1D LiDAR TOF Rangefinder

ECE 445: Senior Design

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Team 28

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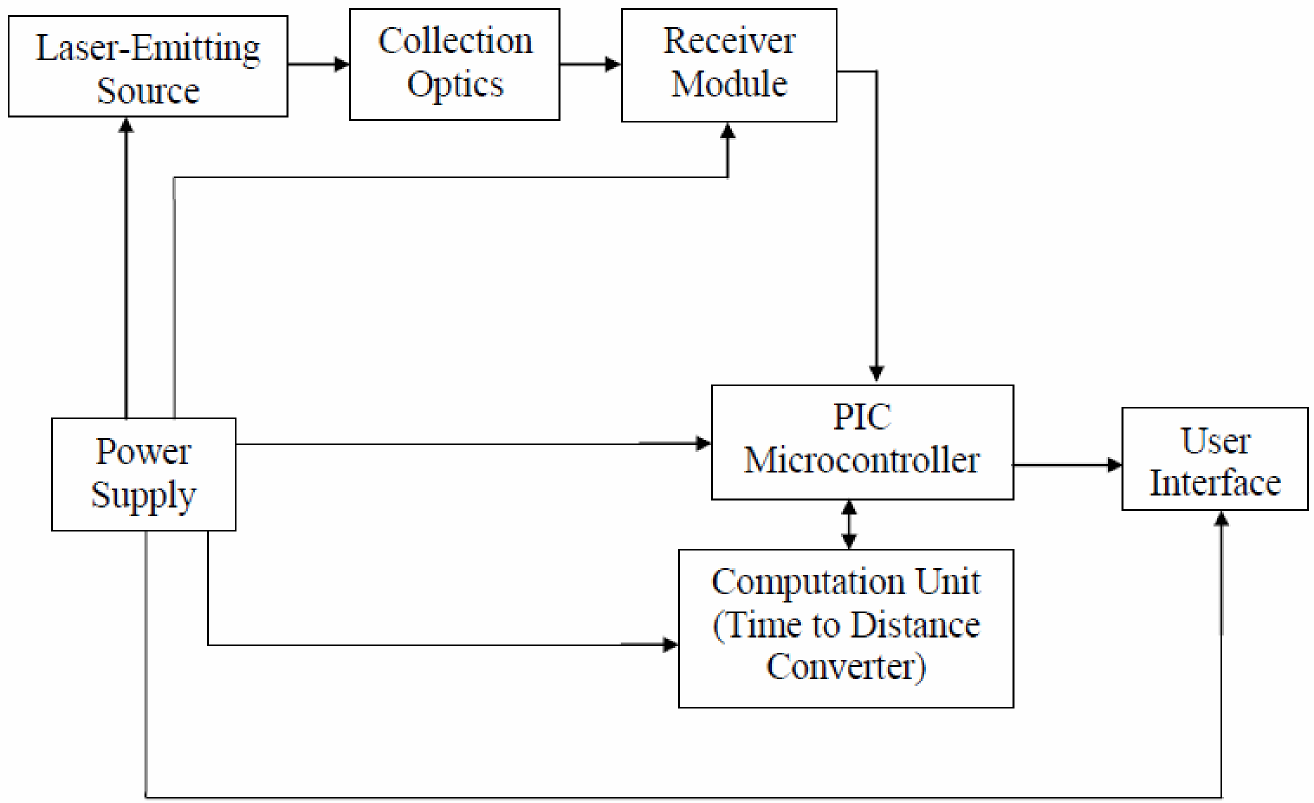
Introduction

- Objective:
  - Create a system that can measure the distance and speed of an object
- Applications
  - Object Detection on Cars
  - Speed Detection
  - Terrain Mapping

System Overview



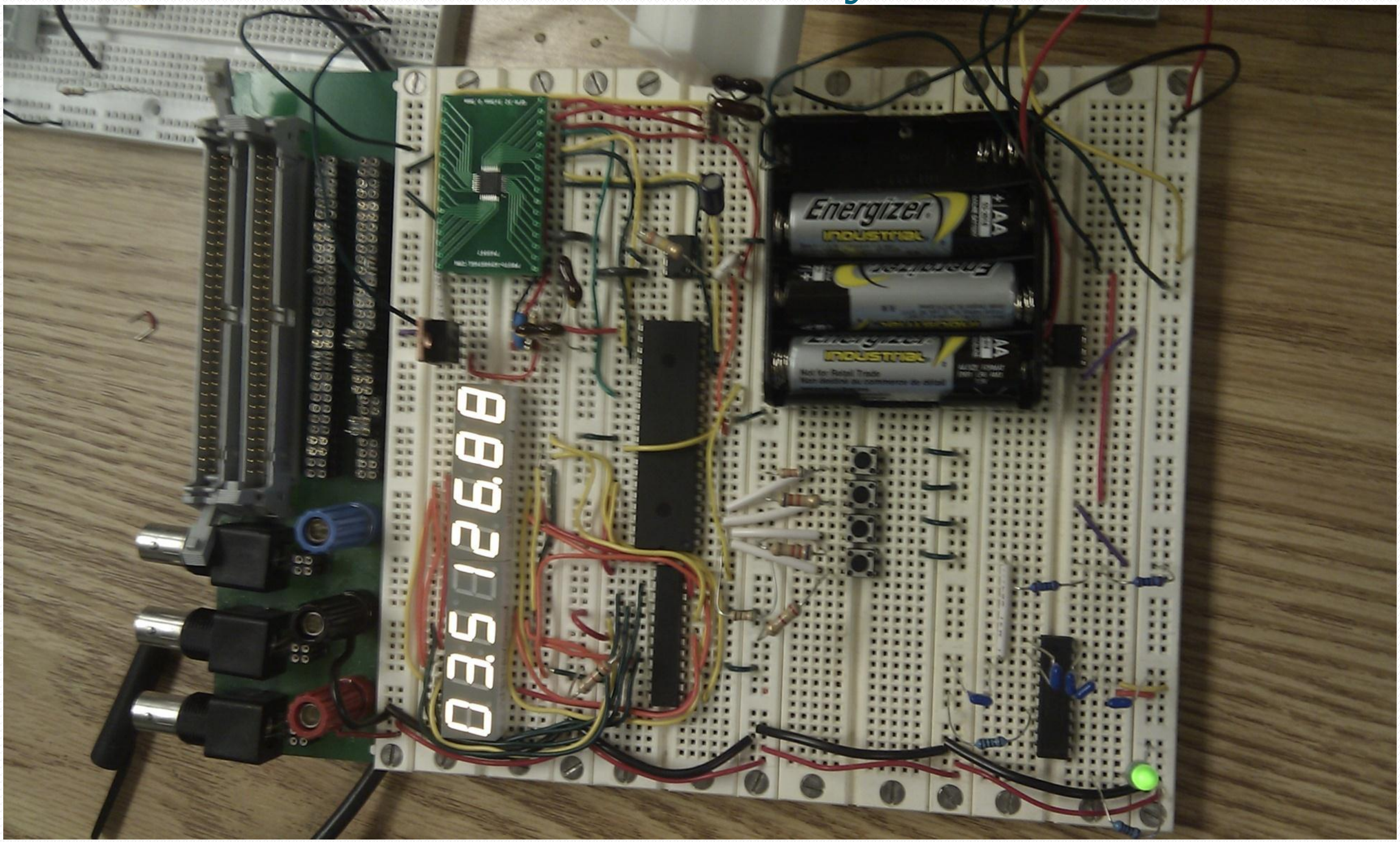
Original Design

- **Single, Avalanche Photodiode Receiver**
  - Costly
  - Requires high reverse bias voltage
  - Requires temperature control circuitry
- **Transimpedance Amplifier**
  - Amplifies both signal and unwanted noise
- **Bare Laser Diode**
  - Does not provide enough reception light
  - Cannot be mounted easily

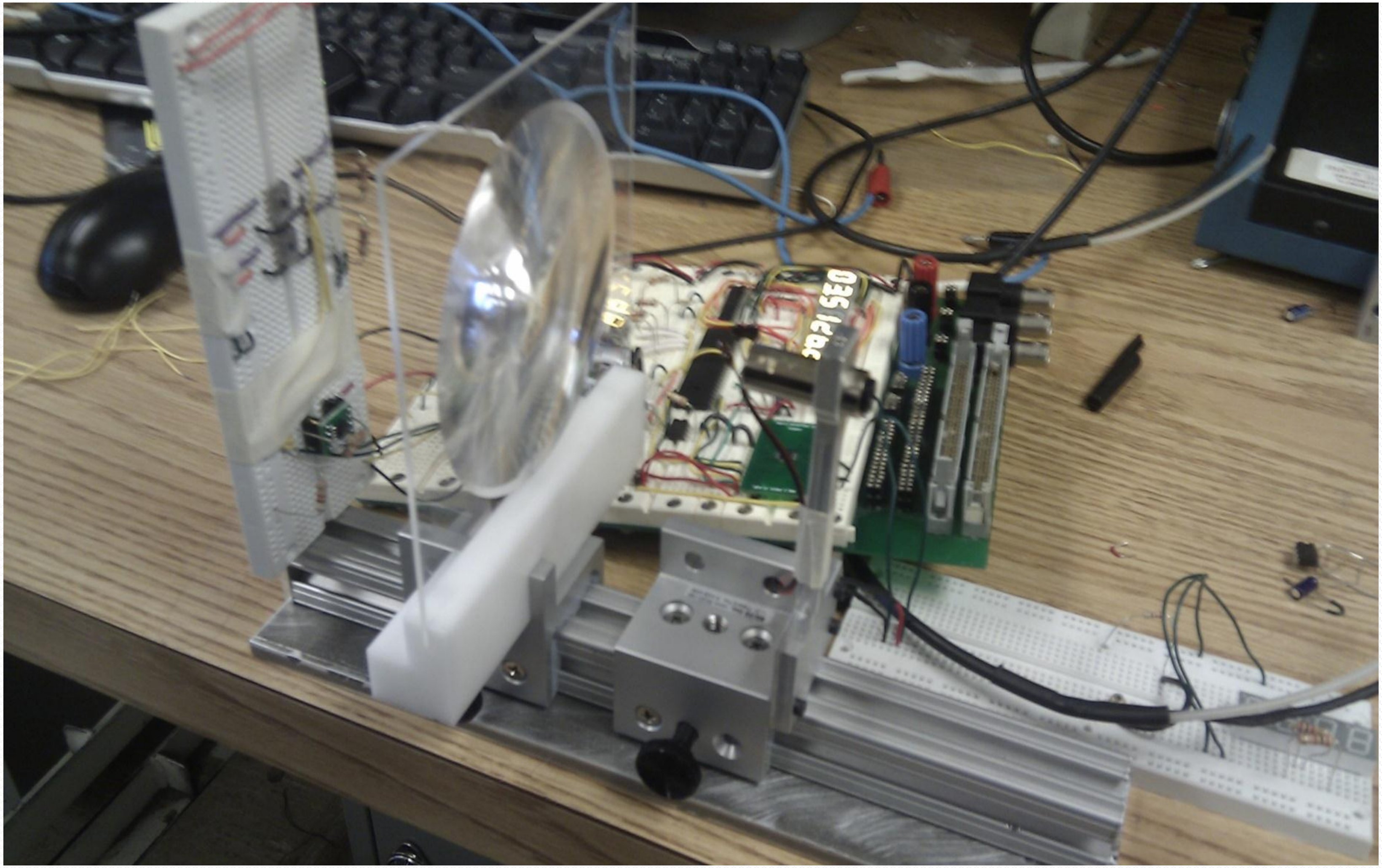
Final Design

- **Dual, Monolithic Photodiode Receiver**
  - Inexpensive
  - Has built in transimpedance amplifier that can be adjusted
- **Differential Amplifier**
  - Subtract out environmental light from signal
- **Collimated Laser Diode Module**
  - Provides focused, current limited laser signal
  - Large module can be mounted more easily

Main Board Layout



Transmission/Receiving Unit

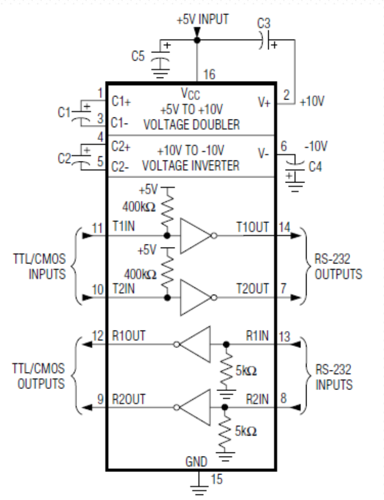


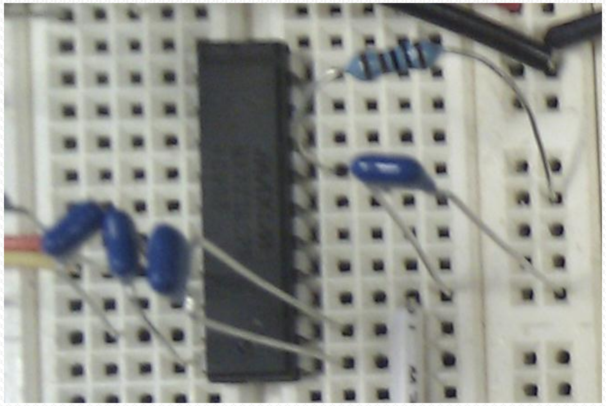
System Overview

- Hardware Components
  - Power Supply, Laser Driver, Transmission/Receiving Unit, Computation and Control Unit(PIC), User Interface, TDC Chip
- Software Components
  - PIC Control and Communication

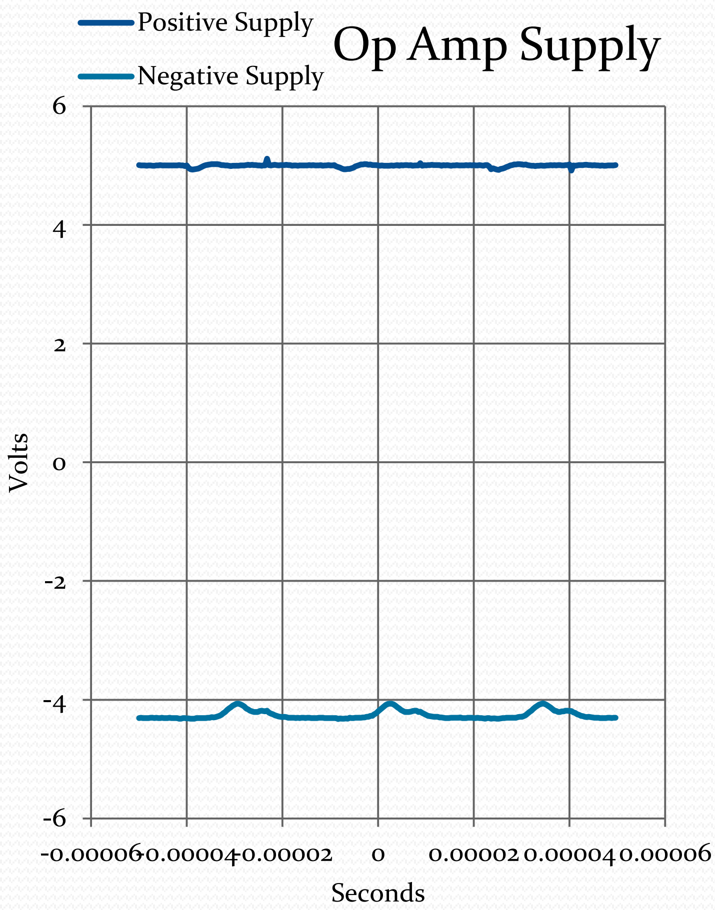
Power Supply

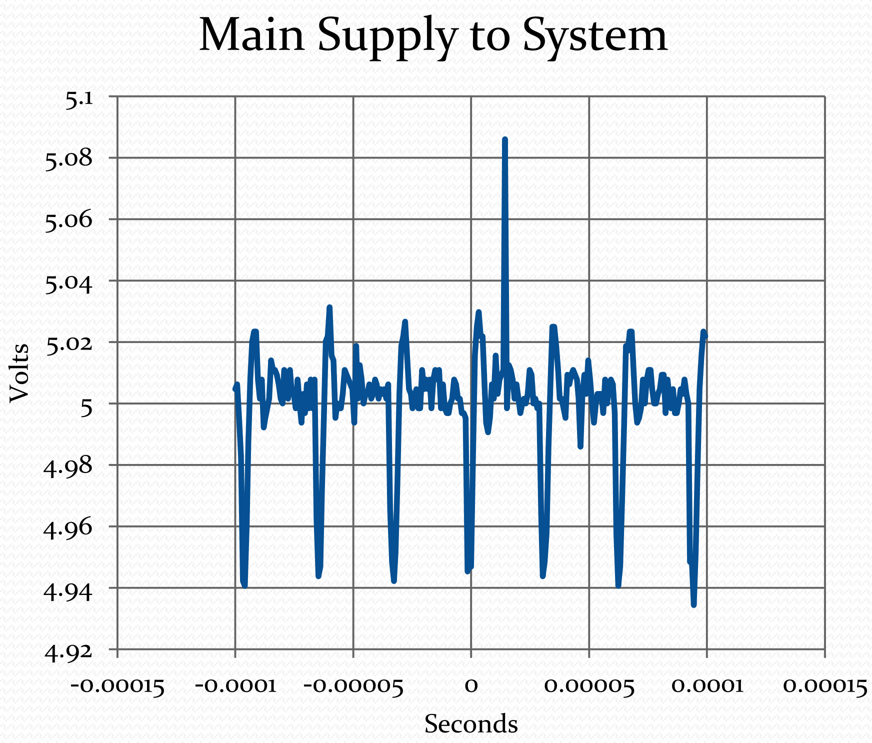
- Provides 4.5 V to the system through AAA batteries
- Batteries used not only for portability but for cleaner power source than typical wall outlet
- Includes DC-DC converter(MAX232) for ±9 V which are used to supply operational amplifiers





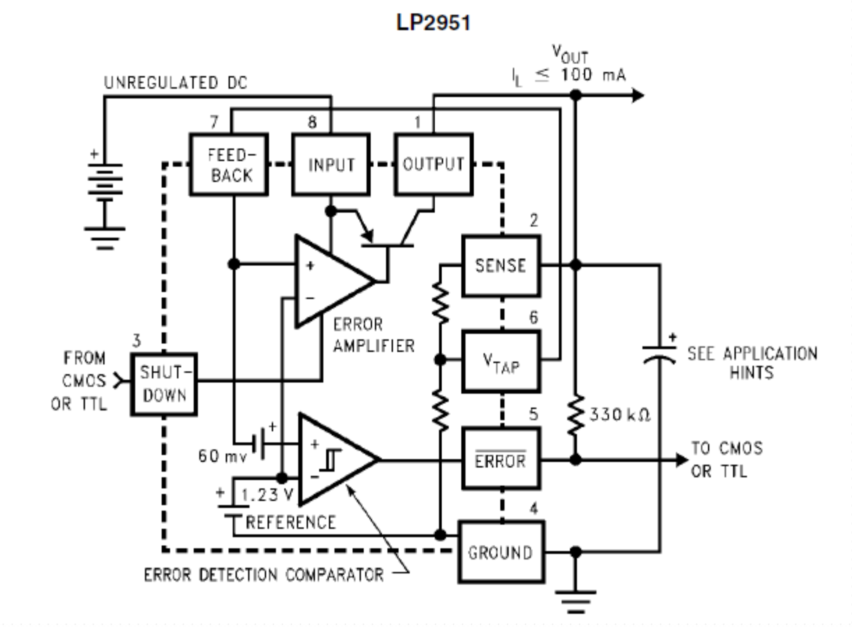
Supply Testing

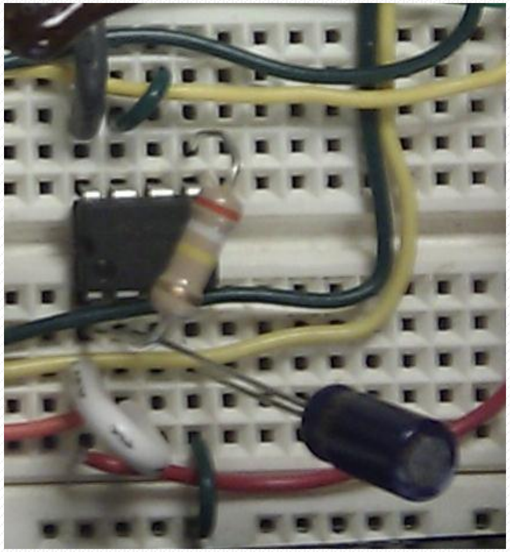




Power Supply

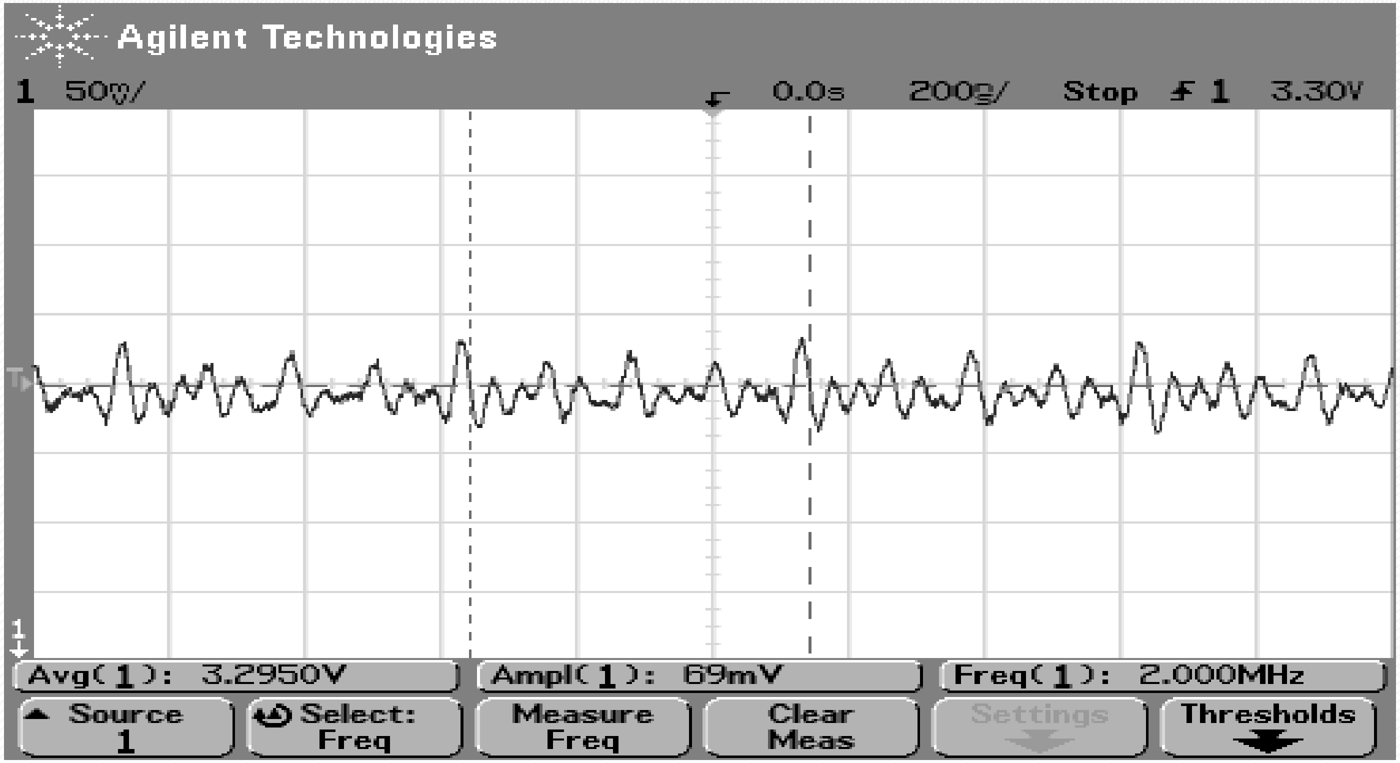
- 3.3 V voltage regulator is also necessary to supply the TDC chip safely





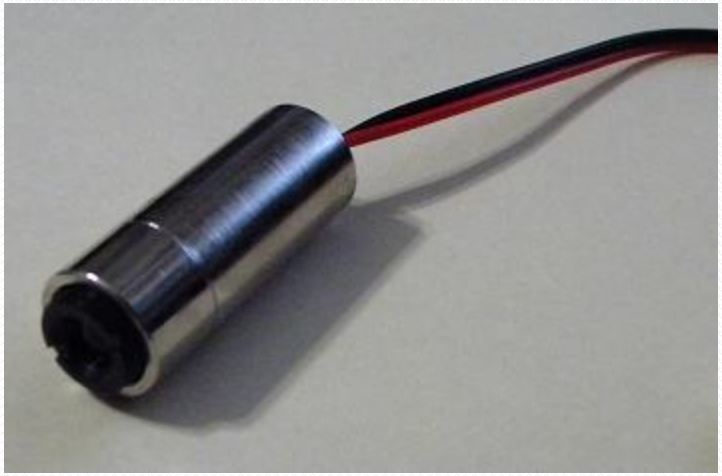
Voltage Regulator Verification

- Average Voltage Level: 3.295 V
- Ripple: 69 mV
- Frequency: 2 MHz



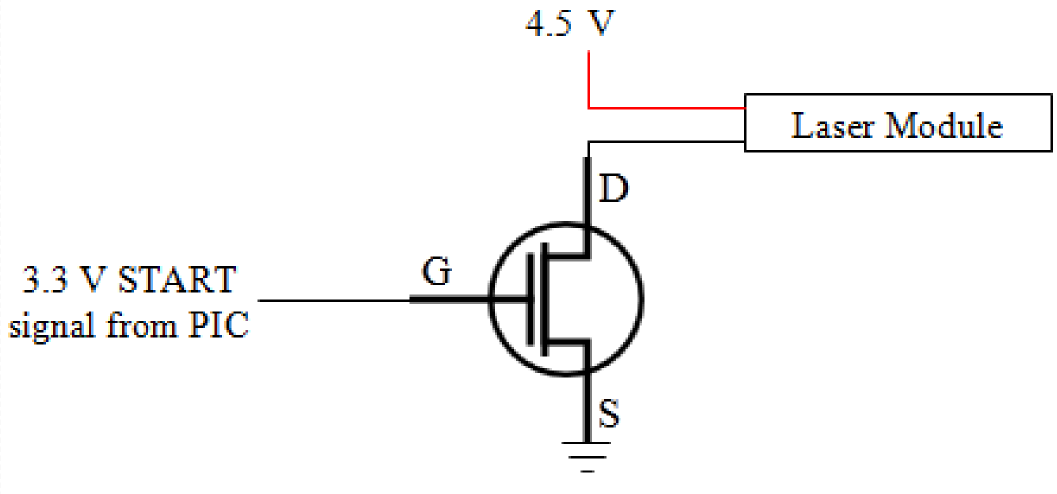
Laser Driver

- A 650 nm, 5 mW laser module is used to send measurement signals
- The module houses an internal current limiting circuit to protect the laser diode when driven



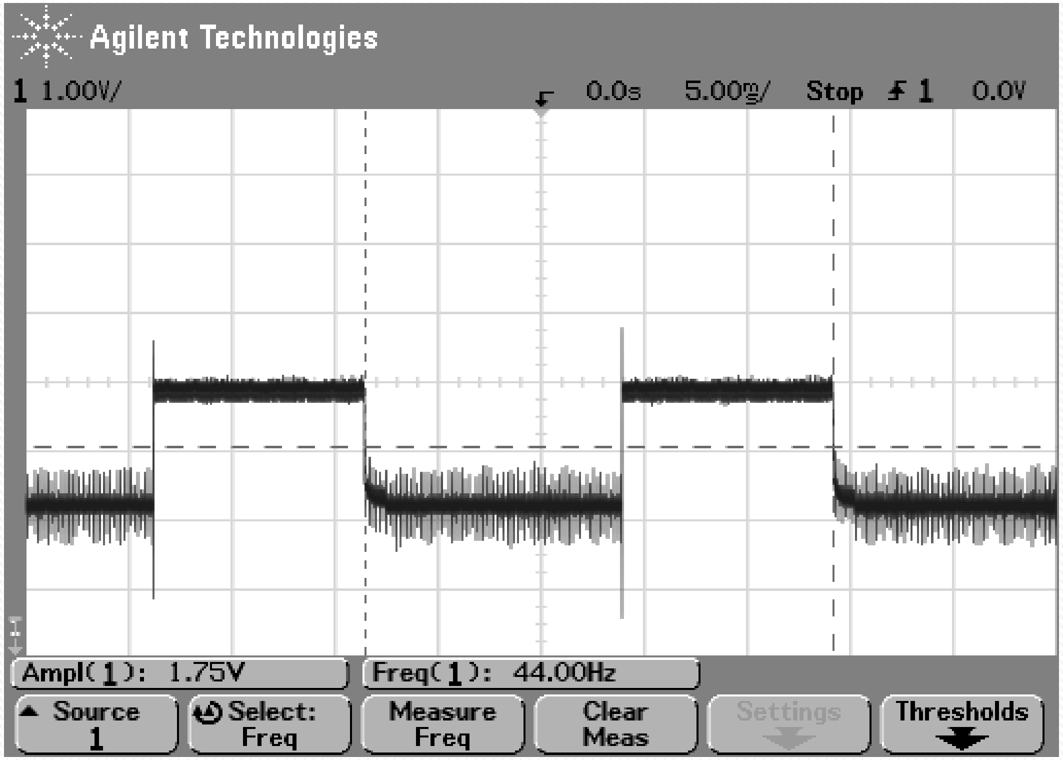
Laser Driver

- In order to supply the 4.5 V needed to source the module, the PIC’s start signal is sent to a simple NMOS(MTP10N10EL) switch that is connected to 4.5 V dc



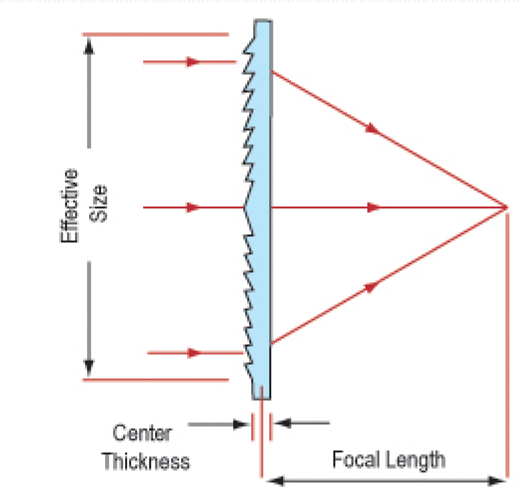
Laser Pulse Verification

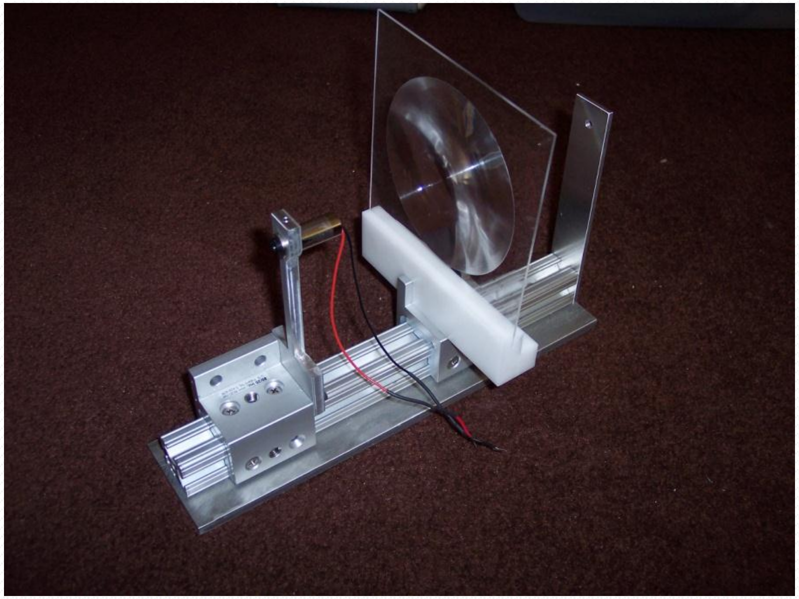
- Total Measuring Time of ≈22.284 ms
- Results in Laser Frequency ≈44.875 Hz



Signal Transmission/Reception

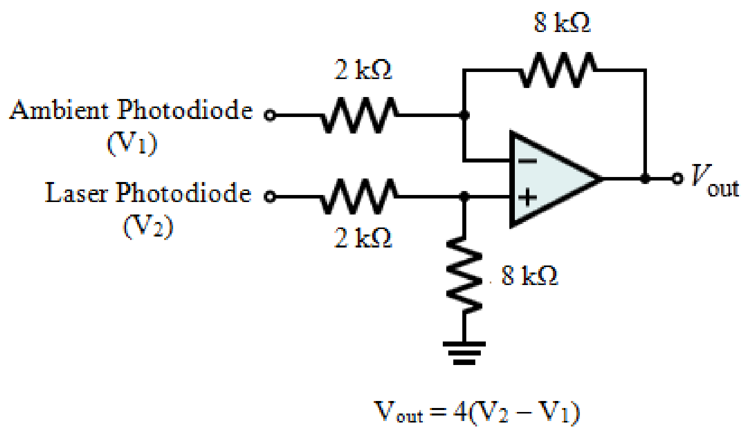
- Original proposal: use simple laser diode
- However, the need for a collimated laser beam called for a laser module
- Fresnel lens implemented to collect return signal

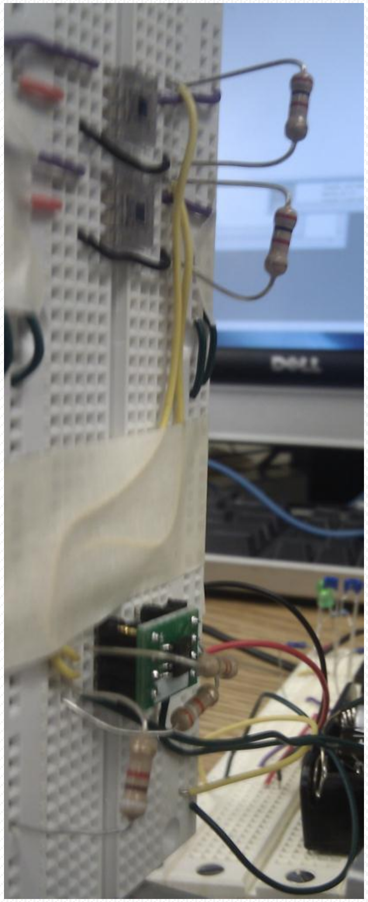




Signal Transmission/Reception

- Photodiode Receiver
  - Switched from APD to regular photodiode in order to eliminate need for high reverse bias
- Differential amplifier implemented to take voltage difference from reception photodiode and ambient light photodiode



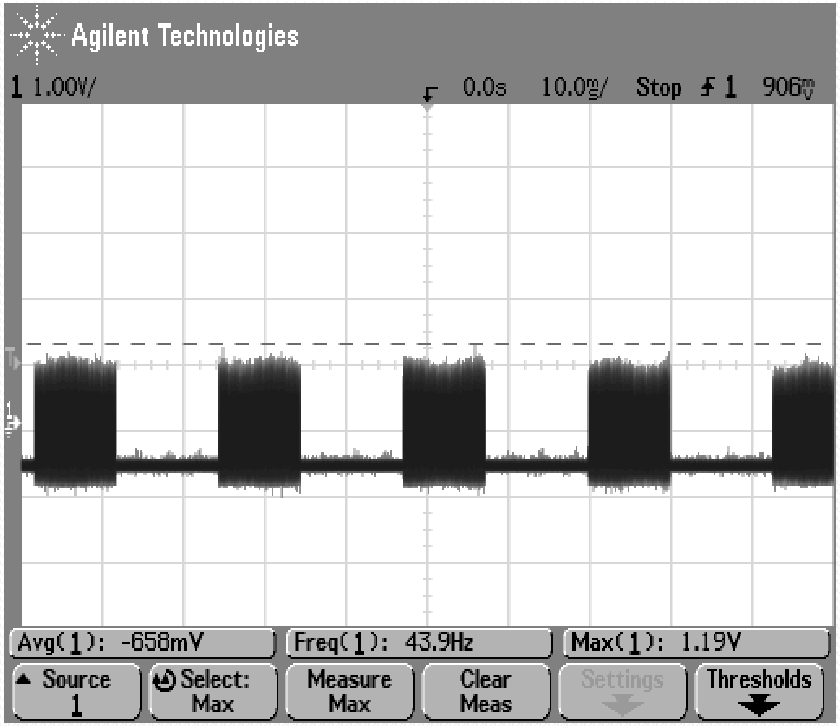


Receiver Response

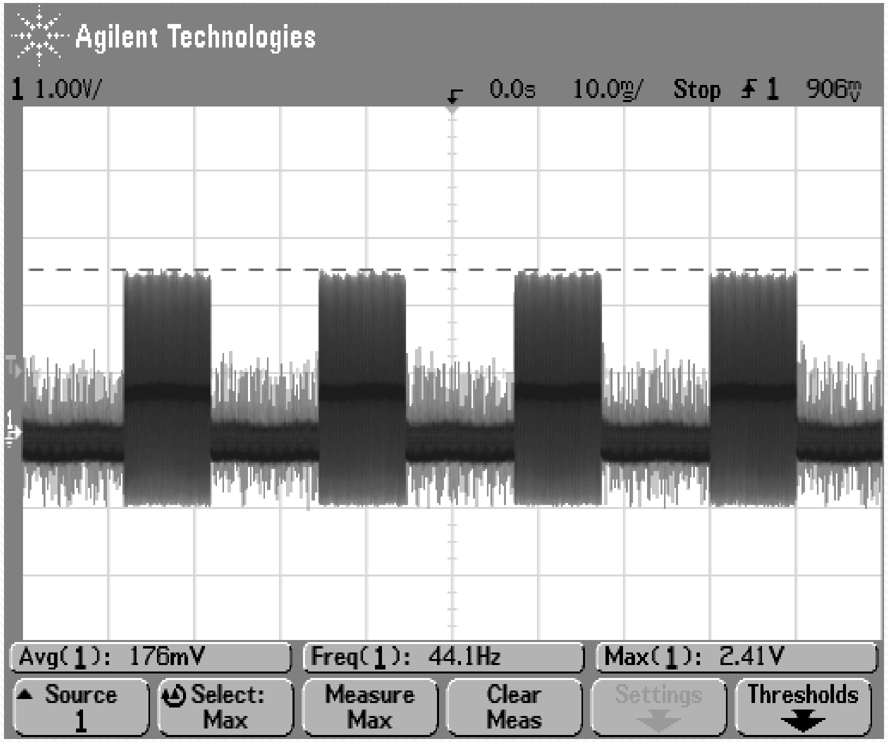
Maximum Distances for Objects of Varying Reflectivity

- Presence of noise is due to divergence of received signal across both photodiodes

Reflective Metal: 5.5 m



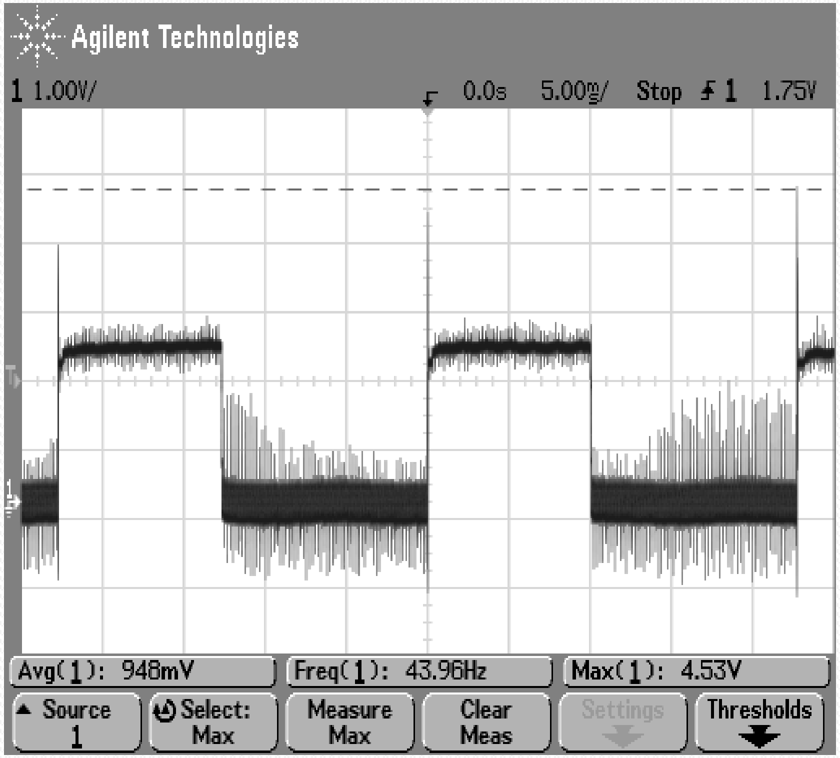
Cardboard : 1.3 m



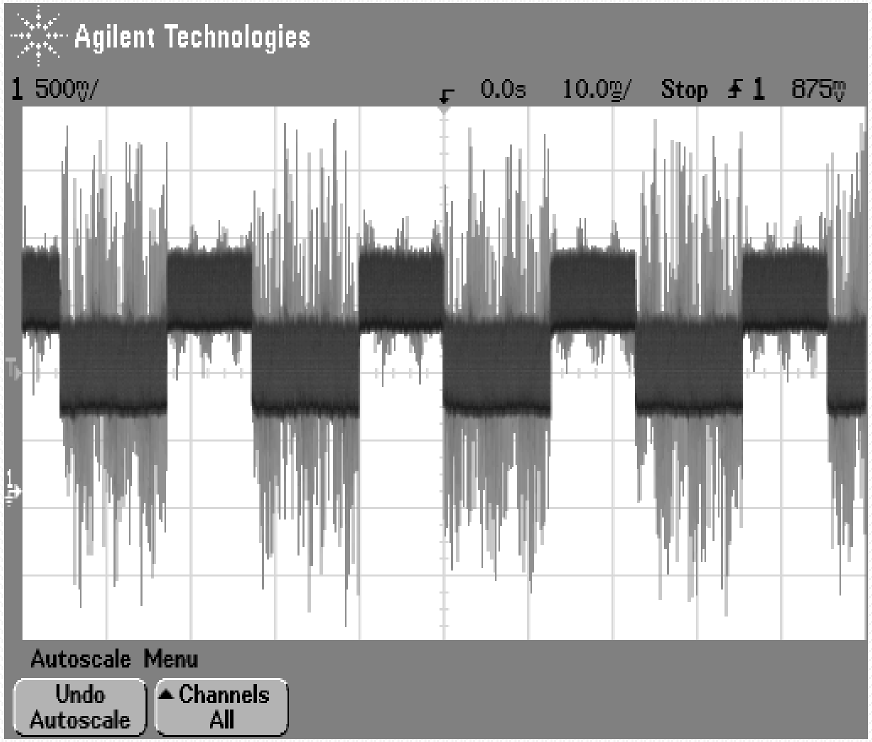
Receiver Response

Maximum Distances for Objects of Varying Reflectivity

Plastic Bottle: 0.7 m

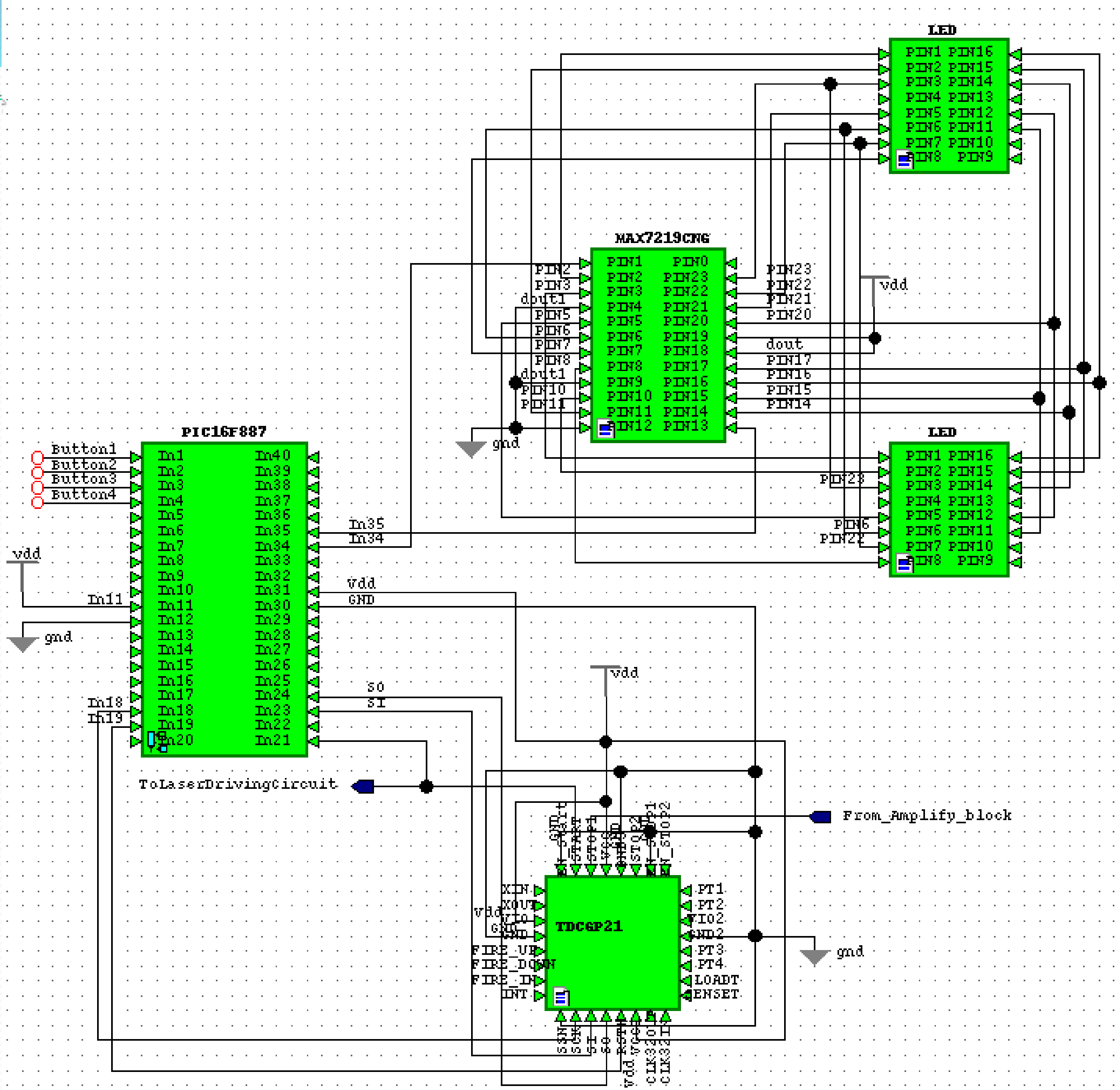


Human Hand : 0.87 m



Control and Display

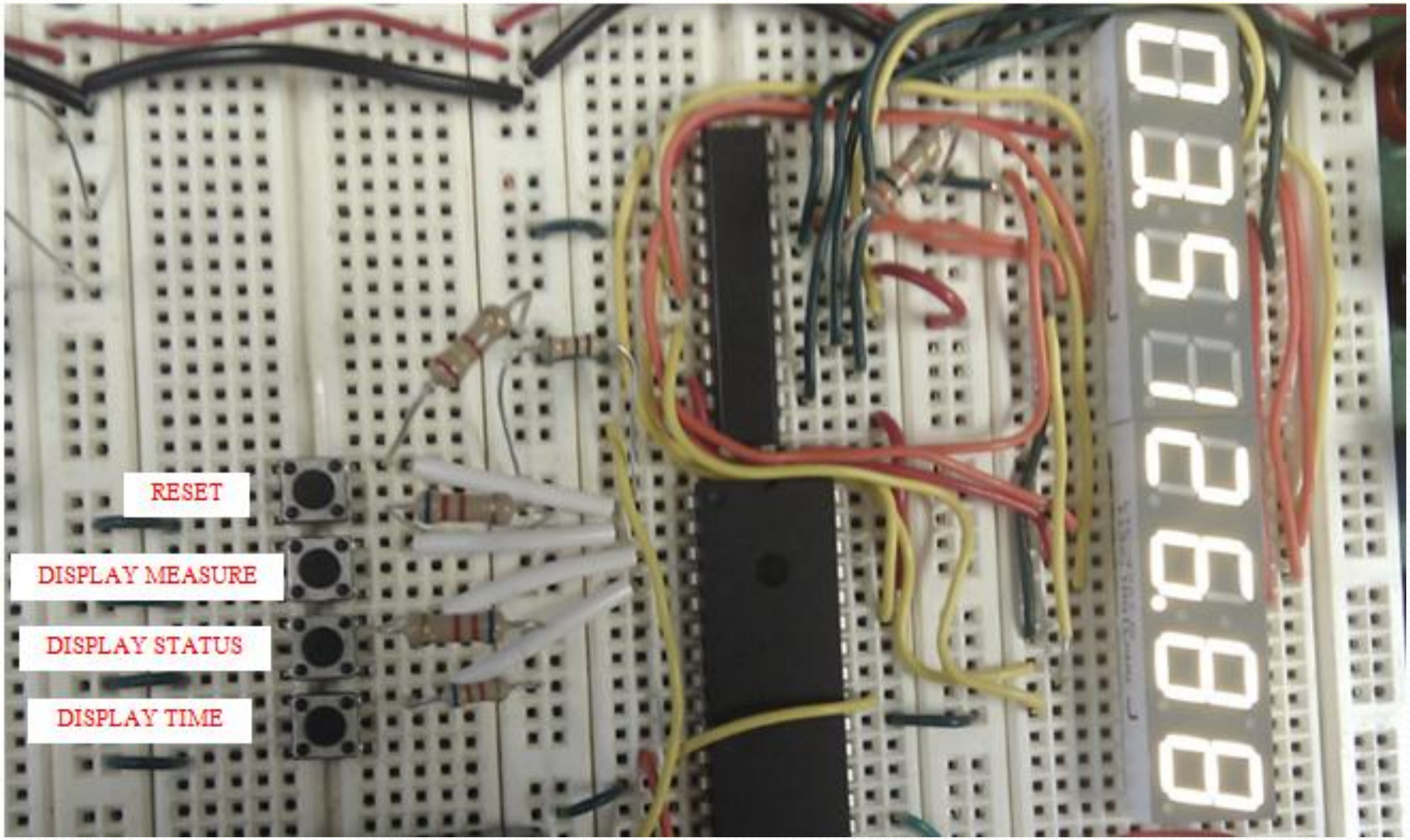
- PIC16F887 provides the main control of our system
- PIC communicates with TDC chip when reading measurements as well as displays results on 7-segment display
- PIC also sends the start signal to the laser module to begin pulses
- A user interface provides: system reset and individual measurements



LED
PIN1 PIN16
PIN2 PIN15
PIN3 PIN14
PIN4 PIN13
PIN5 PIN12
PIN6 PIN11
PIN7 PIN10
PIN8 PIN9
MAX7219CNG
PIN1 PIN0
PIN2 PIN23
PIN3 PIN22
PIN4 PIN21
PIN5 PIN20
PIN6 PIN19
PIN7 PIN18
PIN8 PIN17
PIN9 PIN16
PIN10 PIN15
PIN11 PIN14
PIN12 PIN13
dout
dout1
vdd
gnd
PIC16F887
Button1
Button2
Button3
Button4
In1 In40
In2 In39
In3 In38
In4 In37
In5 In36
In6 In35
In7 In34
In8 In33
In9 In32
In10 In31
In11 In30
In12 In29
In13 In28
In14 In27
In15 In26
In16 In25
In17 In24
In18 In23
In19 In22
In20 In21
In35
In34
In11
In18
In19
Vdd
GND
SO
SI
ToLaserDrivingCircuit
From_Amplify_block
TDCGP21
XIN
XOUT
VIO
GND
FIRE_UP
FIRE_DOWN
FIRE_IN
INT
PT1
PT2
VIO2
GND2
PT3
PT4
LOADT
SENSET
SSN
SCK
SI
SO
RSTN
Vcc
CLK32Out
CLK32In

Control and Display

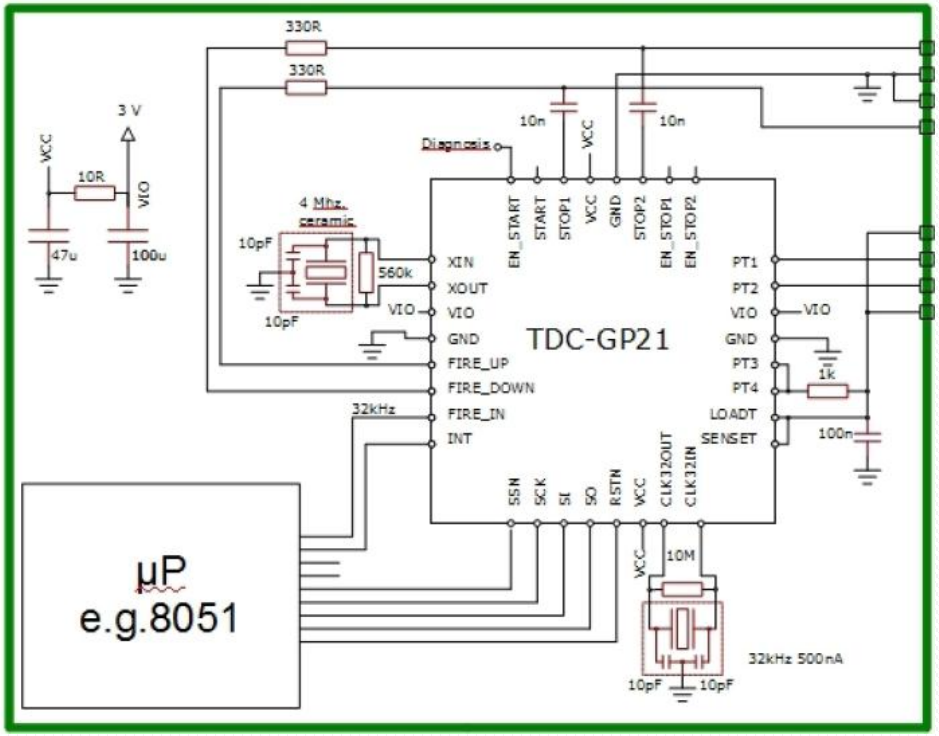
User Interface

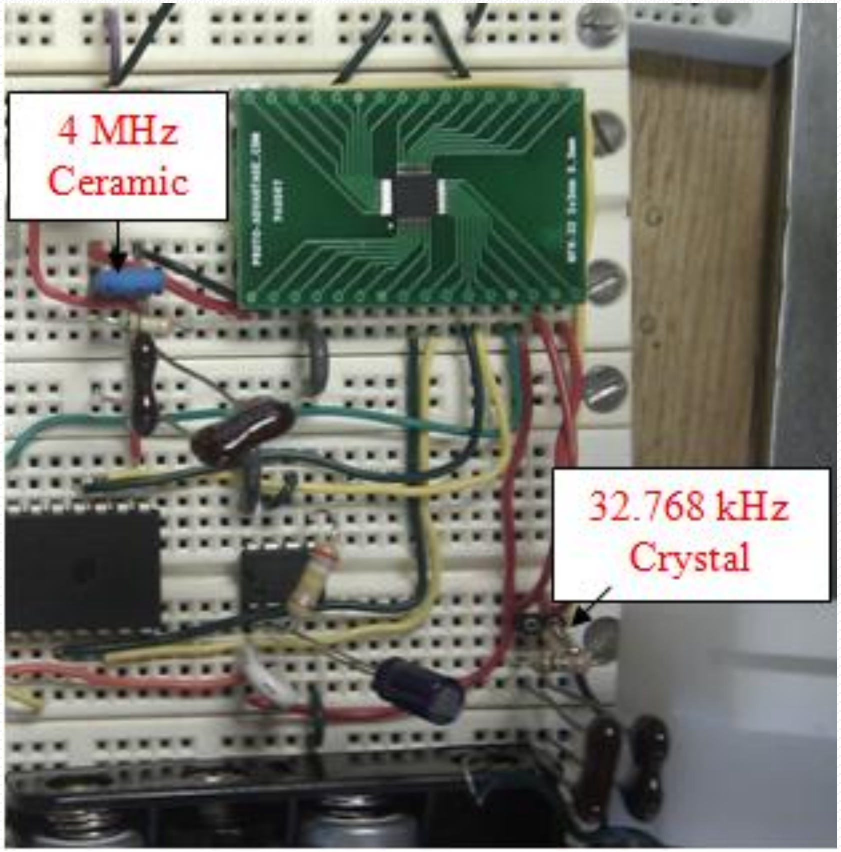


Time-of-Flight Measurement

- The TDC chip represents the most critical computation in our design
- Uses an internal capacitor in order to measure the time of flight of the laser pulse
  - Stop signal triggers a measurement of the voltage on the capacitor, leading to a time measurement
- Very accurate external oscillators(32.768 kHz and 4 MHz) are required for clocking and proper initialization

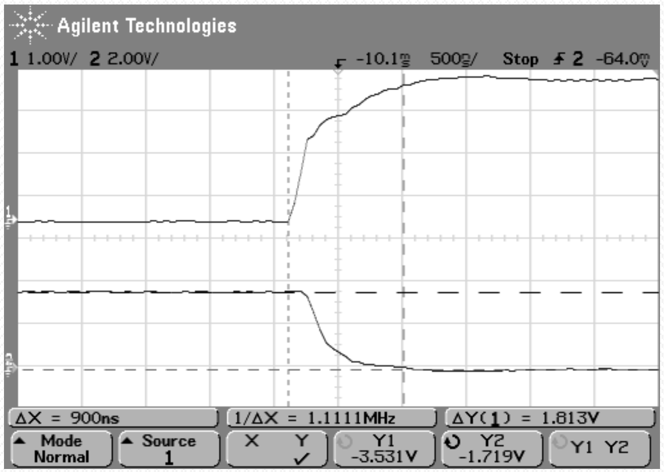
TDC Layout


330R
330R
3 V
VCC
10R
VIO
47u
100u
Diagnosis
4 Mhz. ceramic
10pF
560k
10pF
VIO
10n
VCC
10n
EN_START
START
STOP1
VCC
GND
STOP2
EN_STOP1
EN_STOP2
XIN
XOUT
VIO
GND
FIRE_UP
FIRE_DOWN
32kHz
FIRE_IN
INT
TDC-GP21
PT1
PT2
VIO
VIO
GND
PT3
PT4
1k
LOADT
SENSET
100n
SSN
SCK
SI
SO
RSTN
VCC
CLK32OUT
CLK32IN
VCC
10M
32kHz 500nA
10pF
10pF
µP
e.g.8051

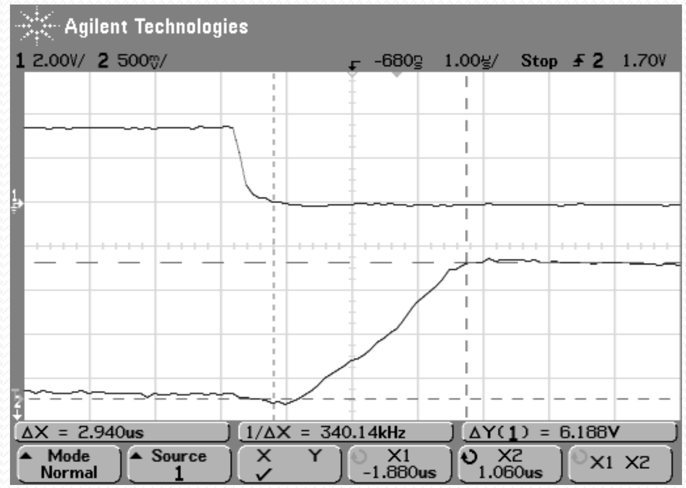

4 MHz
Ceramic
32.768 kHz
Crystal

Measurement Results

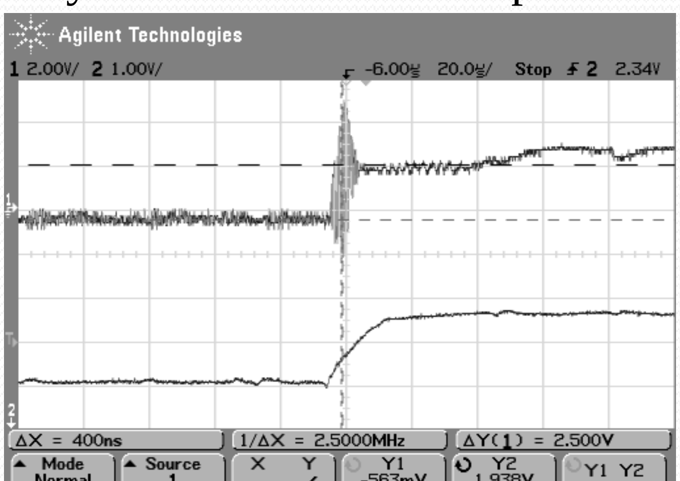
Delay from NMOS Switch



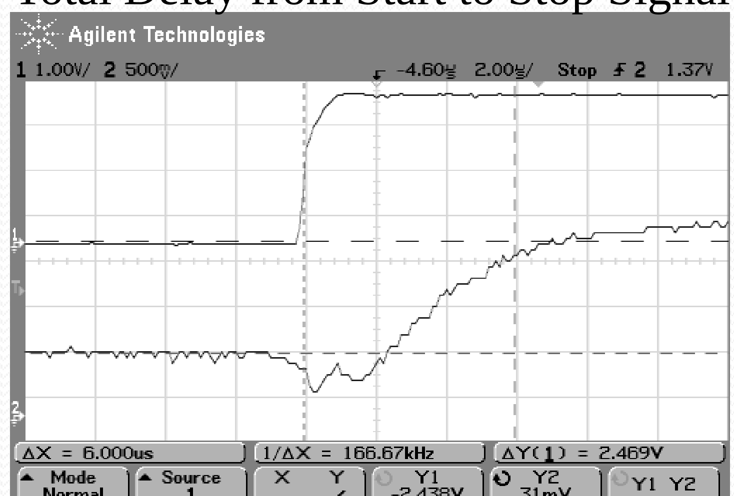
Delay from Laser through photodiode



Delay from Differential Amplifier



Total Delay from Start to Stop Signal



Measurement Results

Distance	Test 1	Test 2	Test 3	Test 4	Test 5	Test 6	Test 7	Test 8	Test 9	Test 10	Test 11	Test 12	1200 Point Average
1	3.02	2.85	1.35	3.97	5.25	1.29	2.94	3.13	2.07	1.02	1.1	1.43	2.942
2	2.21	0.78	0.82	1.44	1.48	2.04	0.85	2.74	1.68	0.78	1.59	1.61	1.802
3	1.35	1.79	1.37	1.17	3.7	0.2	1.75	2.06	3.61	3.73	1.17	1.73	2.363

- Clearly, inconsistencies in measurements lead to inaccurate results that need to be improved…

Successes

- Successful communication with TDC
- Successful transmission and reception of laser signal
- Successful calculation algorithms, user interface, and display

Challenges

- Initial communication with TDC chip
- Maintaining sensitivity as well as responsiveness on photodiodes
- Slow component response times lead to inaccurate and inconsistent results

Suggestions for Future Work

- Improve response times on remaining components
- Upgrade to TDC-GPX for improved resolution
- Upgrade to APD for improved distance and response time
- Implement circuitry on PCB in order to isolate components and minimize parasitic capacitances, further minimizing inconsistencies

Special Thanks

- Generous Funding
  - Professor Carney
- Machine Shop
  - Scott McDonald
- Parts Shop
  - Skot Wiedmann
  - Mark Smart
  - Wally Smith
- TA and Lab Assistance
  - Mustafa Mir
  - Alex Suchko

Questions?

Thank You!

Works Cited

1. http://datasheets.maxim-ic.com/en/ds/MAX220-MAX249.pdf
2. http://www.ti.com/lit/ds/symlink/lp2950-n.pdf
3. http://www.aixiz.com/store/images/1230.jpg
4. http://www.edmundoptics.com/products/displayproduct.cfm?productid=2040
5. http://www.acam.de/uploads/media/DB_GP21_en_04.pdf