DALHOUSIE UNIVERSITY
FACULTY OF ENGINEERING

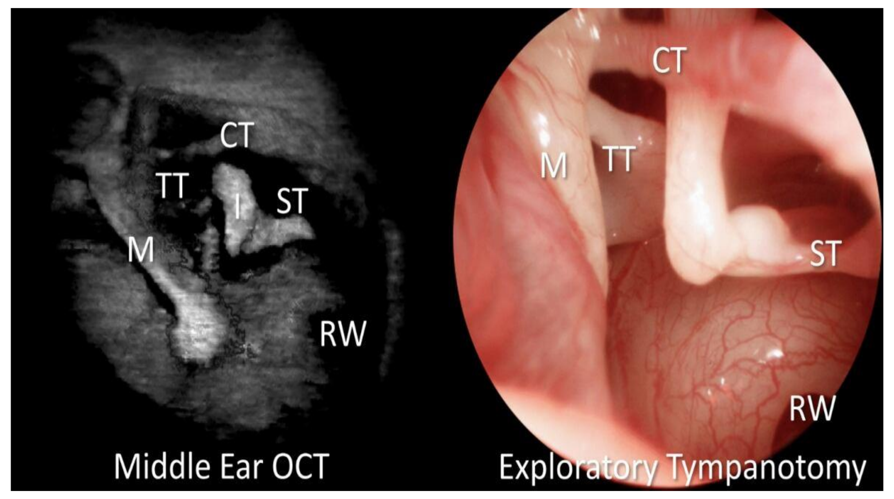
Archa Rajagopalan
Callum Cottrell
Kervin Jones

Sponsor:
Dr. Rob Adamson
AudiOptics Inc.

Department of Electrical and Computer Engineering

Delay Unit for Optical Coherence Tomography

Introduction

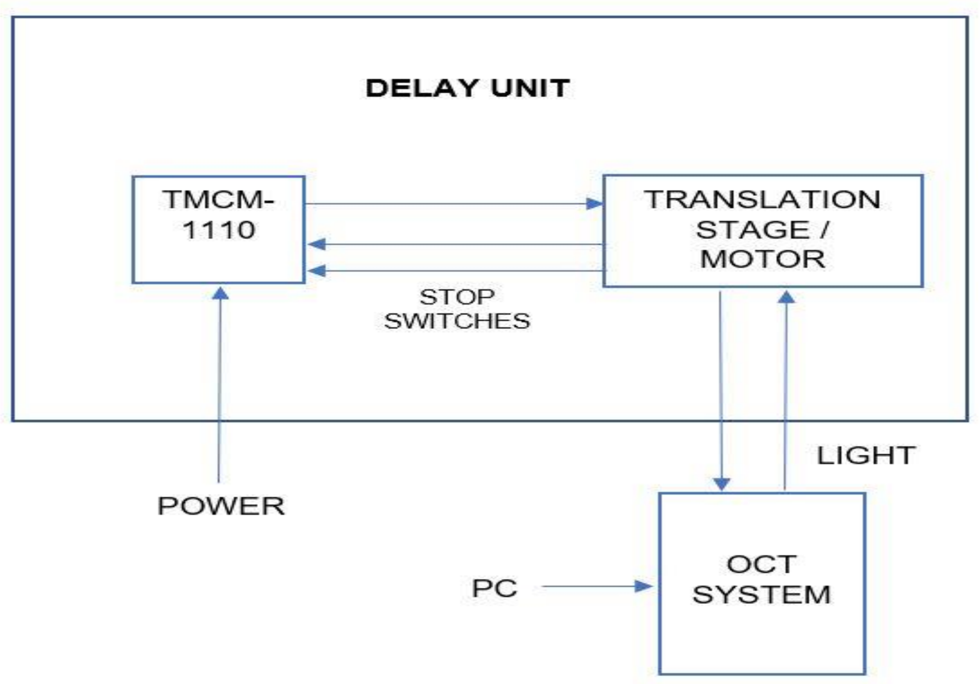


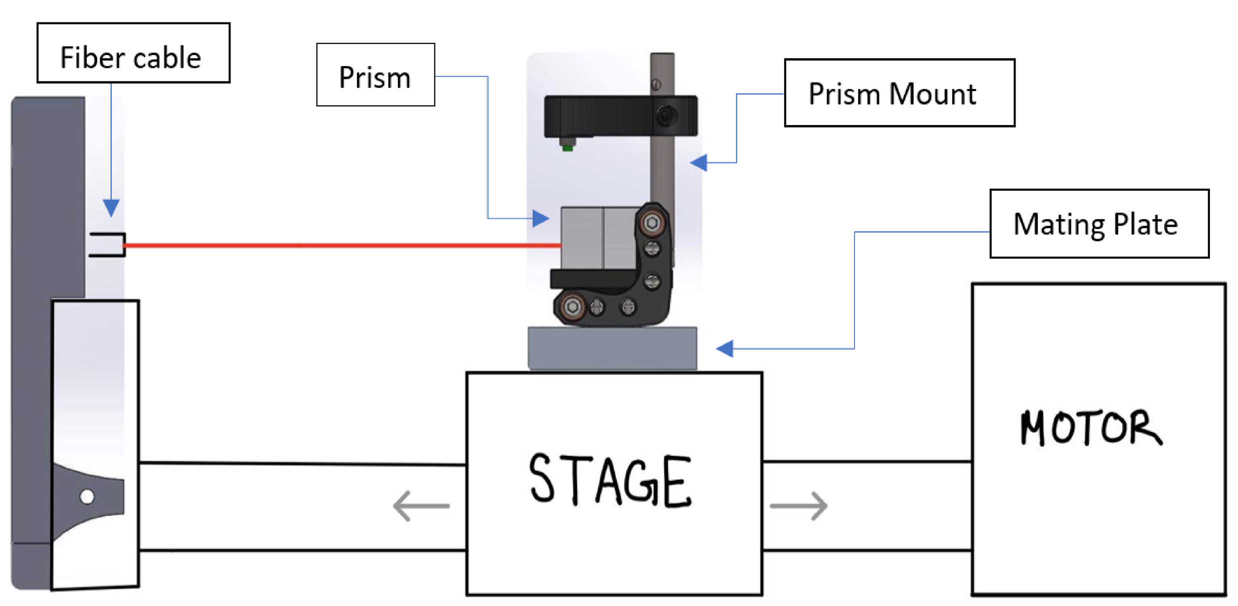
Optical Coherence Tomography (OCT) is a non-invasive medical imaging modality that utilizes optics and scattering properties of light to image tissues at shallow depths (1-2 mm). To construct an image, light is shown onto the sample tissue and reflected back to a detector. The round-trip time delay and scattering of the light translates into a visual representation of the tissue. This beam of light (sample arm) needs a reference beam that is shown onto a prism that reflects the light back to the source with no scattering. This reference beam is used to determine the distance that the sample beam travelled.

The objective of this project iss to design a cheaper reference arm for an OCT system.

System Overview

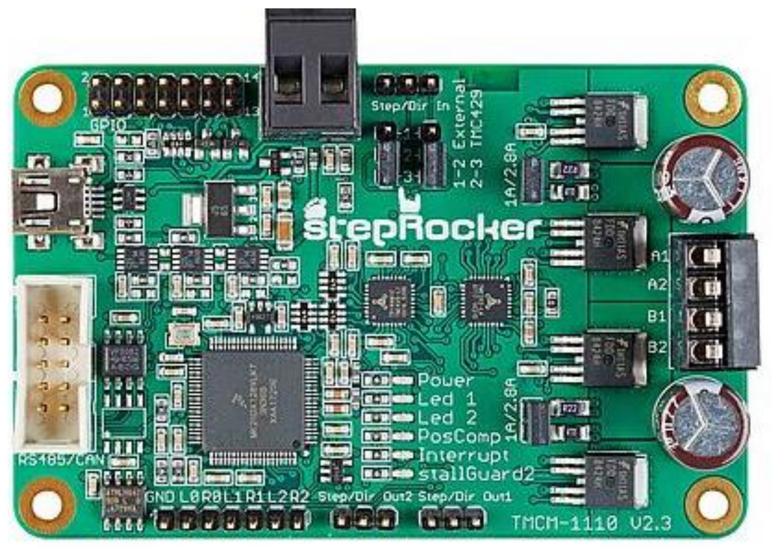
The delay unit is comprised of an off-the-shelf translation stage, motor and motor controller. The motor controller will drive the motor to move the translation stage to the desire position. The translation stage will hold the two fiber optic cables (transmitting and receiving) and a prism, to transmit light and measure the delay of the reference beam. Several attachments will be added to the translation stage to customize it for our uses (see Figure below).





Details of Design

Software



TMCM-1110

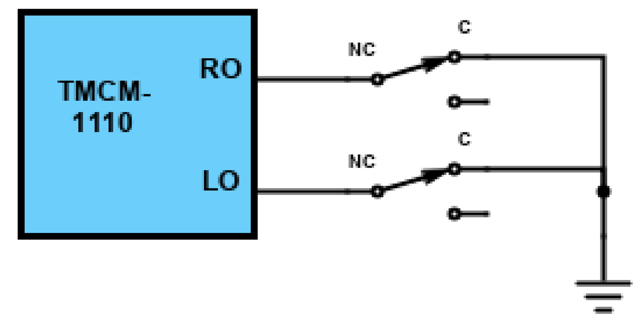
Motor Controller and Driver

The TMCM-1110 “StepRocker” is used to control the motor in the delay unit. It has both a motor driver (for powering the motor) and a motor controller (for controlling the motor) on the same board. The OCT system uses serial transmission to communicate with the motor controller, which expects commands in the format of its “TMCL” language. The software, written in C++, packages a list of common commands and sends them to the TMCM-1110, which allows for full control of the translation stage.

C++ to TMCL

The Motor Controller is always listening for a string of bytes in the format of its “TMCL” language. The software, written in C++, packages a list of common commands and sends them to the TMCM-1110, which allows for full control of the translation stage in real time.

TMCL Command Format	
Bytes	Meaning
1	Module address
1	Command number
1	Type number
1	Motor or Bank number
4	Value (MSB first!)
1	Checksum



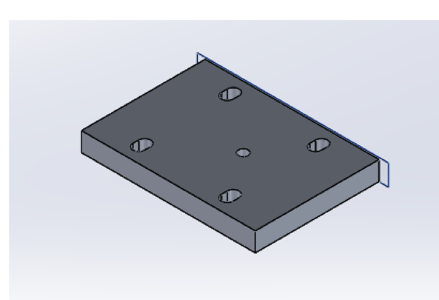
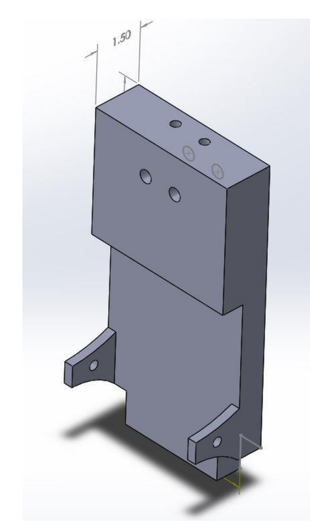
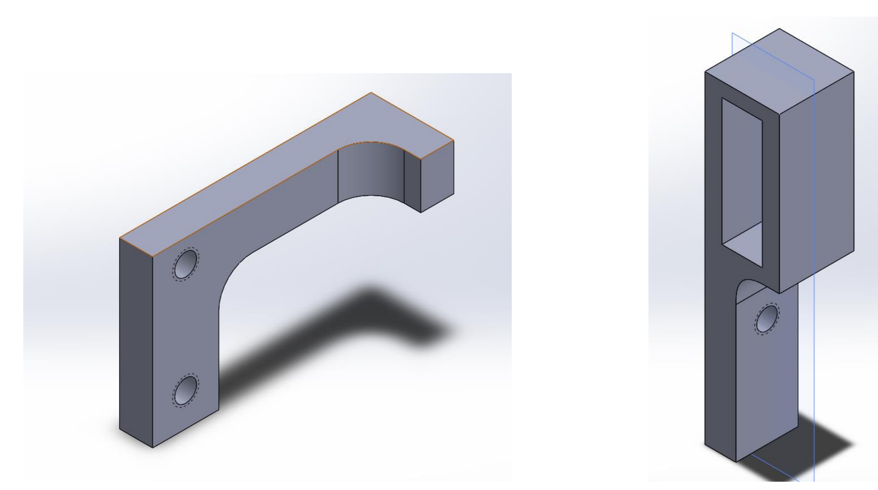
Hardware

An important process of this project was to determine which off-the-shelf components should be chosen to implement the delay unit. The following components were chosen:

- CBX1605-200A translation stage
  - 20 cm range (required: 10 cm range)
  - Delay speed of 111 ps/s (required: 22 ps/s)
- Nema23 RTM23HS6430 Stepper Motor
  - Rated supply of 12 V, 3A (required 12V, 0.5V)
  - Step angle of 1.8º, high precision
  - Resolution of 200 fs (required < 300 fs)

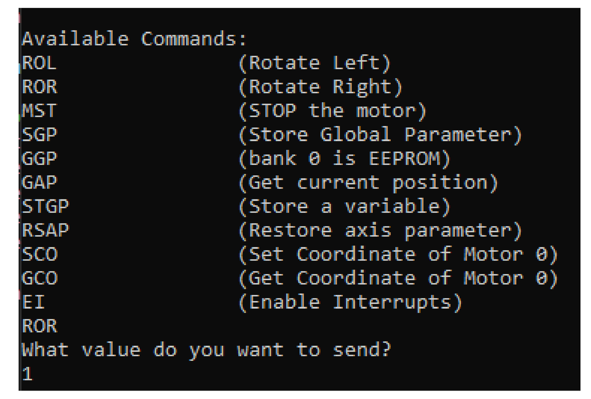
The parts chosen meet the specifications set by client.

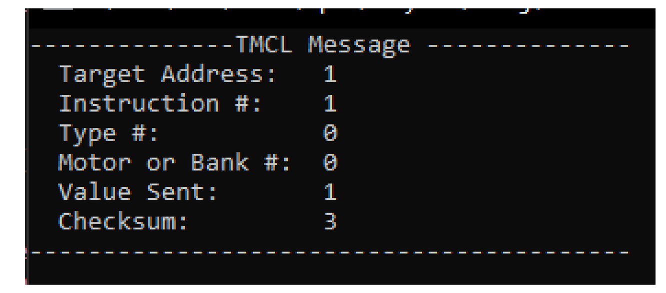
Mechanical Design

		
Mating Plate	Fiber Optic Cable Holder	Stop Switch Mounts
• Adheres a prism mount to the linear stage by means of M4 screws	• Steadily secure fiber cables to direct light onto the prism which sits on the translation stage	• House hinge level switches that halts the movement of linear stage from hitting the edges of the actuator • Attached to the side of the translation stage at both ends of track, with switch in line with translation stage

Testing

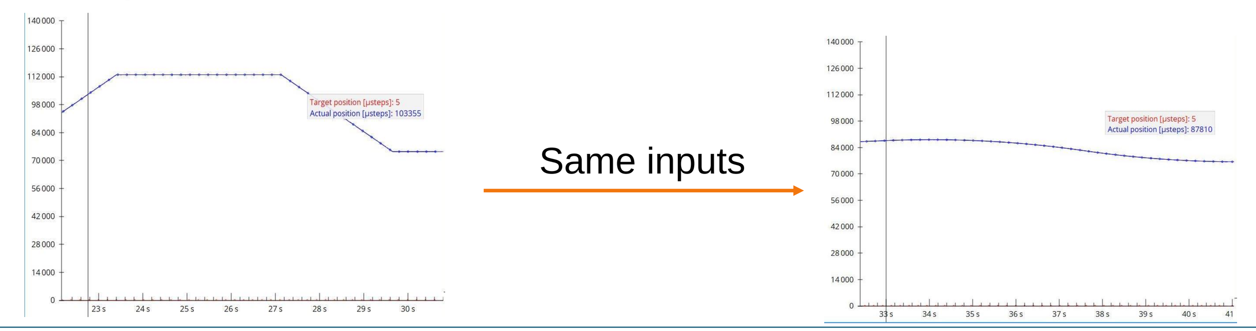
A user interface was developed visually demonstrate and test the C++ to TMCL software. Each command was verified/tested from this menu.





TMCL Format Verification

The physical behavior was tested using software from TMC (Trinamic Motion Control). One of the parameters tested is changing the maximum acceleration. This allows for less noise in the final image by reducing disruptive harsh movements of the motor. On the left is default, with no limit to acceleration, and on the right is with a maximum set.



Conclusion and Recommendations

Despite lack of testing due to COVID-19, individual components of the delay unit were tested. A large component of the delay unit’s functioning is the software driving the motor. Through lab testing, a USB connection between the computer and motor driver was successfully established, and information can be transmitted to the motor driver by the user. Additionally, the stop switch interrupts were successfully wired and tested. The system was not able to be integrated or tested with the OCT system in the end.

Future recommendations include:

- 3D printing the stop-switch mounts and testing optical alignment with 3D printed attachments
- Machining mechanical attachments for final prototype
- Complete SetHome method to set the position of translation stage at startup
- Set axis parameters in code to relate motor driver positioning coordinates to position of translation stage
- Further testing of complete system to test for mechanical vibrations and optical fiber losses.

References

Lipsett, R. A. (n.d.). *Thomson Linear Motion Optimized*. Retrieved from https://www.thomsonlinear.com/downloads/articles/Ball_Screws_and_Lead_Screws_The_Real_World_Difference_taen.pdf

Pitris C, Saunders KT, Fujimoto JG, Brezinski ME. High-Resolution Imaging of the Middle Ear With Optical Coherence Tomography: A Feasibility Study. *Arch Otolaryngol Head Neck Surg.* 2001;127(6):637–642. doi:https://doi.org/10.1001/archotol.127.6.637

Trinamic. “Trinamic/StepRocker-Library.” *GitHub*, 3 Feb. 2012, https://github.com/trinamic/stepRocker-Library.

Trinamic, “TMCM-1110 TMCL™ Firmware Manual.” TMCM-1110 datasheet, [Revised Feb. 2019].