Updating a Script Almost Old Enough to Vote: The Journey of the Fast Feedback System

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Overview of Linac

- Beam energy maintenance in 4 locations: DL1, BC1, BC2, and DL2. DL1
- DL2 are simple energy feedback loops.
- L0 and L1 typically use only 1 klystron to control the energy
- L2 and L3 have multiple klystrons available.
- BC1 and BC2 are energy feedback and bunch length to control the RF phase.

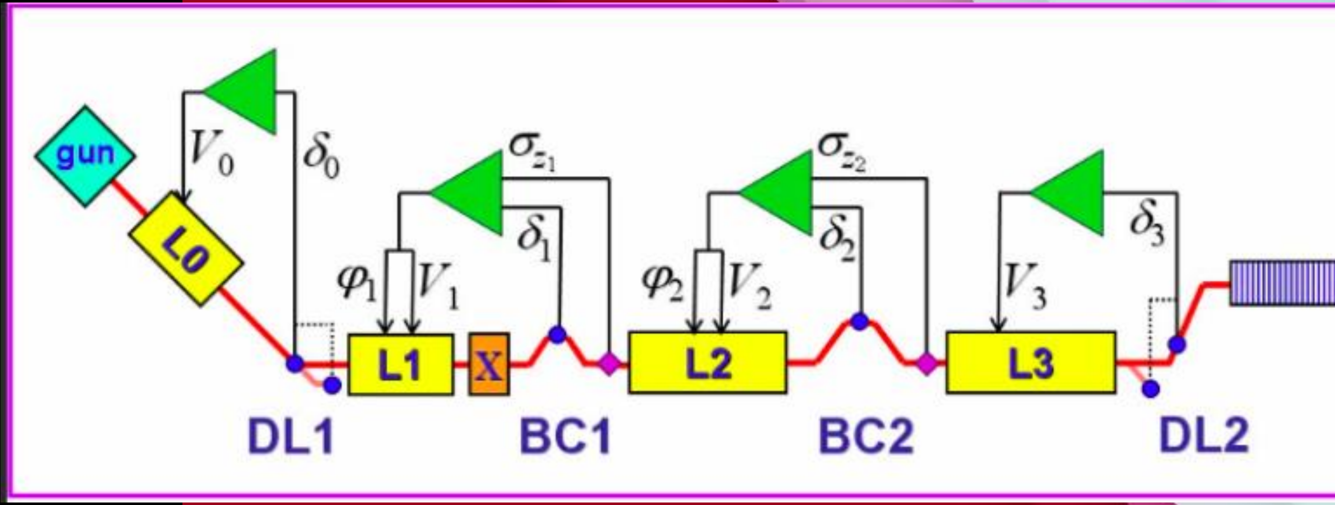


Figure credit: Feedback Physic Requirement #1.1-304

How Feedback ReGold Works

Objectives:

- Collect reference orbit
    - Physicists manually input: # of measurements, beamcode, timeout, number average.
- Write ref orbit to feedback PV
- Zeros out orbit

Talks to the accelerator through Channel Access

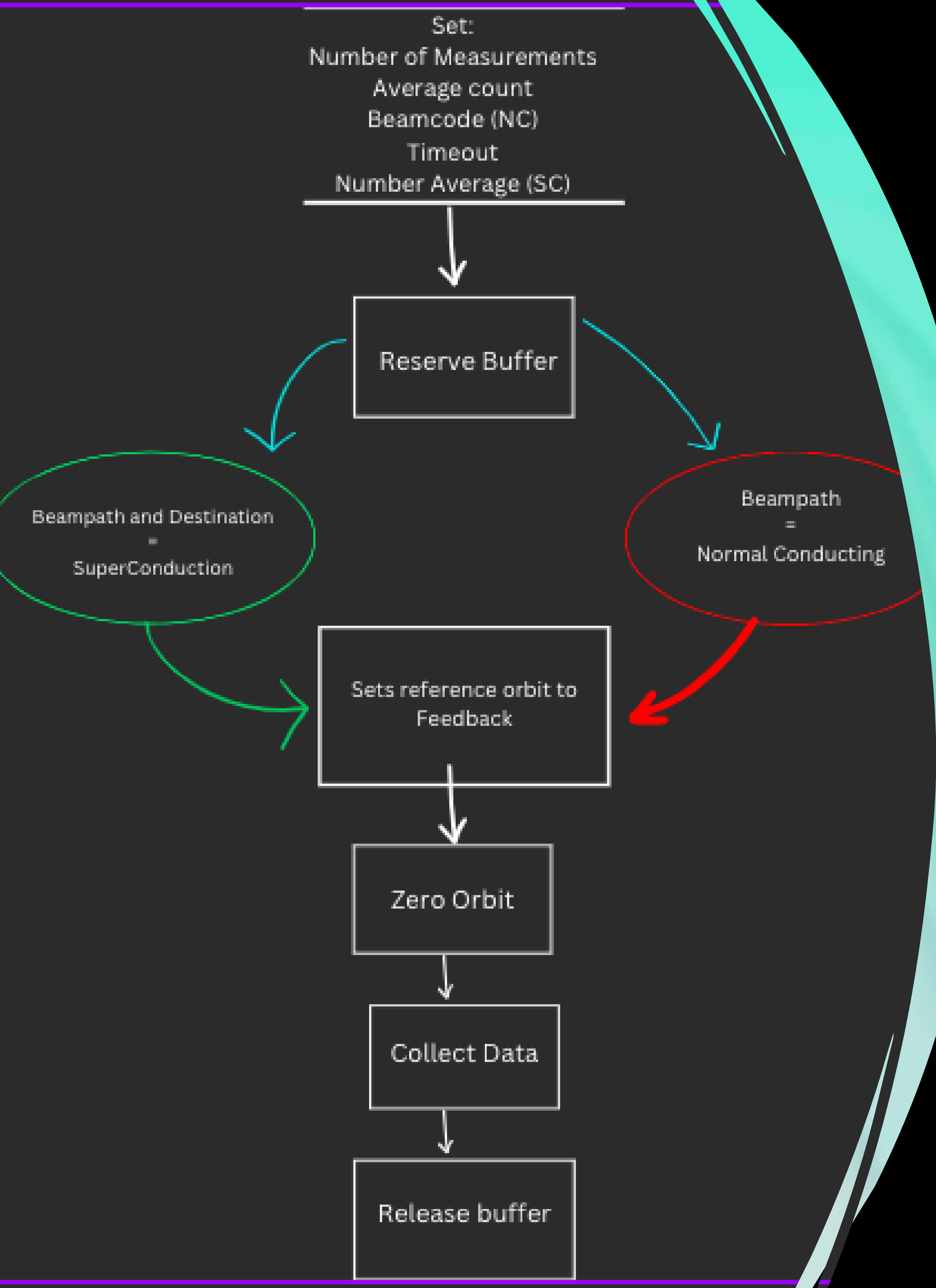
Dictates which BSA is collecting information

Works with the magnets to keep the beam orbit

Klystrons feed the appropriate about of energy needed that was set by operators

Feedback ReGold: “Cause I got Issues…”

- Deprecated python package
- Super Conducting was not implemented…Jenkies!
- No way to differentiate between Normal Conducting versus Super Conducting



The Fix

- Deprecated Python package → PyEpics
- Add FACMODE to determine in Normal Conducting or Super Conducting
- Include Beampath PV for Hard X-ray, Soft X-Ray or both.

Testing procedure

- Familiarize with BSA facilities and wrote test scripts.
- Reserved and released buffers for a few beam pulses.
- Compared with signals coming from the accelerator.
- Why? Avoid caputting.

Acquired Knowledge

- Python Language
- Object-oriented programming
- How LCLS and LCLS-II work

Acknowledgements

Special thanks to

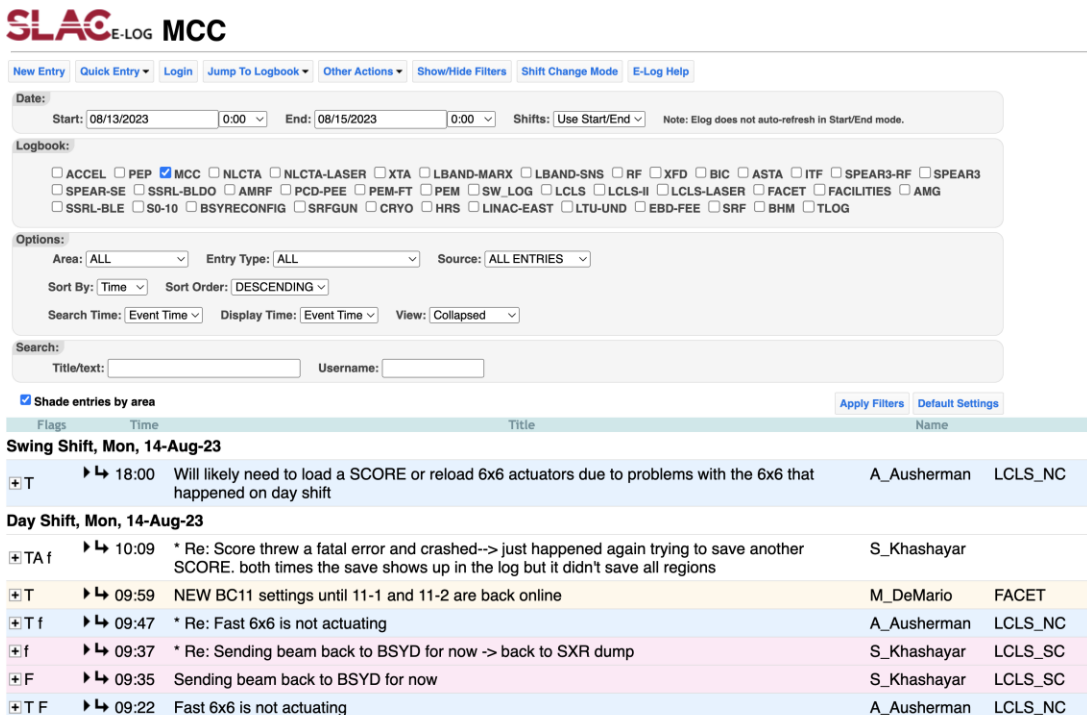
- Kyle, Mentor Extraordinaire
- Matt Gibbs, The Great
- Zach & Evren
- The entire EED team
- Hillary, Arturo and Rebecca!
- Stephany and Isabelle: Dream Team

Building a New E-Log

Eamon "Boogie" Mikulec

Biggest Challenges with the Old E-Logs

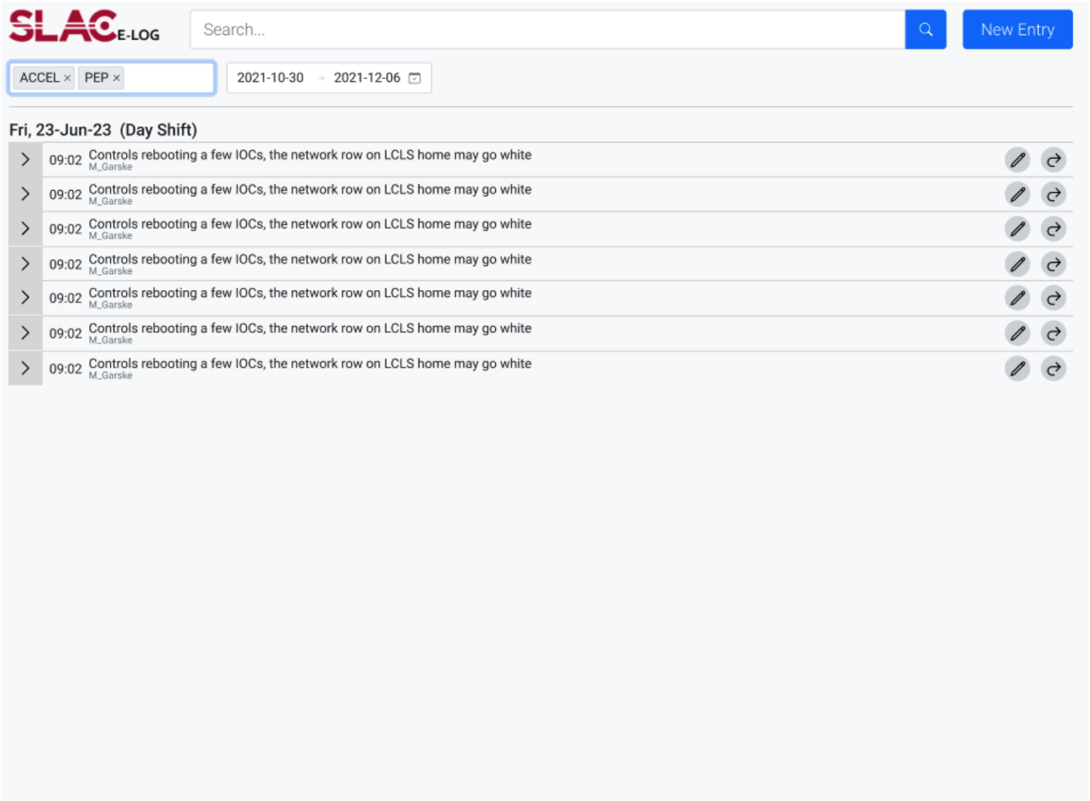
- Split across the Physics E-Log and the MCC E-Log
- Inaccessible from outside the SLAC network
- Incompatible with mobile devices
- Some pain points with searching
- Timeouts while making an entry



Building the New E-Log

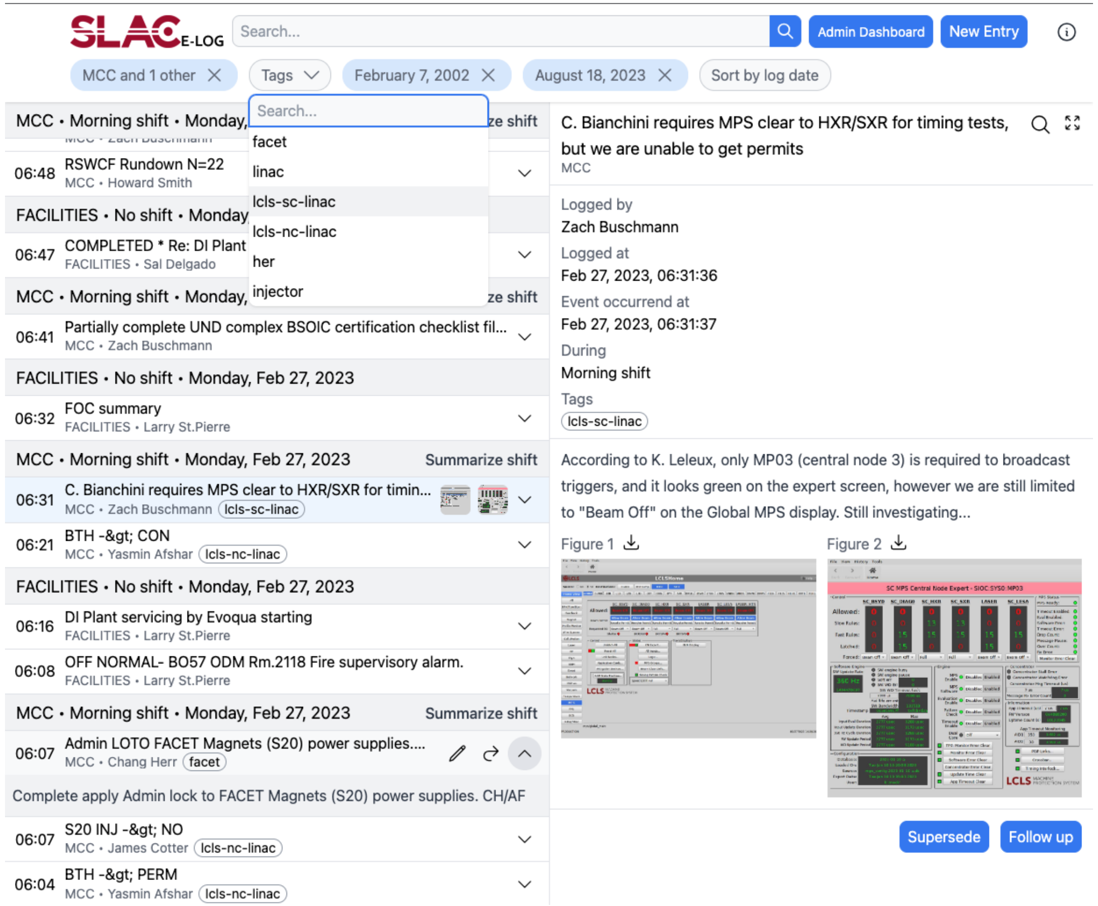
- Merge the Physics E-Log and the MCC E-Log into a unified solution
- Build with current industry standards
- Long term support and extendibility
- Fix pain points with the old E-Logs
- Focus on functionality, usability, and visuals

Initial prototype design for the new E-Log



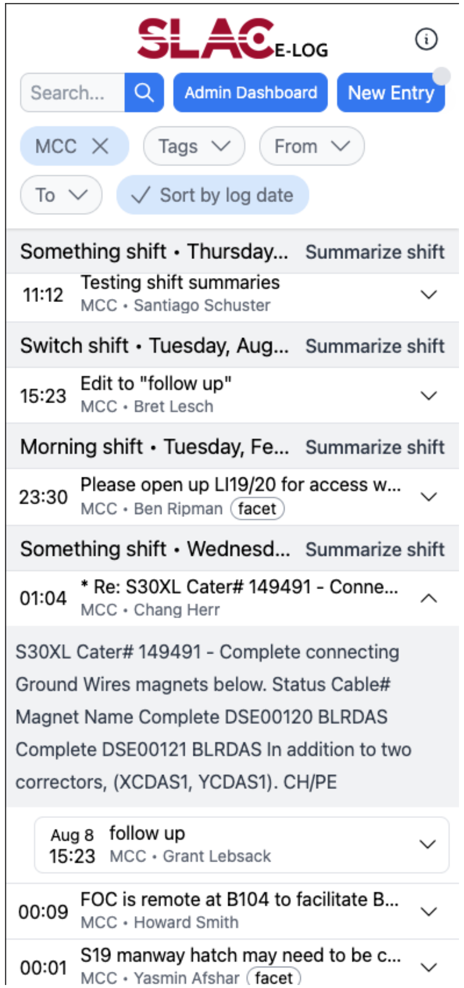
The New E-Log!

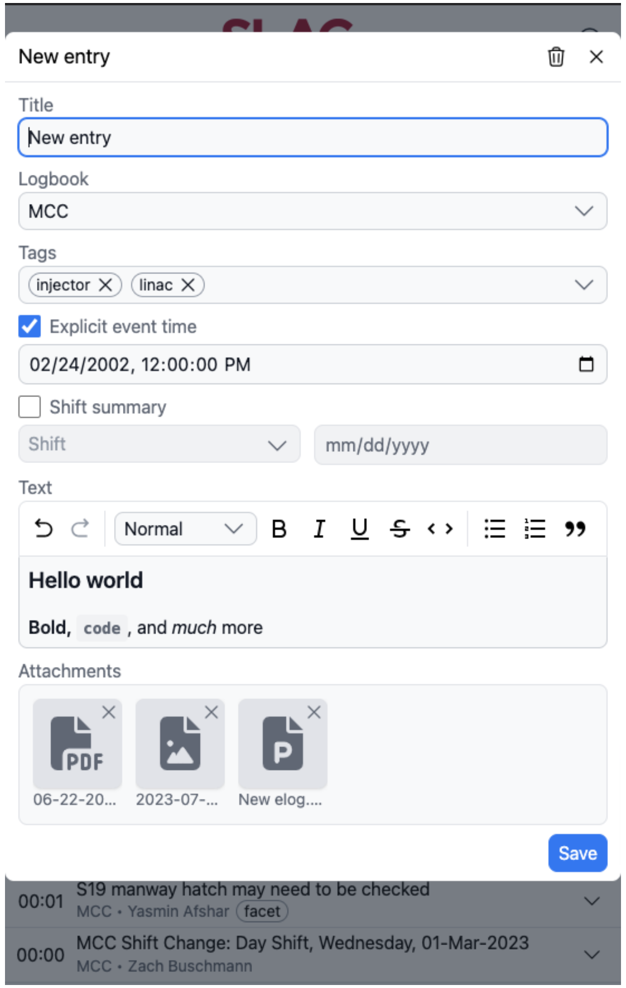
- Built with React and Tailwind
- Performant
  - Can handle thousands of entries loaded on the page
  - Whole app is less than 250kB
- Accessible outside SLAC network
- Works on mobile
- Advanced search capabilities
- Infinite scroll grouped by date and shift
- Tags!



The New E-Log!

- Rich body text
  - Custom WYSIWYG editor
  - Extensible storage format allowing for custom embeddings
- Image previews (full size is downloadable)
- Shift summaries
- Draft storage (If you wrote it, it's saved)
- Admin dashboard





So, let's check it out

Demo time :)

Stepper Motor Test Stand with LVDT Feedback using Beckhoff Drives

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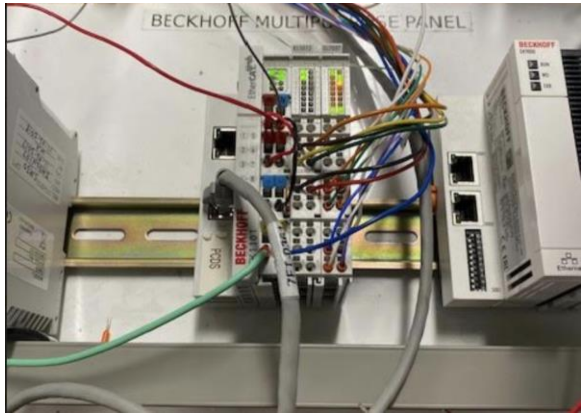
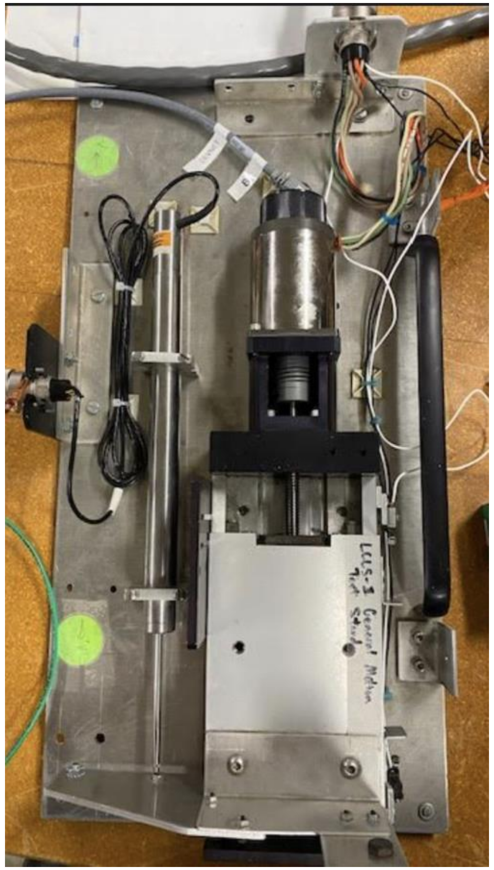
Author: Dylan Matthews
Mentor: Namrata Balakrishnan
Program: SULI

OVERVIEW



- Collimation System
- Beckhoff Devices
- LVDT and Stepper Motor
- EtherCAT communication and TwinCAT
- PLC Program and HMI
- CX5020



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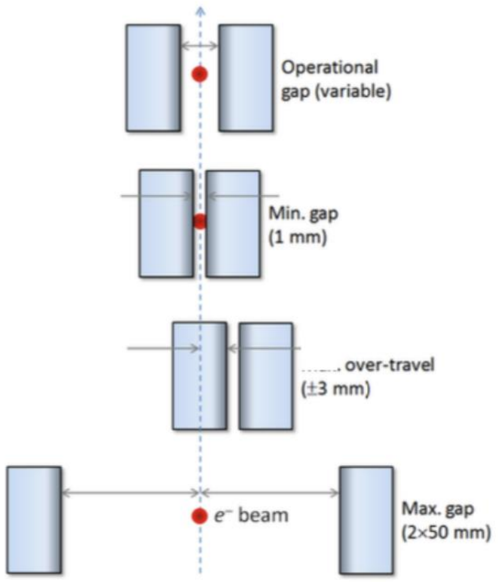
Collimation System

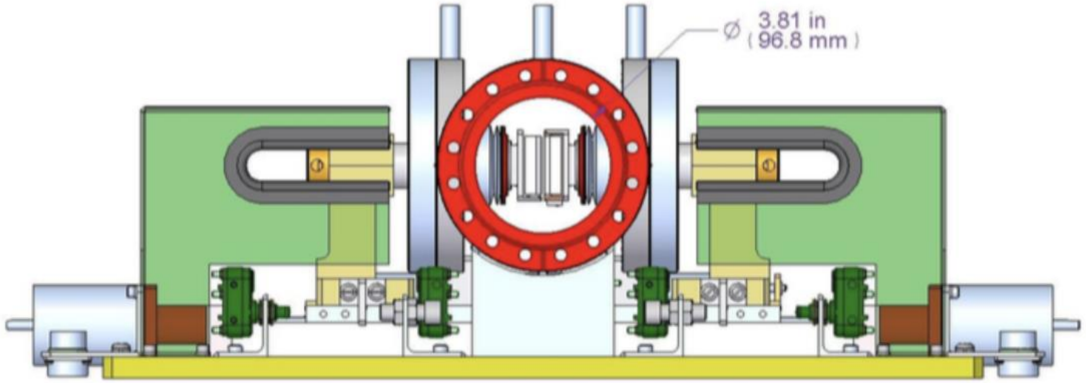
Purpose of Halo Collimation System



The overall goal of the HALO collimation system in LCLS-II is to eliminate undesirable electrons in order to avoid excessive radiation due to beam loss in sensitive area of the accelerator and those with delicate equipment (such as the undulators). The undesirable electrons exist at either the wrong energy, time, or transverse position and angle [3]

Collimator Construction

The collimators are composed of two tungsten jaws that can be moved in either the horizontal or vertical directions depending on the orientation of the individual collimator. This movement is what the stepper motor/LVDT test stand aims to control.



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LVDT

A Linear Variable Differential Transformer (LVDT) is an electromechanical sensor that converts mechanical movement to electrical signals in the form of voltage or current.

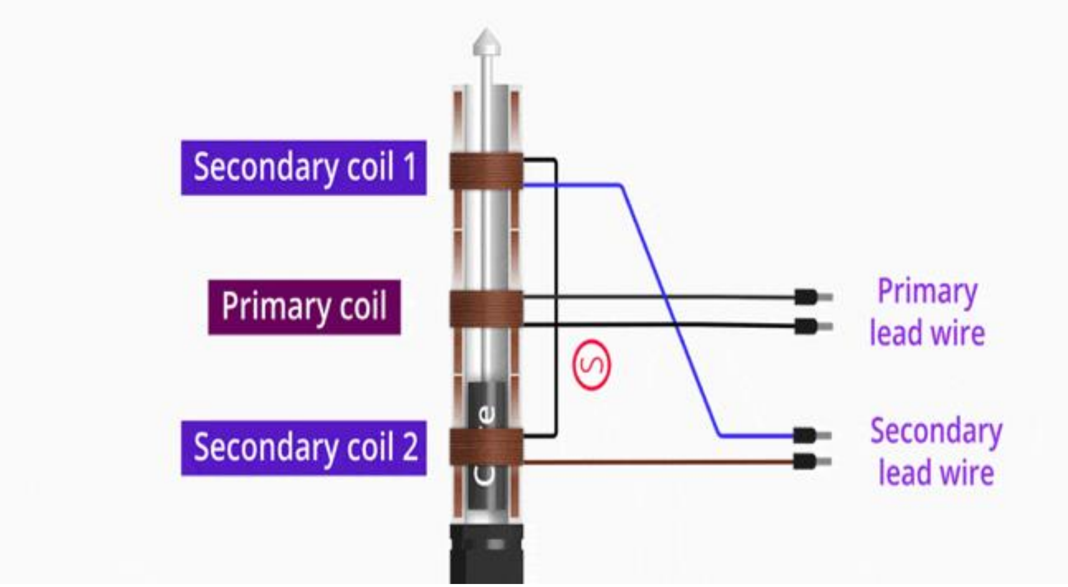
This project uses an AC LVDT with voltage output meaning that is it an LVDT which is powered by and AC signal and converts its mechanical motion into a voltage signal.

LVDT Ratings

- Linear Range: +/- 25.4mm
- Excitation: 2-6 V_{RMS}
- Excitation: 0.4 - 10 kHz
- Sensitivity: 5 mV/V/0.0001"

LVDT Settings

- 6 wire LVDT
- High Impedance
- Linear Range: +/- 25.4mm
- Excitation: 3.5VRMS
- Excitation: 10 kHz
- Sensitivity: 196.8 mV/V/mm



Stepper Motor

Basic Operation

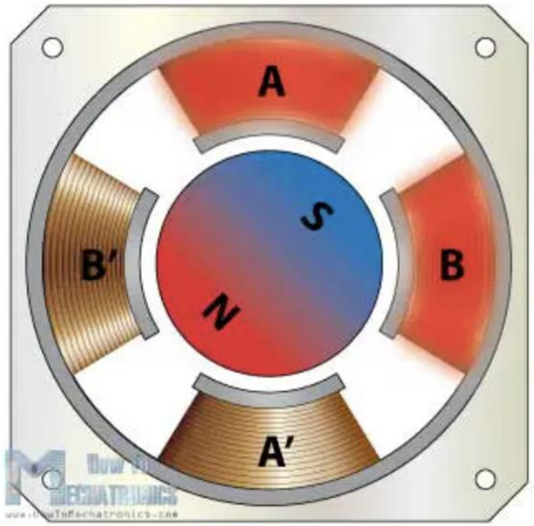
A stepper motor is a brushless motor that rotates in discrete steps. They are useful in that they allow for precise positioning and the ability to hold that position. Construction of a stepper motor involves a permanent magnet acting as a rotor surrounded by windings which make up the stator. The windings are activated by applying current to them creating electromagnetic poles which cause the movement of the rotor.

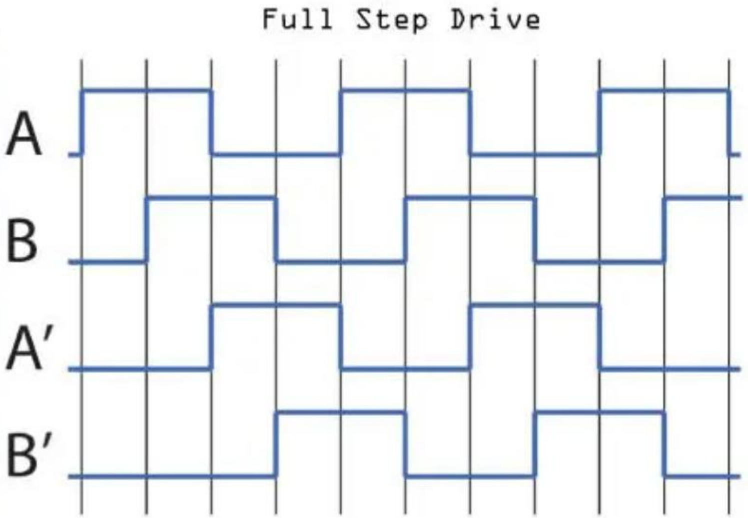
Motor Ratings

1.65 V DC
4.7 A
200 Full Steps/Rev

Motor Settings

- 1.5A Maximal current
- 0.8A Reduced current
- 1.65V Nominal voltage
- 7Ω Motor coil resistance
- 1.6mH Motor coil inductance
- 0.1s drive on delay
- 0.15s drive off delay





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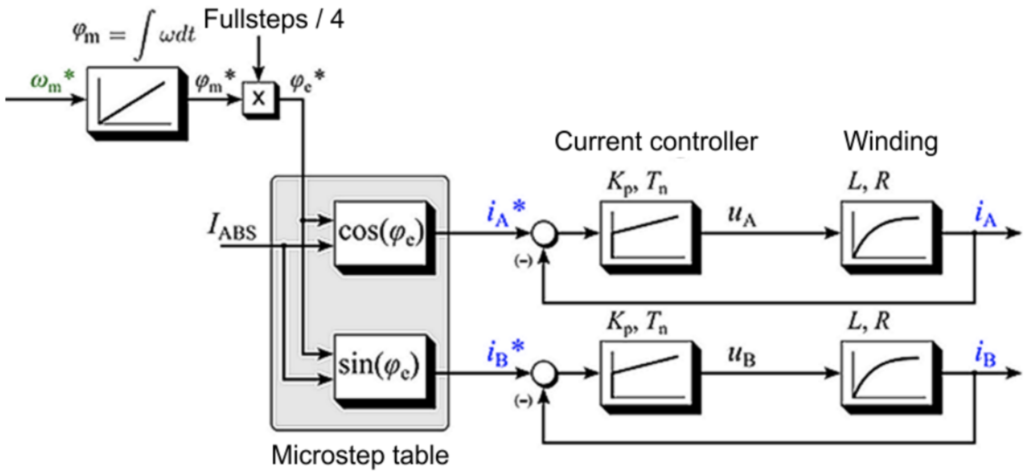
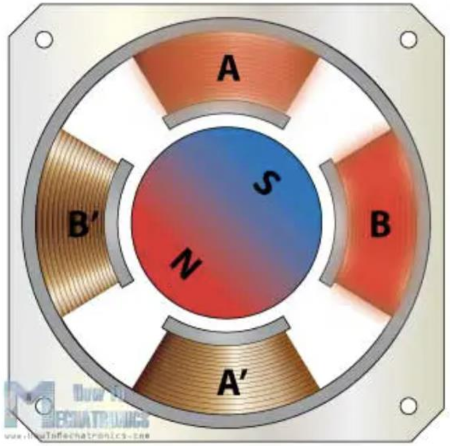
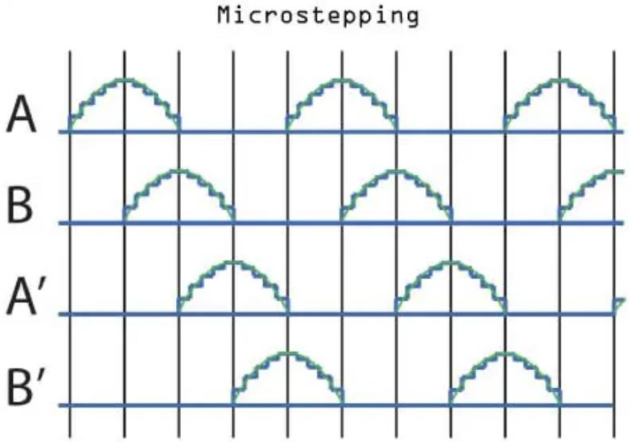
Microstepping and Drive Control







The SLO stepper motor along with the EL7037 drive enabled microstepping to be used in this project. For a 200 step/rev motor like the one used in this project is $\frac{360}{200} = 1.8°$ of rotation per step. The EL7037 drive allows the motor an additionally 64 microsteps per step when connected leading to a microstep size of $\frac{1.8°}{64} = 0.028°$

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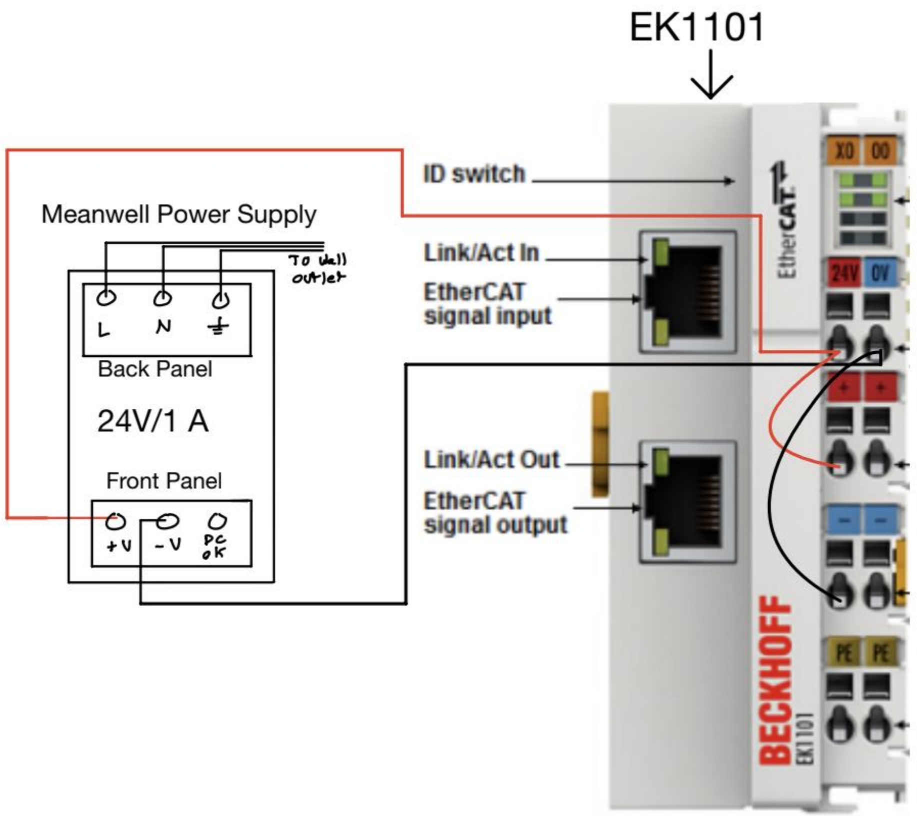
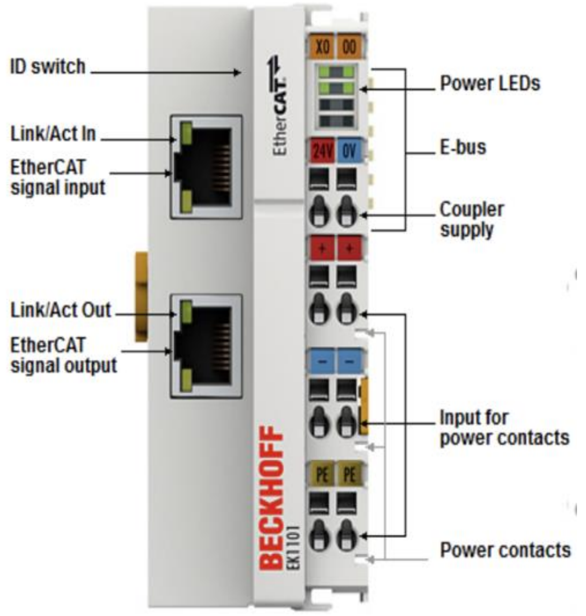
Beckhoff Devices - EK1101

Wiring



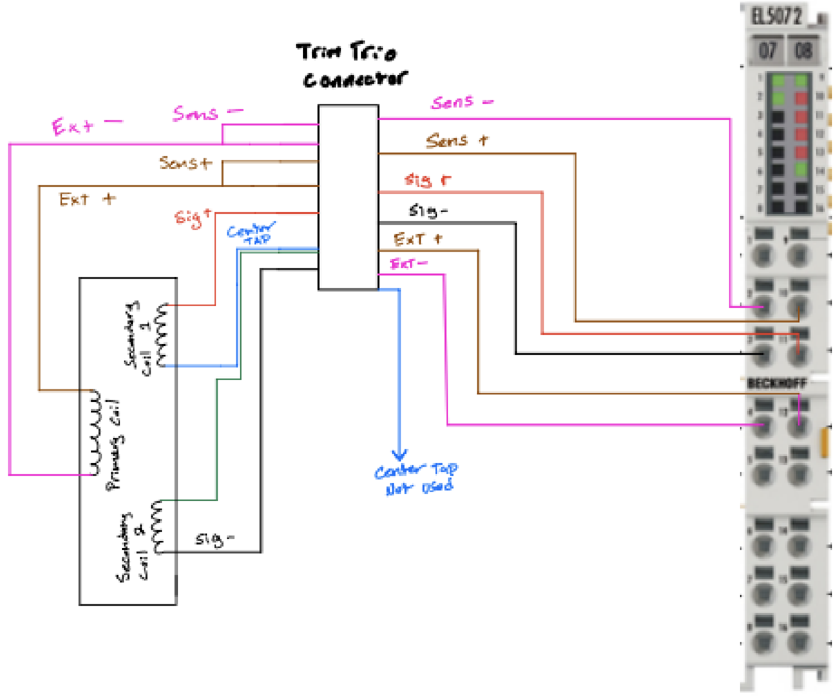
Device

The EK1101 is an EtherCAT coupler. It acts as a link to the EtherCAT protocol at the fieldbus level. The EK1101 attaches to our analog input modules and allows the user to then connect those modules to a PC via EtherCAT protocols



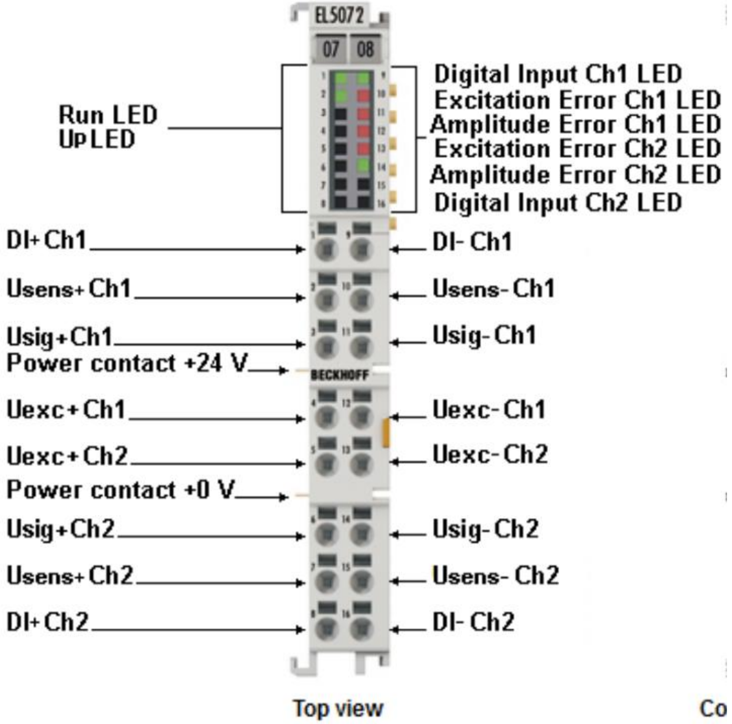
Beckhoff Devices- EL5072

Wiring



The EL5072 is a 2 channel LVDT interface. It allows for adjustable excitation frequencies and voltages and is compatible with 4, 5, and 6 wire LVDT configurations. It measures LVDT positional value as a 32 bit integer variable.

Device



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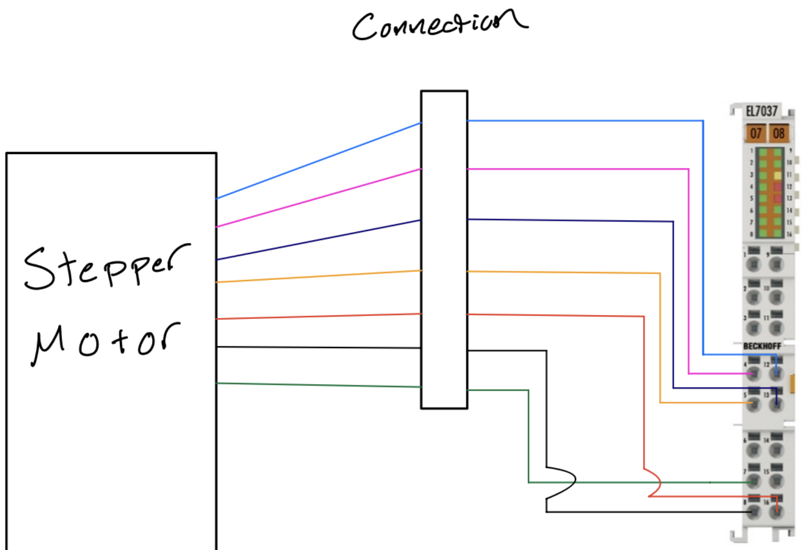
Beckhoff Devices- EL7037

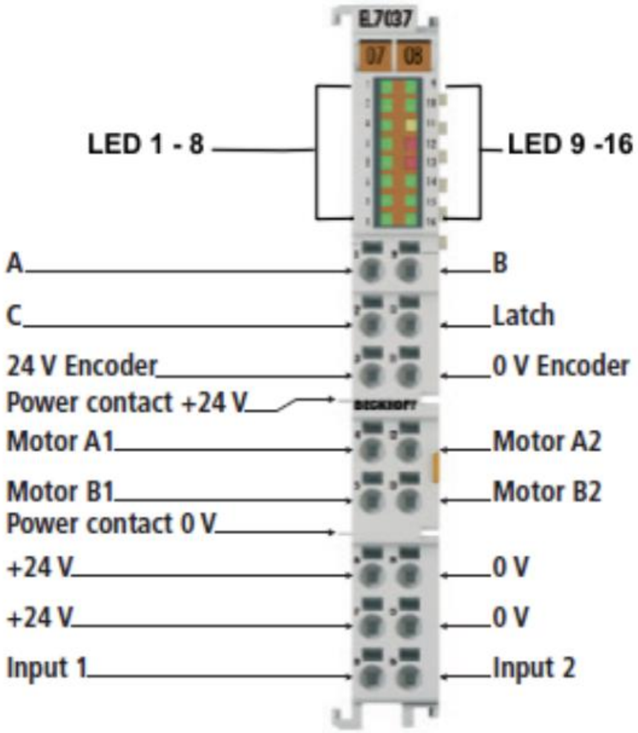
Wiring



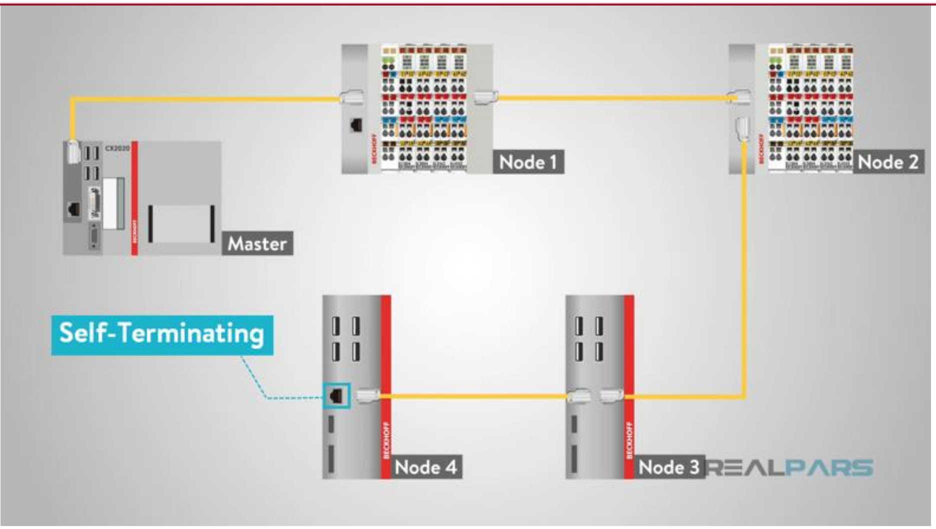
Motor Winding A+	Pink	●
Motor Winding A -	Blue	●
Motor Winding B+	Orange	●
Motor Winding B-	Purple	●
Input 1 CCW Limit	Black	●
Input 2 CW Limit	Red	●
COM	Green	●

Device

The EL7037 is a 1 channel stepper motor drive. It has adjustable parameters including operating currents, voltages and frequencies. These parameters are set to match motor and applications. It contains inputs for 2 limit switches.



EtherCAT Communication

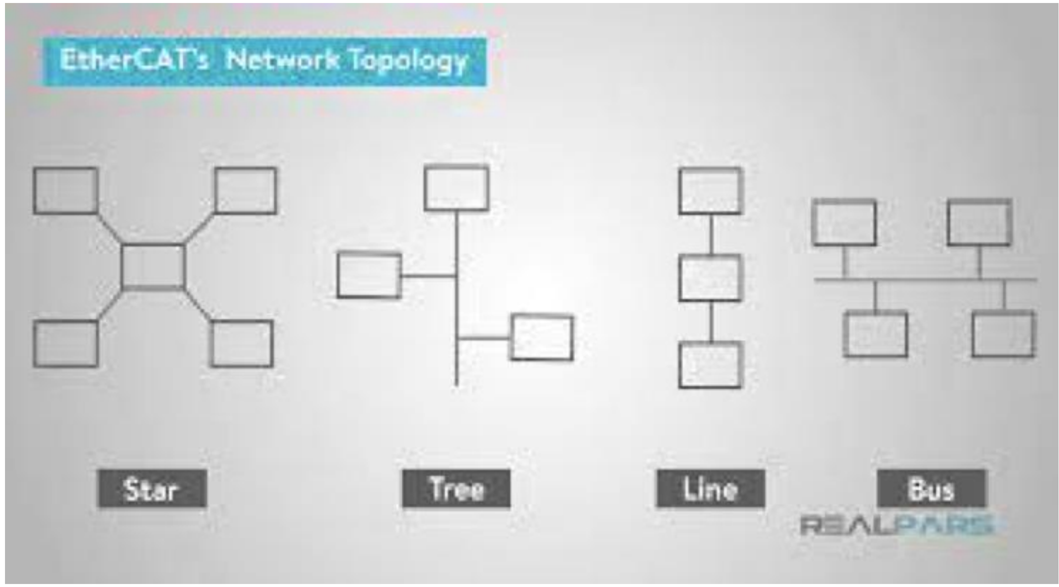


What is EtherCAT

Sometimes called the ethernet fieldbus ethernet is a low cost, high speed ethernet technology with flexible topology

Advantages of EtherCAT

- Many devices can be connected at once
- Internationally standardized
- Fast communication speed
- Multiple topology configurations can be used



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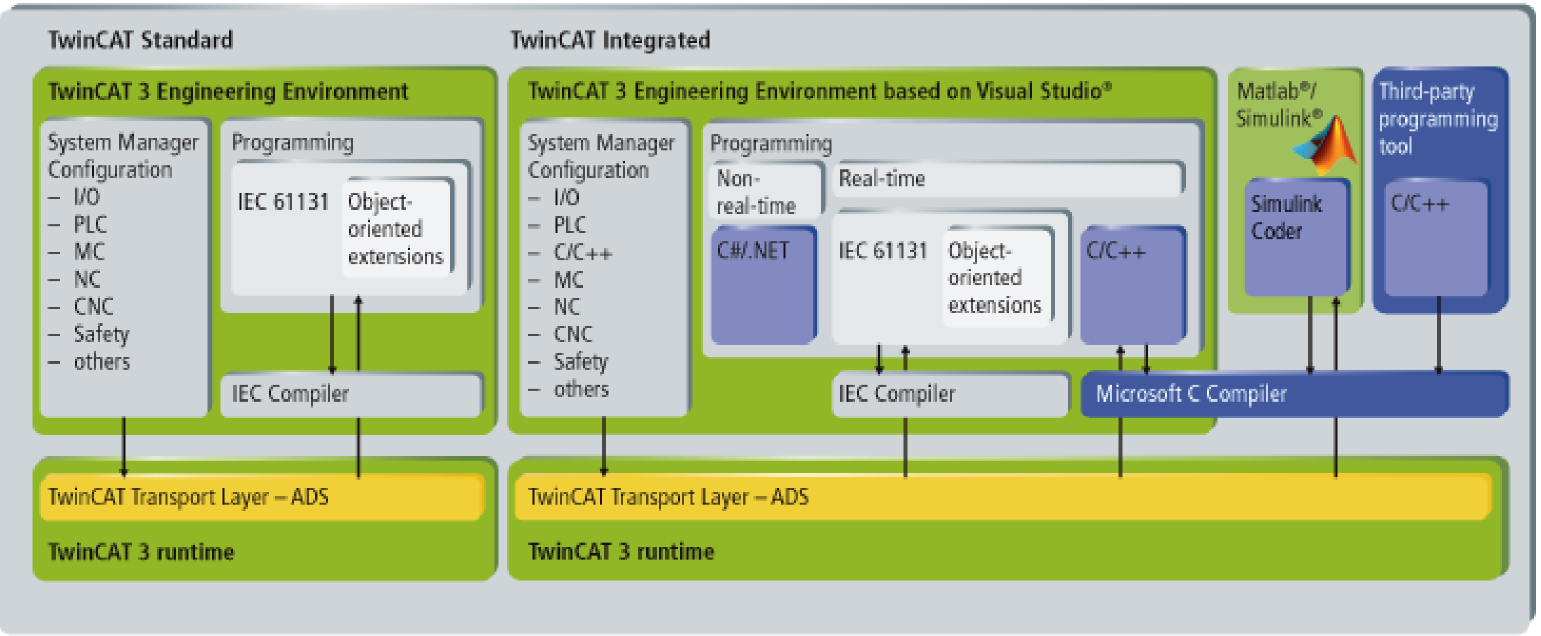
TwinCAT

TwinCAT 3 XAE (Extended Automation Engineering) is a software application developed by Beckhoff that integrates with Microsoft Visual Studios. The goal of TwinCAT is to simplify software engineering and to facilitate the easy control and PLC programming of Beckhoff devices. TwinCAT provides all classic PLC functionalities as well as compatibilities to outside applications such as C, C++, and Matlab.

Communication in TwinCAT is achieved through an ADS (Automation Device Specification) Interface which manages and distributes all messages in the system through EtherCAT and TCP/IP connections.



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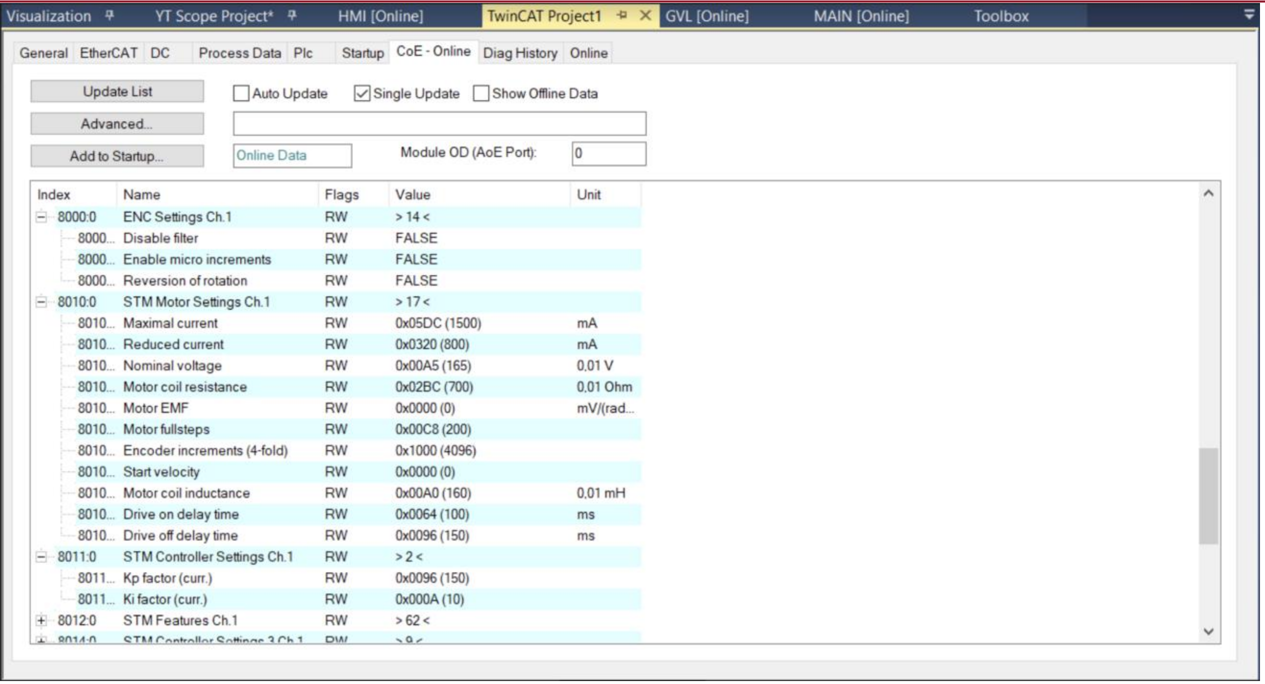
Configuring Devices



Electrical values entered into the EL7037 drive to operate the SLO Stepper motor at optimal performance

The CoE or CANopen over Ethernet interface offered by beckhoff allows the user to set parameter values of the drive specific to the equipment they are using.

Along with electrical parameters for the LVDT, EL5072 also allows manual configuration of gain and offset values to match travel range and center of the stage.

To determine the positional reading of the LVDT given a set user gain and offset is below

$$Position_{Final} = Gain*(Position_{Raw} - Offset)$$

Note: This is not the equation that was given in the datasheet which appears to be wrong

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PLC Program – Linking Variables

Linking Requirements

In TwinCAT input and output variables from the drive (i.e. Actual Position, Velocity Control, Emergency Stop) are connected to the PLC task through the declaration of variables and the subsequent linking of those variables to the real variable values stored in the drive.

Linking Syntax

To successfully link a variable, it must be declared as either an input or an output (TwinCAT uses I for input and Q for output). Additionally, the variable that you want to link must be of the same datatype as the value in the drive which you are attempting to link it too.

Visualization | YT Scope Project* | HMI [Online] | TwinCAT Project1 | GVL [Online] | MAIN [Online] | Toolbox

Name	[X]	Online	Type	Size	>Addre...	In/Out	Linked to
GVL.bStepperError		0x00 (0)	BOOL	1.0	384180.0	Input	
GVL.bStepperRe...		0x00 (0)	BOOL	1.0	384181.0	Input	
GVL.bStepperRe...		0x00 (0)	BOOL	1.0	384182.0	Input	
GVL.bStepperRe...		0x00 (0)	BOOL	1.0	384183.0	Input	
GVL.bStepperMo...		0x00 (0)	BOOL	1.0	385128.0	Input	
GVL.bStepperMo...		0x00 (0)	BOOL	1.0	385129.0	Input	
GVL.dActualVelo...	X	0	INT	2.0	385130.0	Input	Actual velocity . POS Status . Term 3 (EL7037) . Device 2 (EtherCAT) . Devices
GVL.dActualPosit...	X	192000	UDINT	4.0	385132.0	Input	Actual position . POS Status . Term 3 (EL7037) . Device 2 (EtherCAT) . Devices
GVL.bLimPos	X	0x01 (1)	BOOL	1.0	385136.0	Input	Digital input 1 . Status . STM Status . Term 3 (EL7037) . Device 2 (EtherCAT) . Devices
GVL.bLimNeg	X	0x01 (1)	BOOL	1.0	385137.0	Input	Digital input 2 . Status . STM Status . Term 3 (EL7037) . Device 2 (EtherCAT) . Devices
GVL.bMovingPos	X	0x00 (0)	BOOL	1.0	385138.0	Input	Moving positive . Status . STM Status . Term 3 (EL7037) . Device 2 (EtherCAT) . Devices
GVL.bMovingNeg	X	0x00 (0)	BOOL	1.0	385139.0	Input	Moving negative . Status . STM Status . Term 3 (EL7037) . Device 2 (EtherCAT) . Devices
GVL.dDriveTime	X	5105	UDINT	4.0	385140.0	Input	Actual drive time . POS Status . Term 3 (EL7037) . Device 2 (EtherCAT) . Devices
GVL.bAccelerating	X	0x00 (0)	BOOL	1.0	385144.0	Input	Accelerate . Status . POS Status . Term 3 (EL7037) . Device 2 (EtherCAT) . Devices
GVL.bDecelerati...	X	0x00 (0)	BOOL	1.0	385145.0	Input	Decelerate . Status . POS Status . Term 3 (EL7037) . Device 2 (EtherCAT) . Devices
GVL.dPositionLV...	X	29970568	DINT	4.0	385164.0	Input	Position . IND Inputs Channel 1 . Term 2 (EL5072) . Device 2 (EtherCAT) . Devices

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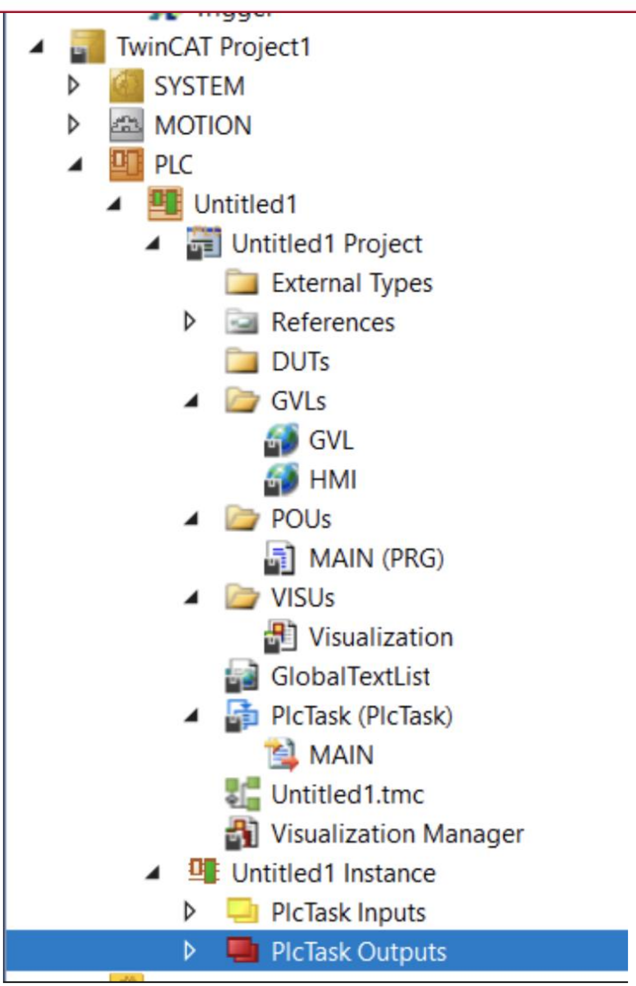
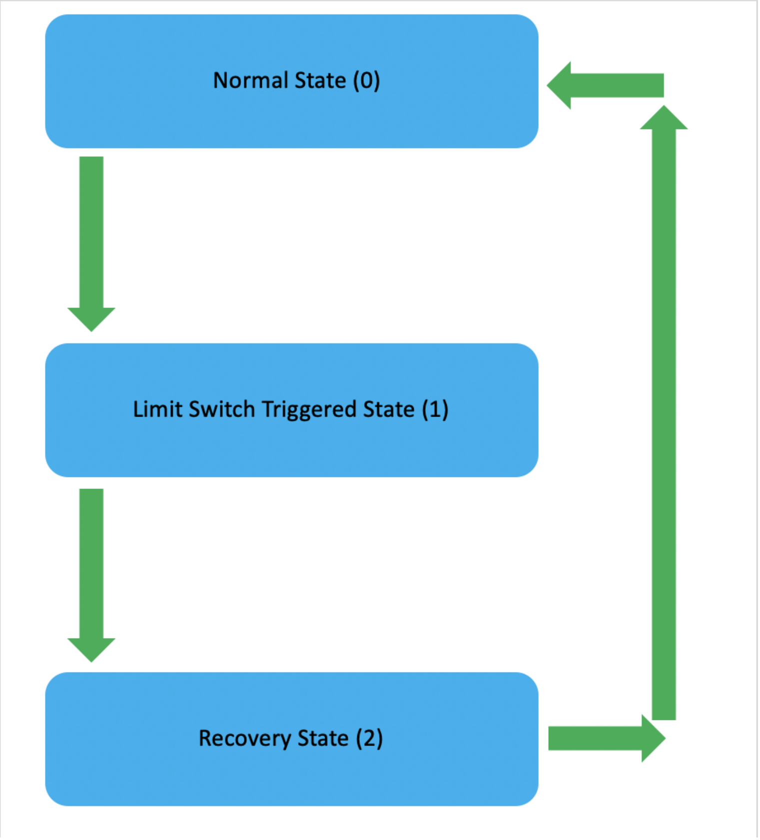
PLC Program Main Task



The main task of the PLC program is continuously repeats by the drive and has a maximum cycle time of 10 microseconds meaning that the PLC must be able to execute all instructions within that time.

Running tasks in the Normal (0) State:

- Automatically updating position and velocity readings
- Conversions to the metric system from the base units of the drive
- Ability to set desired velocity and positional settings



Simple state machine describing behavior of the EL7037 drive when one of the limit switches is triggered

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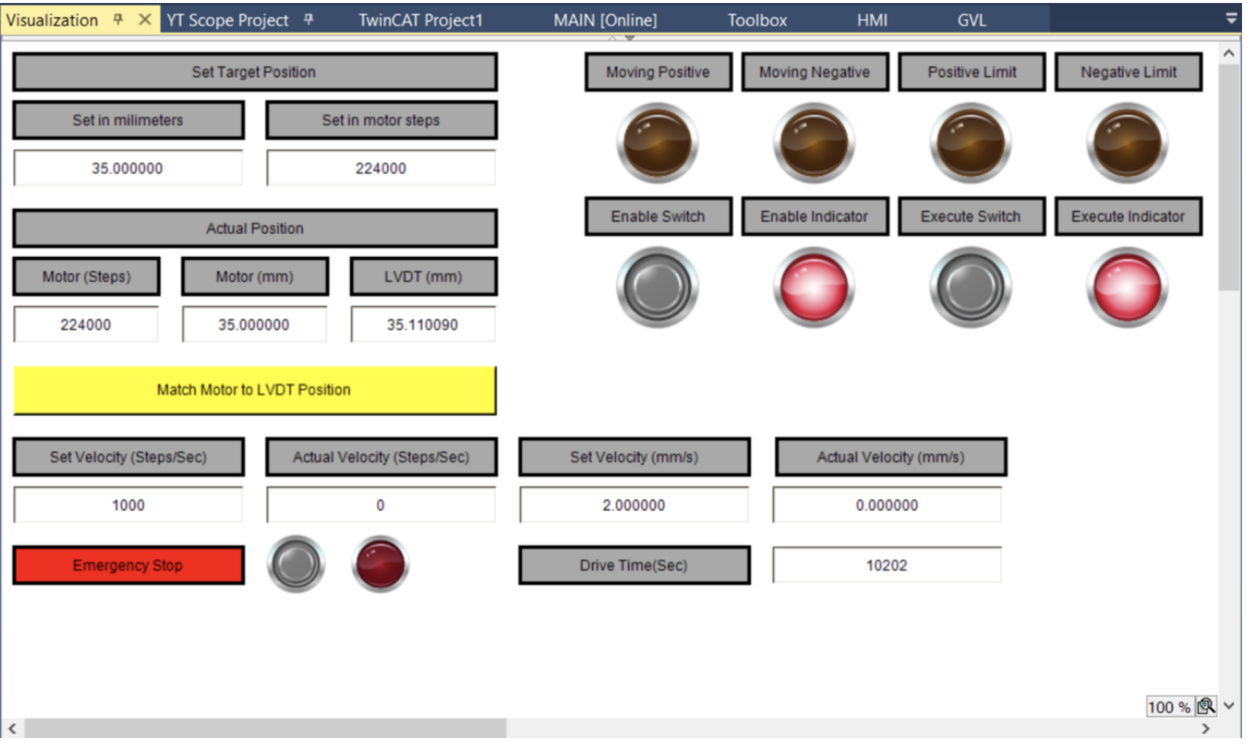
Human Machine Interface



An HMI visualization was created in order to enable easy control of the motor. The visualization interface further links the input/output variables described in previous slides to a series of switches, buttons, and entry boxes to allow uses to easily read and write variables.

Functionalities

- Enable and Execute Switches for the Motor
- Set Target Position (in mm or steps)
- Set Target Velocity (in mm/s)
- Recalibrate internal motor position to LVDT reading
- Emergency Stop Switch
- Indicators for Limit Switches and Motion
- Drive time, Velocity and Positional Readings

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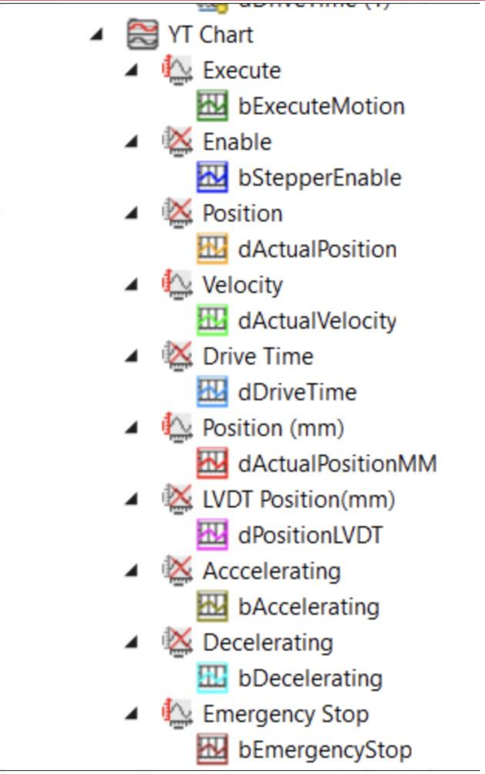
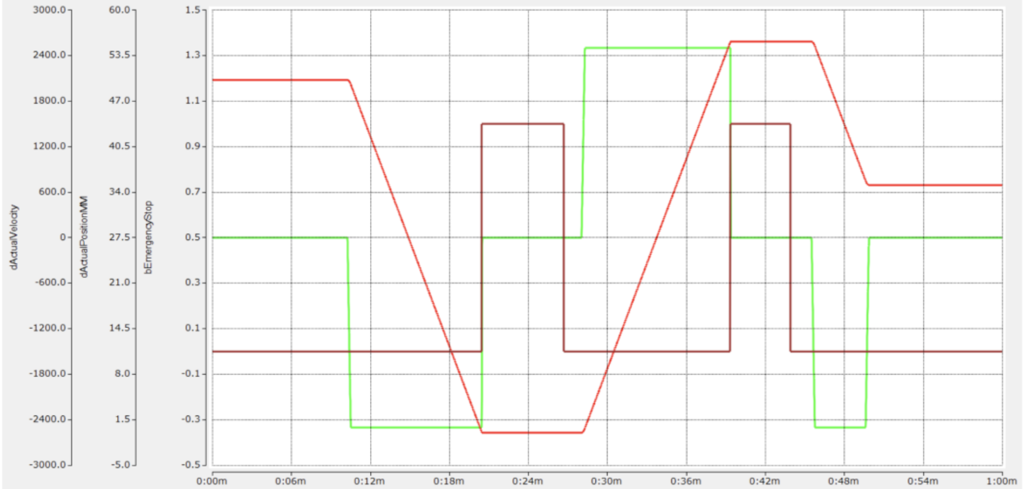
Scope View

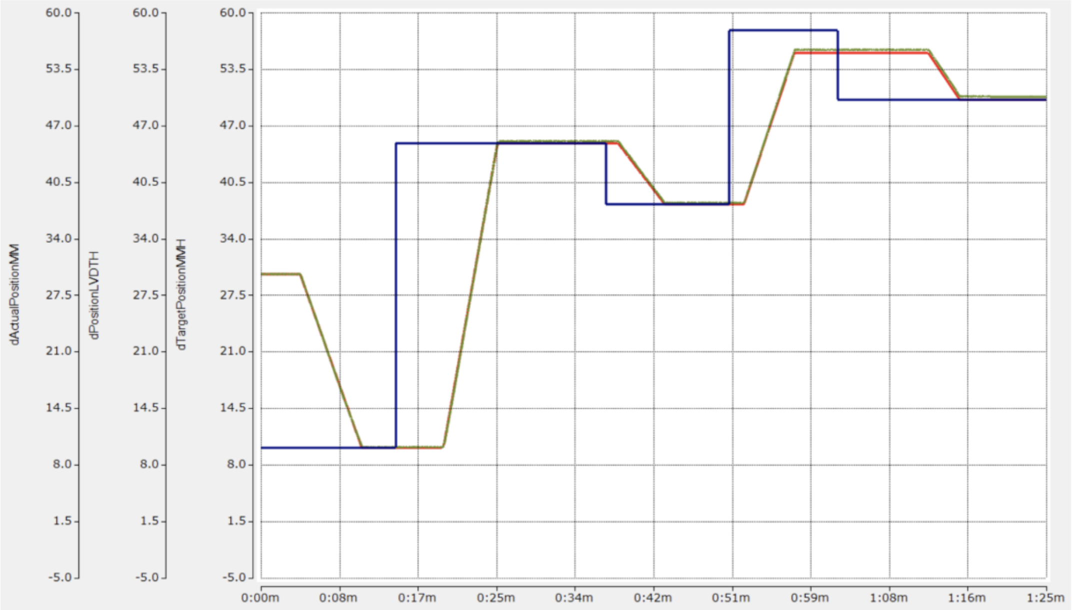


Variables Entered Into Scope Viewer

Scope view showing the motor being moved through its full range from limit switch to limit switch. Red indicates position, Green Velocity, and Brown emergency stop (limit switches).



Scope view showing how motor position (Red) matches LVDT Position (Green) and that both positional reading reach the target position (Dark Blue) except when the target position is out of the range of the limit switches as seen around time 59 seconds.



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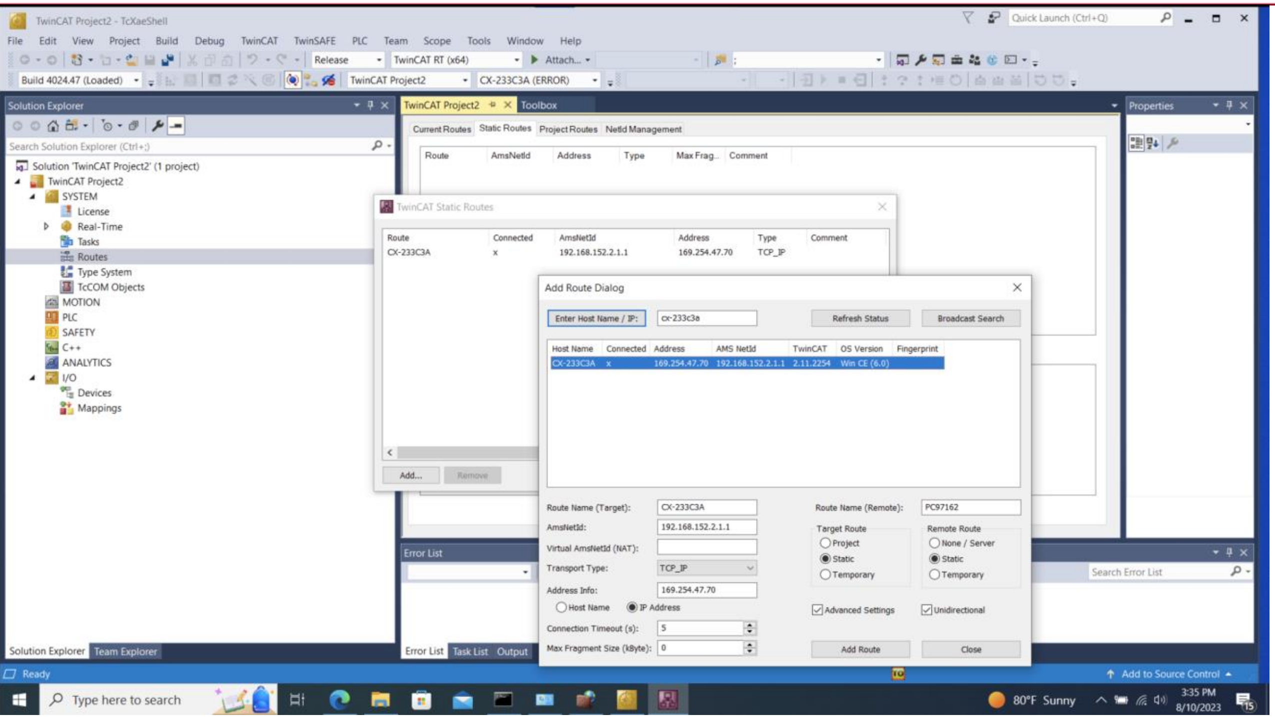
CX5020-Future Steps



The final step of my project involved connecting to a CX5020 embedded PC. This involved the configuration of the IP address and AMS net ID of the CX5020 drive to allow connection with the PC. Once connected it is possible to upload the PLC project to the CX5020 and allowing this device to run the system instead of the laptop the project was developed on.

Next Steps

- Remote connection to CX5020
- Integration into the EPICS system at SLAC
- Motor tuning to reduce response delay

Sources and Acknowledgements

Acknowledgements

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Sources

1. https://download.beckhoff.com/download/document/io/ethercat-terminals/el5072en.pdf
2. https://download.beckhoff.com/download/Document/io/ethercat-terminals/el70x7en.pdf
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Full bibliography can be found with the final paper submission for my SULI project

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