ECEN 5053-001 Lab 3

Monish Nene & Miles Frain

Instructor: James Zweighaft (a.k.a "Prof Z")

Lab Start Date: 10-5-17, due in 1 week. Submit lab report to D2L dropbox individually.

Expected Time to Complete: 8- 10 hours

Equipment Required: same as in previous labs, but add a photodiode & Red LED/ Laser.

Documentation to keep handy: It is suggested that you bring up all relevant data sheets onto your laptop for fast access. I like a program called "PDF-Xchange Viewer" because it allows me to highlight and otherwise markup pdf documents and I can have multiple ones open at once.

Reporting Requirement: Lab report submitted via D2L answering all questions below, and including annotated scope shots.

Procedure:

Circuit Diagram:

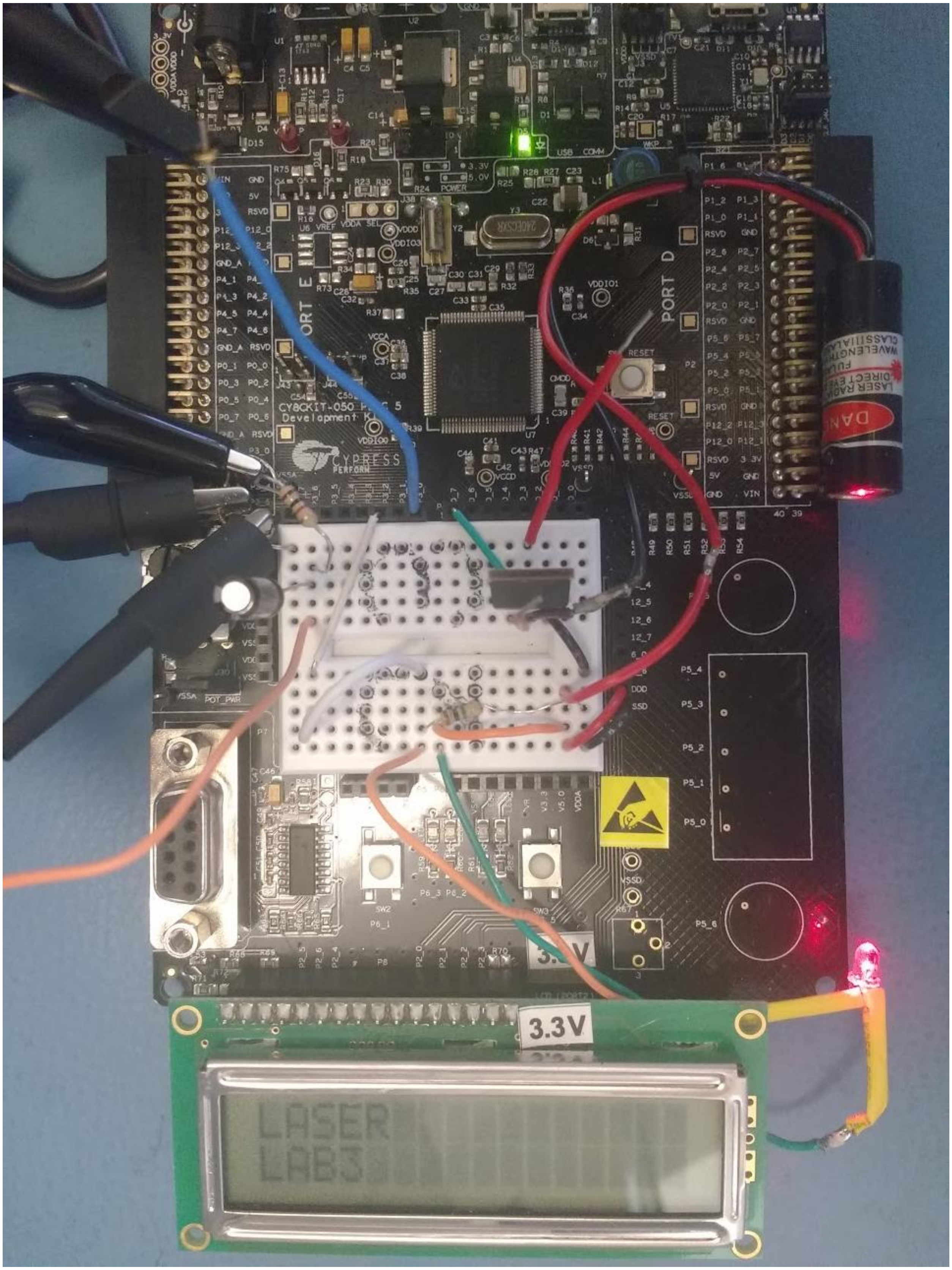
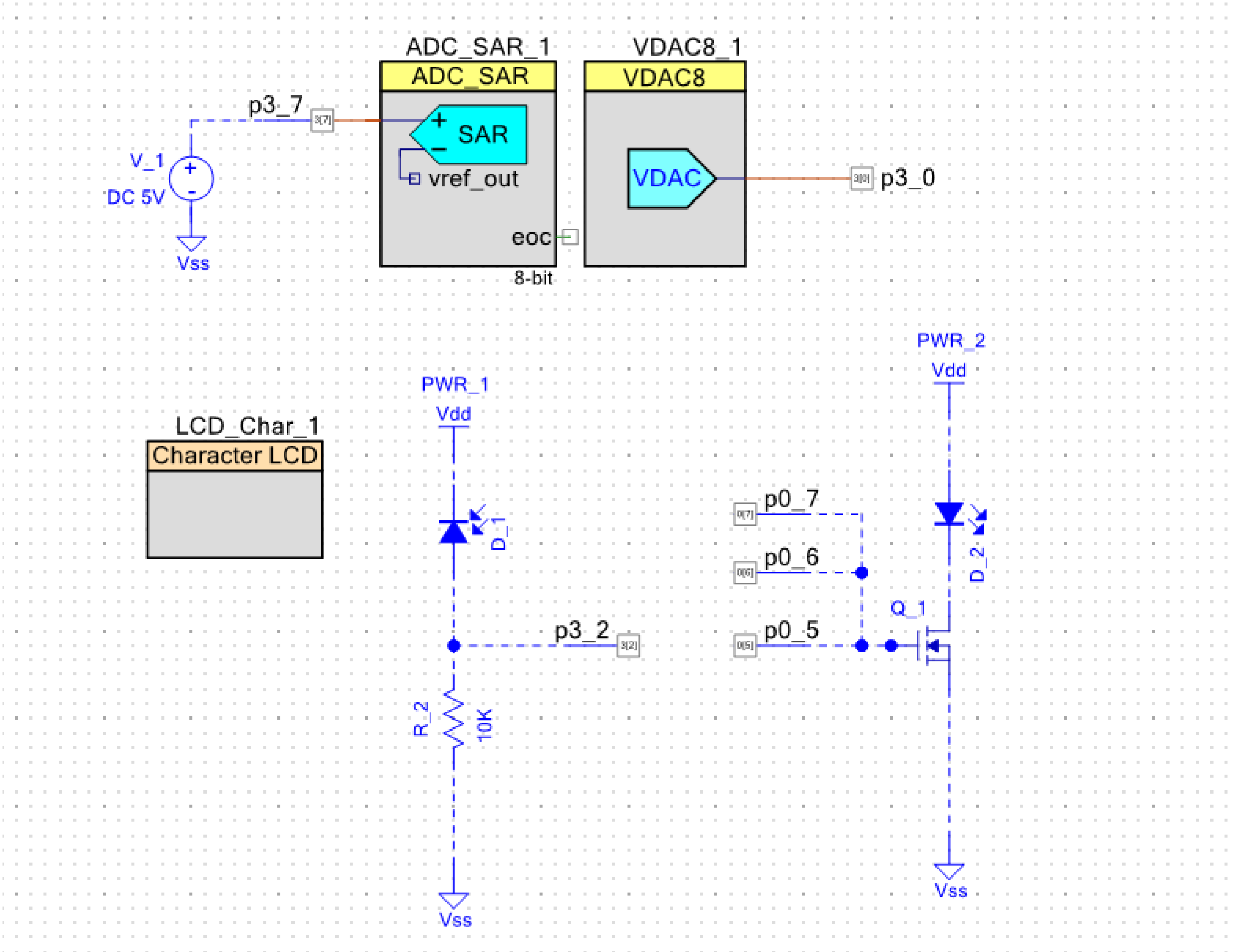

LASER
LAB3
3.3V
PORT D
RESET
CY8CKIT-050
CYPRESS

Image 1: Final Schematic (Top Design)

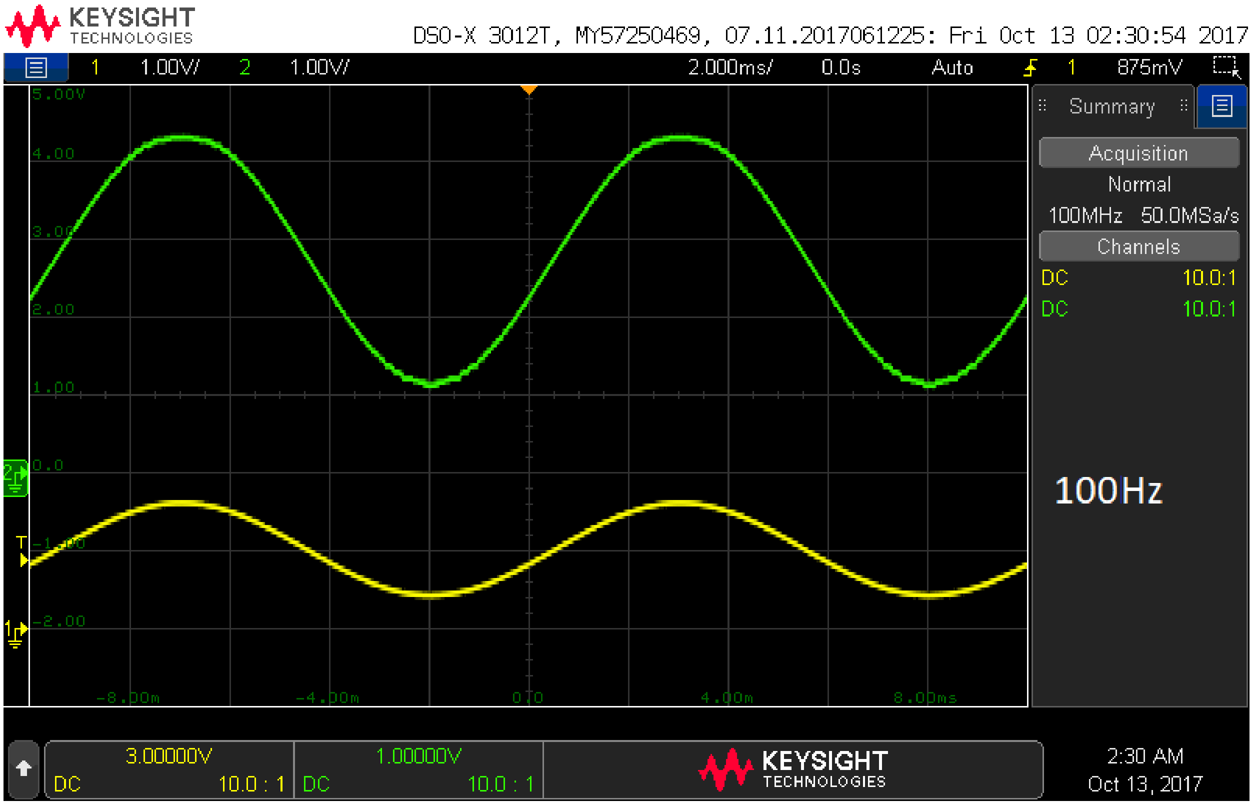


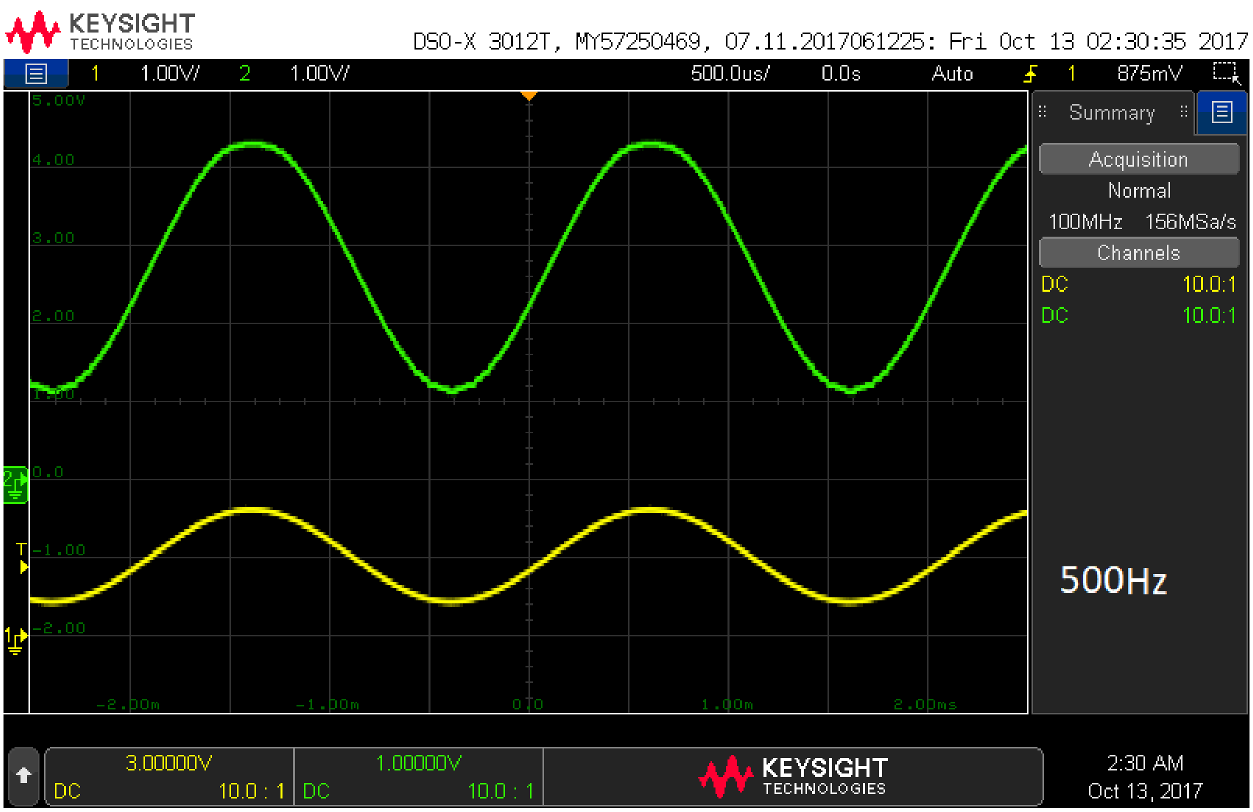
Final Code Snippet:

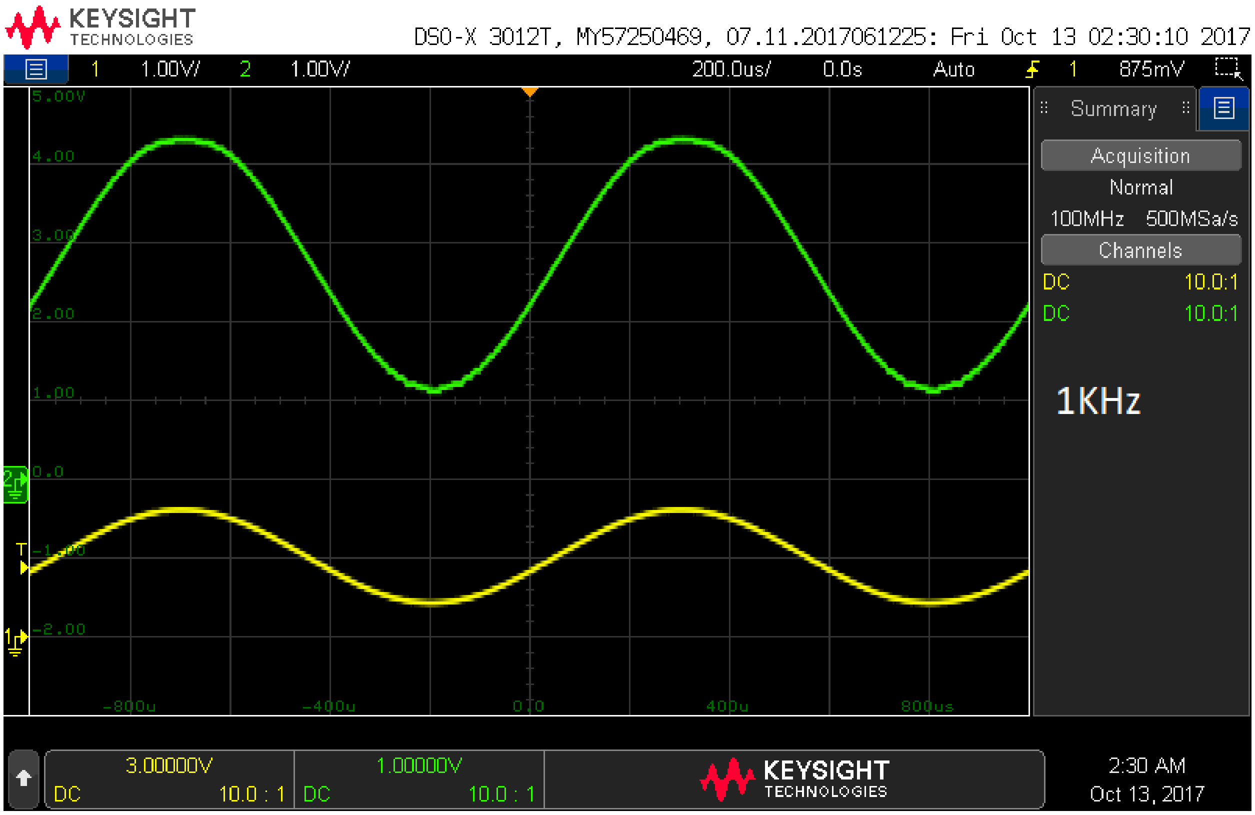
```c
int main(void)
{    int8_t value;
     uint8_t i,count=128,value2;
     CyGlobalIntEnable; /* Enable global interrupts. */
     LCD_Char_1_Start();
     ADC_SAR_1_Start();
     ADC_SAR_1_StartConvert();
     VDAC8_1_Start();
     VDAC8_1_SetRange(255);
     LCD();
     /* Place your initialization/startup code here (e.g. MyInst_Start()) */
     for(;;)
     {
         value = ADC_SAR_1_GetResult8();
         value2=value;
             // input from ADC 2's Compliment form
         if(i<value2)
         {
             p0_0_Write(1);
         }
         else
         {
             p0_0_Write(0);
         }
         /* Place your application code here. */
         if(p3_2_Read()==1u)
         {
         count++;
         }

         if(i==255)
         {
             VDAC8_1_SetValue(count+128);
             count=128;
         }
         i++;
}
}

/* [] END OF FILE */
```

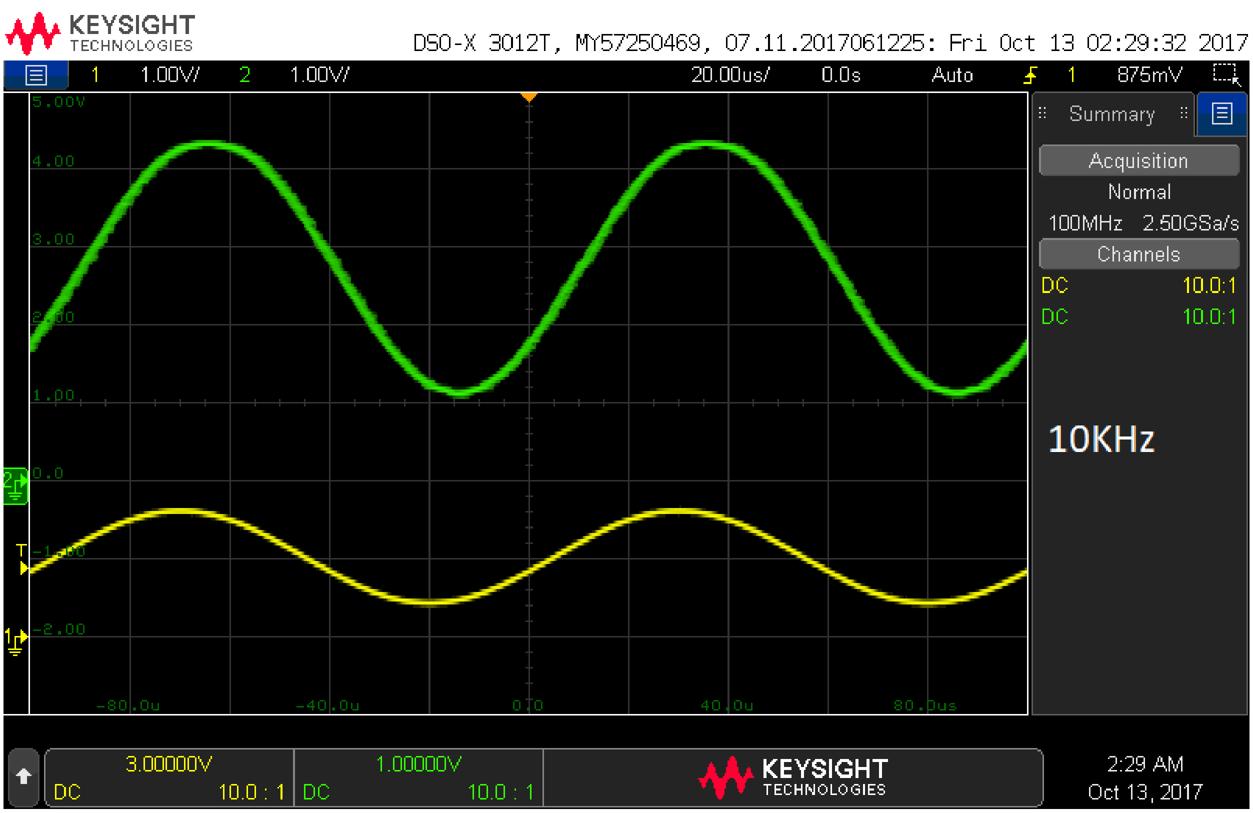
Scope shot 1-4: show the signal generator waveform on channel 1, and the DAC output on channel 1.

Increase the signal frequency to 500Hz, 1K, and 10K and take scope shots for these configurations as well.


KEYSIGHT TECHNOLOGIES
DSO-X 3012T, MY57250469, 07.11.2017061225: Fri Oct 13 02:30:54 2017
1 1.00V/ 2 1.00V/
2.000ms/ 0.0s Auto 1 875mV
Summary
Acquisition
Normal
100MHz 50.0MSa/s
Channels
DC 10.0:1
DC 10.0:1
100Hz
3.00000V
DC 10.0 : 1
1.00000V
DC 10.0 : 1
2:30 AM
Oct 13, 2017

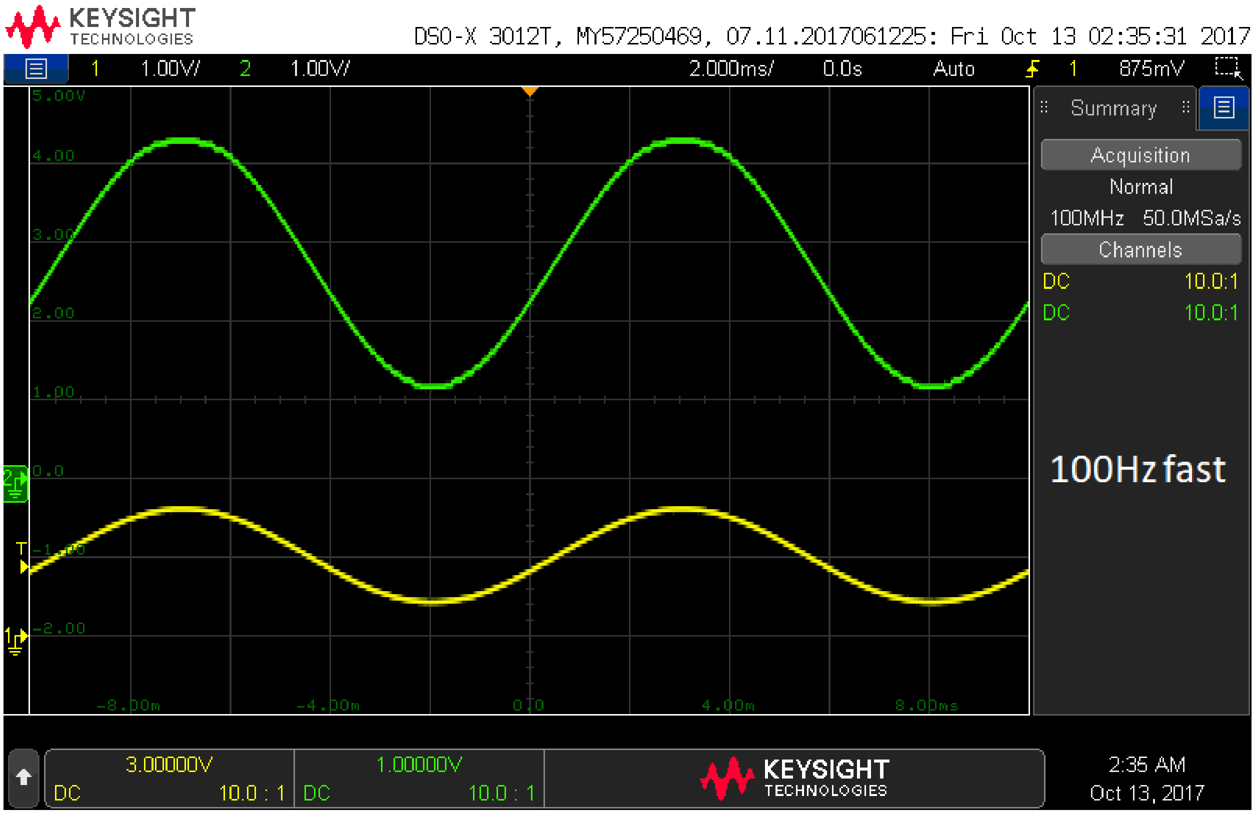

KEYSIGHT TECHNOLOGIES
DSO-X 3012T, MY57250469, 07.11.2017061225: Fri Oct 13 02:30:35 2017
1 1.00V/ 2 1.00V/
500.0us/ 0.0s Auto 1 875mV
Summary
Acquisition
Normal
100MHz 156MSa/s
Channels
DC 10.0:1
DC 10.0:1
500Hz
3.00000V
DC 10.0 : 1
1.00000V
DC 10.0 : 1
2:30 AM
Oct 13, 2017

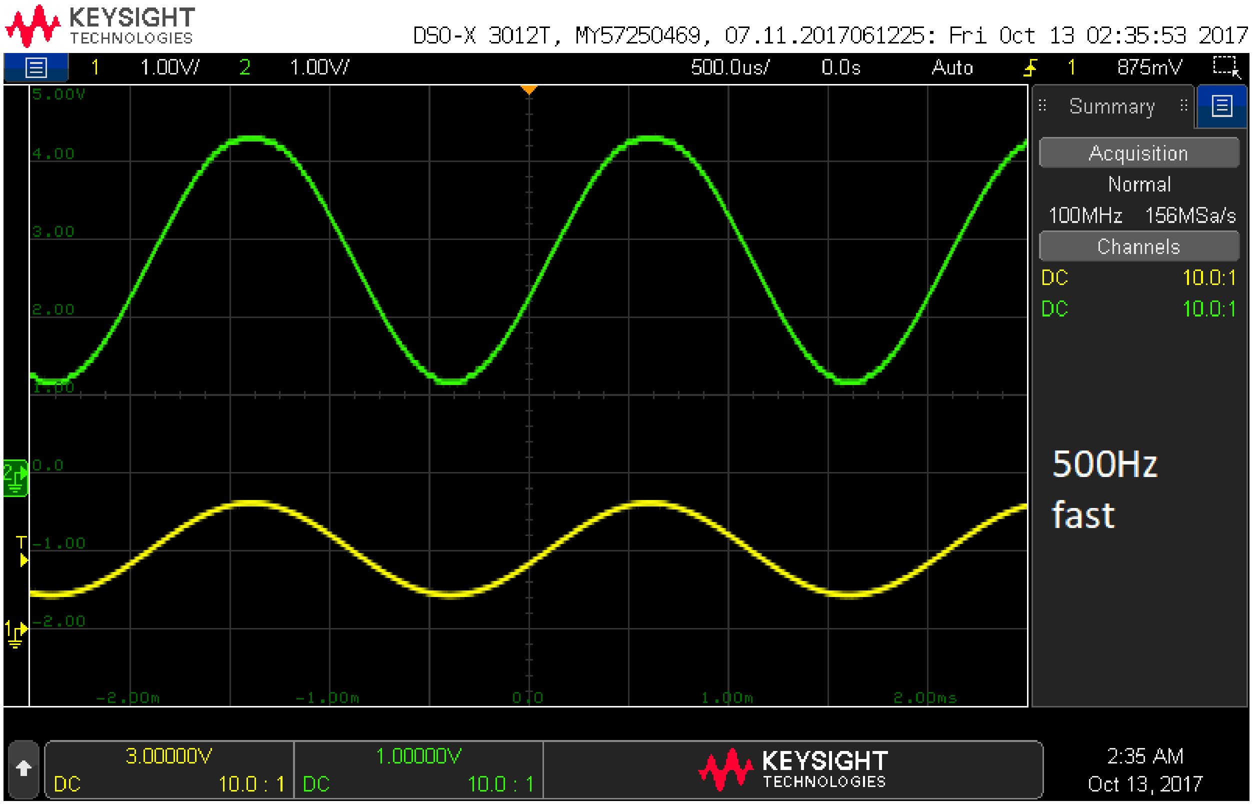


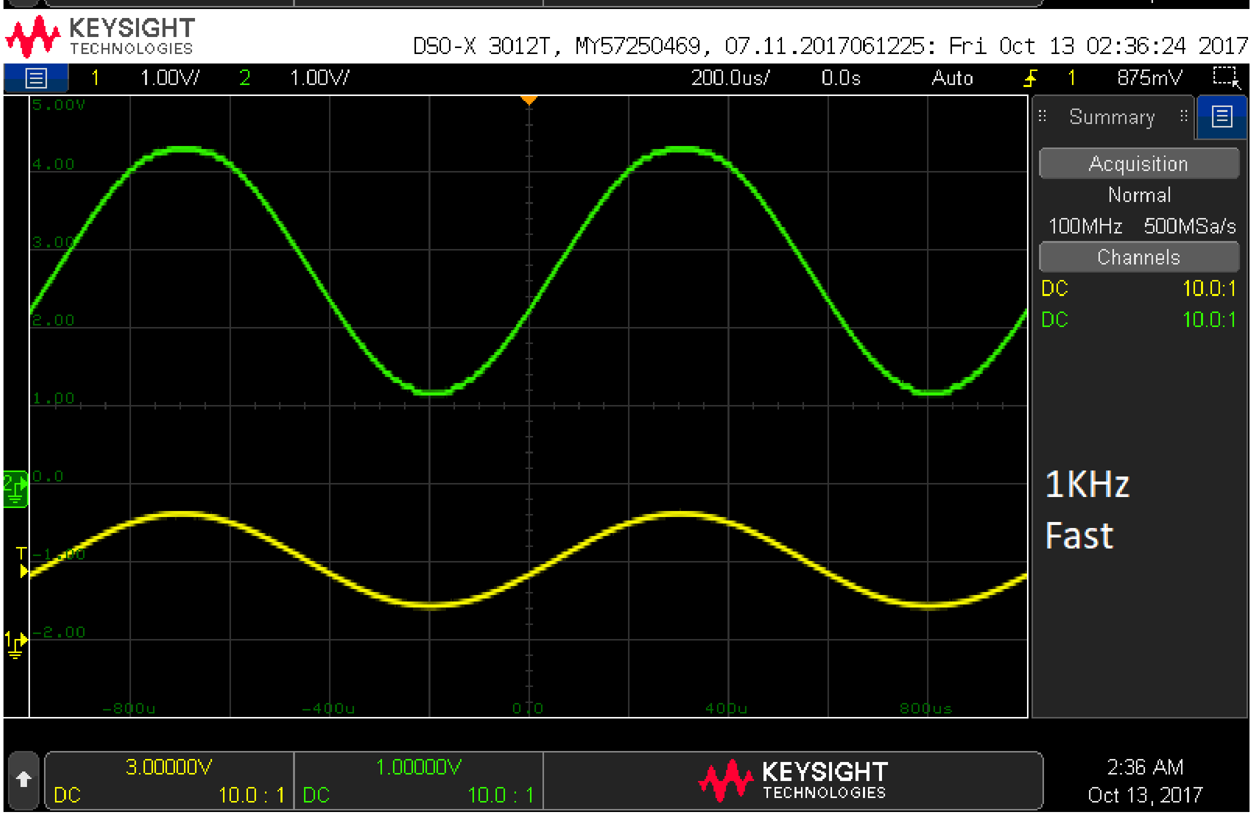


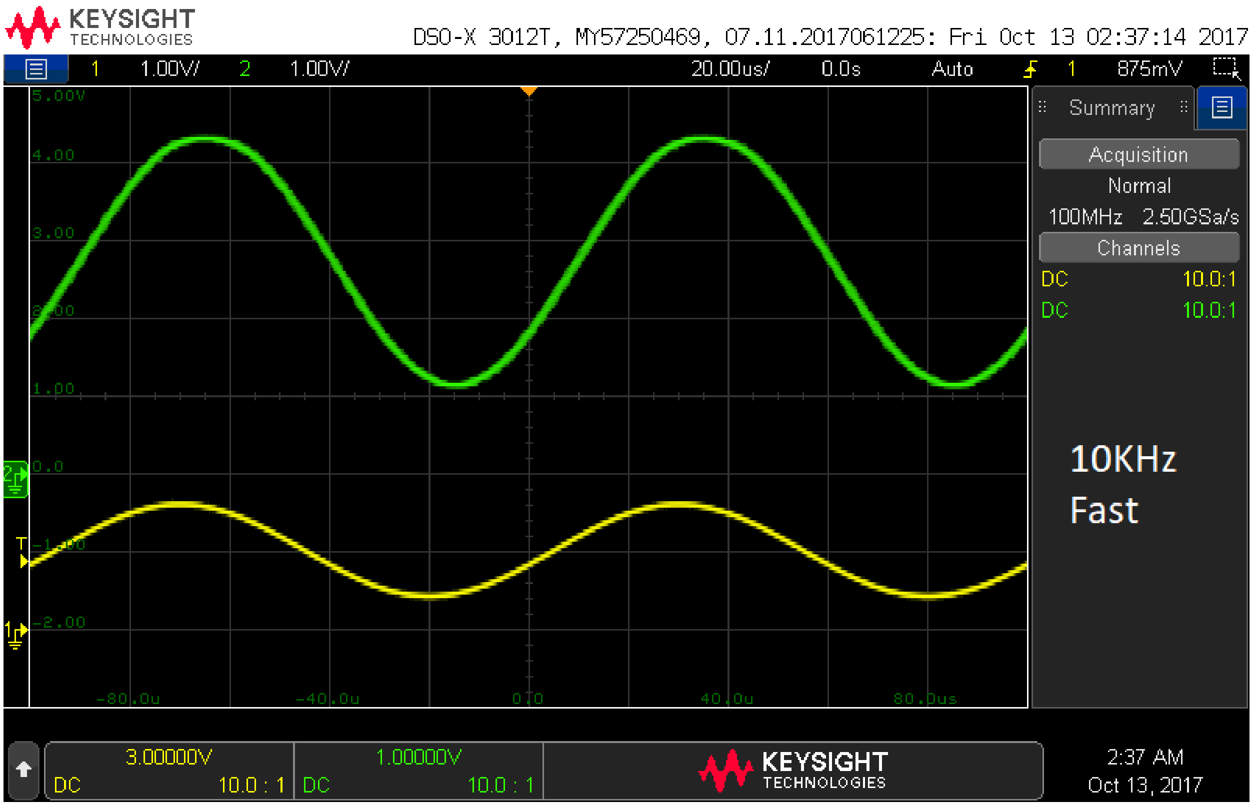
Step 3- Set the DAC & ADC for the fastest output and sampling speeds possible for the configuration. Try to optimize your ADC sampling code as well.

Scope shot 5-8: show the signal generator waveform on channel 1, and the DAC output on channel 1 for this new maximum configuration for the following frequencies 100Hz, 500, 1K and 10K.




KEYSIGHT TECHNOLOGIES
DSO-X 3012T, MY57250469, 07.11.2017061225: Fri Oct 13 02:35:53 2017
1 1.00V/ 2 1.00V/ 500.0us/ 0.0s Auto 1 875mV
Summary
Acquisition
Normal
100MHz 156MSa/s
Channels
DC 10.0:1
DC 10.0:1
500Hz
fast
3.00000V
DC 10.0 : 1
1.00000V
DC 10.0 : 1
2:35 AM
Oct 13, 2017


KEYSIGHT TECHNOLOGIES
DSO-X 3012T, MY57250469, 07.11.2017061225: Fri Oct 13 02:36:24 2017
1 1.00V/ 2 1.00V/ 200.0us/ 0.0s Auto 1 875mV
Summary
Acquisition
Normal
100MHz 500MSa/s
Channels
DC 10.0:1
DC 10.0:1
1KHz
Fast
3.00000V
DC 10.0 : 1
1.00000V
DC 10.0 : 1
2:36 AM
Oct 13, 2017

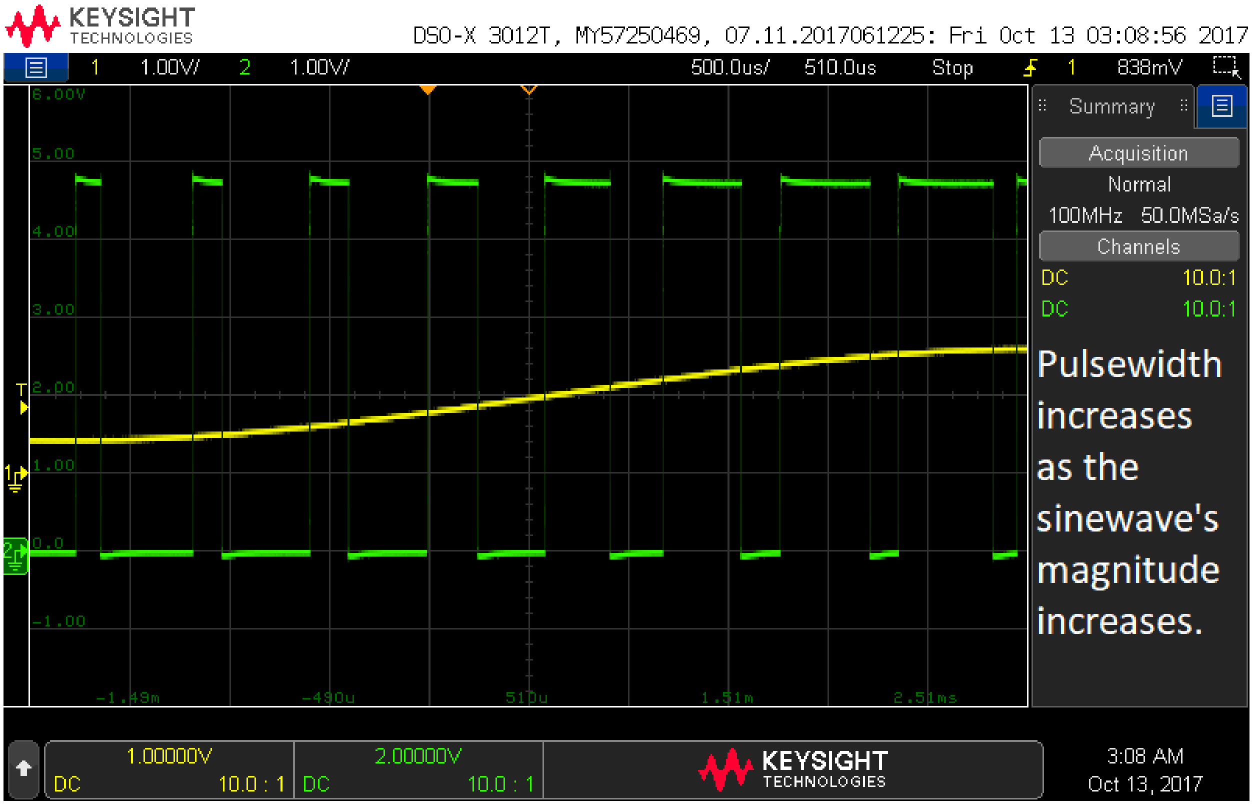


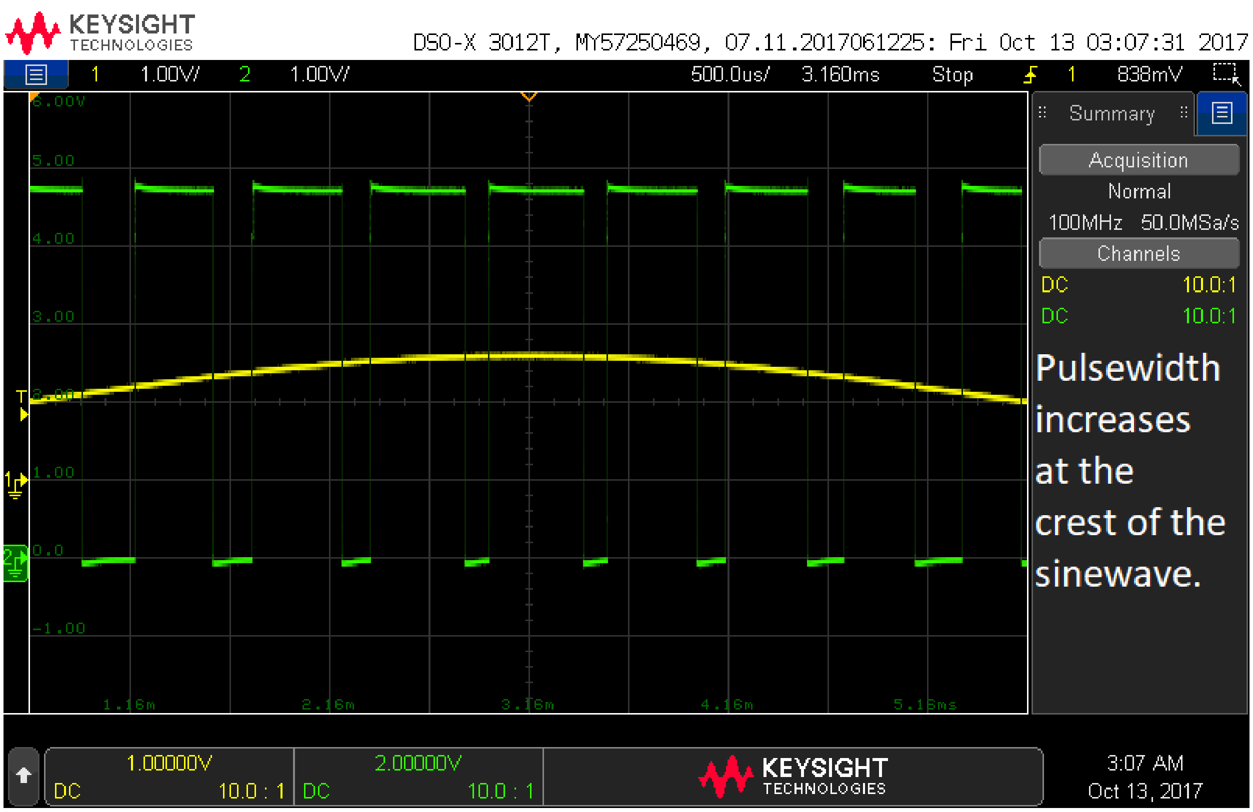
Question 1: Do you notice a difference in the waveforms in the first set (1-4) and the second set (5-8)? Explain this difference.

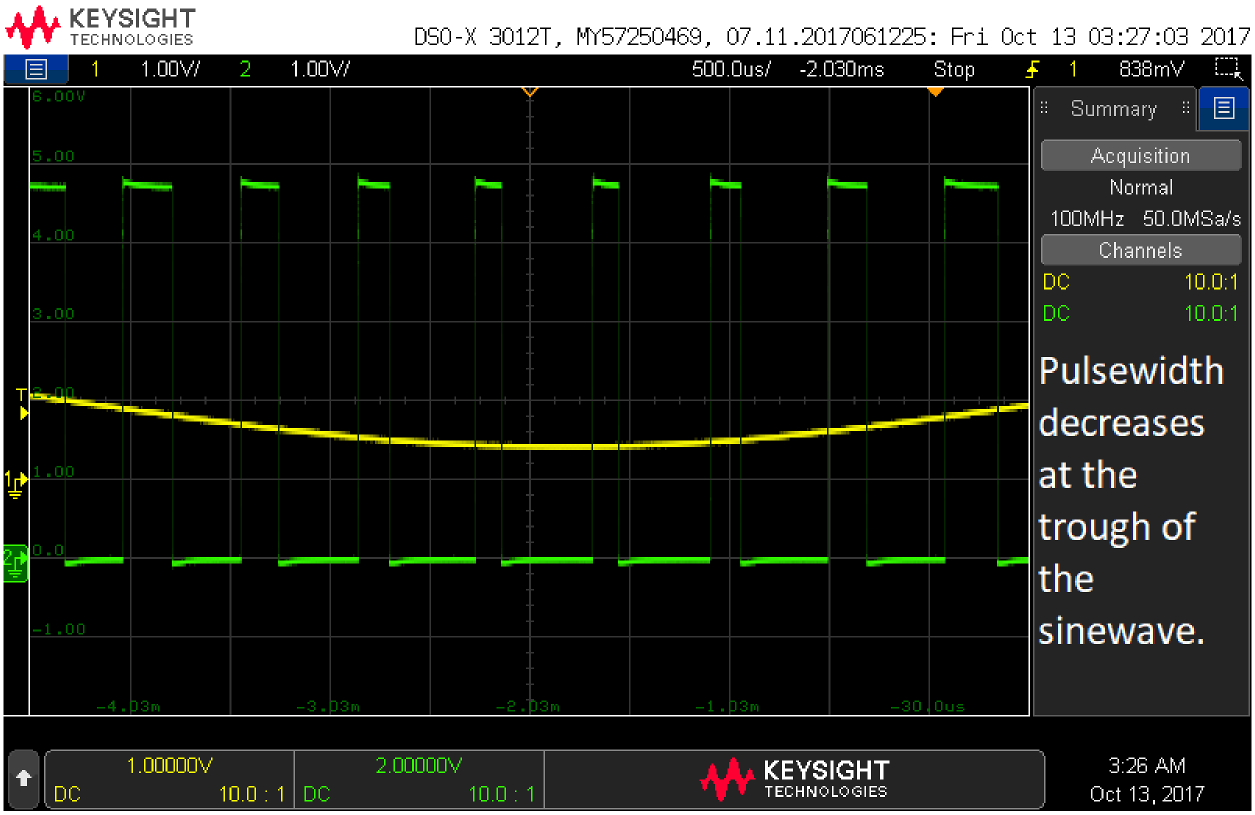
Answer: The output of DSO is a little blur for 1KHz and 10KHz (scopeshot 3 and 4). i.e. The no. of sampling rate is less with respect to the sample frequency. When we increase the sampling rate for scopeshots 5 to 8, we get sharp waveforms for 1KHz and 10KHz (scopeshot 7 and 8).

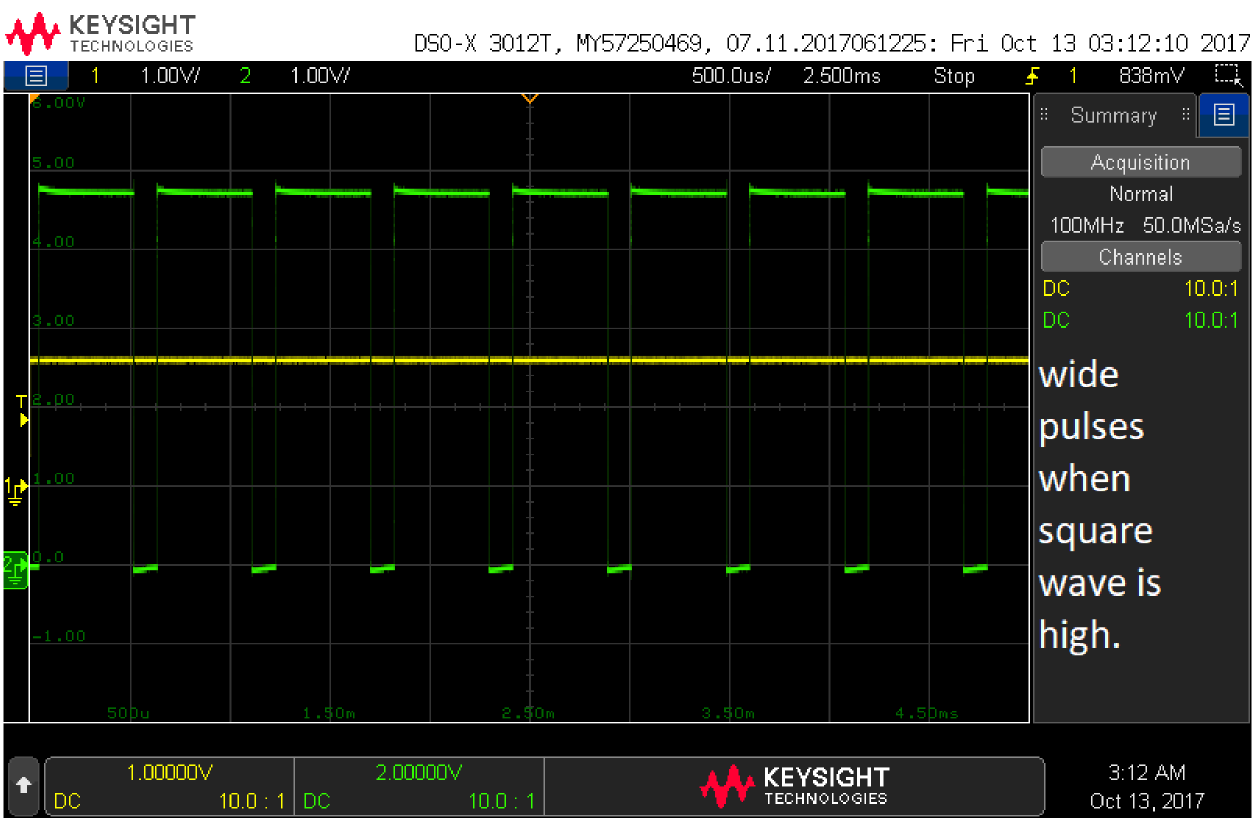
Encoding

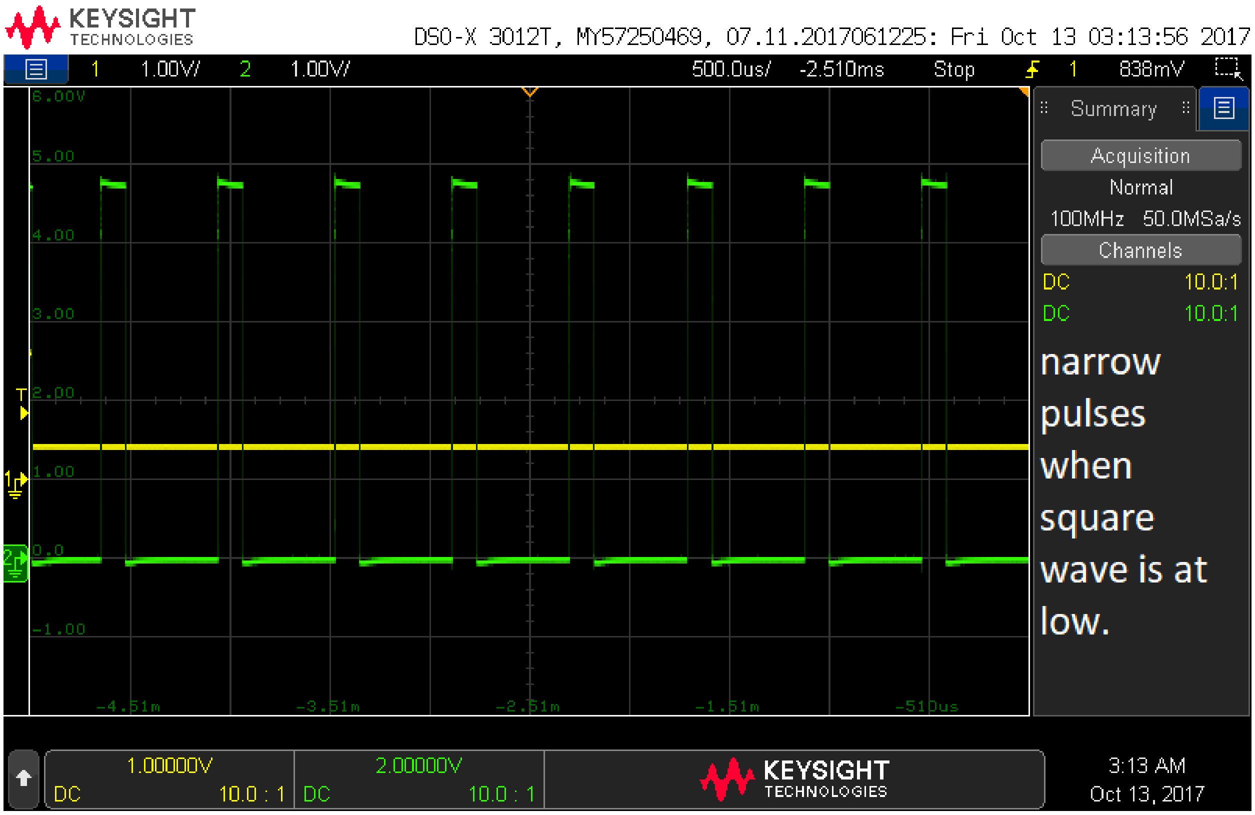
Scope shot 9-11: ch 1 = sinewave from signal generator. Ch 2 = Output of your encoding method for different sections of your sine wave. 1 scope shot zoomed in.

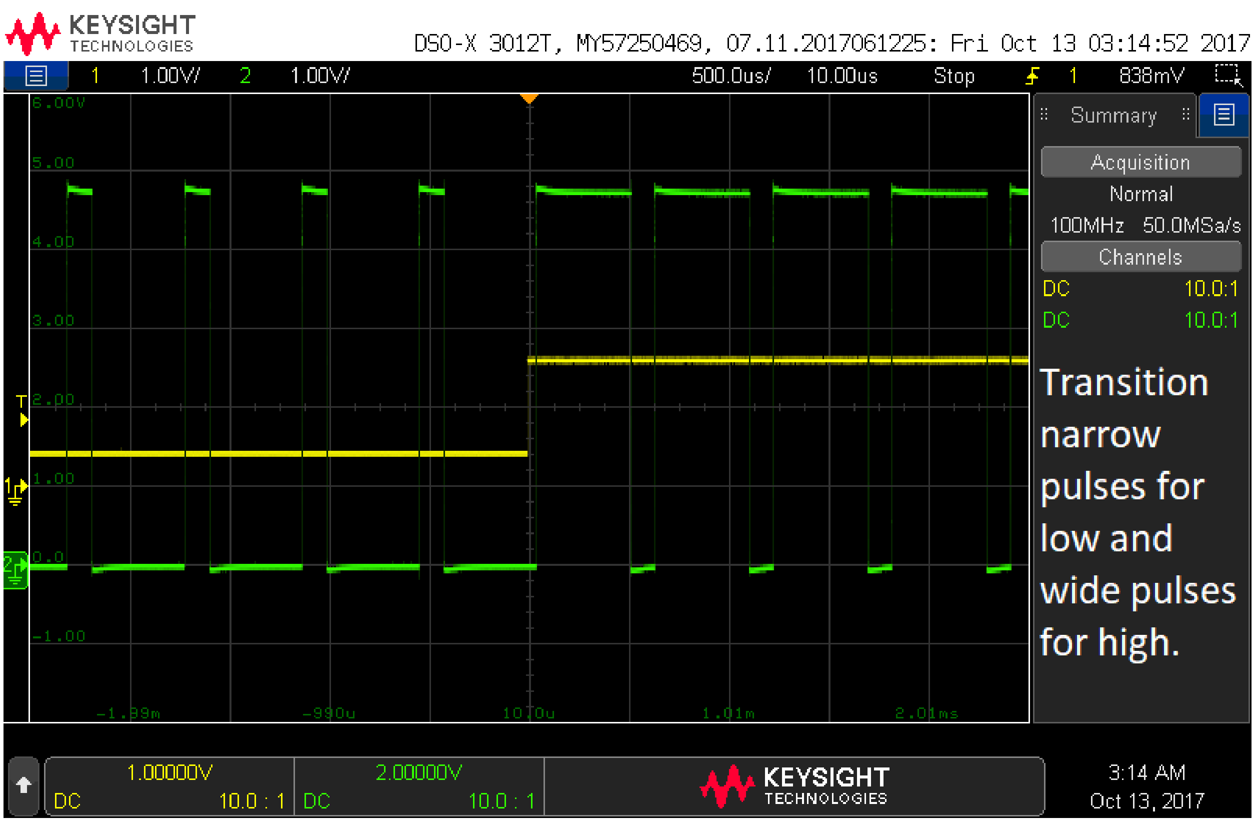

KEYSIGHT TECHNOLOGIES
DSO-X 3012T, MY57250469, 07.11.2017061225: Fri Oct 13 03:08:56 2017
1 1.00V/ 2 1.00V/ 500.0us/ 510.0us Stop 1 838mV
Summary
Acquisition
Normal
100MHz 50.0MSa/s
Channels
DC 10.0:1
DC 10.0:1
Pulsewidth increases as the sinewave's magnitude increases.
1.00000V DC 10.0 : 1
2.00000V DC 10.0 : 1
3:08 AM Oct 13, 2017

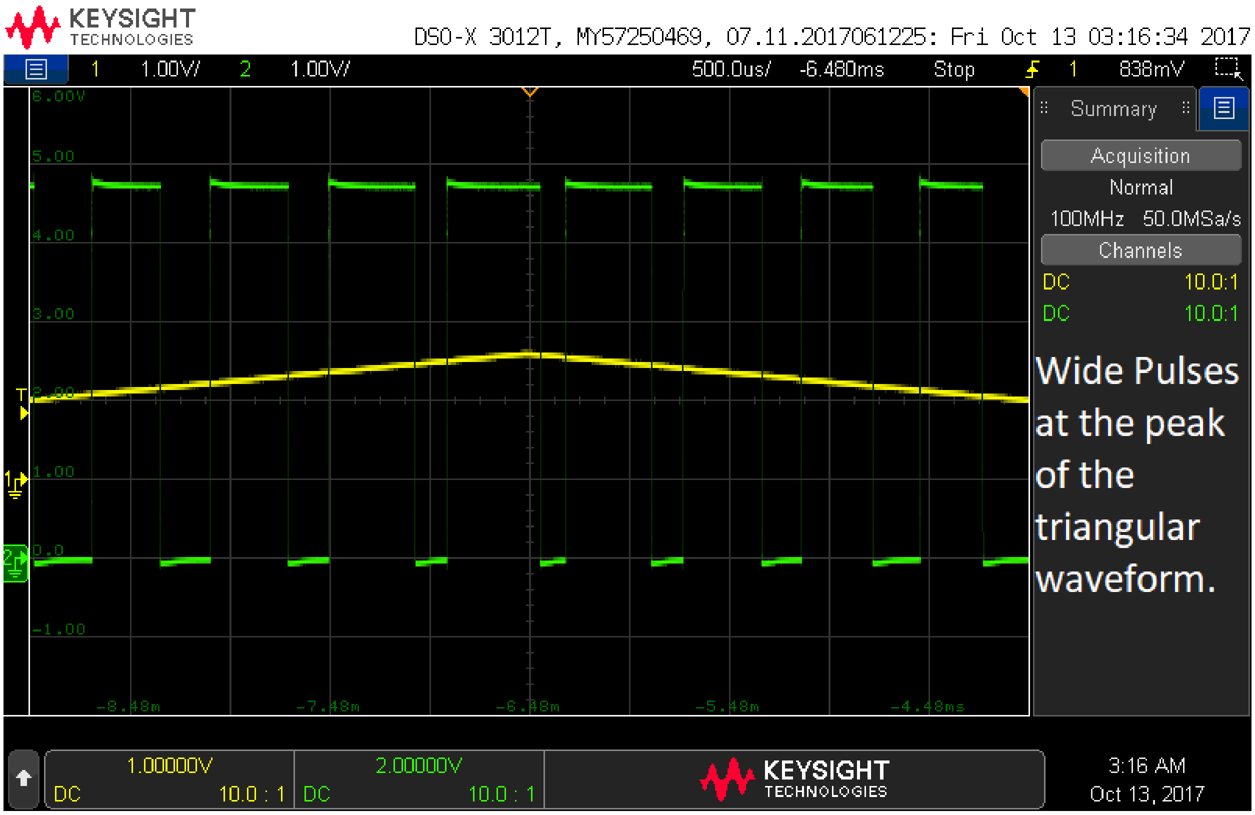

KEYSIGHT TECHNOLOGIES
DSO-X 3012T, MY57250469, 07.11.2017061225: Fri Oct 13 03:07:31 2017
1 1.00V/ 2 1.00V/ 500.0us/ 3.160ms Stop 1 838mV
Summary
Acquisition
Normal
100MHz 50.0MSa/s
Channels
DC 10.0:1
DC 10.0:1
Pulsewidth increases at the crest of the sinewave.
1.00000V DC 10.0 : 1
2.00000V DC 10.0 : 1
3:07 AM Oct 13, 2017

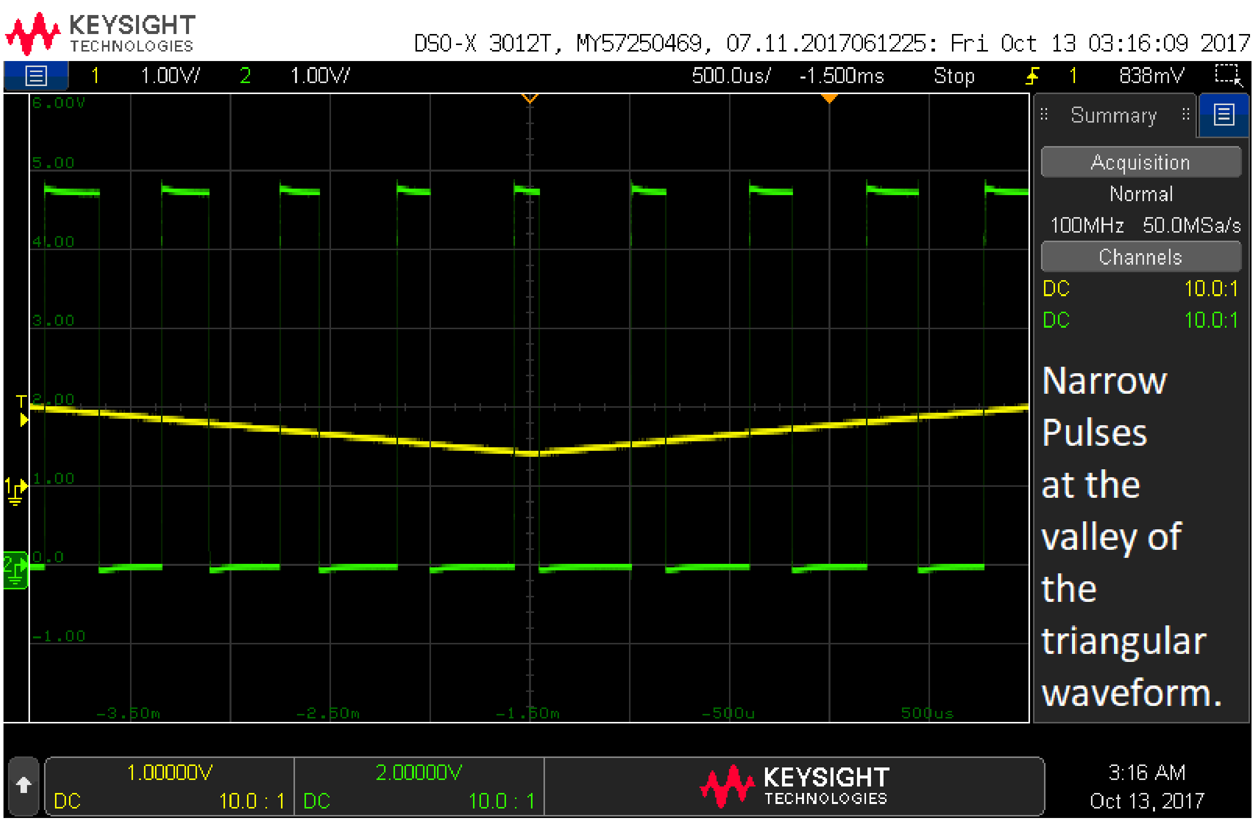

KEYSIGHT TECHNOLOGIES
DSO-X 3012T, MY57250469, 07.11.2017061225: Fri Oct 13 03:27:03 2017
1 1.00V/ 2 1.00V/ 500.0us/ -2.030ms Stop 1 838mV
Summary
Acquisition
Normal
100MHz 50.0MSa/s
Channels
DC 10.0:1
DC 10.0:1
Pulsewidth decreases at the trough of the sinewave.
1.00000V DC 10.0 : 1
2.00000V DC 10.0 : 1
3:26 AM
Oct 13, 2017

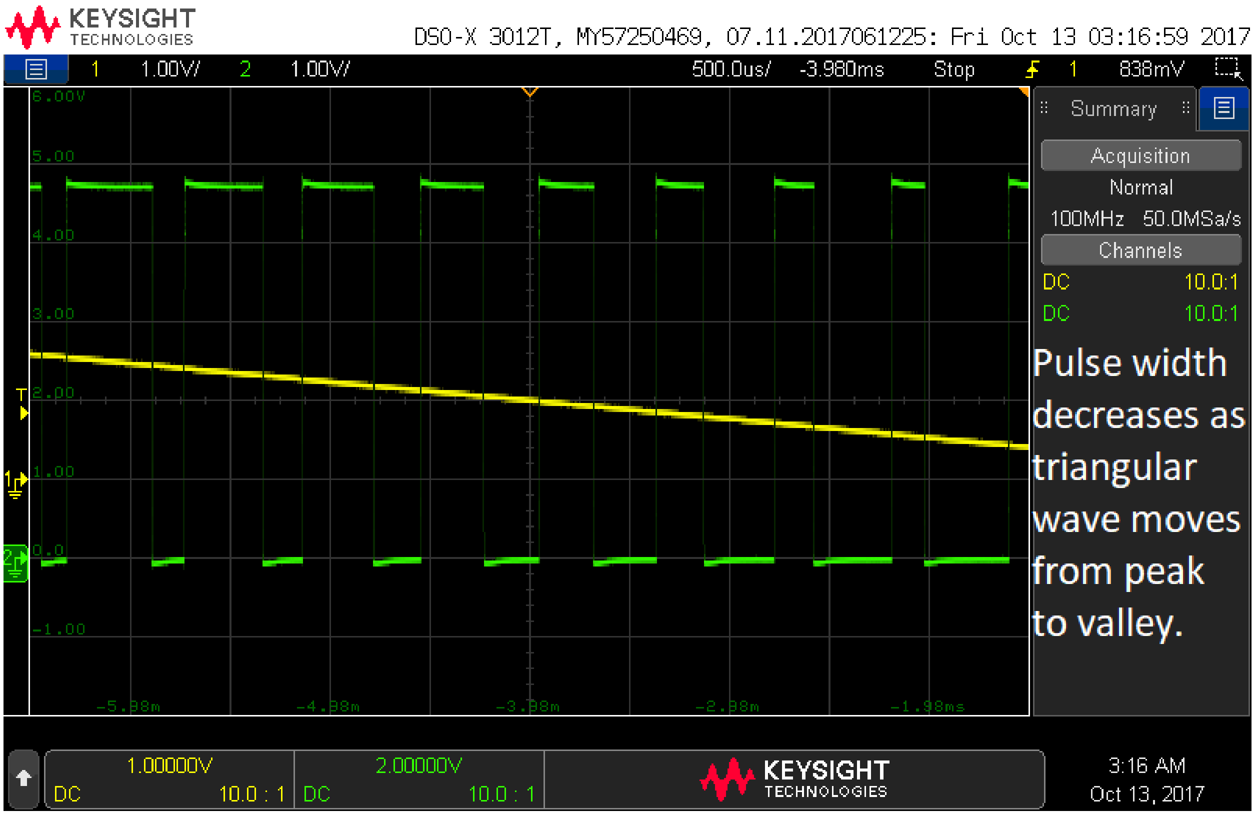

KEYSIGHT TECHNOLOGIES
DSO-X 3012T, MY57250469, 07.11.2017061225: Fri Oct 13 03:12:10 2017
1 1.00V/ 2 1.00V/ 500.0us/ 2.500ms Stop 1 838mV
Summary
Acquisition
Normal
100MHz 50.0MSa/s
Channels
DC 10.0:1
DC 10.0:1
wide pulses when square wave is high.
1.00000V DC 10.0 : 1
2.00000V DC 10.0 : 1
3:12 AM
Oct 13, 2017


KEYSIGHT TECHNOLOGIES
DSO-X 3012T, MY57250469, 07.11.2017061225: Fri Oct 13 03:13:56 2017
1 1.00V/ 2 1.00V/
500.0us/ -2.510ms
Stop
1 838mV
Summary
Acquisition
Normal
100MHz 50.0MSa/s
Channels
DC 10.0:1
DC 10.0:1
narrow pulses when square wave is at low.
1.00000V
DC 10.0 : 1
2.00000V
DC 10.0 : 1
3:13 AM
Oct 13, 2017

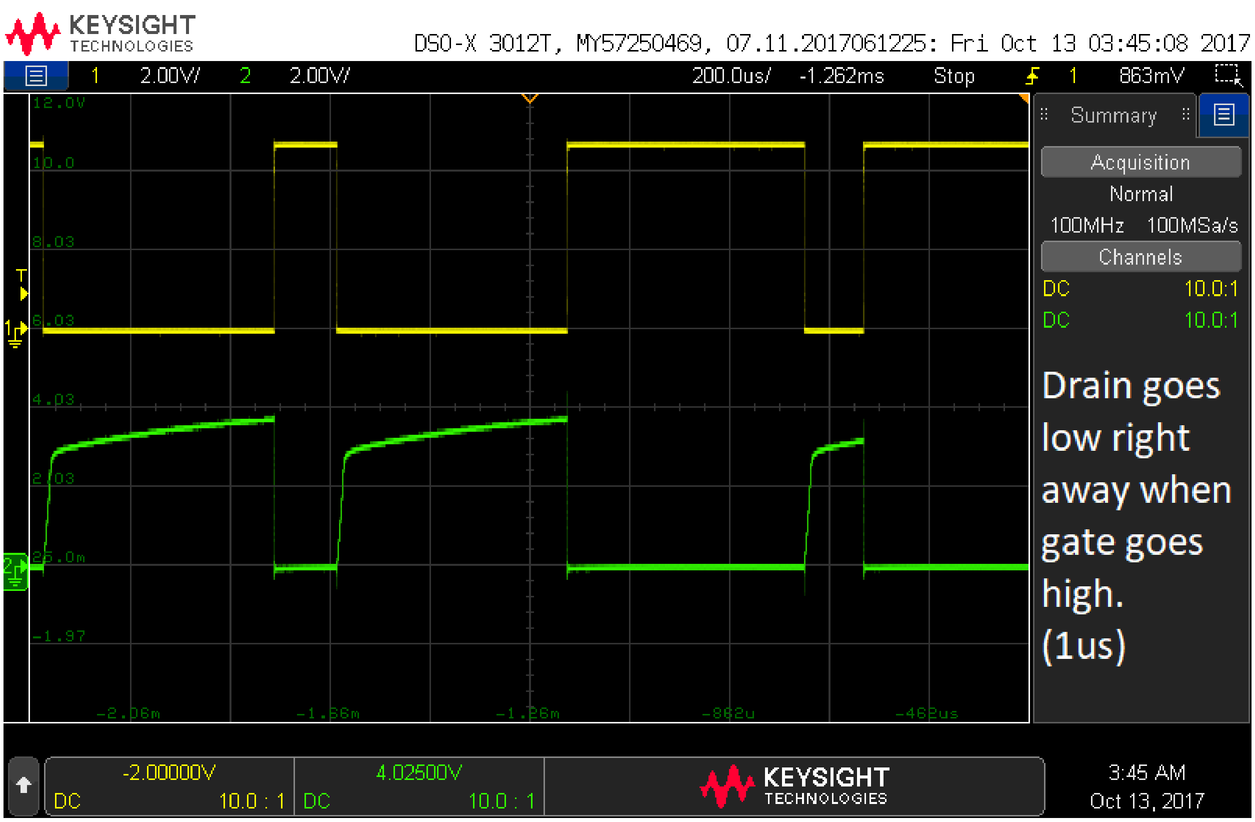

KEYSIGHT TECHNOLOGIES
DSO-X 3012T, MY57250469, 07.11.2017061225: Fri Oct 13 03:14:52 2017
1 1.00V/ 2 1.00V/
500.0us/ 10.00us
Stop
1 838mV
Summary
Acquisition
Normal
100MHz 50.0MSa/s
Channels
DC 10.0:1
DC 10.0:1
Transition narrow pulses for low and wide pulses for high.
1.00000V
DC 10.0 : 1
2.00000V
DC 10.0 : 1
3:14 AM
Oct 13, 2017


KEYSIGHT TECHNOLOGIES
DSO-X 3012T, MY57250469, 07.11.2017061225: Fri Oct 13 03:16:34 2017
1 1.00V/ 2 1.00V/
500.0us/ -6.480ms Stop
1 838mV
Summary
Acquisition
Normal
100MHz 50.0MSa/s
Channels
DC 10.0:1
DC 10.0:1
Wide Pulses at the peak of the triangular waveform.
1.00000V
DC 10.0 : 1
2.00000V
DC 10.0 : 1
3:16 AM
Oct 13, 2017


KEYSIGHT TECHNOLOGIES
DSO-X 3012T, MY57250469, 07.11.2017061225: Fri Oct 13 03:16:09 2017
1 1.00V/ 2 1.00V/
500.0us/ -1.500ms Stop
1 838mV
Summary
Acquisition
Normal
100MHz 50.0MSa/s
Channels
DC 10.0:1
DC 10.0:1
Narrow Pulses at the valley of the triangular waveform.
1.00000V
DC 10.0 : 1
2.00000V
DC 10.0 : 1
3:16 AM
Oct 13, 2017

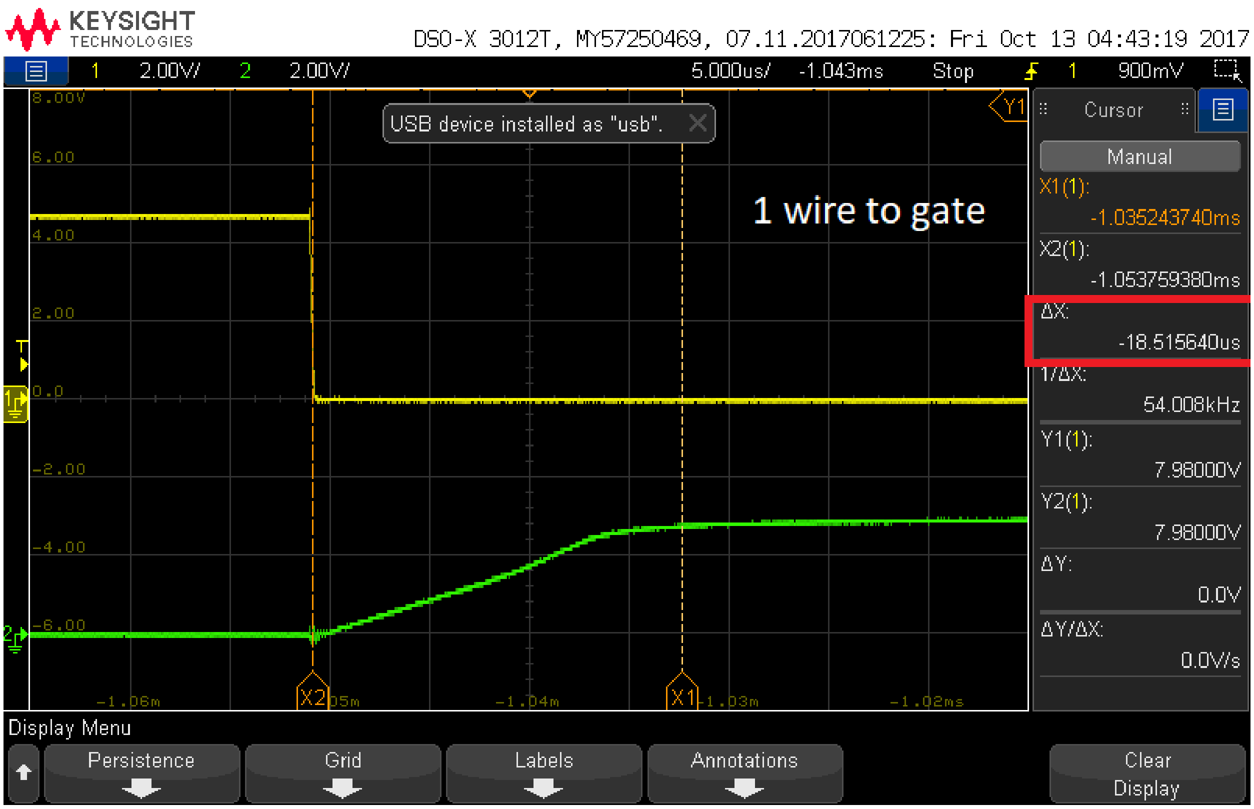


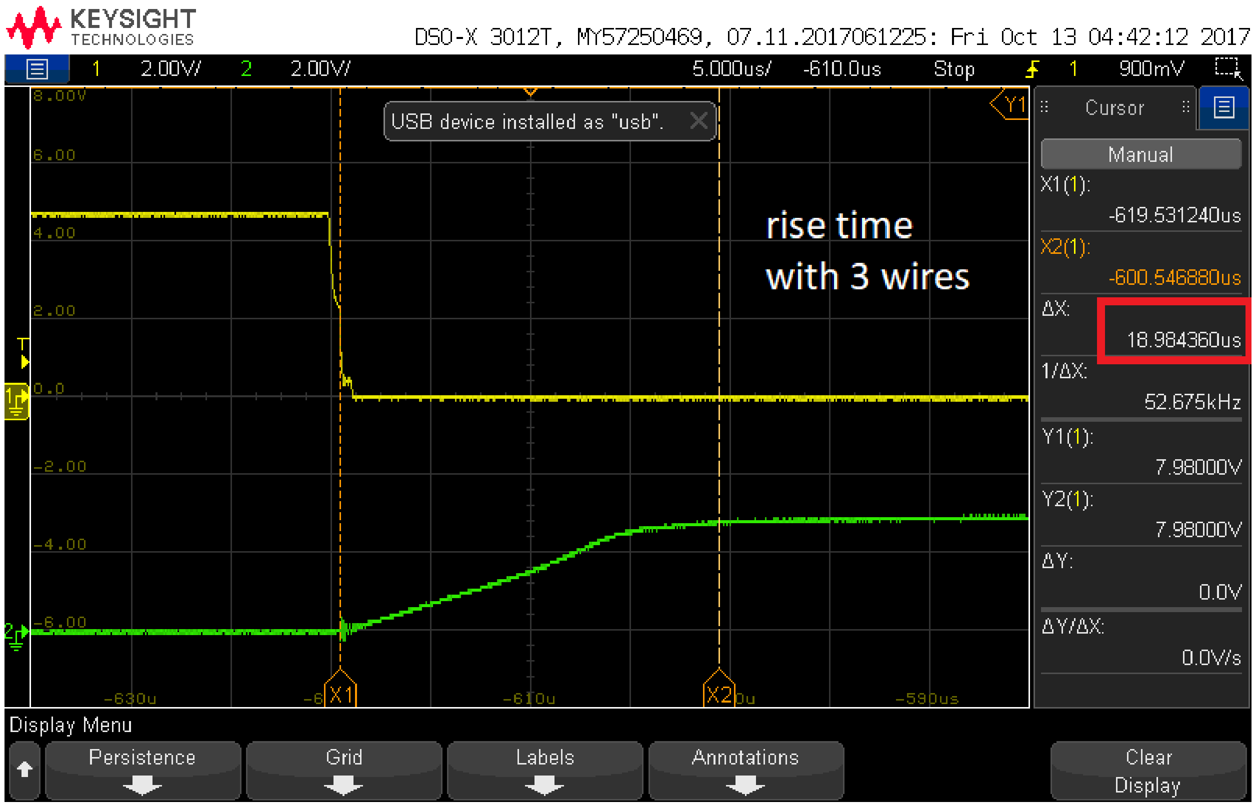
Scope shot 12: ch 1 = FET gate (from a single PSoC GPIO pin), ch 2 = FET drain (which shows the Laser turning on). The drain should go right to ground when the FET gate goes high (+/- 100 mV).

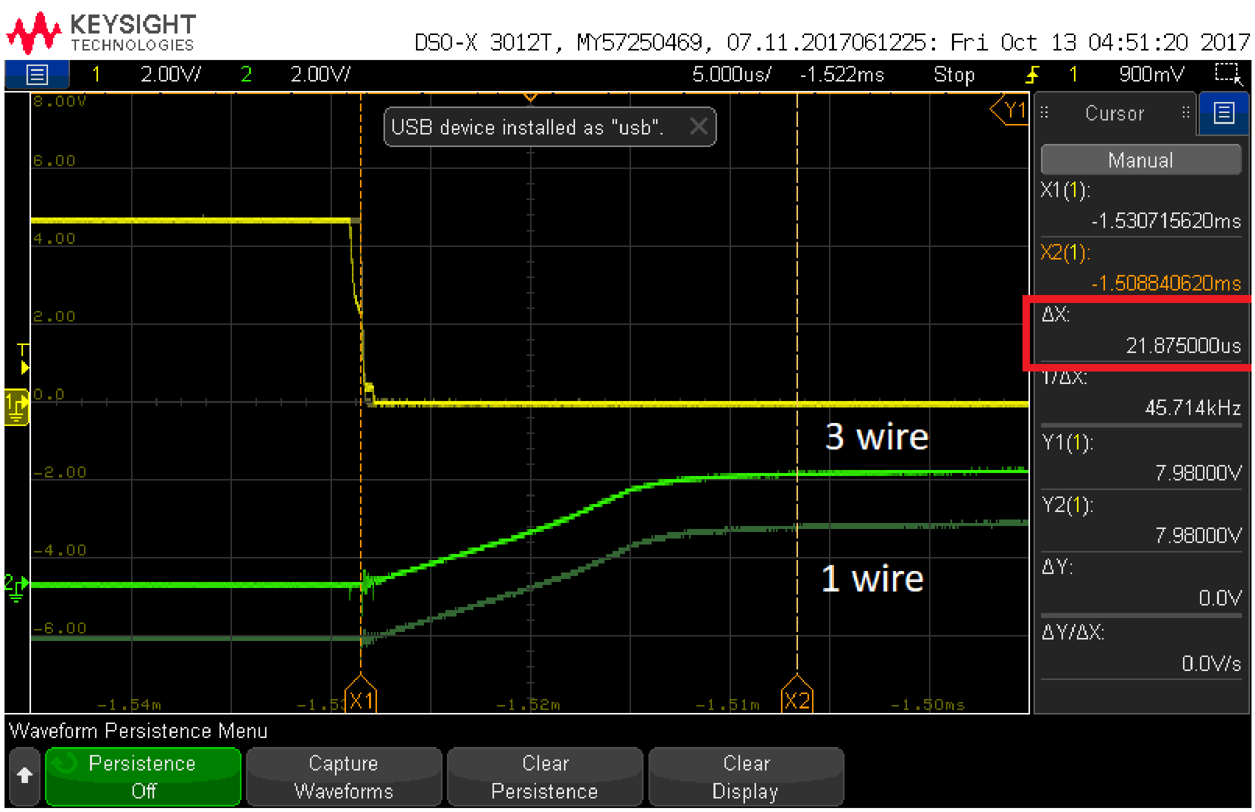


Scope shot 12a: same as scope shot 3, but using 3 GPIO pins in parallel to achieve faster rise time

The rise time is approximately the same even if we use 3 GPIO pins in parallel instead of 1. This is may be because the Gate terminal of the MOSFET has a high impedance. The Switching in MOSFET depends on the voltage and not on the current. So adding parallel tracks of same voltage won't affect the switching time.







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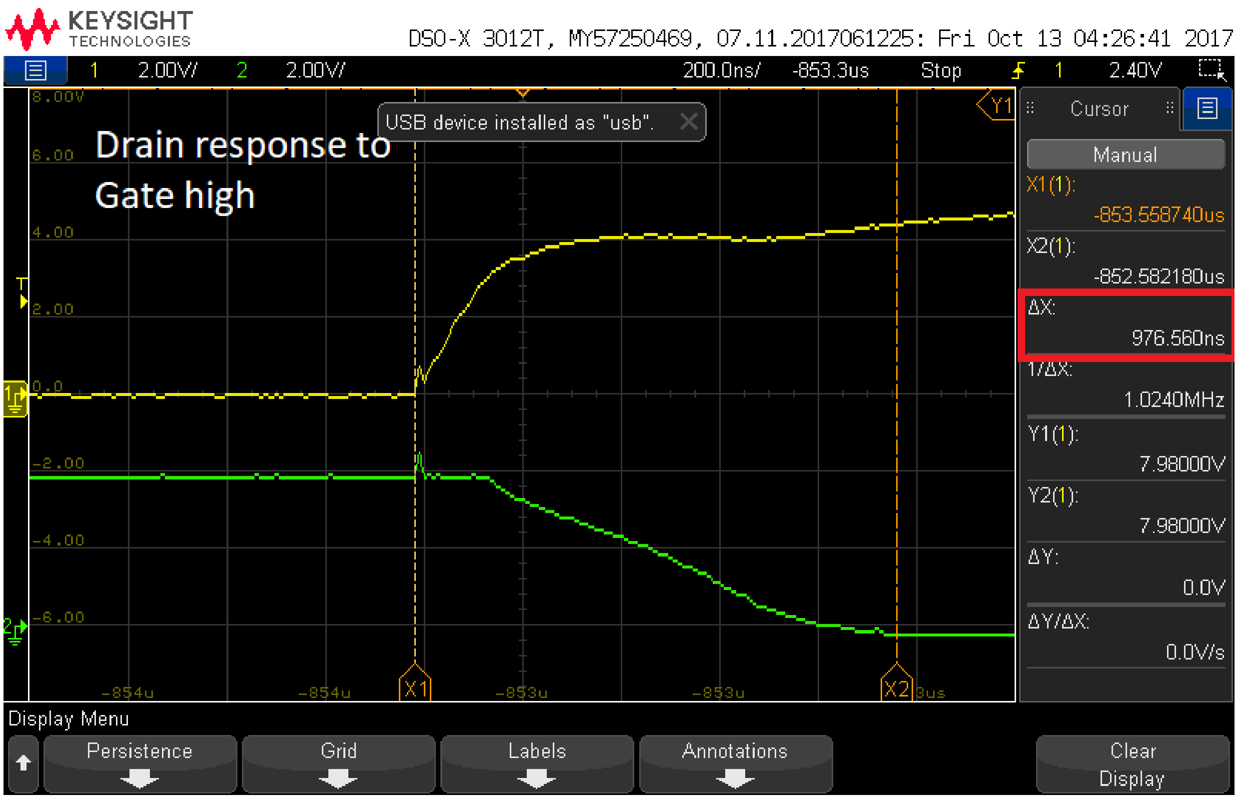
Suggestion: using the scope's internal memory to save traces, combine scope shots 3 and 3a into one image for easy comparison.

Question 2: Given the measured rise times, approximately how fast can this circuit turn the laser on and off before the signal degrades?

Answer: The rise time of the LASER is approximately 20us. So the maximum sampling frequency will be 1/20us=50KHz. Therefore, by Nyquist criteria it can decode a signal of upto 25KHz. But to get an undistorted output, the sample frequency must be 1/10th of the sampling frequency. i.e. to get an undistorted output the maximum sample frequency is **5 KHz.** Above this frequency the signl degrades.

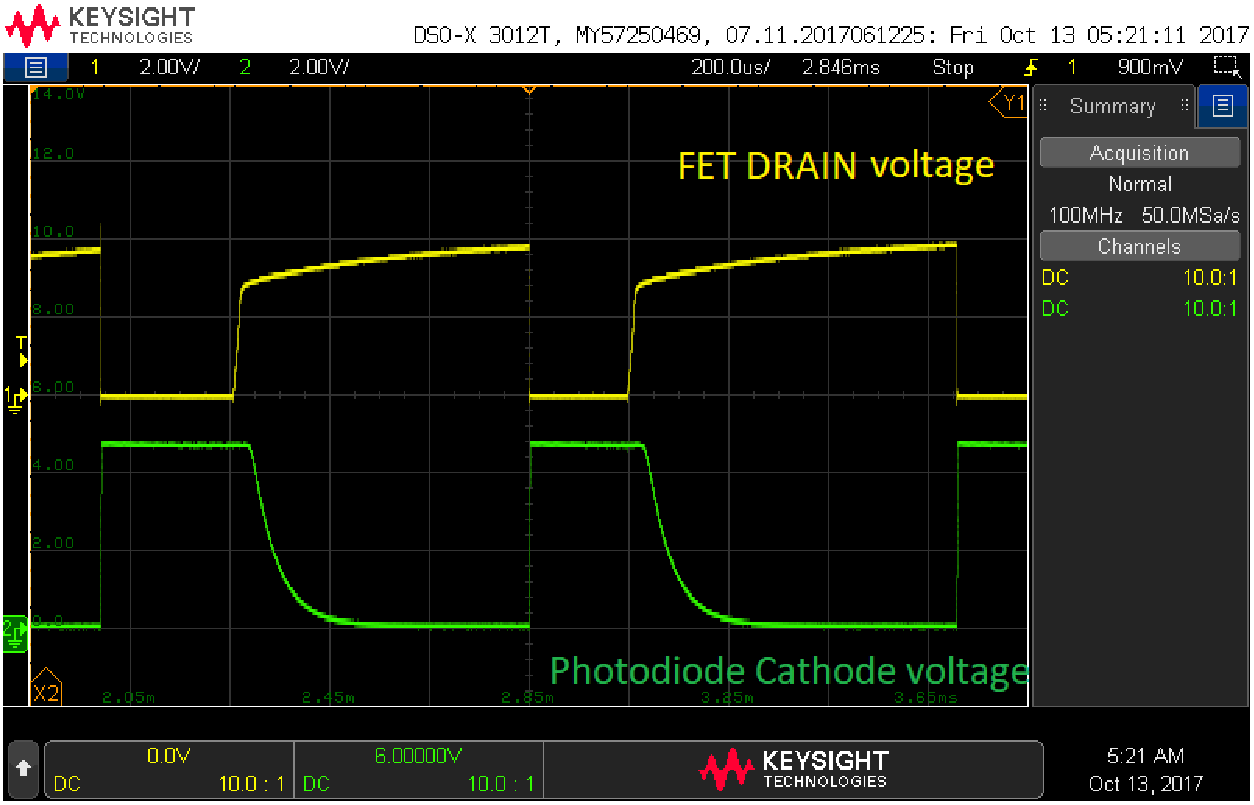
Question 3: How long is the delay between the FET gate rising and the FET drain going to near 0 volts?

Answer: The delay between the FET gate rising and the FET drain going to near 0 volts is 976.560ns which is approximately equal to 1us.



Decoding

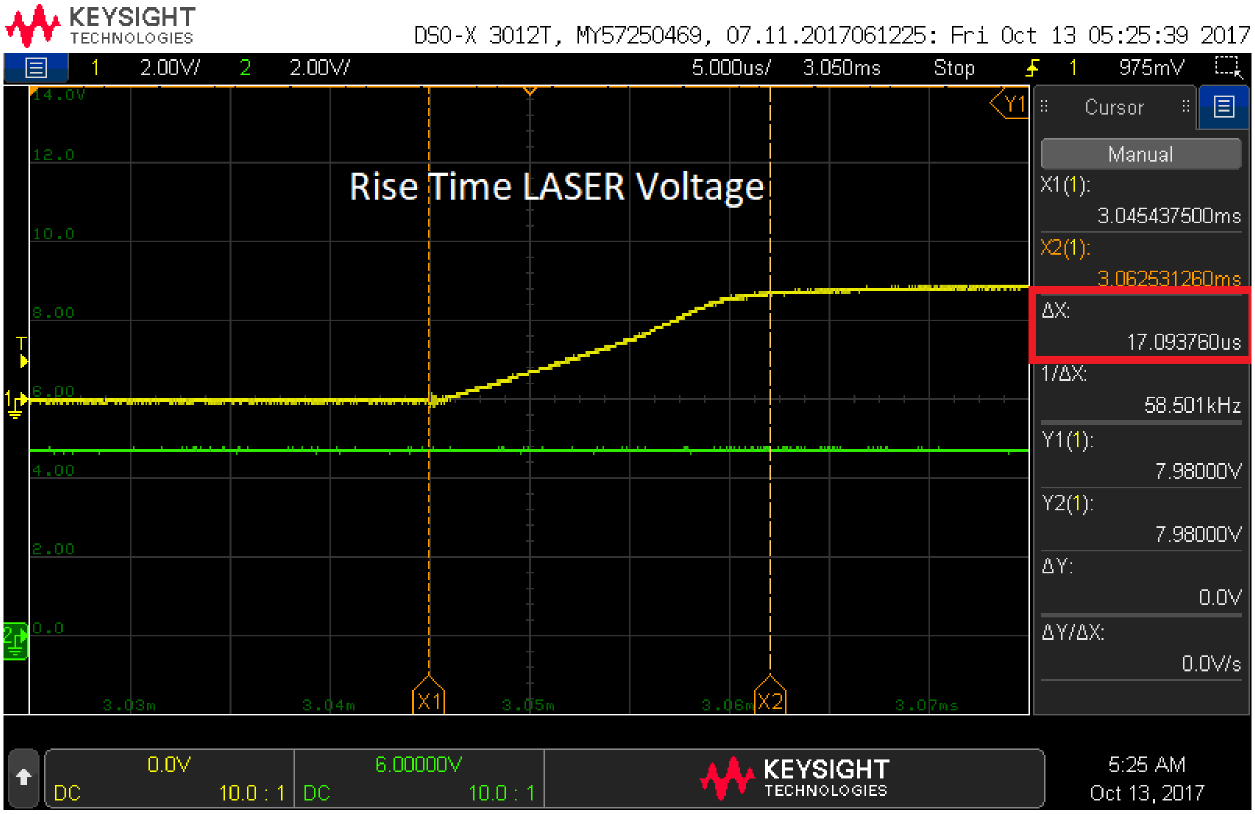
Scope shot 13: ch 1 = FET drain (which shows the laser turning on when it is near 0 volts), ch 2 = photodiode cathode voltage changing when the laser is pointed at it.

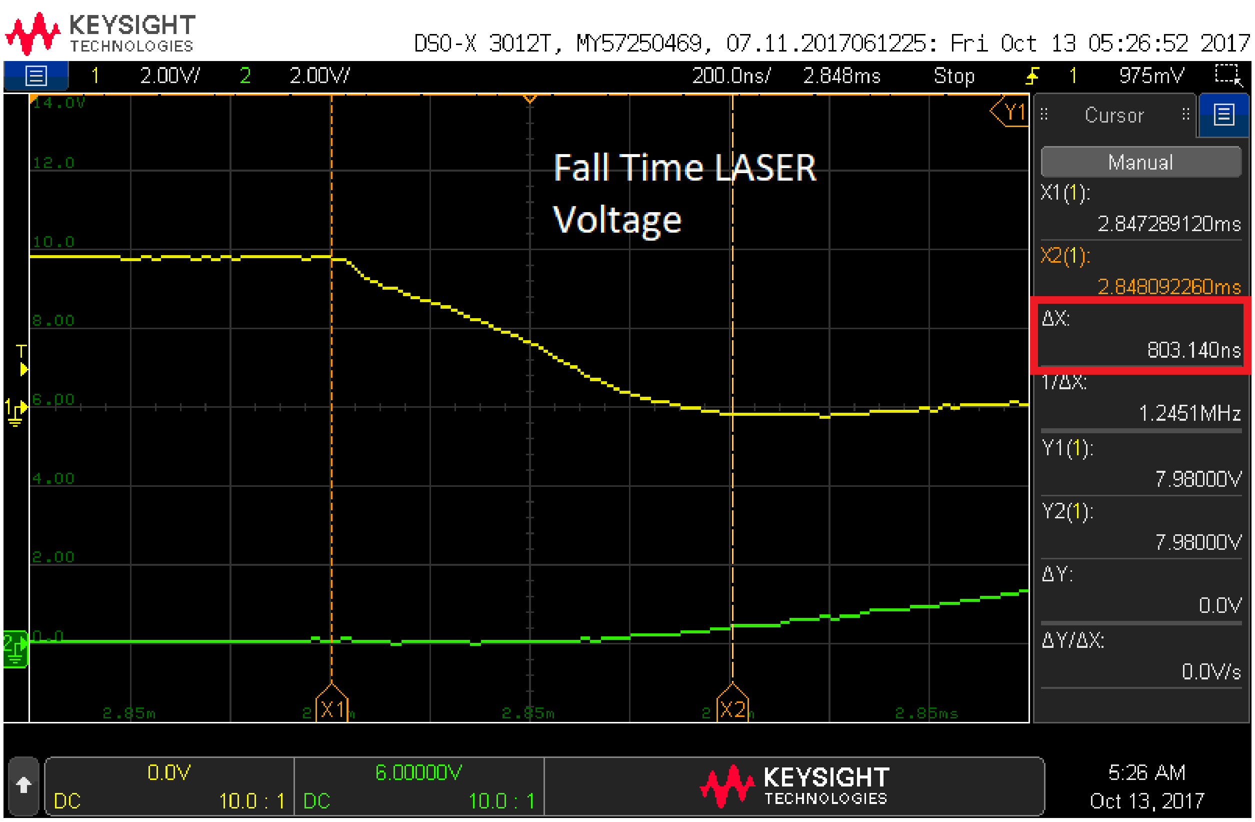


Question 4: What are the rise and fall times of the Laser voltage?

Answer: Rise time LASER voltage= 17.09us

Fall time LASER voltage= 803.14ns

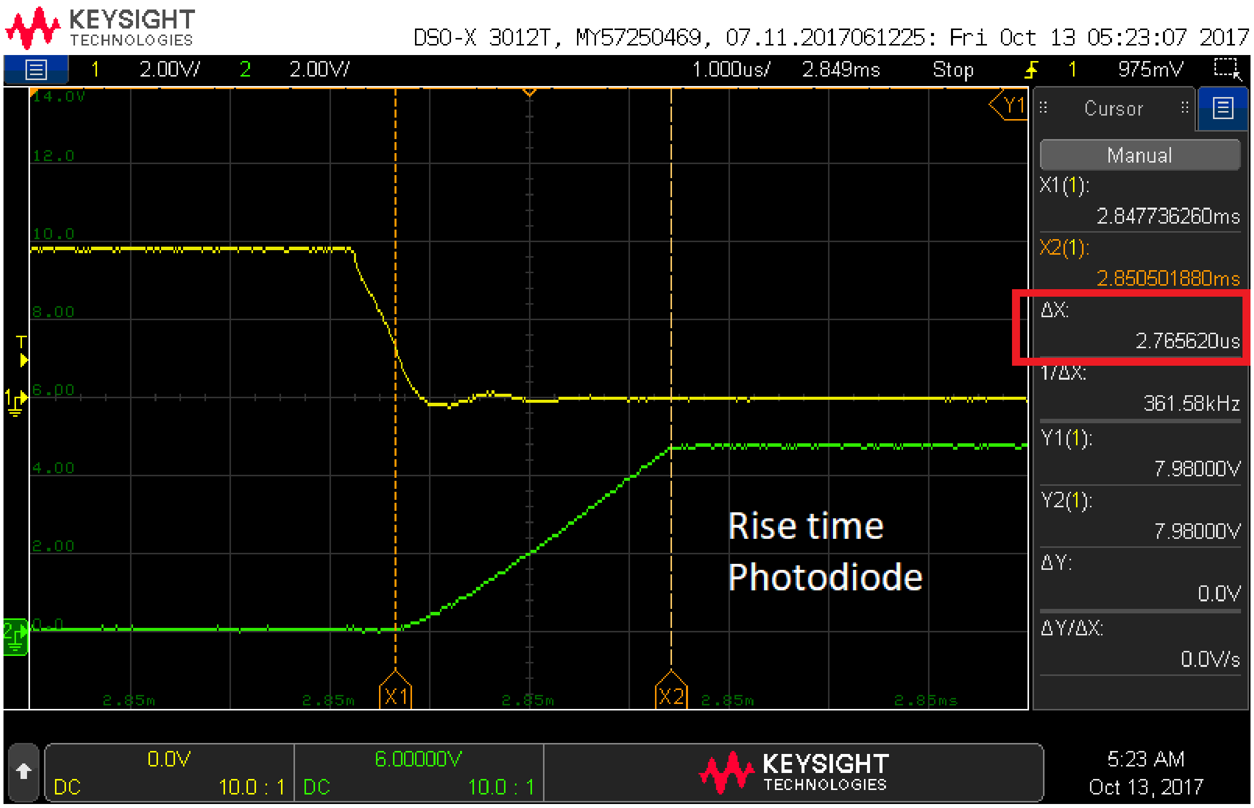

KEYSIGHT TECHNOLOGIES
DSO-X 3012T, MY57250469, 07.11.2017061225: Fri Oct 13 05:25:39 2017
1 2.00V/ 2 2.00V/ 5.000us/ 3.050ms Stop 1 975mV
Rise Time LASER Voltage
Cursor
Manual
X1(1):
3.045437500ms
X2(1):
3.062531260ms
ΔX:
17.093760us
1/ΔX:
58.501kHz
Y1(1):
7.98000V
Y2(1):
7.98000V
ΔY:
0.0V
ΔY/ΔX:
0.0V/s
0.0V DC 10.0 : 1
6.00000V DC 10.0 : 1
5:25 AM
Oct 13, 2017

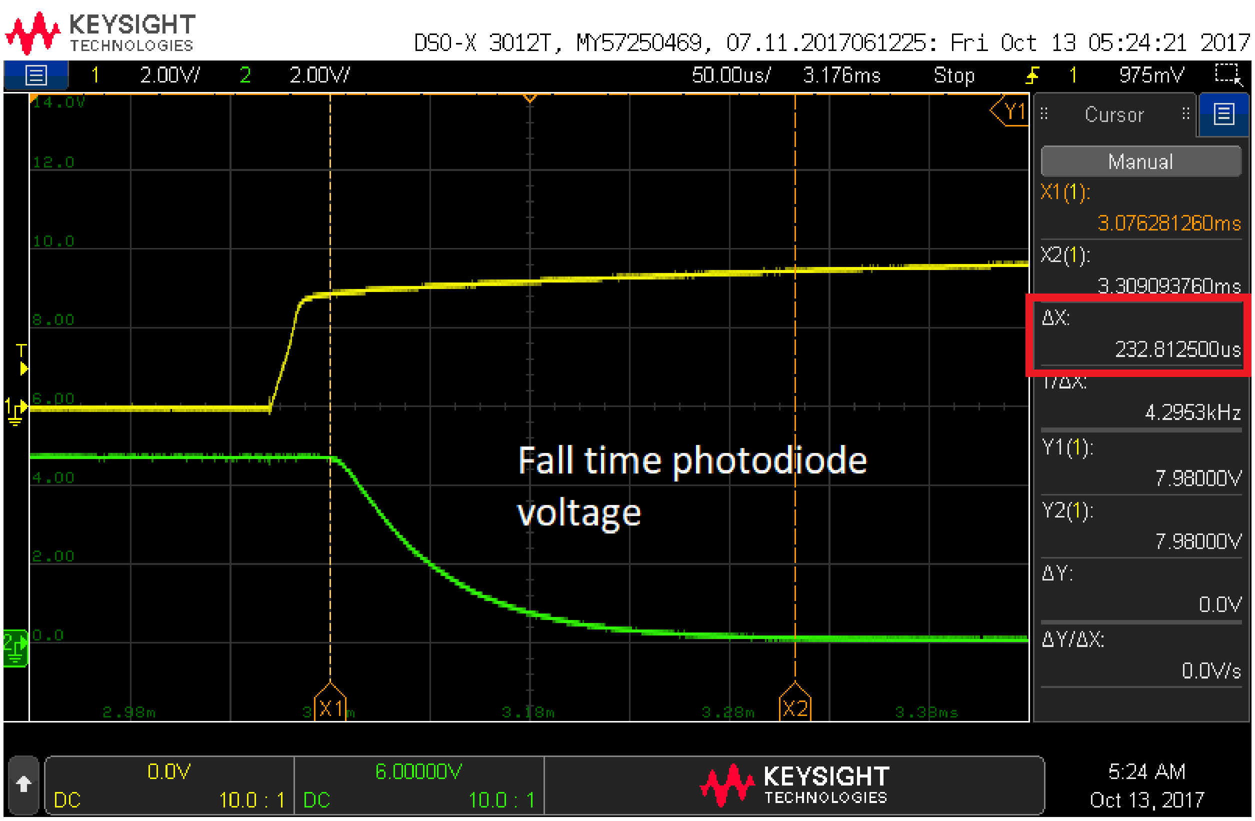

KEYSIGHT TECHNOLOGIES
DSO-X 3012T, MY57250469, 07.11.2017061225: Fri Oct 13 05:26:52 2017
1 2.00V/ 2 2.00V/ 200.0ns/ 2.848ms Stop 1 975mV
Fall Time LASER Voltage
Cursor
Manual
X1(1):
2.847289120ms
X2(1):
2.848092260ms
ΔX:
803.140ns
1/ΔX:
1.2451MHz
Y1(1):
7.98000V
Y2(1):
7.98000V
ΔY:
0.0V
ΔY/ΔX:
0.0V/s
0.0V DC 10.0 : 1
6.00000V DC 10.0 : 1
5:26 AM
Oct 13, 2017

Question 5: What are the rise and fall times of the photodiode voltage?

Answer: Rise time photodiode voltage= 2.765us

Fall time photodiode voltage=232.81us

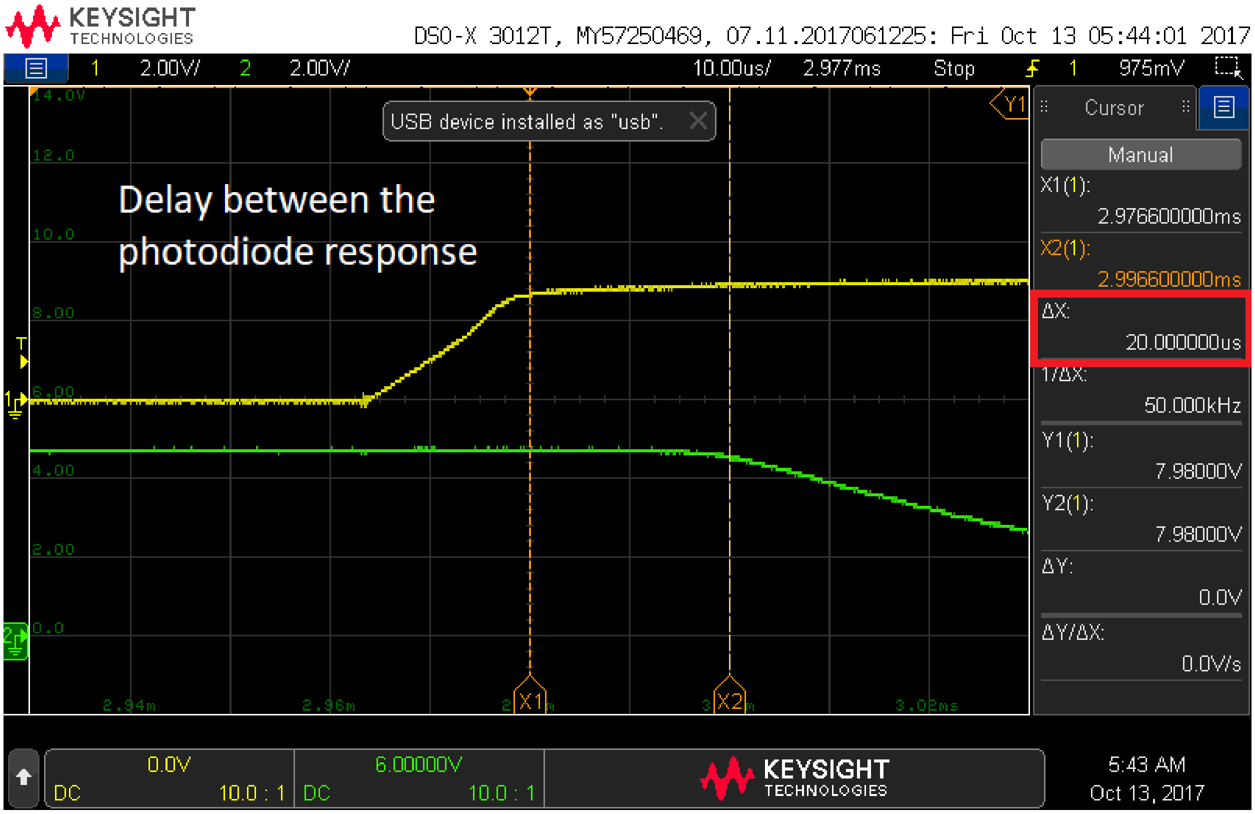




Question 6: How long after the laser voltage begins to rise does the photodiode voltage begin to rise?

Answer: The Delay between the laser voltage rise and photodiode voltage rise is 20us.

An



Question 7: What do you think causes this delay?

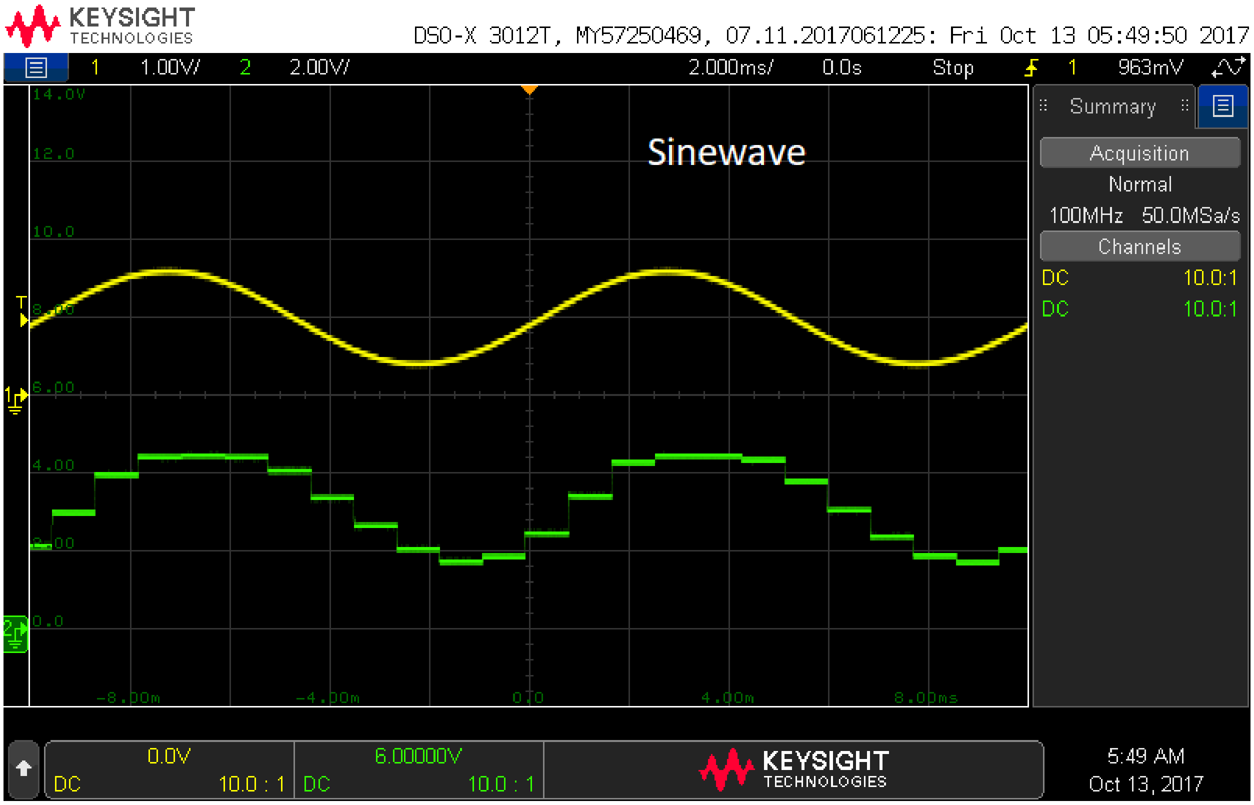
Answer: There is a current regulator in the LASER that has a capacitance. The Capacitance charges before the LASER actually turns on. The Delay of 20us is due to this capacitive effect.

Question 8: Given these waveforms, approximately how fast could this circuit operate and still have the photodiode reach its maximum voltage on each cycle?

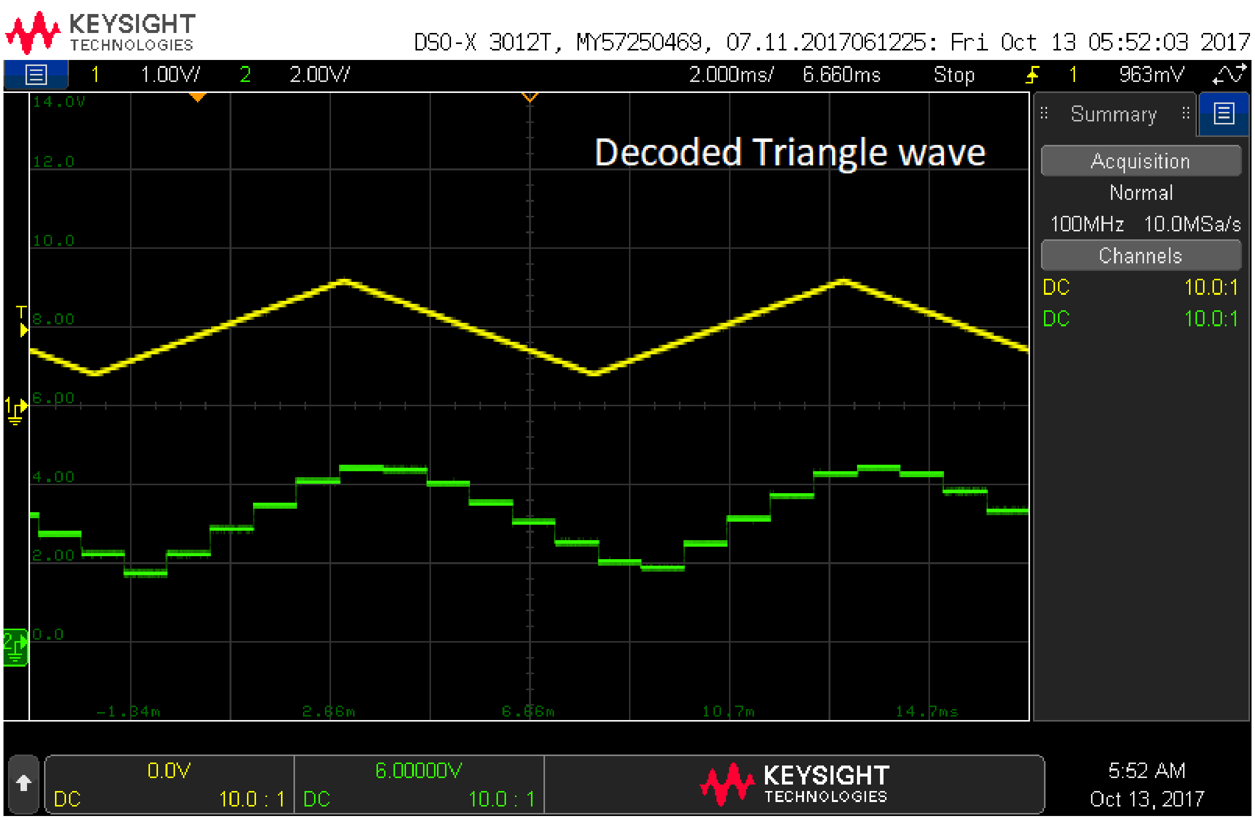
Answer: If we add all the delays related to photodiode it comes around 250us. So, the maximum sampling frequency can be 1/250us= 4KHz. To get an undistorted we will have to operate at 1/10th of the sampling frequency i.e **400Hz**. Thus, the circuit could operate at maximum sample frequency of **400Hz.**

Step 7: Decode your signal.

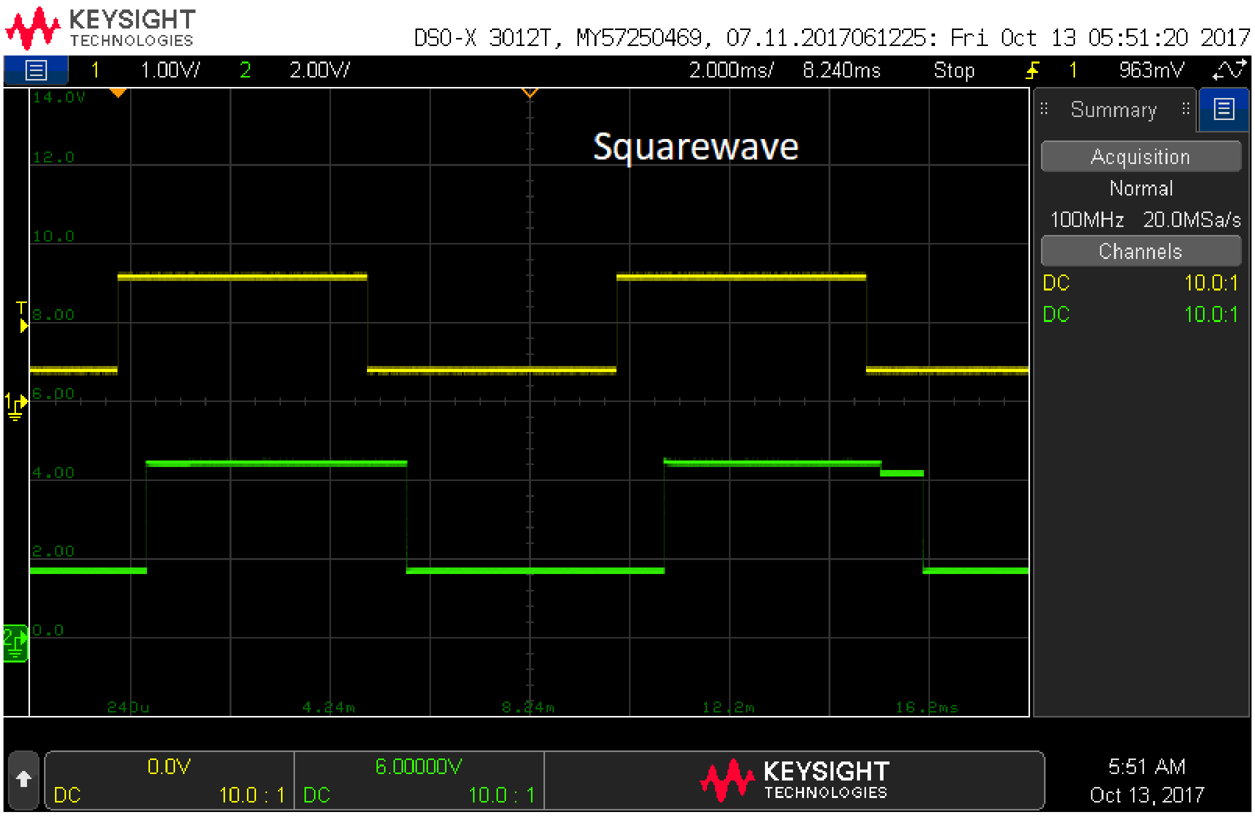
Scope shot 14: ch 1= input sine wave from the signal generator, ch 2 = output sine wave from the second DAC. They should match except for delay and noise.



Scope shot 15: Same as above, but use a triangle wave.



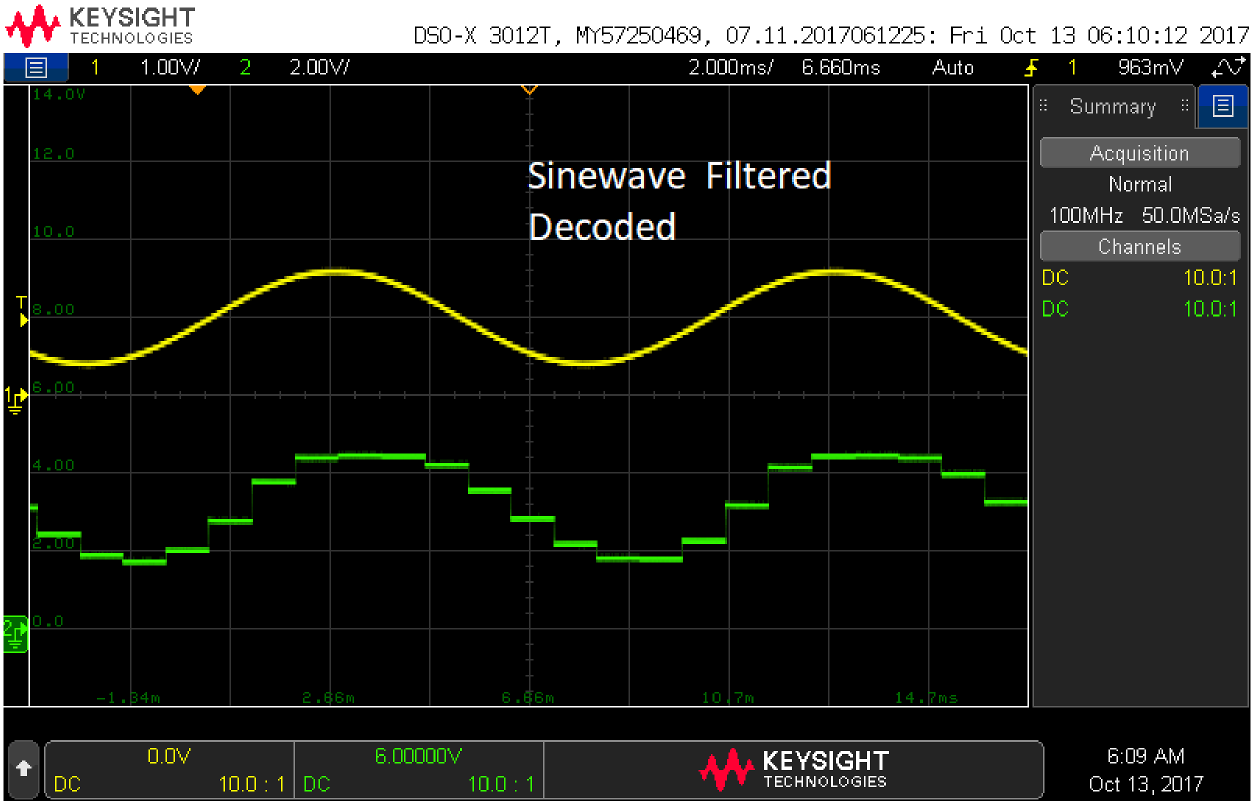
Scope shot 16: Same as above, but use a square wave.



Step 8: Add a passive analog filter to smooth out your sine wave input signal as much as possible.

Scope shot 17: ch1: Input sine wave from signal generator ch2: filtered output sine wave. Mention your R, C value and Fc in your labelling.

Answer: R=1k ohm C=1uF Fc=159.15Hz (Lowpass)



Extra Credit (1 point): Get the optical link to work over a distance of ten feet or more.

Extra Credit (upto 2 points): Submit the highest frequency (with a scope shot of the same configuration as SS 12) you can transmitted and decode with more than 6 quantized steps on the output. You need to explain what improvements you made, over the basics of the lab (with circuit diagrams and relevant code snippets) to get it to pass the highest frequency. The top 4 groups will get 2-1.5-1.-0.5 points of extra credit.

Grading criteria:

1- Does your system work at all?

2- How clean is the output?

3- Is the code straightforward, well documented and easy to understand?

4- How complex is the design (simpler is better!)

5- What is the frequency response?

End