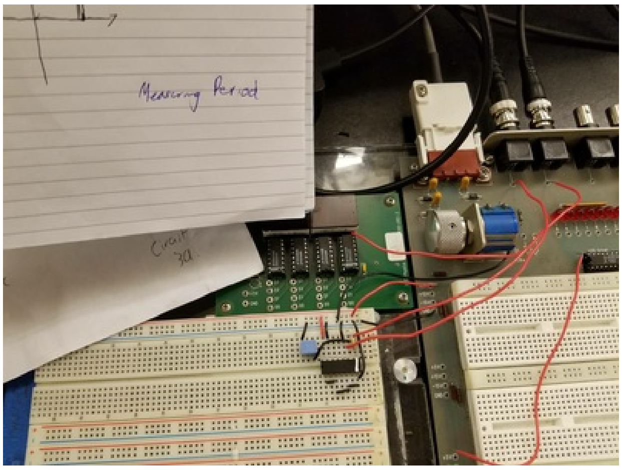

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These are our measured values from the Period Generator

Resistor = 98.590 kΩ

Capacitor = 1 +/- 0.1 µF

Output Voltage changes (off to on) at Voltage 1.58 +/- 0.08 V

Output Voltage changes (on to off) at Voltage 2.68+/- 0.08 V

Measured Period = 93.2 +/- 0.8 ms

Note - The hysteresis values for the voltages were slightly different than the values measured in 3.1.1

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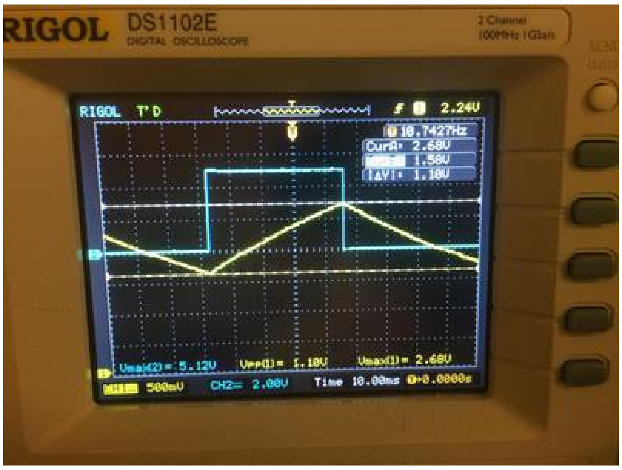

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I then calculated the expected period using the following formulas below and calculated the uncertainties.

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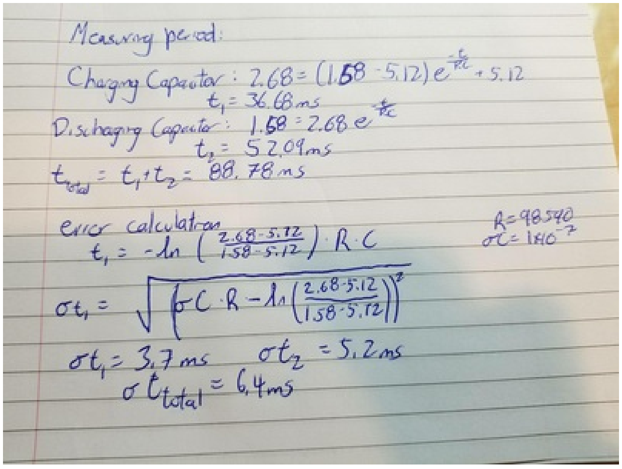

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Note: The capacitance had the largest effect on error by a large margin so I only did error calculations with the capacitance error taken into account.

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Calculated Period = 88.9 +/- 6.4 ms

Measured Period = 93.2 +/- 0.8 ms

When the uncertainties are taken into account, it is clear to see that the values are within the uncertainty range of each other so I can be confident in my answers.

• John van der Kuur • Nov 20, 2017 @06:24 PM PST

3.1.3 Measuring Delay

• John van der Kuur • Dec 04, 2017 @04:33 PM PST

Now, similarly to measuring the period, the delay component of the circuit must be constructed and measured.

Using the same technique for the other components build the Delay Component shown below:

- Measure the inputs and outputs using the oscilloscope

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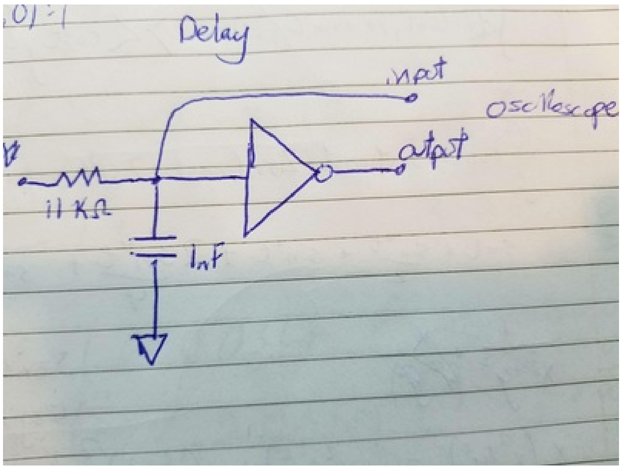

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• John van der Kuur • Nov 20, 2017 @08:20 PM PST

Two resistors were used in series, a 10 kΩ and a 1 kΩ resistor to obtain a 11 kΩ resistor.

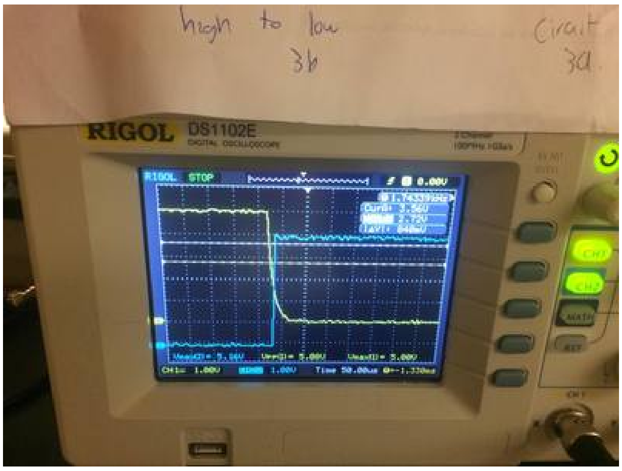
The total measured resistor from the new resistor was measured as 10.820 +/- 0.021 kΩ

A 1 +/- 0.1 nF capacitor was used as well.

• John van der Kuur • Nov 20, 2017 @08:39 PM PST

The waveform was obtained from the oscilloscope when measuring the high to low output Voltage to measure the delay.

• John van der Kuur • Nov 20, 2017 @08:38 PM PST



23825491_10212806549696683_1697933281_o.jpg(528 KB) - download Photo taken by Jeremy Wiens

• John van der Kuur • Dec 04, 2017 @04:33 PM PST

Measuring the delay:

Vout - (Low to high) = 2.72 V, Delay = 48.0 +/- 1.2 µs

Vout - (High to Low) = 1.76 V Delay = 12.8 +/- 1.2 µs

• John van der Kuur • Nov 20, 2017 @09:03 PM PST

The delay component in the circuit delays the signal by charging and discharging the 1nF capacitor. It receives the output from the Measuring Period Generator. When the output of the Measuring Period generator is high, the input to a high input for the delay component. Eventually the capacitor in the delay component will be fully charged and the output of the "measuring period" will then be low. The delay's input will switch to low after the capacitor is discharged, so during that time when the capacitor is discharging, the output of the "measuring period" is low and the input of the delay is high. Once both the "measuring period" is low and the capacitor is discharged, the delay will be at a high voltage level. The "measuring period" will then be switched back to high, and once the capacitor is charged, the output of the delay will revert back to a low position.

• John van der Kuur • Nov 20, 2017 @06:26 PM PST

3.1.4 Measuring the Reset Pulse Generator

• John van der Kuur • Nov 20, 2017 @08:49 PM PST

We then built the Reset Component of the circuit shown below:

- Use two inverters from the inverter package and connect them in series
- Measure the inputs and outputs once again using the oscilloscope
- For the input signal, attach the function generator using a BNC cable
    - Set the function generator to the pulse function with a 10% duty cycle and a Vpp of 5V

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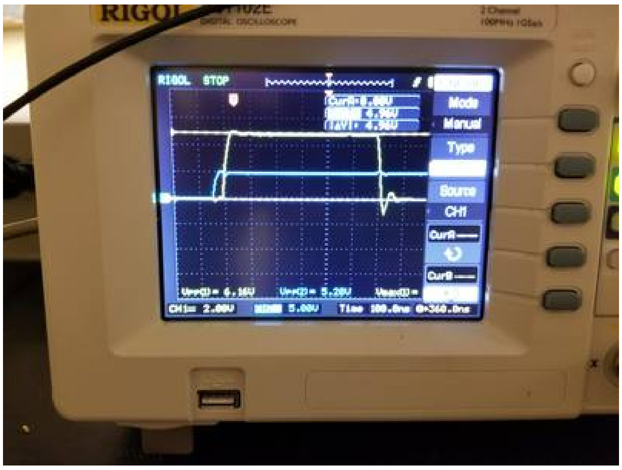

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Our constructed circuit shown below:

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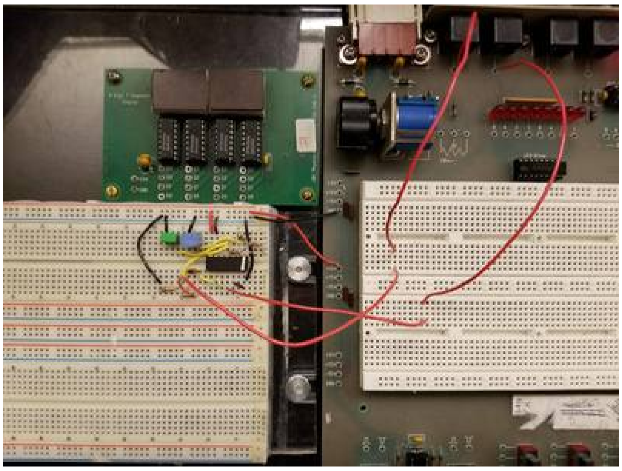

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• John van der Kuur • Nov 20, 2017 @09:07 PM PST

Two resistors in parallel were used again for the 11kΩ resistor.

R_{Total} = 10.841 +/- 0.21 kΩ

Capacitance is 47 +/- 4.7 pF

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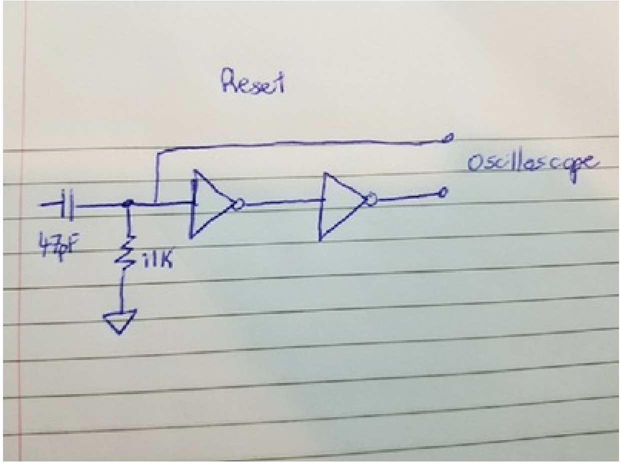

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• John van der Kuur • Nov 20, 2017 @09:04 PM PST

Measuring the Reset function:

Delay for reset pulse to turn on: 40.0 +/- 1.6 ns

Period of Reset pulse: 616 +/- 20 ns

Vpp = 4.96 +/- 0.08V (Starts at 0V and amplitude of 4.96 V)

• John van der Kuur • Nov 20, 2017 @09:44 PM PST

The Reset works by taking the input from the Delay. When the Delay input is high, the capacitor is initially uncharged and acts as a short circuit. This results in a high voltage for the input of the Reset which in turn is a high output voltage from the reset. Then the capacitor acts as a open circuit until the output of the delay is low, where the capacitor then discharges and gives a low input voltage to the Reset which changes the output of the Reset to low

• John van der Kuur • Nov 20, 2017 @09:19 PM PST

Figure out measured values and describes how the Reset function works

• John van der Kuur • Nov 20, 2017 @06:47 PM PST

3.1.5 Prepare for Integration

• John van der Kuur • Nov 20, 2017 @06:49 PM PST

Now with all the different components of the circuit created, save this component for integration by ensuring that the circuit is neat and tidy. Label the Reset and Latch wires so those can be easily identified later.

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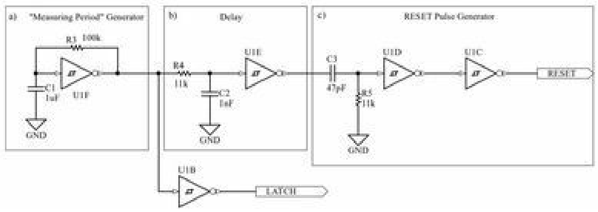


Part_1_Circuit_Integration.JPG(44.8 KB) - download

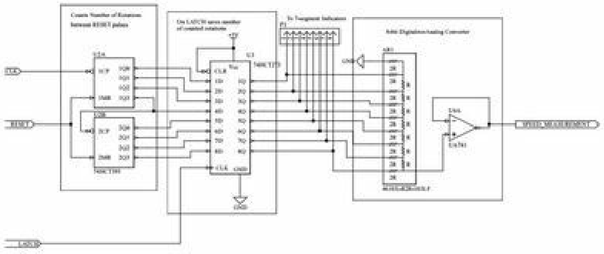
• John van der Kuur • Nov 15, 2017 @03:45 PM PST

3.2 Counter, D-Latch and DAC

• John van der Kuur • Nov 20, 2017 @09:16 PM PST

The overall circuit for the counter component is shown below:

• John van der Kuur • Nov 20, 2017 @09:16 PM PST



Second_Part_Circuit.JPG(47.4 KB) - download

• John van der Kuur • Dec 04, 2017 @06:30 PM PST

3.2.1 Counter

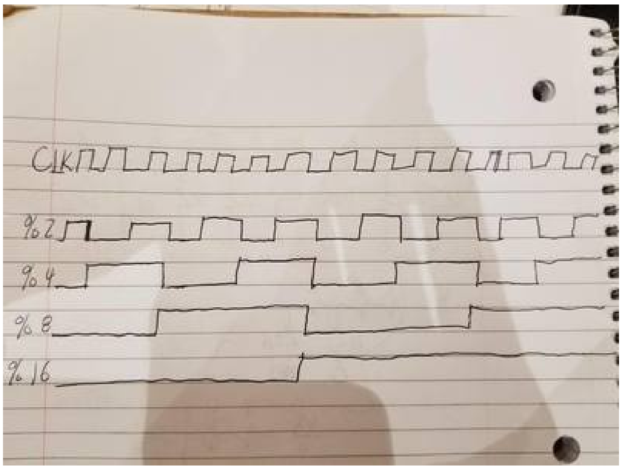
• John van der Kuur • Dec 04, 2017 @05:42 PM PST

The %16 counter works as shown below, every time the clock pulses, the %2 counter switches between on and off (0 and 1). The %4 counter turns on every second pulse and turns off every 4th pulse. The %8 turns on every 4th pulse and off after every 8th pulse, and by extension, %16 turns on after 8 pulses, and off after 16 pulses. To create a %256 counter, all that needs to be done is to put the output of the %16 counter into the input of another %16 counter as shown in the circuit diagram. This will create a hexadecimal output.

• John van der Kuur • Dec 04, 2017 @05:46 PM PST

Binary Representation	Hexadecimal representation
00000001	1
00000010	2
00000011	3
00000100	4
00000101	5
00000110	6
00000111	7
00001000	8
00001001	9
00001010	A
00001011	B
00001100	C
00001101	D
00001110	E
00001111	F
00010000	10
00010001	11
...	...

• John van der Kuur • Dec 04, 2017 @05:37 PM PST



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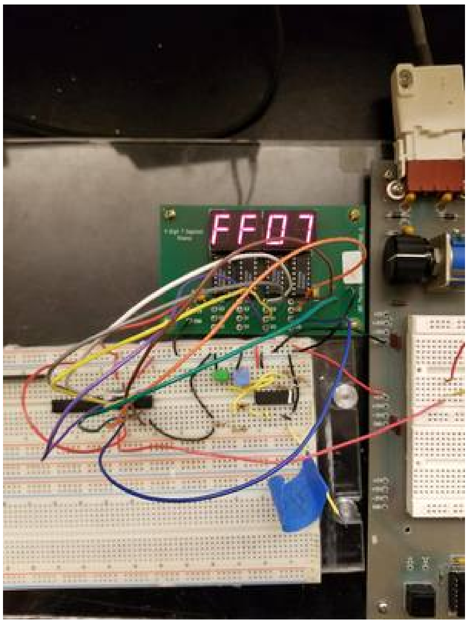
• John van der Kuur • Nov 20, 2017 @09:30 PM PST

First build the counter and test it:

- Attach the two %16 counters to each other in series to create a %256 counter
    - Attach the last input Q3 into the input of the second counter.
    - Disable both Master Resets
- Use a function generator as the input for the clock pulses
    - Set input Vcc to +5V with a 2.5V offset
    - Set the frequency to 1 Hz
- Attach 1Q0 from the counter to D0 on the 7 segment, 1Q1 to D1....
- Test the 7 segment display to ensure that it is working properly

• John van der Kuur • Dec 04, 2017 @08:44 PM PST



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• John van der Kuur • Dec 04, 2017 @04:36 PM PST

The maximum our counter counts to is FF in hex format which is 256 in hexadecimal format. After it reaches FF, the next number is 00, so the counter is set-up in such a way that it resets every time the maximum value of FF is reached.

• John van der Kuur • Dec 04, 2017 @08:45 PM PST

When the reset function was applied with a button, it just reset the counter and the LEDs back to 00

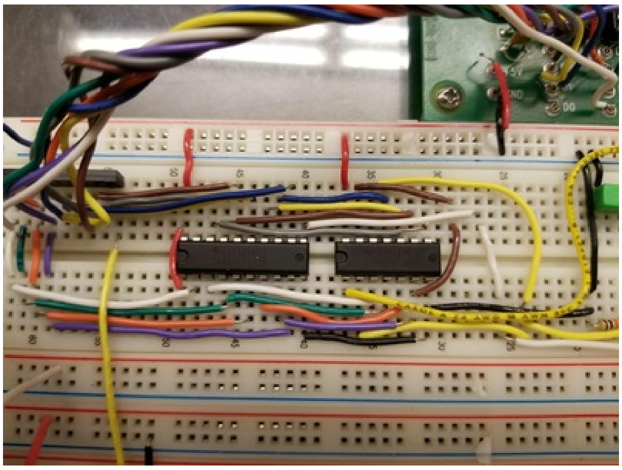
• John van der Kuur • Dec 04, 2017 @06:31 PM PST

Note: The two pins to the right of the 7-segment display must either be grounded or shorted together to get the display to work properly, we only found that out after consulting the TA.

• John van der Kuur • Dec 04, 2017 @05:51 PM PST

Now attach the output of the counters into the input of the D-Latch as shown in the circuit diagram and connect the output of the D-Latch into the 7-segment display as well as carefully connect to the right pin of the resistor ladder.

• John van der Kuur • Dec 04, 2017 @06:17 PM PST



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The counter is the device on the right and the latch is the device on the left

• John van der Kuur • Dec 04, 2017 @06:29 PM PST

We ran into a few issues when constructing this part of the circuit since there were so many wires. The one thing we did which helped us immensely was to have all the inputs and outputs of the counter and latch to be color coded. So the output 1Q0 went into 1D on the latch and 1Q wen into the correct ladder position and the right connection for the 7-segment display and all of this was one colour. This made things very easy to see if they were plugged into the wrong pin. A couple times when going over the circuit we noticed that the wires were in the wrong spot as numbers were skipped on the LEDs when it was counting. Additionally, we accidentally attached the 1st counter input into the output of the 1st counter which didn't enable the the counter to count properly. After looking over the circuit again we were able to quickly identify the issues and fix it. Another problem we ran into was the orientation of the grounding pin for the R-2R ladder. We didn't realize there was a specific orientation for the grounding pin and that gave us a faulty output even though we knew the input to the R-2R were all correct due to using the oscilloscope and seeing the correct waveform with the right frequency for each input pin. The last issue we ran into was putting the output pin of the Op-Amp into the input of the the positive terminal instead of the negative terminal which caused some issues for us when trying to record values. We identified that the oscilloscope is the best way to trouble shoot because it can show you what the voltage is doing over time as opposed to the DMM which caused issues. The oscilloscope is a better version of the DMM especially when dealing with logic diagnoses.

• John van der Kuur • Dec 04, 2017 @05:54 PM PST

DAC Counter Values

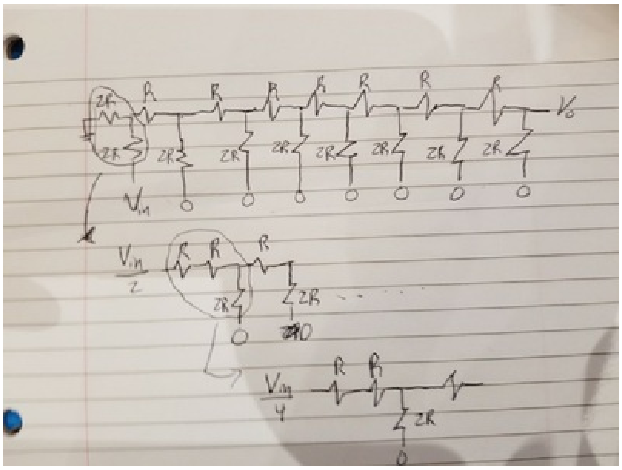
LED Value	Voltage Reading out of Op-Amp
93	2.695 +/- 0.005 V (fluctuating a lot)
C5	3.600 +/- 0.005 V
EF	4.145 +/- 0.005 V
09	0.211 +/- 0.005V

• John van der Kuur • Dec 04, 2017 @05:13 PM PST

R-2R Resistor Ladder:

The R-2R resistor ladder converts a digital signal to an analog signal by providing a weighted sum of the digital input signals. For example, when the first input is on (00000001): +5V, the voltage at the top node is Vin/2 and then since the resistors are in parallel, and at the next node when you add the resistors in parallel it becomes Vin/4, and then the next node Vin/8 etc... until it reaches the end of the ladder and Vout = Vin/256. The same happens when the second input is on (00000010). The process is repeated but one less time so Vout = Vin/128. Then with the 3rd input, (00000011), The 2 values are added and Vout = 3*Vin/256. This is then done all the way down the chain until the last value (11111111) = 255*Vin/256. And the it resets back to 0. This ,=means that each time the digital count increases by 1, the output voltage of the resistor ladder increases by Vin/2^8. The process can be seen in the diagram below.

• John van der Kuur • Dec 04, 2017 @05:04 PM PST



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• John van der Kuur • Dec 04, 2017 @05:23 PM PST

The Op-Amp in this circuit allows the circuit to have a load and different components after the DAC. The whole functionality of the DAC is based on the specific values and orientations of the resistors, if a new resistor was added in series after the DAC it would disrupt the digital to analog capabilities of the DAC and it would no longer be linear. By butting a buffer there with a gain of one, any circuit component can be added after the DAC and have no impact on the functionality of it.

• John van der Kuur • Dec 04, 2017 @06:14 PM PST

Using the table of values obtained above, we can compare the output of the Latch (7-segment display) to the output of the output of the op-amp. The formula for calculating the Vout of the Op amp is: $V_{out} = V_{in} * (\frac{Q_0}{256} + \frac{Q_1}{128} + \frac{Q_2}{64} + \frac{Q_3}{32} + \frac{Q_4}{16} + \frac{Q_5}{8} + \frac{Q_6}{4} + \frac{Q_7}{2})$

Assuming Vin is 5V Our expected values should be:

HexaDecimal	Expected Output from Op-Amp
93	2.87 V
C5	3.84 V
EF	4.66 V
09	0.18 V

All of the expected values are higher than the measured values but I hypothesize that this could be due to the fact that the input voltage was not 5V exactly. It is probably slightly lower due to the the voltage lost when travelling through the the different devices. And since they are all consistently lower, I feel confident that this part of the circuit is functioning correctly.

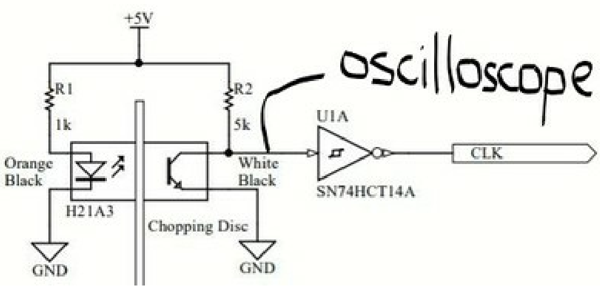
• John van der Kuur • Dec 04, 2017 @06:34 PM PST

3.3 Motor sensor and motor driver

• John van der Kuur • Dec 04, 2017 @12:22 PM PST

The first thing to do when wiring up the motor is to make sure that the motor and it's components are working. To do this, we first tested the functionality of the phototransistor and the LED to ensure that a reading could be obtained as the disk from the motor was spinning. We constructed the circuit as seen below:

• John van der Kuur • Dec 04, 2017 @12:22 PM PST



Oscilloscope_PhotoTransistor_circuit_Moment.jpg(776.6 KB) - download

• John van der Kuur • Dec 04, 2017 @12:33 PM PST

A 5kΩ was created by putting to 10 kΩ resistors in parallel

Our measured values for our resistors were:

4.9309 +/- 0.049 kΩ

0.98881 +/- 0.00891 kΩ

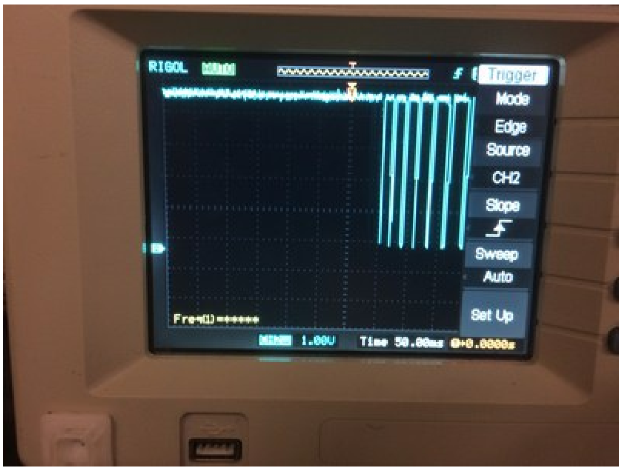
• John van der Kuur • Dec 04, 2017 @12:40 PM PST

This component of the circuit works by shining the LED light at the phototransistor and when it sees the LED, a signal of -5V is sent to the inverter and then the clock. The phototransistor can only read a value when the chopping disk is not blocking the light from the LED, or when the hole of the chopping disk allows the light to be transferred through. So as the disk spins, and at each hole in the chopping disk, a signal is sent out and the clock is initiated.

• John van der Kuur • Dec 04, 2017 @12:52 PM PST

The photo of the oscilloscope shown below shows the working function of the circuit. When the disk was stationary, no voltage was being produced. But when the disk was spun manually the circuit was outputting a short pulse of negative voltage (hence why the inverter is necessary).

• John van der Kuur • Dec 04, 2017 @12:49 PM PST



IMG_0492.JPG(546.4 KB) - download Photo taken and shared by partner Jeremy Wiens

• John van der Kuur • Dec 04, 2017 @12:42 PM PST

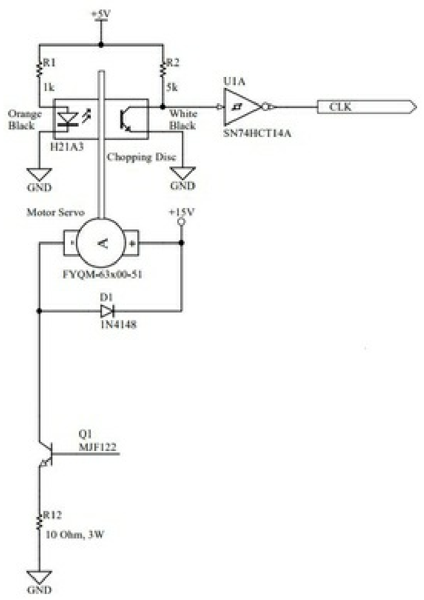
Note: When we tried to obtain a reading form the Oscilloscope we ran into some issues. The oscilloscope had a constant reading of 0V even when we manually turned the disk. We directly allowed the LED to shine through a hole in the chopping disk and the voltage drop across the LED was still 0 which didn't make any sense. So we consulted with a TA and we realized that we had been using a +15V source for the power supply which most likely melted the LED, so once a new one was obtained the circuit worked as expected. So be wary of what voltage source is being used to power the LED and phototransistor.

• John van der Kuur • Dec 04, 2017 @12:55 PM PST

Now wire up the remaining portion of the circuit as shown below:

NOTE: Ensure that R12 is a not a regular 10kΩ resistor but a 3W 10kΩ resistor!

• John van der Kuur • Dec 04, 2017 @12:11 PM PST



InkedMotor_circuit_component_LI.jpg(569.6 KB) - download

• John van der Kuur • Dec 04, 2017 @03:32 PM PST

Note: We realized we didn't test the functionality of the motor without the reset enabled. What I imagine would occur is that the display would count up in hexadecimal at the speed the clock is pulsing (same speed as the output of the phototransistor/LED signal) and would keep counting up at that speed until it reaches FF and then resets back to 0. What the reset function does is to cap the counter at how ever many pulses are coming through the clock in the time it takes for one period of reset.

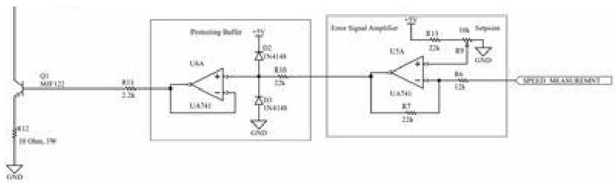
• John van der Kuur • Dec 04, 2017 @06:35 PM PST

3.4 Error Signal/Amplifier Buffer

• John van der Kuur • Dec 04, 2017 @01:29 PM PST

The final circuit components are the protecting buffer and error signal amplifier. Build these components as shown in the circuit diagram below and test the functionality of the overall circuit. When the potentiometer is adjusted the speed of the motor should be increase or decrease.

• John van der Kuur • Dec 04, 2017 @01:20 PM PST

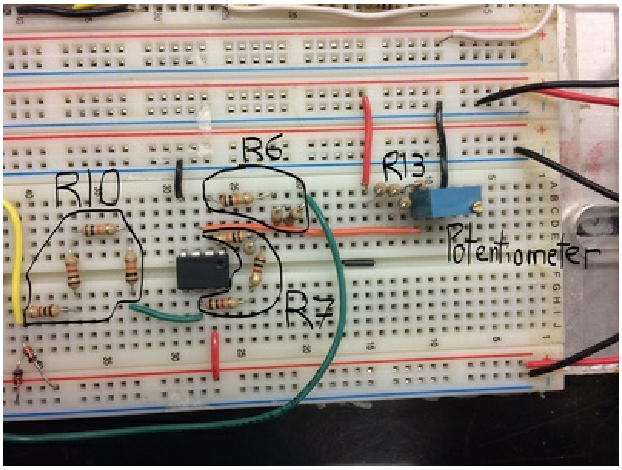


Buffer_and_Signal_Amplifier.JPG(36.2 KB) - download

• John van der Kuur • Dec 04, 2017 @01:43 PM PST

Our Error signal amplifier can be seen below

• John van der Kuur • Dec 04, 2017 @01:43 PM PST



Error_Signal_Amplifier_still.jpg(2.5 MB) - download

• John van der Kuur • Dec 04, 2017 @01:51 PM PST

For the 22kΩ resistors for R7, R10 and R13, a series combination of 2 10kΩ and 2 1kΩ were used.

the measured values for the resistors are:

R13: 21.690 kΩ +/- 0.574 kΩ

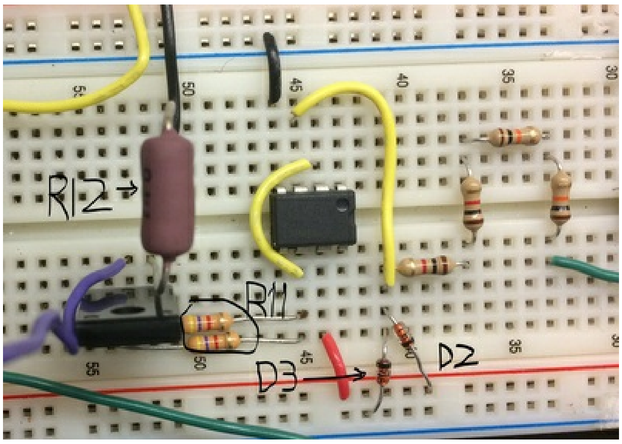
R7: 21.659 +/- 0.572 kΩ

R10: 21.719 +/- 0.574 kΩ

For the 12 kΩ resistor of R6, a series combination of 1 10kΩ and 2 1kΩ were used.

R6: 11.866 +/- 0.494 kΩ

• John van der Kuur • Dec 04, 2017 @01:43 PM PST



Protecting_Buffer_still.jpg(1.6 MB) - download

• John van der Kuur • Dec 04, 2017 @01:55 PM PST

For the 2.2 kΩ resistor, two 5 kΩ resistors were used in parallel

the measured value for R11 is:

2.353 +/- 0.058824 kΩ

• John van der Kuur • Dec 04, 2017 @02:02 PM PST

When we turned the final circuit on, everything was working perfectly and there was no need to troubleshoot the error signal amplifier/buffer but because of the complexity of the components, if so replace the speed measurement with a slow input square wave from the function generator and run through each component to see where the problem may arise.

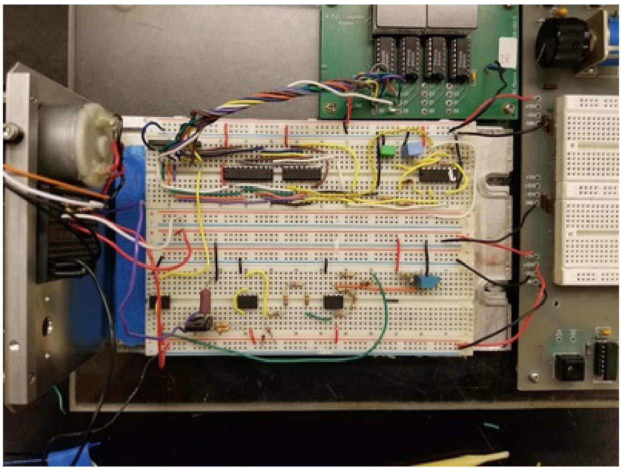
• John van der Kuur • Dec 04, 2017 @12:57 PM PST

4 Conclusion

• John van der Kuur • Dec 04, 2017 @03:34 PM PST

Our final constructed circuit can be seen below

• John van der Kuur • Dec 04, 2017 @03:33 PM PST



24650958_1883027941710729_529656956_o.jpg(2.6 MB) - download

• John van der Kuur • Dec 04, 2017 @06:37 PM PST

Problems and Troubleshooting

• John van der Kuur • Dec 04, 2017 @03:02 PM PST

We ran into quite a few problems with our circuit. The biggest issue that came up over and over again was individual device failure. Our counter malfunctioned and had to be replaced once and our Schmitt Trigger malfunctioned and had to be replaced twice. further more our photo transistor and LED component had to be replaced. We would build the circuit and get individual parts working and then when it came time to combine it with earlier parts of the circuit, there would be no output. To troubleshoot, each time we would plug in the oscilloscope to the breadboard and have a long wire which could then be attached to different components of the circuit to see if the reading on the oscilloscope was what was expected or not. Many time the input was totally correct and when measuring the output from a counter or a Schmitt-Trigger, there would either be no output or it would not be what we were expecting and then we would switch it out. Besides the device failures we didn't run into too many other problems with our circuits that couldn't be quickly resolved by looking at the diagram and confirming that our wires were in the right location. One other minor issue we ran into was figuring out that the Op-Amps need to be powered by +/- 15V instead of +5V and ground. When using the +5V and ground, the bottom value would be clipped at 1.8 V for some reason but as soon as it was switched over to +/- 15V they functioned properly.
Additionally, sometimes we were unsure what our oscilloscope was supposed to be reading so we would compare our results with other students or consult with TAs to ensure that our results were what was to be expected. But the key point of troubleshooting with this many components is to have a DMM and an oscilloscope to be easily accessible to see if the inputs and outputs of devices and components are what they are expected to be.

• John van der Kuur • Dec 04, 2017 @06:37 PM PST

Reason for Diodes and Buffers

• John van der Kuur • Dec 04, 2017 @03:23 PM PST

A diode acts like a valve for a circuit. If the voltage is higher on the positive terminal of a diode compared to the negative terminal, then current flows through. The Diode D1 in the circuit connected to the motor is a safety diode for the motor so that the feedback loop can only flow one way. Diodes D2 and D3 are used in the protective buffer so as to only allow voltages between 0V and 5V into the Op-Amp and into the circuit.

As mentioned earlier, the diodes D2 and D3 protect the circuit from overvoltage so the protective buffer, protects the circuit from going above +5V and below 0V

The reason for the Error Signal Amplifier is to check what the feedback signal is coming from the motor through the speed measurement, and adjust it to match up with the desired voltage and speed set by the potentiometer. This is how the circuit is able to control the speed of the motor, by reading what is coming through and matching it to the desired voltage inputted by the user through the potentiometer.

• John van der Kuur • Dec 04, 2017 @06:38 PM PST

Conversion table from RPM, 7-Segment, and Voltage

• John van der Kuur • Dec 04, 2017 @04:07 PM PST

With the final circuit created, we were able to take a few measurements to find a relationship between the LED Display, the RPM and the Voltage given to the motor. We obtained a table of raw data shown below.

LED Display	Time for 5 pulses	Voltage Drop across LED
38	8.32 +/- 0.20 ms	6.3 +/- 0.2 V
27	12.3 +/- 0.20 ms	9.1 +/- 0.2 V
9	52 +/- 2 ms	13.3 +/- 0.2 V
4B (max speed)	6.16 ms +/- 0.20 ms	3.4 +/- 0.2 V

The error from the Voltage was +/- 0.2 V instead of the usual DMM error because the fluctuations in the Voltage Drop was so large that I only felt confident with an error of +/- 0.2 V

The error of the 5 pulses was obtained by +/- the smallest time division on the oscilloscope screen since we had to manually use the tracking tool and had to identify where the beginning and end of the the 5 pulses were by hand.

To calculate the RPM of the motor, we measured the period for 5 pulses of the clock using the oscilloscope. This is equivalent to 5 pulses of the phototransistor/LED as demonstrated in part 3.3 which correlates to half a revolution of the motor since there are 10 holes. We used 5 pulses because the motor speed seemed to fluctuate a little bit even with a steady voltage so we felt that more pulses were needed to obtain an accurate reading. We considered using 10 pulses but it was so zoomed out on the oscilloscope that we didn't feel confident in the error introduced. So we decided 5 pulses would provide an accurate measurement.

• John van der Kuur • Dec 04, 2017 @02:31 PM PST

To calculate the RPM the Time for 5 pulses must be multiplied by 2 to obtain one revolution, and then one minute (60s) divided by the period for 10 pulses. E.g.

$\frac{60}{2T}$ where T is the time for 5 pulses.

• John van der Kuur • Dec 04, 2017 @03:57 PM PST

We also decided to take the voltage drop across the LED since the speed was fluctuating we felt if would be more accurate to measure the voltage closer to the motor itself instead of the voltage drop across the potentiometer. The voltage into the motor was 15V. The voltage provided into the motor would then be 15V - voltage drop across the LED.

• John van der Kuur • Dec 04, 2017 @04:13 PM PST

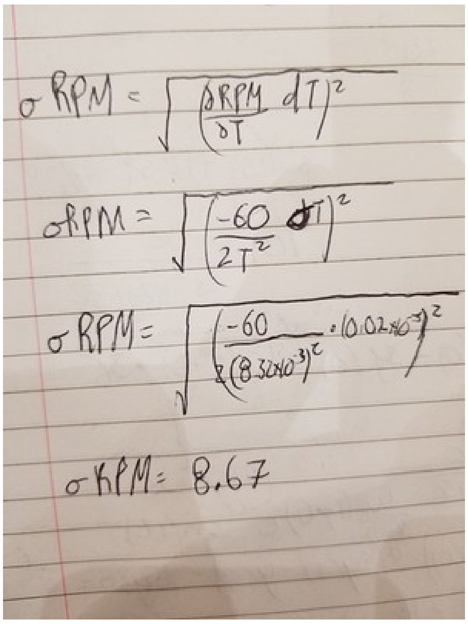
A new data table can then be constructed comparing RPM, the LED Display, and the Voltage supplied to the motor

LED Display (Hexadecimal)	RPM of Motor	Voltage Drop across LED
38	3605.8 +/- 86.7	8.7 +/- 0.2V
27	2439 +/- 39.7	5.9 +/- 0.2V
9	576.9 +/- 22.1	1.7 +/- 0.2V
4B (max speed)	4870.1 +/- 158.1	11.6 +/- 0.2V

• John van der Kuur • Dec 04, 2017 @04:13 PM PST

The error calculations for RPM are shown below:

• John van der Kuur • Dec 04, 2017 @04:15 PM PST



$$\sigma RPM = \sqrt{\left(\frac{\partial RPM}{\partial T} dT\right)^2}$$

$$\sigma RPM = \sqrt{\left(\frac{-60}{2T^2} dT\right)^2}$$

$$\sigma RPM = \sqrt{\left(\frac{-60}{2(8.32\times10^{-3})^2} \cdot (0.02\times10^{-3})\right)^2}$$

$$\sigma RPM = 8.67$$

24550328_1883179341695589_706020972_n.jpg(52.4 KB) - download

• John van der Kuur • Dec 04, 2017 @08:40 PM PST

To be able to display the RPM on the 7-segment display, all that would be needed to do is to have the latch and reset pulse at every 6ms. This would grab a reading from the counter every 6ms and reset the counter every 6ms which would display the RPM x1000 because every 10 pulses of the clock of the counter is 1 full revolution.

• John van der Kuur • Dec 04, 2017 @08:47 PM PST

Maximum Speed

• John van der Kuur • Dec 04, 2017 @04:15 PM PST

As shown above the maximum speed of our motor with our circuit was 4870 +/- 158 RPM as measured by our circuit.