Stepping Up Precision:

Automated SiPM Characterization

for nEXO Experiment

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Double beta decay and neutrinoless beta decay diagram (Gruszko, n.d.)

The nEXO Experiment



nEXO is a proposed detector searching for a hypothetical rare nuclear decay called **neutrinoless double beta decay** ($Ov\beta\beta$).

We are using ~50 000 silicon
 photomultipliers (SiPMs) in our TPC

SiPM Characterization

Why Use SiPMs?

- Allow us to derive timing information of events in TPC
- Can detect single photons
- Can operate in cryogenic temperatures (165 Kelvin)

- We need to scan over the SiPMs with a light source to calibrate them
- We plan to use precision actuators consisting of stepper motors and encoders

1920 SiPMS





Time Projection Chamber (Right) Stave (left) (nEXO 2024 June Pictures, n.d.)

What is a Stepper Motor and Encoder?

encoder Stepper motor 4

- The **<u>stepper motor</u>** rotation is controlled by discrete electrical signals that will move it a 'step'
 - This stepper motor as 25000 steps
- The <u>encoder</u> can measure rotation angle and speed of the motor and will enable **positioning as small as 0.0001 mm**



Stepper motor and encoder diagram

Getting Started



 The software used with Applied Motion Products is STF Configurator

Goal: Use the stepper motor and encoder to make precise scanning movements necessary to scan over the SiPMs

Applied Motion Products software: ST Configurator

Feature Failures

	🖪, Encoder Feedback (optional) 🛛 🕹 🗙						
Would cause motor to stall	Encoder 8000 counts/turn (2000 lines) Ch A leads Ch B when shaft turns: Ch C ccw Ch B ch B						
	Single Ended (not recommended) shaft turning ccw						
	Stall Detection						
	Fault drive if motor stalls (or is forced out of position)						
	Stall Prevention Automatically adjust torque utilization to prevent stalling. Use 10 % max Hard stop: fault drive if motor stalls for more than 20 msec						
Would cause	Help Cancel OK						
motor to move sporadically	Encoder features popup on ST Configurator						

Initial Solutions

- Studied the datasheets and manuals for the driver, motor, and encoder
- **Disassembled** the encoder and reassembled using the driver manual

 Contacted encoder manufacturer for the encoder count

Decoding the Encoder

 Received the encoder count however features still did not work....

Product-ID 118		9-05	Ver 00							
Name	R35i-20	2000/2-5mm-LD/LD-5V-6-R-H-M								
¥ GenData Dat	a_Sheet	Sales	Documents	Software	TecNotes	Successor	Spare_Parts	Accesso		
Name			Numeric Value	String valu	eDescription					
Name	Name			R35i	Counts/Rev = 2000?					
Line count		500.000								
Number of signal periods		2000.000)	0000						
Number of signal pe	Number of signal periods commutation		2.000)						

Manual sent by encoder manufacturer

Readout on ST Configurator

Counts/revolution = Line count * 4

After various tests, it was
 verified that the encoder
 readout was correct finally
 unlocking the next stage

Stepper Motor Control Program

<u>Goals:</u>

- To organize program into classes
- Include functions such as:
 connect, reset device, home, go
 to position, read encoder, read
 back
- Write short return time functions (<5sec)



Building Functional Code



Command Logic: DistanceSet

DistanceSet

ExecuteCommand

Receives and prints output from the drive

Verifies connection to drive User inputs distance Encodes the command (ex. Calls ExecuteCommand 'DI') as bytes to send to drive to set distance **Timeout** function if connection is lost Calls ExecuteCommand to read distance

In Summary & Onward

Successes:

- Troubleshooting initial issues
- Code development
- It works!

Remaining Challenges:

- Occasional connection errors
- Temperature limits

Next Steps:

- Homing function
- Further refinement to program

Thank You!

Contact me!

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References

- 1. Nature. (2021, July 27). *Researchers find potential clue to dark matter's origin*. Nature. Retrieved from https://www.nature.com/articles/d41586-021-01955-3
- 2. Neilson, R. G. (2011). *Discovery of the two-neutrino double-beta decay of xenon-136 with EXO-200* (Doctoral dissertation, Stanford University). Stanford Digital Repository. http://purl.stanford.edu/bg856gy1187
- 3. nEXO 2024 June Pictures [PDF slides]. (n.d.).
- 4. nEXO Overview. (n.d.). *nEXO: The next-generation neutrinoless double beta decay experiment*. Retrieved from https://nexo.llnl.gov/nexo-overview
- 5. ScienceDirect. (2019). Title of the article. Journal Name, Volume(Issue), pages. <u>https://doi.org/10.1016/j.nima.2019.03.015</u>
- 6. TRIUMF. (n.d.). *nEXO: Next Enriched Xenon Observatory*. Retrieved from <u>https://fiveyearplan.triumf.ca/teams-tools/nexo-next-enriched-xenon-observatory/index.html</u>
- Fermilab Today. (2012, September 21). *Title of the article*. Fermilab Today. Retrieved from <u>https://www.fnal.gov/pub/today/archive/archive_2012/today12-09-21_NutshellReadMore.html#:~:text=lf%2Oneutrinos%</u> <u>20are%20Dirac%20particles,particles%20in%20the%20Standard%20Model</u>.
- ** All figures created by author unless otherwise noted

Mastering Host Commands

 Built in programming software written in Applied Motion's Serial Command Language (SCL)

- Created a test to ensure motor and driver communications
- Initial test was **successful**

Q Programmer V1.6.20 test.qpr							_		\times
Show Drive Help									
DRS-232/485 Comm Port		1/0	Status	Drive Statu	is Ala	rm Status			Applied Motion
Ethernet POLLING ST10-E	<u> </u>	🔵 Ena	abled	Moving 🔘	Saving 🔘) Reserved	1	Γ'	Products
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R	2	DI	25000						
R5	3	FL							
M V	4	FL							_
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