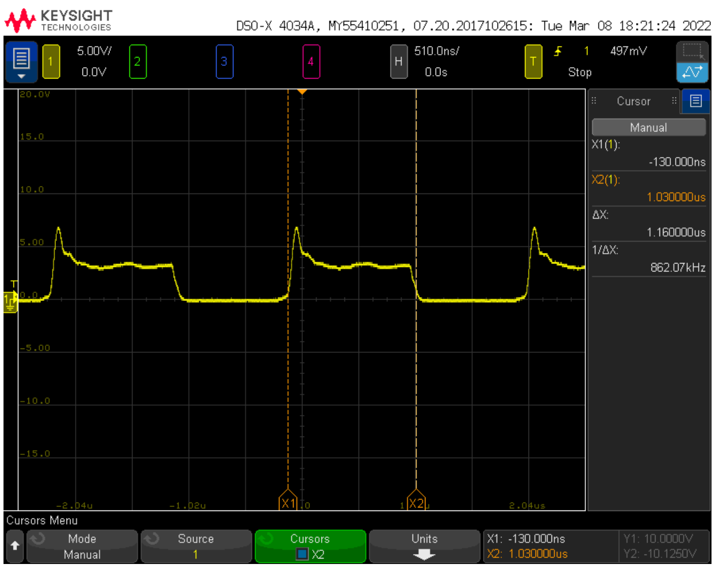
All plots must be labeled with the appropriate units. If you took a picture of the oscilloscope, make sure to note in a caption what the units of the xand yaxes are! Label all of your traces, indicating clearly which trace is measuring which node. Record any changes to the lab you may have made, such as changing the frequency. If you found a measurement particularly difficult to obtain, explain why it was difficult to obtain instead of leaving the answer blank. This rubric is subject to change, but this is an outline of how we expect to grade this lab.

•Q1

– 4 points Experimentally determine the relationship between the frequency and duty cycle with respect to R2. Explain your process: how you took the measurement data to determine these relationships.

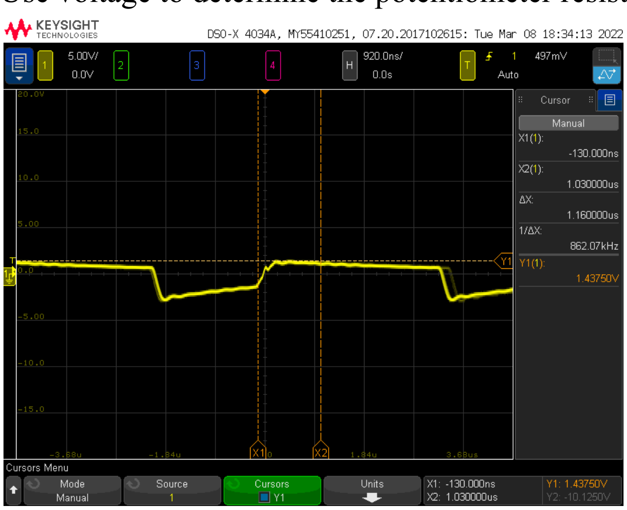
FIRST READING:

DO X2-X1 FOR FREQUENCY ie for the duty cycle



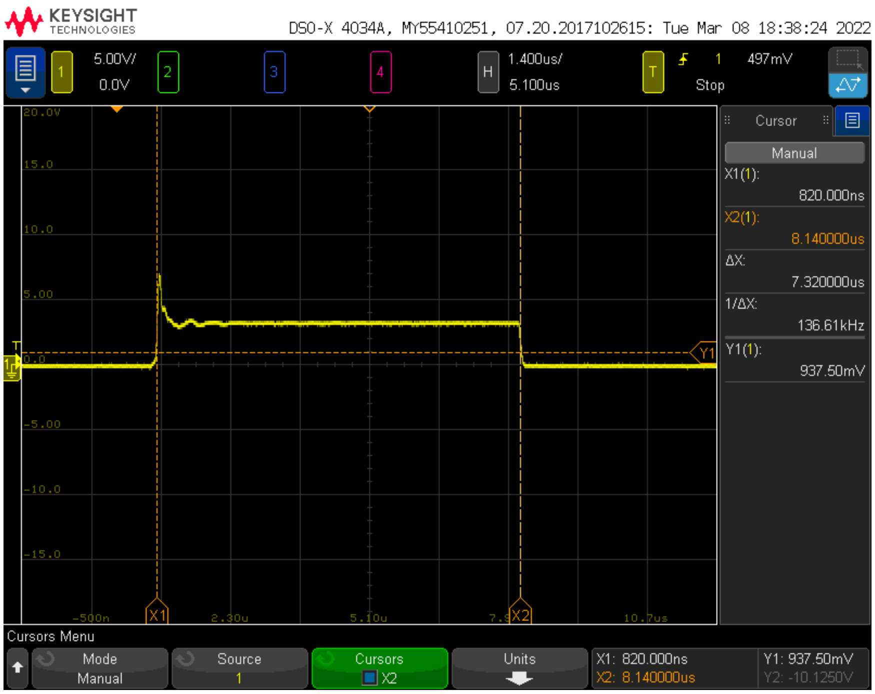
X2-X1: 1.16 microseconds

Use voltage to determine the potentiometer resistance



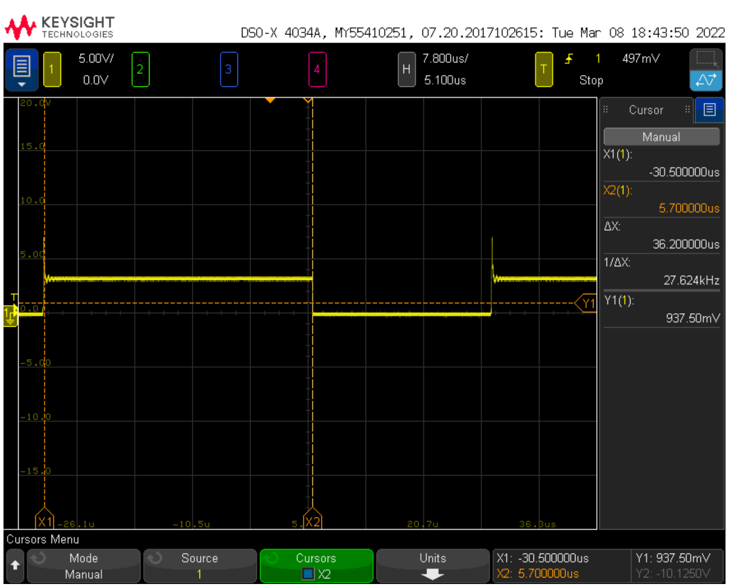
1.43750 V → 287.5 kOhms

Experimental duty cycle: 50.191%, experimental frequency: 862.07 kHz
Theoretical duty cycle:
SECOND READING:
X2-X1 for duty cycle: 7.32 microseconds



937.50 mV (analogous to the voltage corresponding to the second graph from the first reading) → 187.5 kOhms
Experimental duty cycle: 50.292%, experimental duty cycle: 136.612 kHz

THIRD READING:

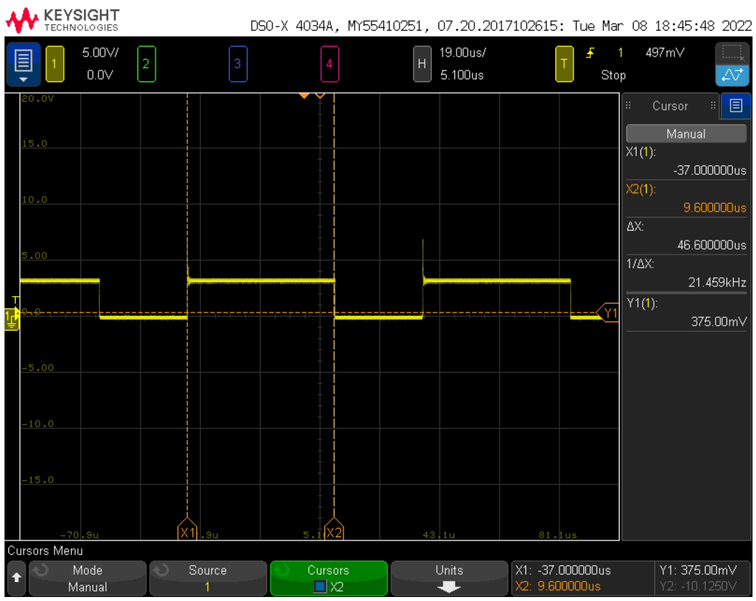


36.2 microseconds

687.50 mV → 137.5 kOhms

Experimental duty cycle: 50.397%, experimental duty cycle: 27.624 kHz

FOURTH READING:

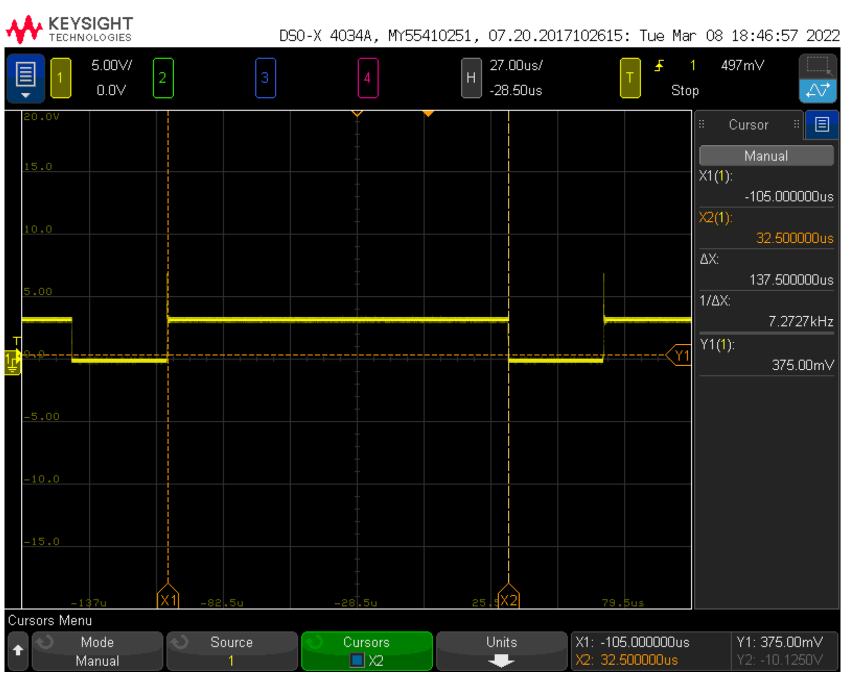


375.00 mV → 75.000 ohms

46.6 microseconds

Experimental duty cycle: 50.723%, experimental frequency: 21.459 kHz

FIFTH READING:



137.5 microseconds
250.00 mV → 50 kOhms
Experimental duty cycle: 51.076%, experimental frequency: 7.273 kHz

Calculated values using 5 microAmps as current through the pot

– 2 points Provide the theoretical values for the output frequency and duty cycle given the minimum and maximum values for R2.
•Q2:
– 4 points Explain how the circuit in Figure 3 functions.
– 1 points What R and C did you choose to produce a pulse duration of 1 second theoretically?
– 2 point Was your initial guess within a 10% tolerance? If not, why? What R and C did you use to get an experimental 1 second pulse duration?

•Design question
– 4 points Explain your approach to this design problem. How do you plan to measure the frequency of a signal using the 555 timer, a counter, and a gate?
– 4 points Provide a schematic of your design.
– 4 points Show that your design works. Have a TA confirm, and make sure that the TA marks down your name and your partner's name.
– 4 points Discuss the challenges you had in this design. W

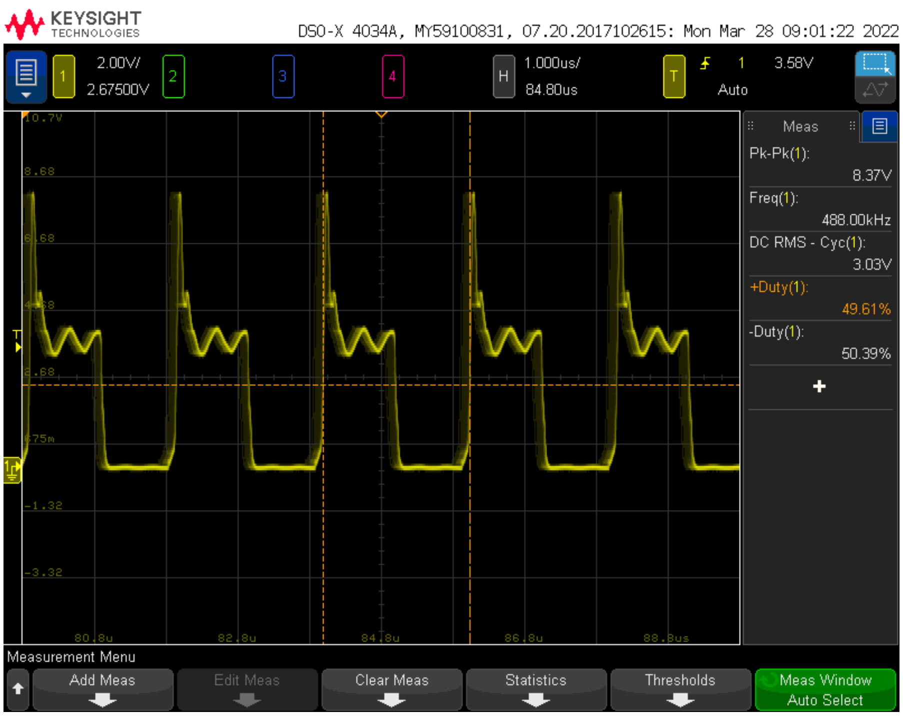
All plots must be labeled with the appropriate units. If you took a picture of the oscilloscope, make sure to note in a caption what the units of the xand yaxes are! Label all of your traces, indicating clearly which trace is measuring which node. Record any changes to the lab you may have made, such as changing the frequency. If you found a measurement particularly difficult to obtain, explain why it was difficult to obtain instead of leaving the answer blank. This rubric is subject to change, but this is an outline of how we expect to grade this lab.

•Q1

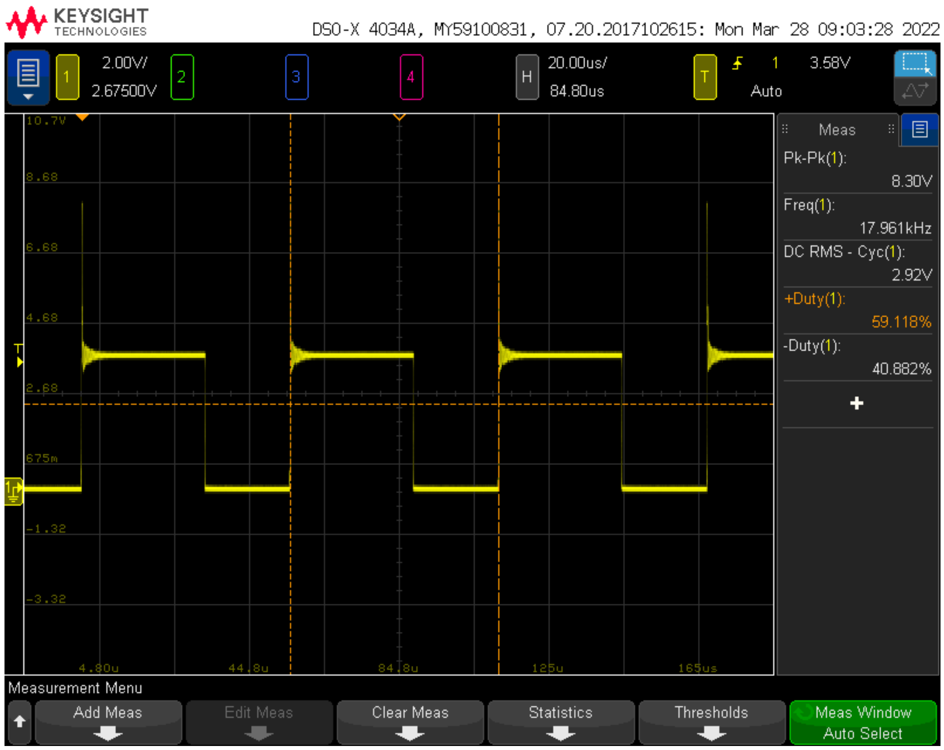
– 4 points Experimentally determine the relationship between the frequency and duty cycle with respect to R2. Explain your process: how you took the measurement data to determine these relationships.

FIRST MEASUREMENT:

4.07500 V

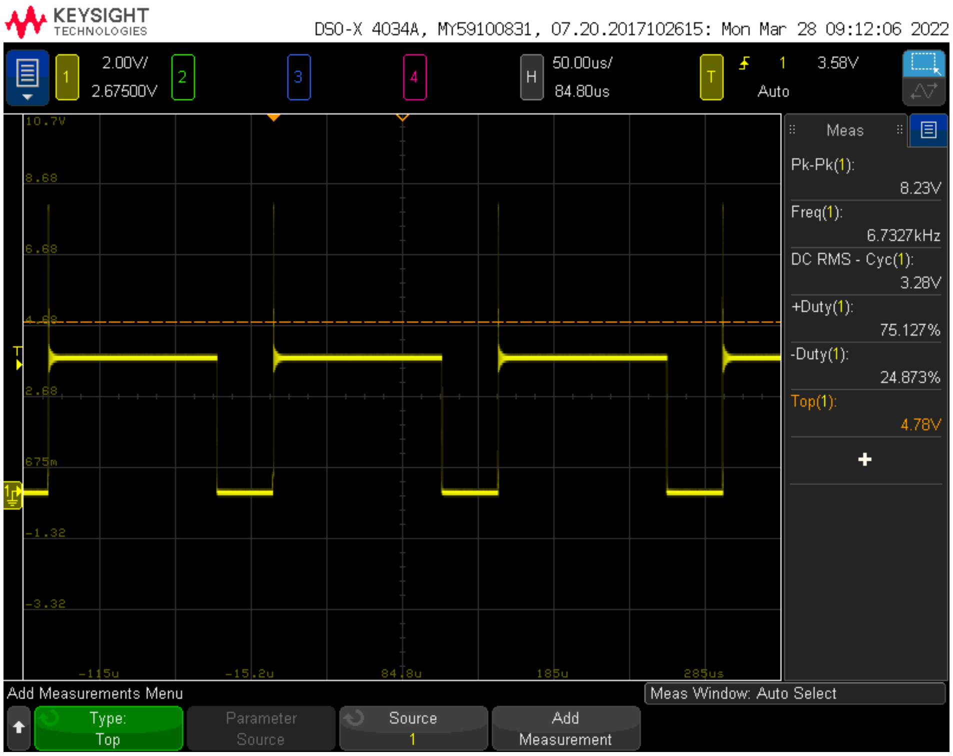


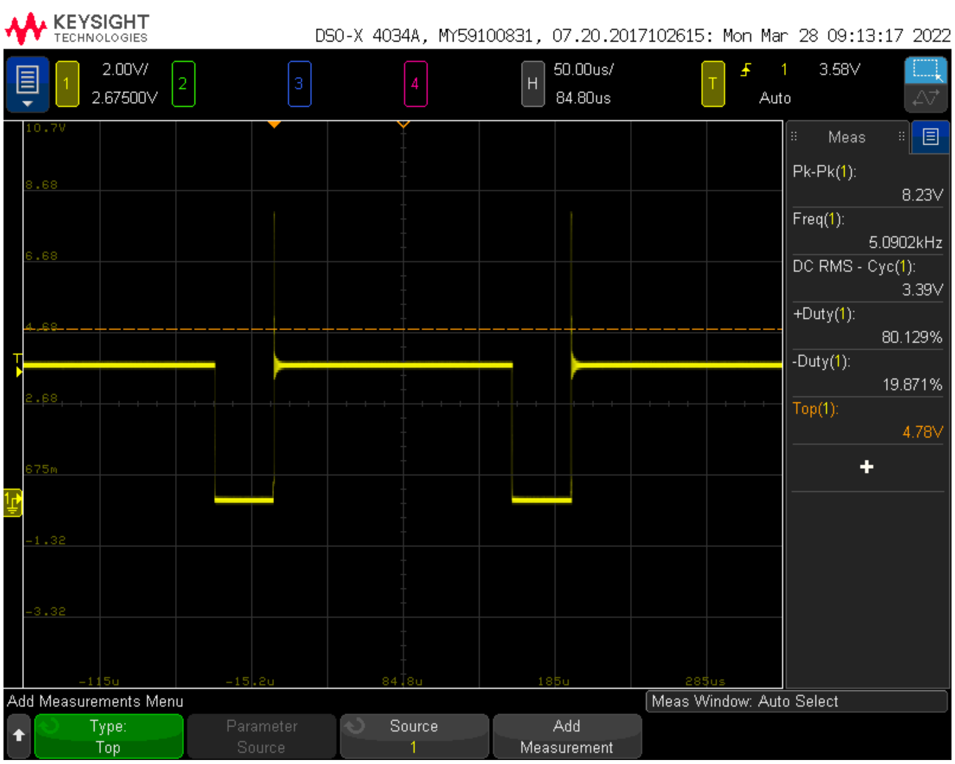
SECOND MEASUREMENT:
3.775 V

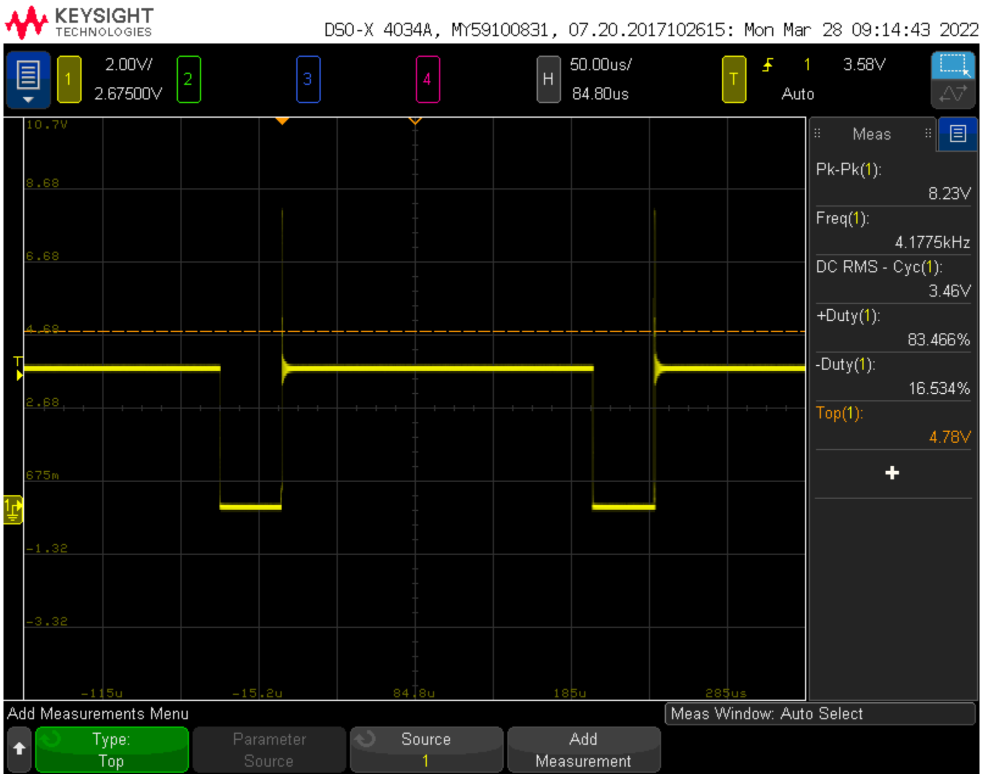


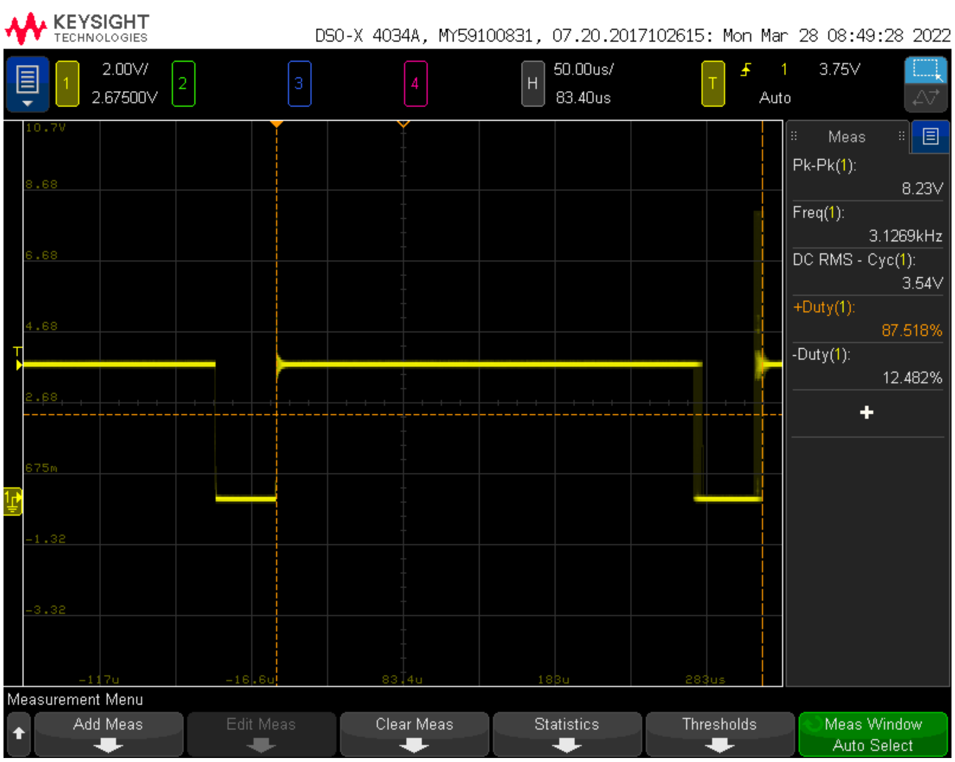
THIRD MEASUREMENT:

VOLTAGE MEASUREMENT (FOR THE REST OF THE MEASUREMENTS):
3.75 V


KEYSIGHT TECHNOLOGIES
DSO-X 4034A, MY59100831, 07.20.2017102615: Mon Mar 28 09:12:06 2022
2.00V/
2.67500V
50.00us/
84.80us
3.58V
Auto
Meas
Pk-Pk(1):
8.23V
Freq(1):
6.7327kHz
DC RMS - Cyc(1):
3.28V
+Duty(1):
75.127%
-Duty(1):
24.873%
Top(1):
4.78V
Add Measurements Menu
Meas Window: Auto Select
Type:
Top
Parameter
Source
Source
1
Add
Measurement

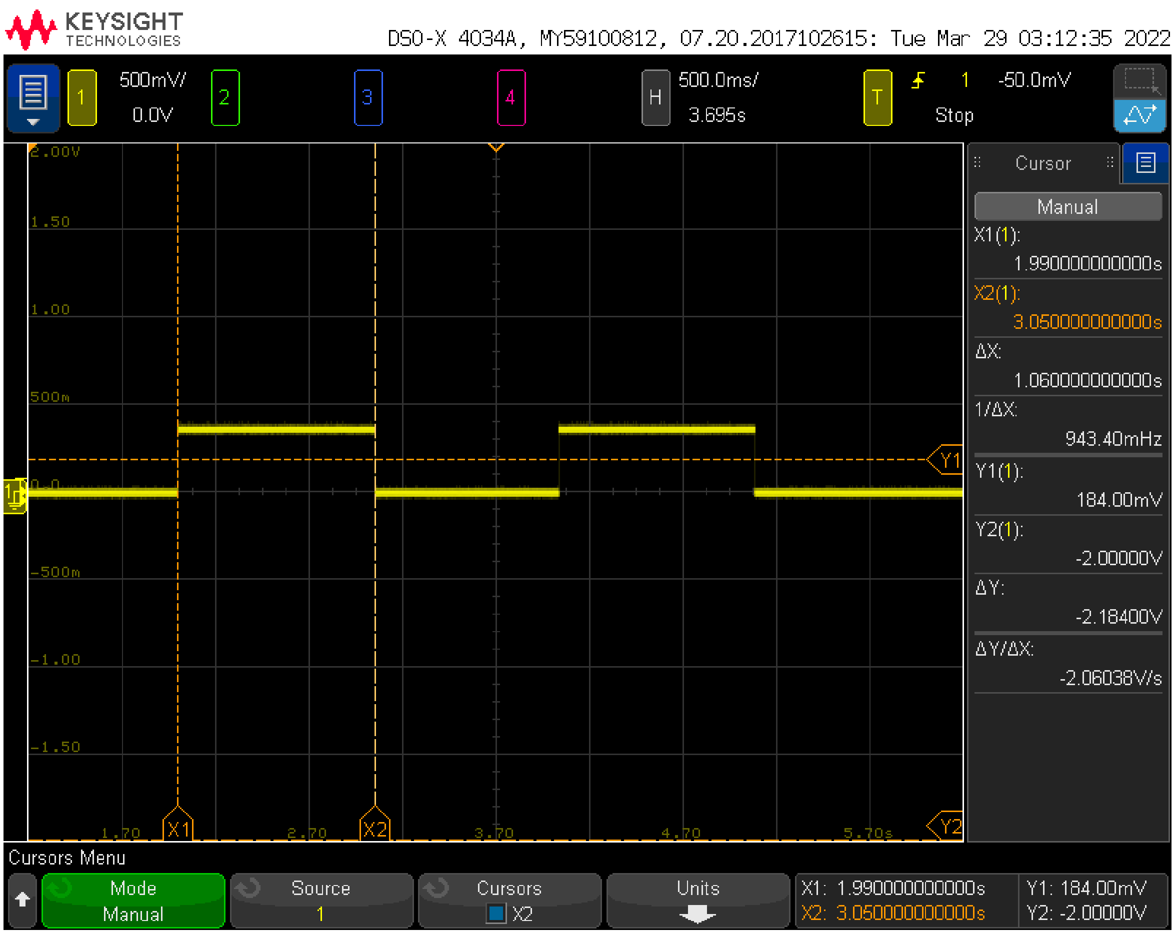

KEYSIGHT TECHNOLOGIES
DSO-X 4034A, MY59100831, 07.20.2017102615: Mon Mar 28 09:13:17 2022
2.00V/
2.67500V
50.00us/
84.80us
3.58V
Auto
Meas
Pk-Pk(1):
8.23V
Freq(1):
5.0902kHz
DC RMS - Cyc(1):
3.39V
+Duty(1):
80.129%
-Duty(1):
19.871%
Top(1):
4.78V
Add Measurements Menu
Meas Window: Auto Select
Type:
Top
Parameter
Source
Source
1
Add
Measurement


KEYSIGHT TECHNOLOGIES
DSO-X 4034A, MY59100831, 07.20.2017102615: Mon Mar 28 09:14:43 2022
2.00V/
2.67500V
50.00us/
84.80us
3.58V
Auto
10.7V
8.68
6.68
4.68
2.68
675m
-1.32
-3.32
-115u
-15.2u
84.8u
185u
285us
Meas
Pk-Pk(1):
8.23V
Freq(1):
4.1775kHz
DC RMS - Cyc(1):
3.46V
+Duty(1):
83.466%
-Duty(1):
16.534%
Top(1):
4.78V
Add Measurements Menu
Meas Window: Auto Select
Type: Top
Parameter Source
Source 1
Add Measurement


KEYSIGHT TECHNOLOGIES
DSO-X 4034A, MY59100831, 07.20.2017102615: Mon Mar 28 08:49:28 2022
2.00V/
2.67500V
50.00us/
83.40us
3.75V
Auto
10.7V
8.68
6.68
4.68
2.68
675m
-1.32
-3.32
-117u
-16.6u
83.4u
183u
283us
Meas
Pk-Pk(1):
8.23V
Freq(1):
3.1269kHz
DC RMS - Cyc(1):
3.54V
+Duty(1):
87.518%
-Duty(1):
12.482%
Measurement Menu
Add Meas
Edit Meas
Clear Meas
Statistics
Thresholds
Meas Window Auto Select

Q2:
This circuit takes the trigger and, interacting with the resistor and capacitor using the equation t = 1.1*R*C, results in a clock-like oscilloscope trace that is triggered by a debounced push button.

We chose a 19.3k resistor and a 47 microFarad capacitor, and we ended up with a pulse that's 1.06 seconds.



Shilpita Mitra-Behura
Nolan Tremelling
Department of Electrical Engineering
Columbia University
EE E3082. Digital Electronics Laboratory
Laboratory 2: 555 Timer

555 Timer as a Relaxation Oscillator

We took six measurements, varying the potentiometer value very time, while measuring the output on the oscilloscope. Specifically, we measured across the resistor connected to pin 3 on the 555 timer, as this functions as the output of the timer. We could have also measured the potentiometer value directly each time we took a measurement, but we were not aware that this was necessary at the time that we did the lab, so we have made a necessary assumption for the theoretical portion of this lab. Each measurement can be seen in *Figure 1* through *Figure 5*.

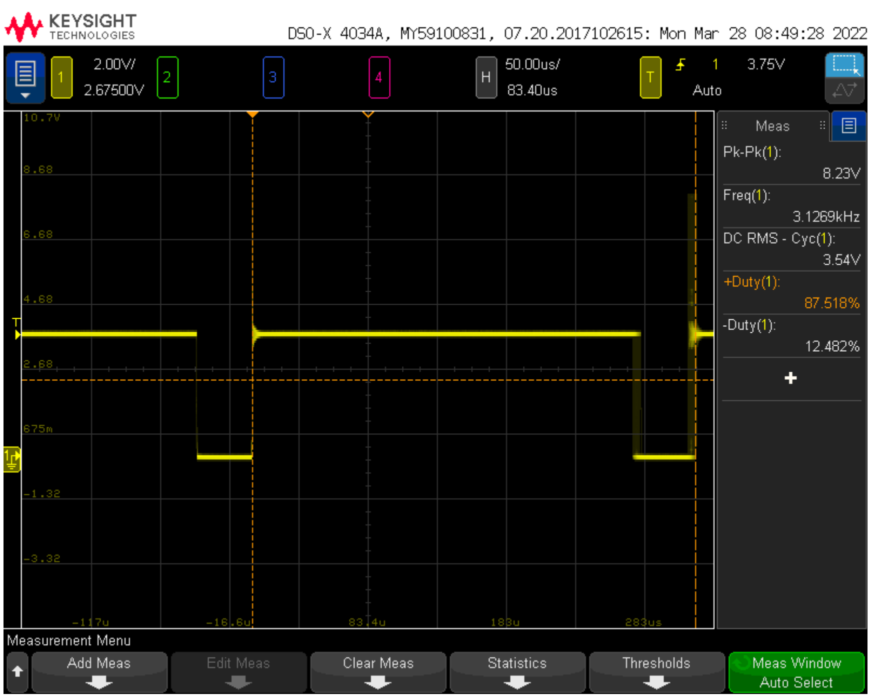


Figure 1: lowest pot value; y axis is voltage (V), x axis is time (µs).

For *Figure 1*, the duty cycle is 87.52%, with a frequency of 3.127 kHz. This was our lowest potentiometer value that created oscillation values; when the potentiometer was decreased to values lower than this, the cycles broke down, as the resistance became too high.

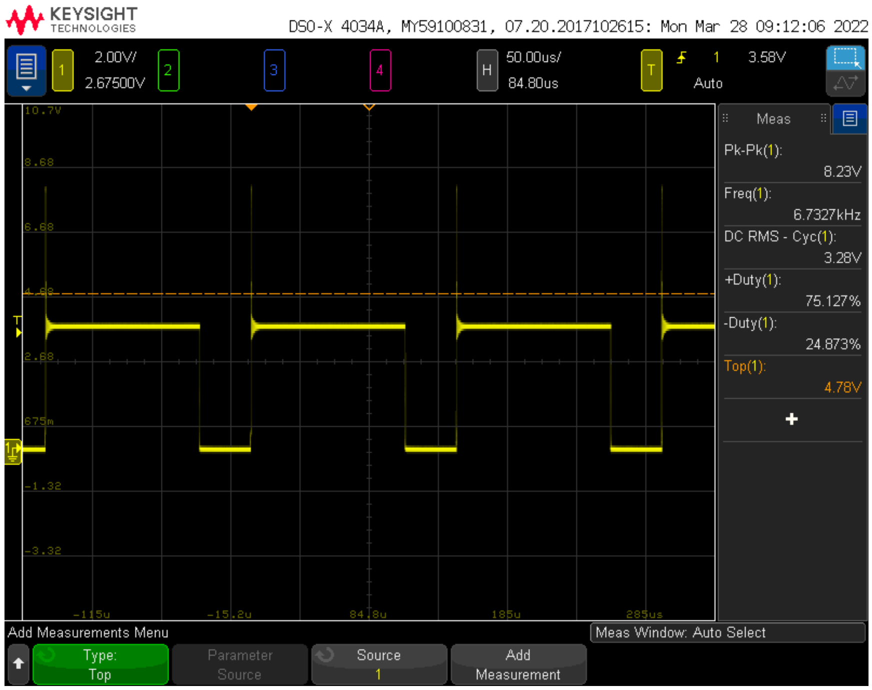


Figure 2: Increasing pot values; y axis is voltage (V), x axis is time (μs).

In *Figure 2*, with a higher pot value, our duty cycle decreased to 75.13%, with a frequency of 6.7327 kHz.

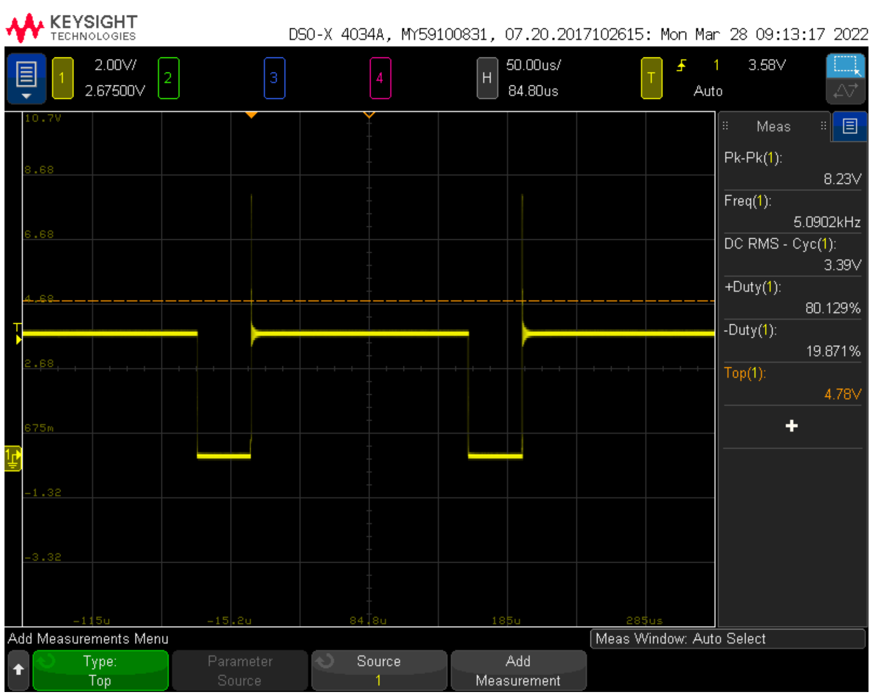


Figure 3: Higher pot value than in Fig 1 and 2; y axis is voltage (V), x axis is time (μs).

This relationship continues with the pot value in *Figure 3*; as the potentiometer value increased, the duty cycle decreased to 80.13% with a frequency of 5.09 kHz.

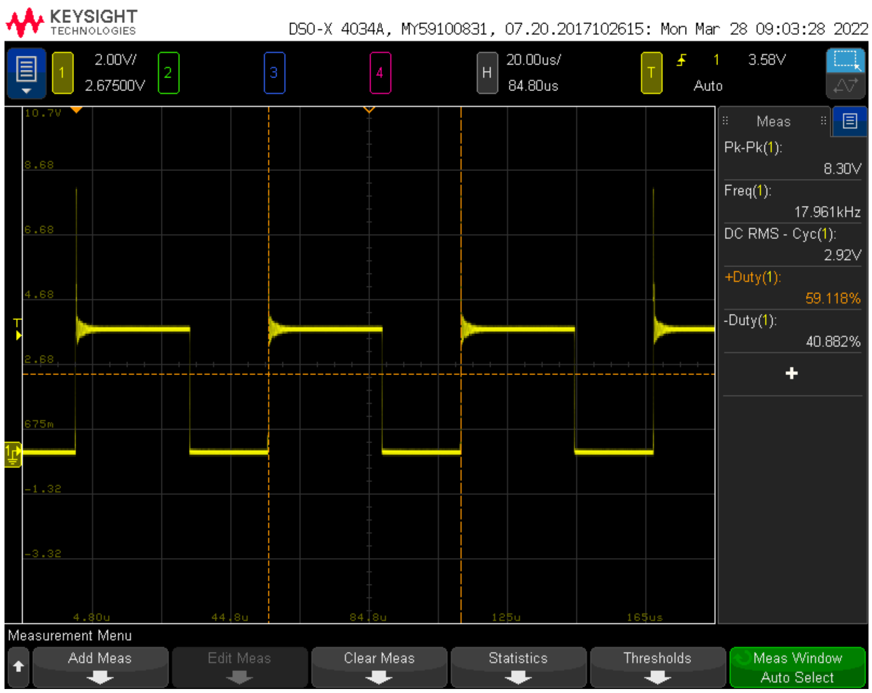


Figure 4: Even higher pot value; y axis is voltage, x axis is time.

This relationship continues in *Figure 4*, with a duty cycle of 59.1% and a frequency of 17.96 kHz.

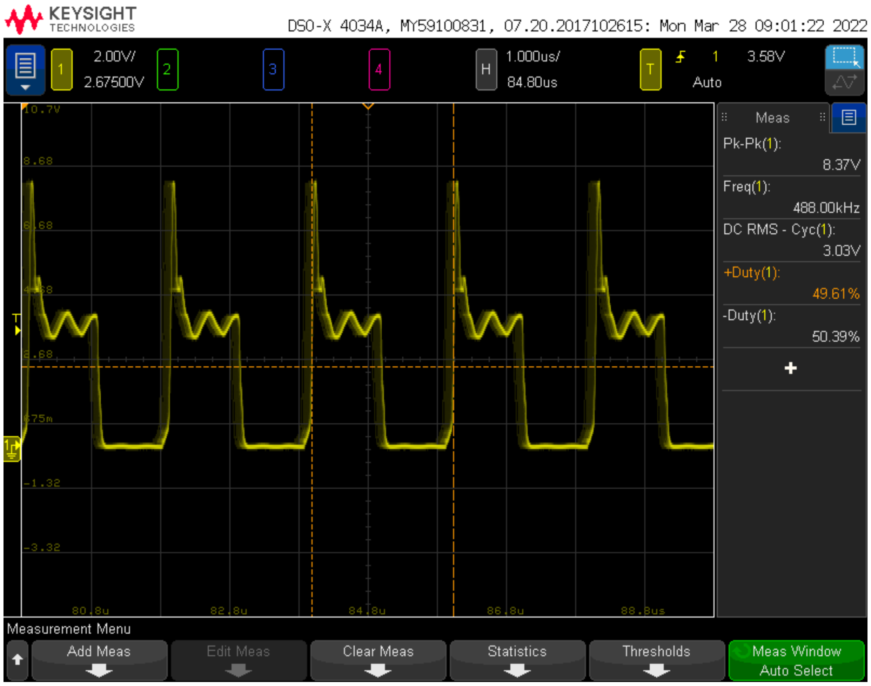


Figure 5: Final pot value, largest pot value; y axis is voltage (V), x axis is time (µs).

In our final measurement, we get a duty cycle of 49.61% and a frequency of 488.00 kHz. The decreasing duty cycle and increasing frequency value with larger pot values pattern continues in our final measurement; this was the largest pot value that we were able to measure. It was experimentally fairly clear that the relationship between pot value and the duty cycle was not linear. As the pot value increased, increasing its value changed the duty cycle and frequency by much larger magnitudes than at lower pot values. This makes sense considering the equation for duty cycle:

$$Duty\ cycle\ =\ 100\ *\frac{(R_{!}+R_2)}{(R_1+2R_2)}$$

This is very clearly heavily dependent on R2, which in our case, was the potentiometer value.

To theoretically determine what our values should have been, we could have collected the potentiometer value at each of our measurements, but instead we will assume that the measurement range we could take was the full range of the potentiometer, from 0 Ω to 1 MΩ.

We are given the following equations to calculate the duty cycle and frequency where our R1 = 2.2k Ω, R2 = our pot value, and C = 270 pF.

$$t_{high} = ln(2)(R_! + R_2)C$$
$$t_{low} = ln(2)(R_1 + R_2)C$$
$$Period = t_{high} + t_{low}$$
$$Duty\ cycle = \frac{100*t_{high}}{t_{high}+t_{low}} = 100 * \frac{(R_1+R_2)}{(R_1+2R_2)}$$
$$Frequency = \frac{1}{period}$$

At the minimum, where R2 = 0 Ω, the duty cycle is 100%, as t_{low} = 0 seconds. This is physically impossible, and we were not able to attain this value as the graphs broke down at these values. The frequency is 2.43 MHz.

At the maximum, where R2 = 1 MΩ, the duty cycle is 50.05%. This matches our final value fairly well, as our duty cycle was 49.61%, which is within a half percent difference. The frequency is 2.66 kHz.

We can assume a straight line relationship between duty cycle and frequency for the intermediate values then.
We get the equations below as a result:

$$|Duty\ cycle| = 0.00004995R_2$$
$$|Frequency| = 2.42611R_2$$

Returning to our 5 values, we can assign R2 values to each of them retroactively using the above equations.

555 Timer as a One Shot Trigger

The 555 timer can release a single, mono-stable output when placed into "one-shot mode." This mode relies on the press of a debounced button that lowers the input of the 555 to ground. This results in the output of a signal for a time constant t, whose pulse width is solely dependent upon the combination of a resistor and capacitor. This time constant, t, can be found in the equation $t = 1.1RC$.

This can be calculated theoretically by acknowledging that $f = \frac{1}{2\pi RC}$. Using any combinations of resistors and capacitors that equal 0.159 should provide a 1Hz output. This deviated experimentally, as values of R = 53kΩ and C = 3μF resulted in an RC value of 0.9071.

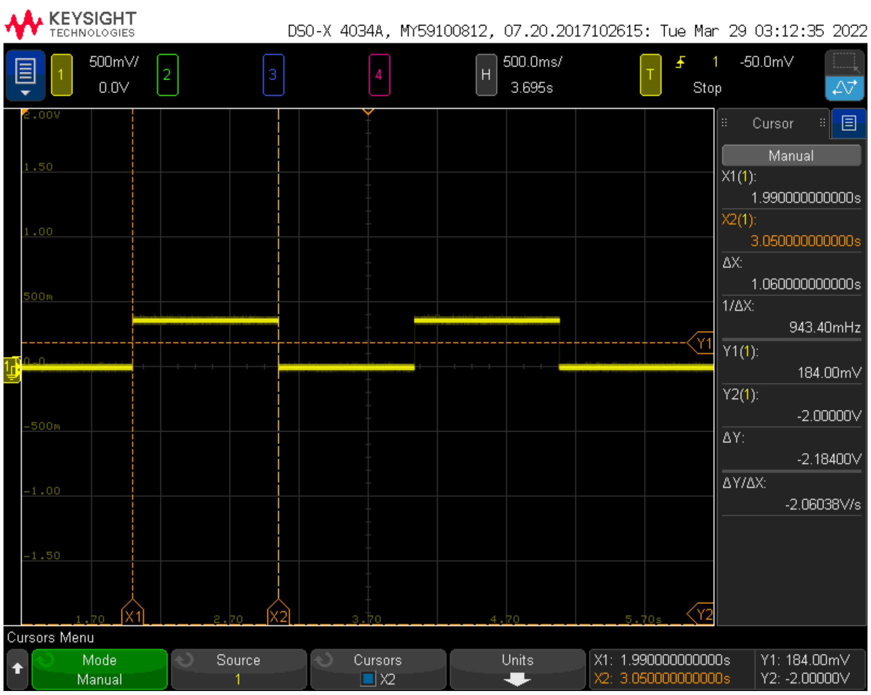


Figure 6: Oneshot of one second; y axis is voltage (V), x axis is time (μs).

Our initial guess was not within 10% tolerance. We chose a 19.3kΩ resistor and a 47μF capacitor, and we ended up with a pulse that was 1.06 seconds. Our RC value was 0.9071, as we quickly realized that period was too short with the theoretical value.

Digital Frequency Meter Design

A digital frequency meter that measures the frequency of 5V square waves from a signal generator can be constructed using the 555 in one-shot mode. By counting the AND of the 555 pulse with the frequency signal and outputting to a 7-seg display, this is achieved. A basic schematic for this circuit is *Figure 7*. The working digital frequency meter [can be seen working here]. While there were no inherent challenges, we were reminded of the importance of checking the data sheets for each component to avoid floating pins and having indeterminate outputs.

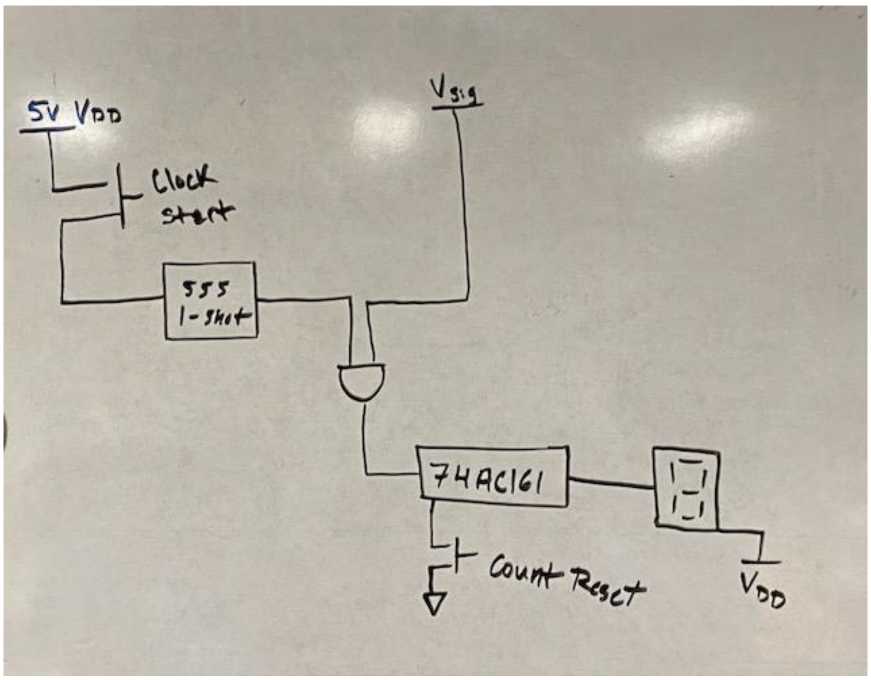


Figure 7: Overview schematic of the digital frequency meter.