LINEAR INDUCTION MOTOR

BRADLEY UNIVERSITY

Electrical and Computer Engineering

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Project Advisor: Steven Gutschlag

10/1/2015

Outline of Presentation

- Background Information
- Design Approach
- Economic Analysis
- Societal and Environmental Impacts
- Timeline
- Division of Labor
- Conclusion

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Background Information

Linear Induction Motor Background

- Alternating Current electric motor
- Powered by a multiple phase voltage scheme
- Force and motion are produced by a linearly moving magnetic field
- Used to turn large diameter wheels

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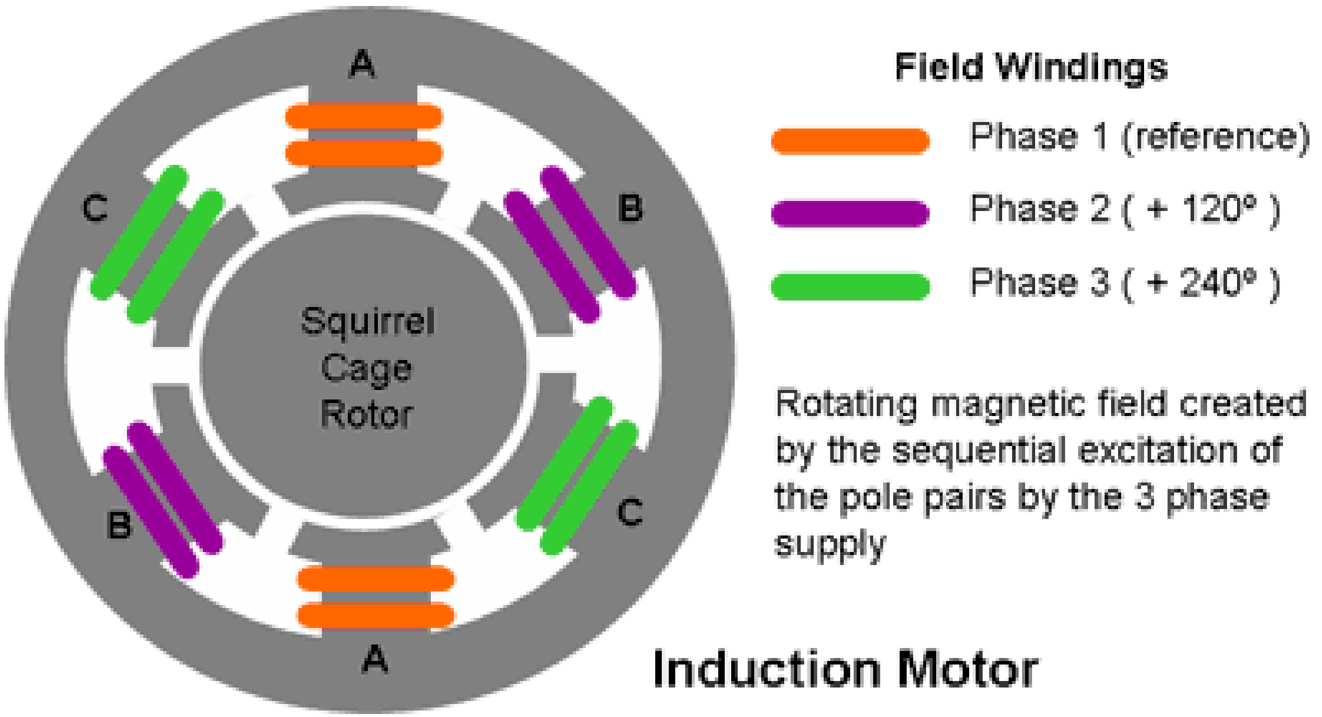
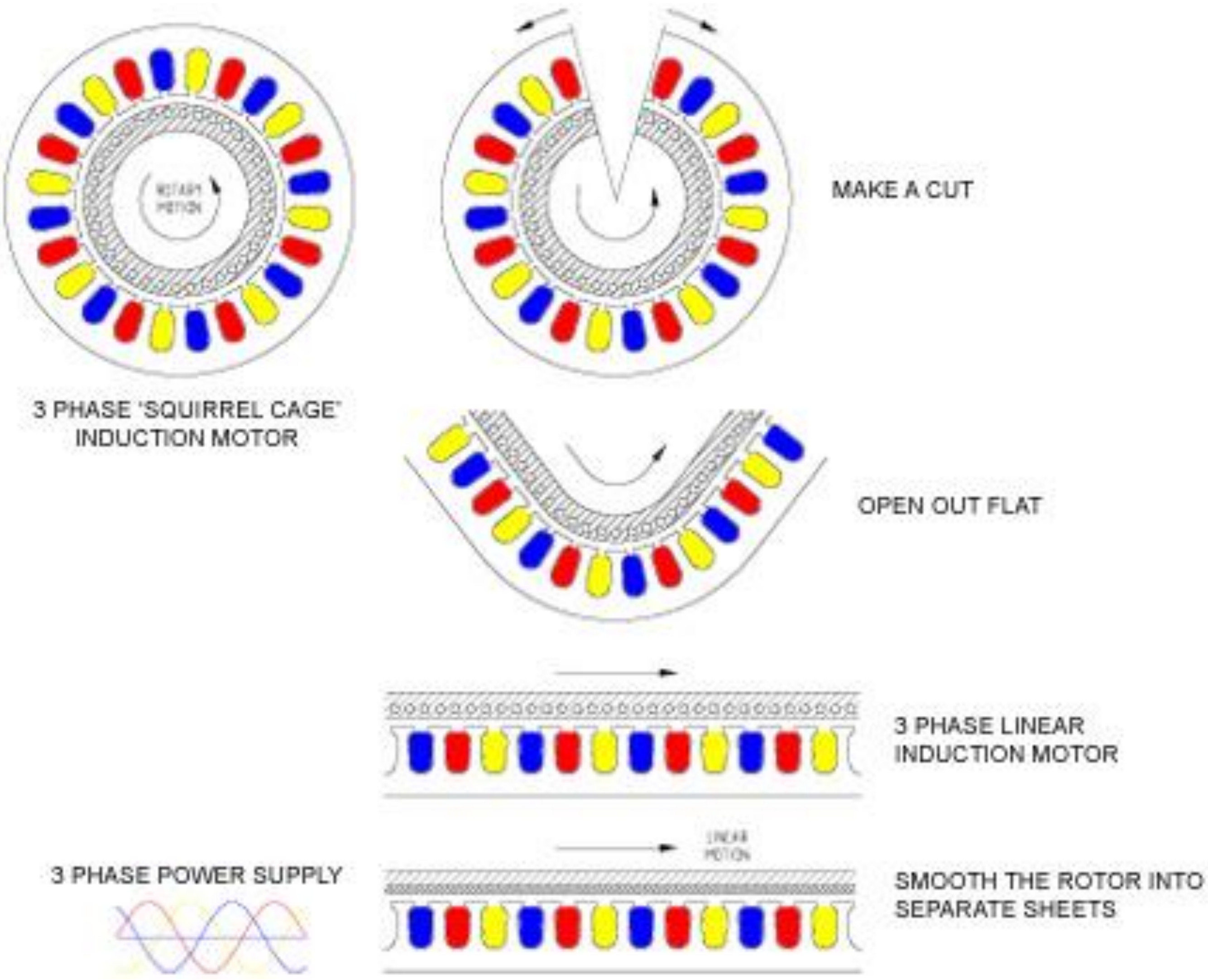
Alternating Current Induction Machines

- Most common AC machine in industry
- Produces magnetic fields in an infinite loop of rotary motion
- Stator wrapped around rotor



[2]

Rotary to Linear



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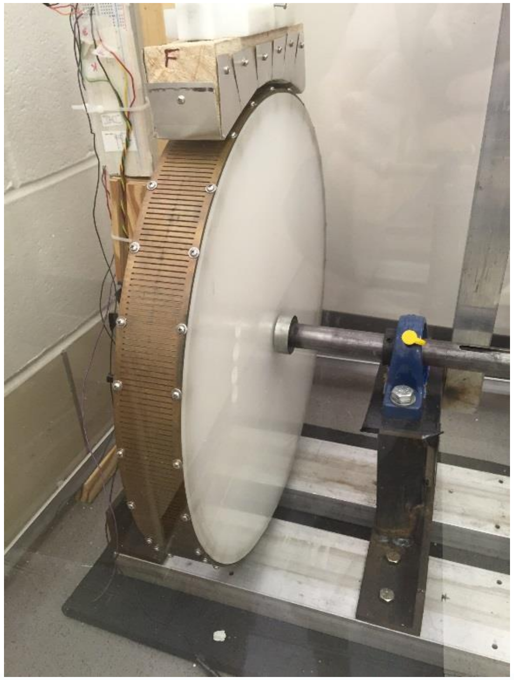
Design Constraints

- 3 Phase Voltage Scheme
- Simulated linear track cannot exceed 1,100 rotations per minute (RPM)



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Patent/ Product/ Literature Review

- Datasheets
  - Atmega 128 Documentation
  - Lenze Tech MH250B Documentation
- Journal
  - Design of a Single Sided Linear Induction Motor(SLIM) Using a User Interactive Computer Program [32]
- Books
  - Linear Induction Motor [33]
- Patents
  - Linear Induction Motor Construction [34]
  - Secondary member for single-sided linear induction motor [35]
  - Linear Induction Motor [36]

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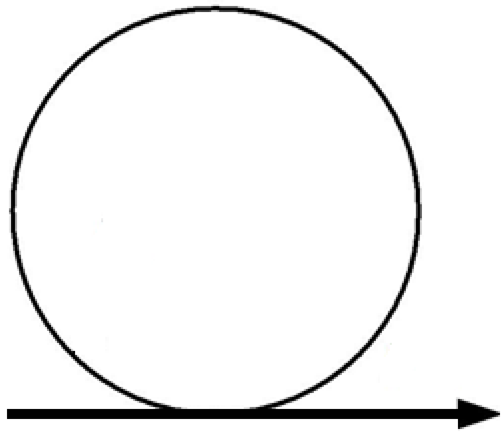
Design Approach

Problem

- Rotate the simulated linear track
- Rotate under safe speeds (<1100 RPM)



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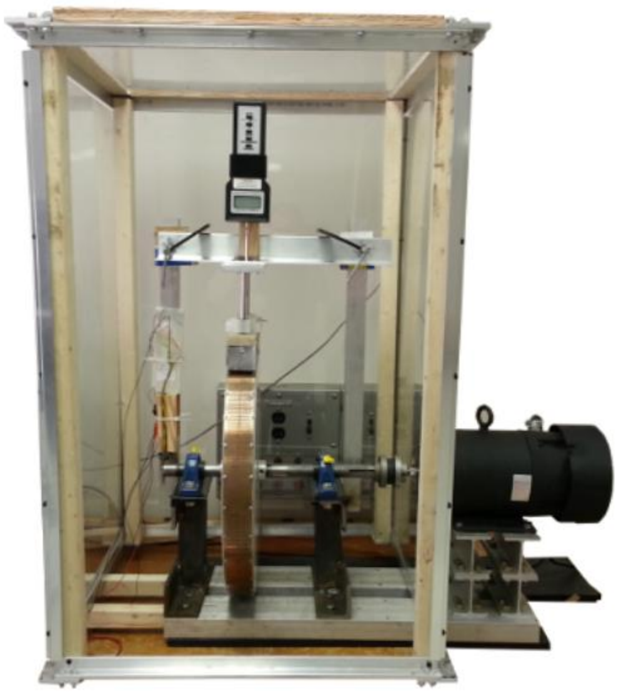

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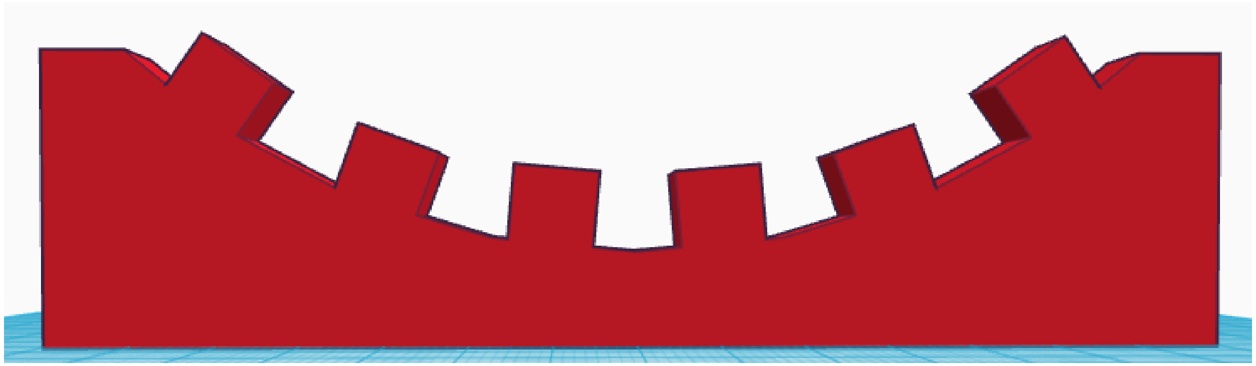
Solution to Problem

- Develop
- Design
- Implement a Linear Induction Motor to produce linear motion



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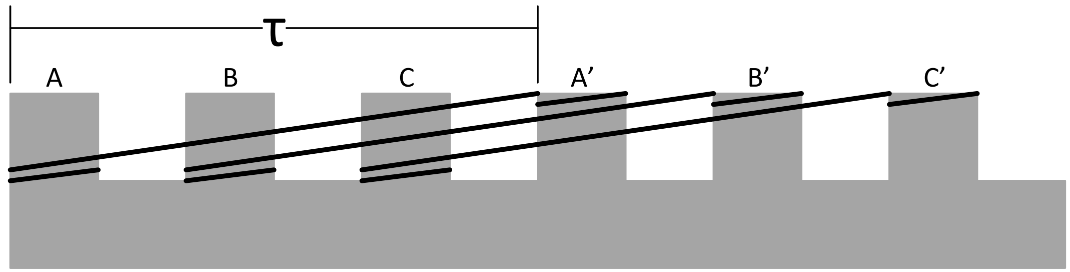
Additional Research

- Pole Pitch
  - Design phase
- Pole Arrangements
  - Salient vs. non-salient
  - Design phase
- Interfacing sensors
  - Implementation phase



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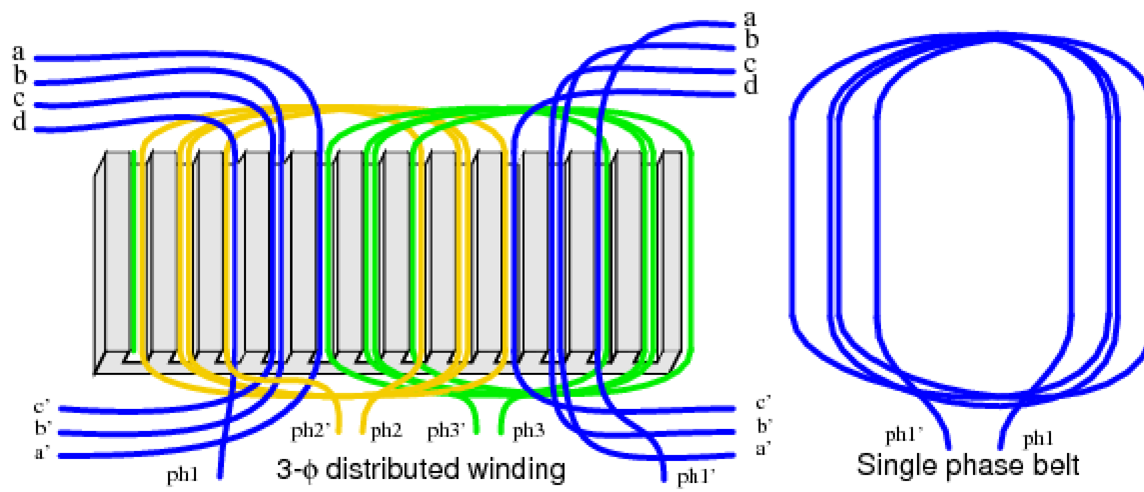

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Key Components

- Stator Lamination Segments
- VFD
  - Lenze-tech MH250B
- Microcontroller
  - Atmega 128

[15]

Key Components Availability

- Stator
  - Design and have manufactured
- VFD
  - Provided by Caterpillar
- Microcontroller
  - Provided by Bradley

[16]

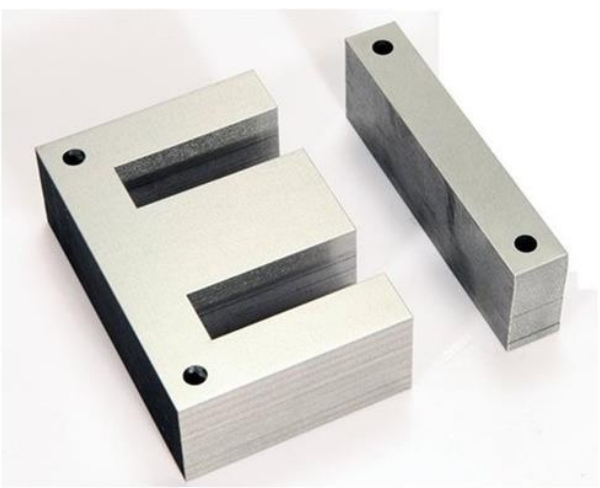
[17]

Alternative Solutions

- Lower velocity output
- Different material
- Change the number of poles
- Vary the dimensions of motor
- Lower frequency range

Alternative Components

- Solid manufactured stator
- Transformer E laminations
- Different Microcontroller



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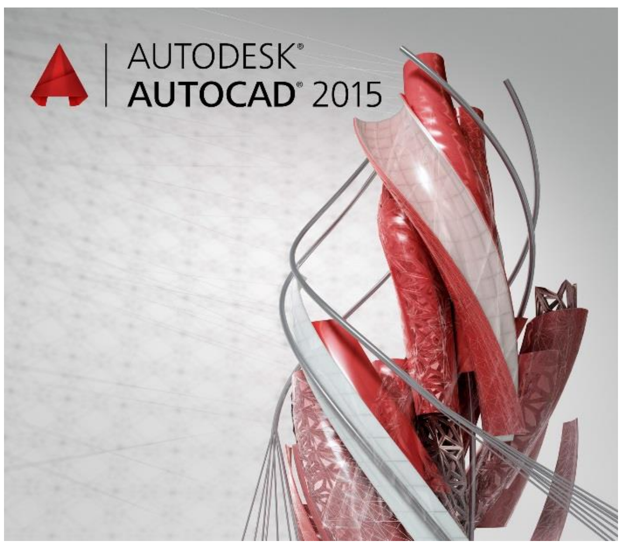
Skill Set Required

- Experience Interfacing components in C++
- MATLAB
- Understand of high level mathematics
- Power electronics
- Manufacturing skills

Multidisciplinary

- Main focus on Electrical Engineering
- Stator design may take some Mechanical Engineering background
  - May require additional help in 3-D modeling



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SOLIDWORKS

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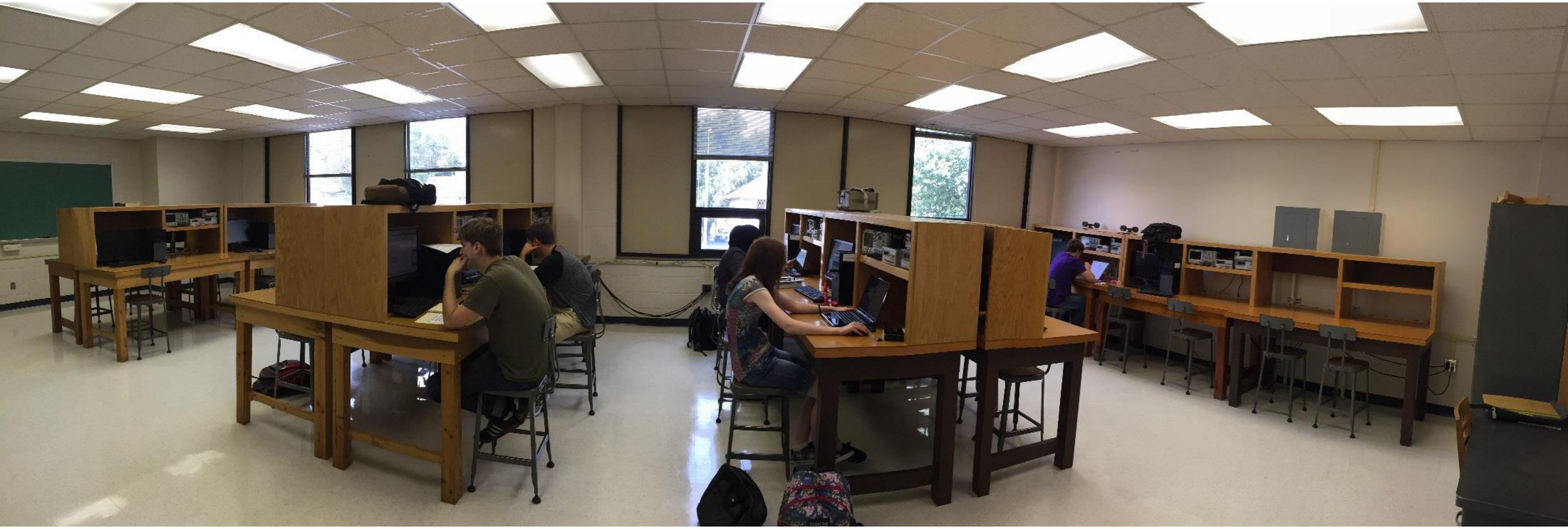
Work Locations

- Bradley University
  - Power Lab
  - Senior Lab



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Experimentation

- Location – Power Lab
- Supervisor – Professor Gutschlag

[23]

Solution Testing

- Current measurements
- Efficiency calculations
- RPM measurements
- Torque measurements
- Comparison to simulated/calculated results

Criteria for Solution Testing

- Rotation of the simulated linear track
- Output max speed within 50% of calculated max speed

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Economic Analysis

Project Feasibility

- Highly feasible
- Work is divided equally
- Staying focused on objective goals

Consumer Market

- Lab Setting Only
- No Market
- Will not be sold

Overview of Total Component cost

Components	School Provided or Purchase	Cost (If Applicable)
Stator	Purchase	$800.00
Variable Frequency Drive	School	$848.00
Sensors	Purchase	$20.00
Tachometer EE-SG3	School	$2.00
Microcontroller/ LCD Screen	School	$80.00
Miscellaneous	Purchase	$100.00
	Total Cost:	$1850.00

Cost Expenditures

Components	Cost
Stator	$800.00
Sensors	$20.00
Miscellaneous	$100.00

Cost Constraints

- Major:
  - Stator
  - VFD
- Minor
  - Coil Windings
  - Tachometer photo-interrupter

Maintenance Cost

- Power consumption usage
- Dedicated Atmega128 Board for usage on only that device
- New coil windings

[24]

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Societal and Environmental Impacts

Affected Individuals

- The project group
  - Tyler Berchtold, Mason Biernat and Tim Zastawny
- Project Advisor
  - Professor Gutschlag
- Course Instructor
  - Doctor Sanchez
- Fellow students in ECE 498

Natural Resource

- Metal
  - Steel Laminates
  - Copper
- Reusing equipment instead of purchasing new equipment
  - VFD
  - Variac
  - Tachometer
  - ATmega128

[6]

Ethical Development

- Does not violate Human Rights
- Not a weapon of mass destruction
- Ethically Made
- Ethical Use

[7]

Ensuring Safety

- Respecting Power Lab rules
  - Always wear safety glasses
  - Work in pairs
  - Turn off power when not using
- Checking power connections to the motors
- Observing Motor for possible issues
- Monitoring sensors
- Construction and implementation is done correctly

Safety Concerns

- Putting unsafe current levels through the stator.
- Heat Levels on Stator
- RPM of Simulated Linear Track
- Unauthorized individual attempting to use
  - Children, Adults, Disabled

[8]

Outcomes of Ignoring Safety

- Stator meltdown
- Stator exploding
- Electrocution
- Fire
- Microcontroller and sensor destruction
- Simulated Linear Track vibrations
- Personal Injury

[9]

Additional Safety Protocol

- Used under proper supervision and settings
- More monitoring equipment
- Integrated heat sensor with sound alert when temperatures are to high
- Shielding around stator to prevent accidently contact
- Adequate airflow to allow for proper cooling

Liability Concerns

- Damage to lab space
- Injury to others

$$$

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Timeline / Division of Labor

High Level - Division of Labor

- Design
  - Microcontroller
    - Tyler
  - Stator
    - Mason and Tim
- Purchasing
  - Entire Group

High Level - Division of Labor

- Construction
  - Sensors
    - Tyler
  - Motor
    - Mason and Tim
- Implementation
  - Tyler, Mason and Tim
- Testing
  - Tyler. Mason and Tim

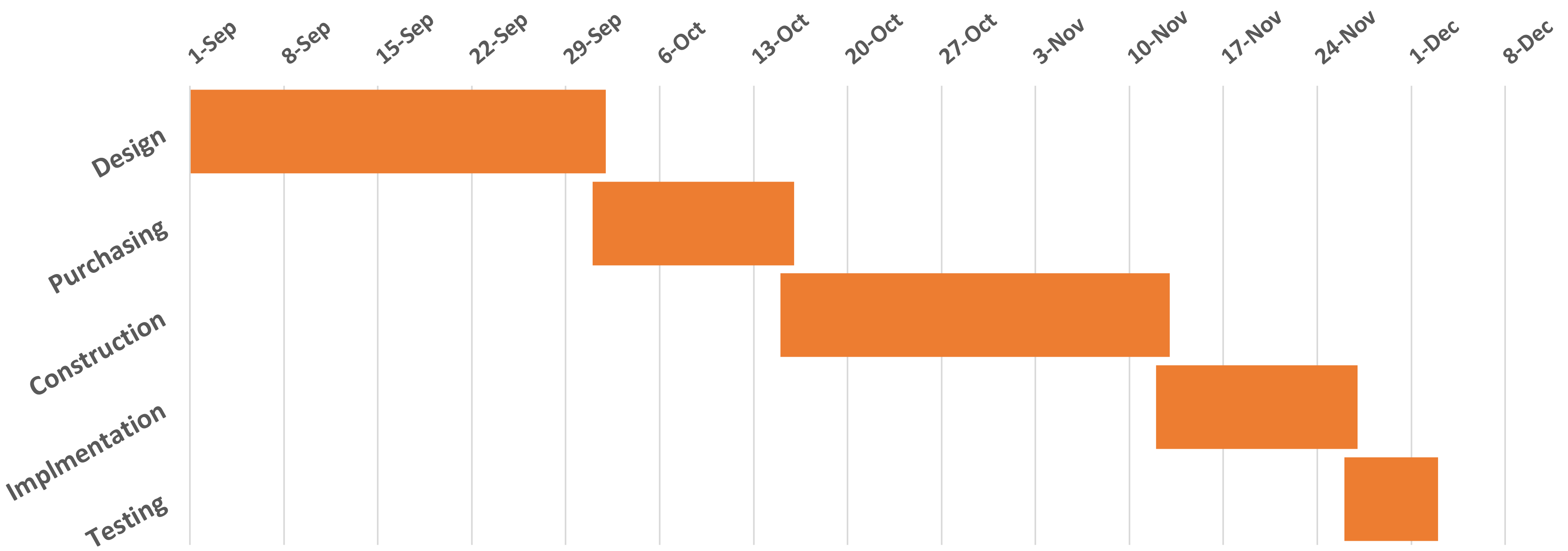
Interfacing Work – Tyler B.

- Interfacing
  - Input from Sensors
    - Tachometer
    - VFD Frequency
    - Voltage
  - LCD Screen
    - Voltage
    - Slip
    - Speed

Stator Work – Mason B. and Tim Z.

- Stator
  - Dimensions
    - Pole Pitch
    - Length
    - Width
    - Height
  - Mounting hardware
  - Coil Windings
    - Gauge
    - # of wraps

Gantt Chart – Main Components



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Conclusion

- Overall Goals:
  - Complete Design and Implementation if a linear machine
    - Prototype a linear stator
    - Develop working subsystems for control
    - Achieve linear motion
  - Gain experience
    - Power systems
    - Design and construction
    - Interfacing
    - Group dynamics
    - Useful engineering skills

Questions?

References #1-5

[1] A. Needham. *A maglev train coming out of the Pudong International Airport.* [Photograph]. Retrieved from https://en.wikipedia.org/wiki/Maglev#/media/File:A_maglev_train_coming_out,_Pudong_International_Airport,_Shanghai.jpg

[2] *Linear Induction Motor.* [Photograph]. Retrieved from http://www.mpoweruk.com/motorsac.htm

[3] Force Engineering. *How Linear Induction Motors Work.* [Photograph]. Retrieved from http://www.force.co.uk/linear-motors/how-linear.php

[4] T. Zastawny. *Simulated Linear Track Shot 1*. [Photograph].

[5] T. Zastawny. *Simulated Linear Track Shot 2*. [Photograph].

References #6-10

[6] Laser Laminations. *Stator Core.* [Photograph]. Retrieved from http://laserlaminations.com/stator-laminations-product-samples.html

[7] Amazon. *Applications Peace No Bombs Patch.* [Photograph]. Retrieved from http://www.amazon.com/No-Bombs-Peace-Signs-Embroidered/dp/B00KGKC0DA

[8] Safety Signs. *Electrical Hazard Sign*. [Photograph]. Retrieved from http://www.safetysign.com/products/p521/danger-electrical-hazard-sign

[9] Clip Art Best. *Explosive Symbol Vector*. [Image]. Retrieved from http://www.clipartbest.com/clipart-xTgo4e88c

[10] T. Zastawny. *Wheel Turning.* [Figure].

References #11-15

[11] *Old Lab Simulated Linear Track Shot.* [Photograph].

[12] T. Zastawny. *3-D Prototype Model of Stator.* [Figure].

[13] T. Zastawny. *Polepitch.* [Figure].

[14] All About Circuits. *Phase Belt*. [Image]. Retrieved from http://www.allaboutcircuits.com/textbook/alternating-current/chpt-13/tesla-polyphase-induction-motors/

[15] Newegg. *ATmega128 ATMEL AVR Development Board ATmega128A-AU Core*. [Image]. Retrieved from http://www.newegg.com/Product/Product.aspx?Item=9SIA5FB2053831&cm_re=ATmega128_ATMEL_AVR_Development_Board_ATmega128A-AU_Core-_-9SIA5FB2053831-_-Product

References #16-19

[16] Polaris Laser Laminations. *Segment Laminations.* [Photograph]. Retrieved from http://www.polarislaserlaminations.com/images/slide-45.jpg

[17] Electric Wholesale Motor. Lenze Tech MCH250B. [Photograph]. Retrieved from http://www.electricmotorwholesale.com/LENZE-ESV152N02YXC.html

[18]

[19] *Solid Stator.* [Photograph]. Retrieved from http://4.bp.blogspot.com/-XWGCOFz7xB8/UCOGQdLxeFI/AAAAAAAABXk/haRdh1NHZ2I/s1600/solid_slot_stator.jpg

References #20-25

[20] Modena. *AutoCAD Logo.* [Photograph]. Retrieved from http://www.modena.co.za/wp-content/uploads/2014/10/autocad-2015-badge-2048px.jpg

[21] Solidworks. *Logo*. [Photograph.] Retrieved from http://www.solidworks.com/

[22] T. Zastawny. *Senior Lab*. [Photograph].

[23] T. Zastawny. *Power Lab*. [Photograph].

[24] My Door Sign. *Maintenance in Progress*. [Photograph]. Retrieved from http://www.mydoorsign.com/maintenance-in-progress-caution-sign/sku-s-5712

[25] T. Zastawny. *Main Component Gantt Chart.* [Figure].

References #26-31

[26] T. Zastawny. *Detailed Gantt Chart*. [Figure].

[27] M. Beirnat. *Ideal Linear Synchronous Speed Vs. Frequency*. [Figure].

[28] T. Zastawny. *System Block Diagram*. [Figure].

[29] T. Zastawny. *System Block Diagram with highlighted portion*. [Figure].

[30] T. Zastawny. *Close up of VFD Block Diagram*. [Figure].

[31] T. Zastawny. *Flowchart of Internal Interrupt*. [Figure].

References #32-36

[32] S. P. Bhamidi. “Design of a Single Sided Linear Induction Motor (SLIM) Using a User Interactive Computer Program.” Internet: https://mospace.umsystem.edu/xmlui/bitstream/handle/10355/4308/research.pdf?sequence=3 , 2005. [Sept. 24, 2015]

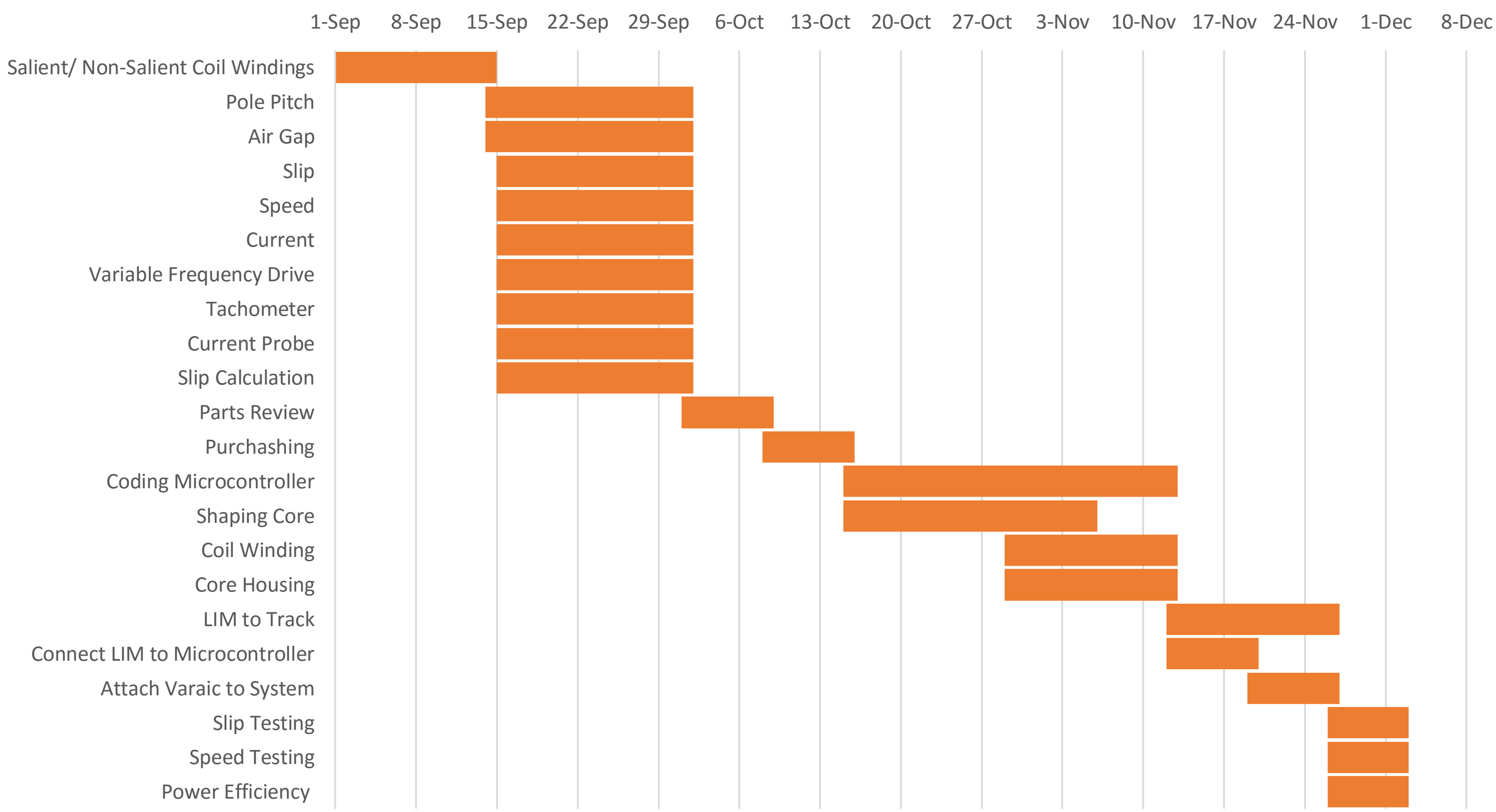
[33] C. I. Hubert, “Linear Induction Motor,” in *Electrical Machines Theory, Operation, Applications, Adjustment, and Control*. New York, Merril, 1991, ch. 7, sec. 8, pp. 263-265.

[34] G. A. Francis. “Linear induction motor construction.” U.S. Patent 3155851 A, Nov. 3, 1964.

[35] T. Fellows, E. Laithwaite. “Secondary member for single-sided linear induction motor.” U.S. Patent 3824414 A, Mar. 13, 1973.

[36] N. B. John. “Linear induction motor.” U.S. Patent 3628072 A, Jun. 17, 1970.

Detailed Gantt Chart



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Detailed Budget – Buying

Component	Cost
Stator Laminates	$800.00
Copper Wire	$10.00
Metal Bracing	$50.00
Fasteners	$10.00
Speed Sensor	$5.00
Tachometer	$2.00
Miscellaneous Small Components	$100.00
Total Cost:	$967.00

Equipment Already Have

Component
Simulated Linear Track
Variable Frequency Drive (Lenze AC Tech MH250B)
Variac
High Voltage Current Meter
Microcontroller (Atmega128)
Tachometer (EE-SG3)

Formal Test procedures

- Measuring input and output current
- Measuring torque
- Measuring speed
- Calculating efficiencies

Preliminary Test Results

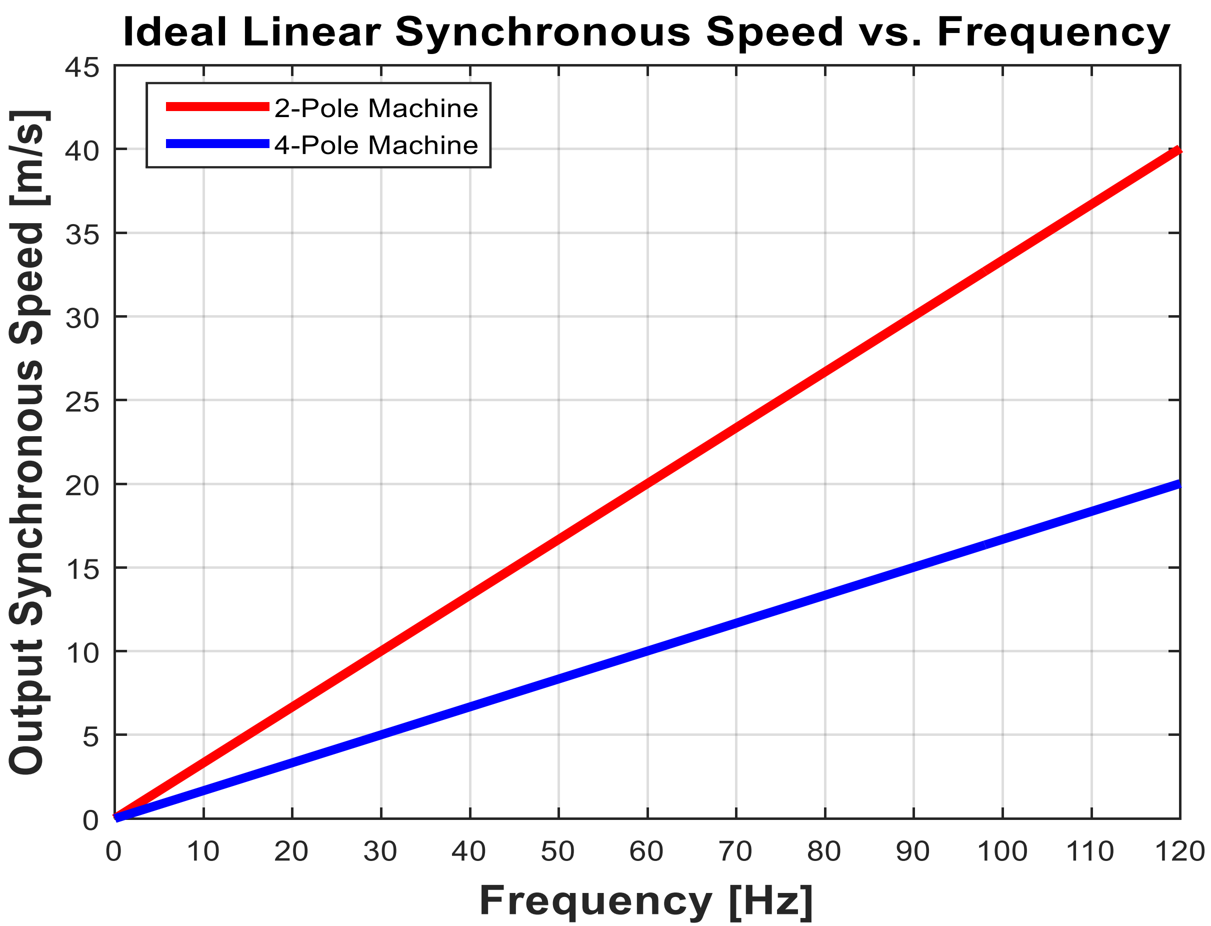

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Diagram of Entire System

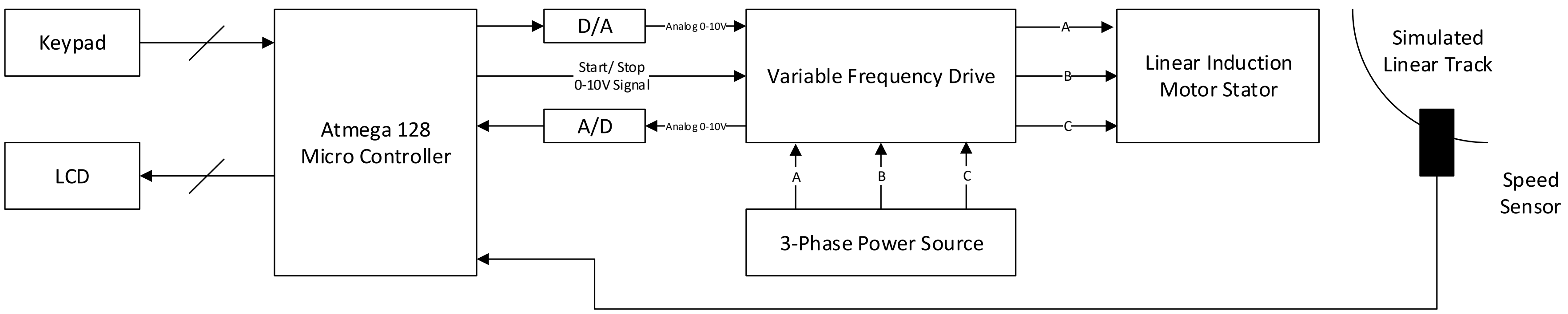

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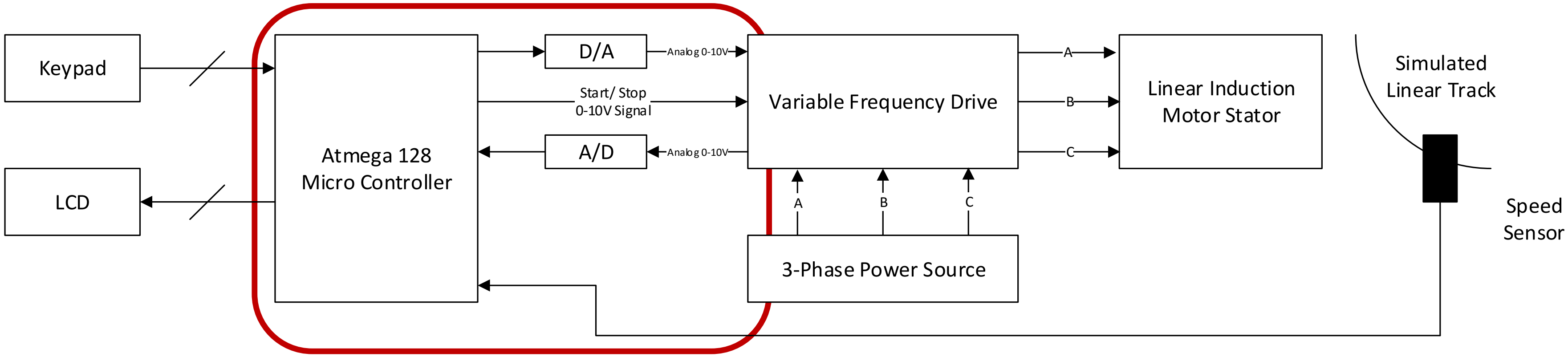
Diagram of Entire System



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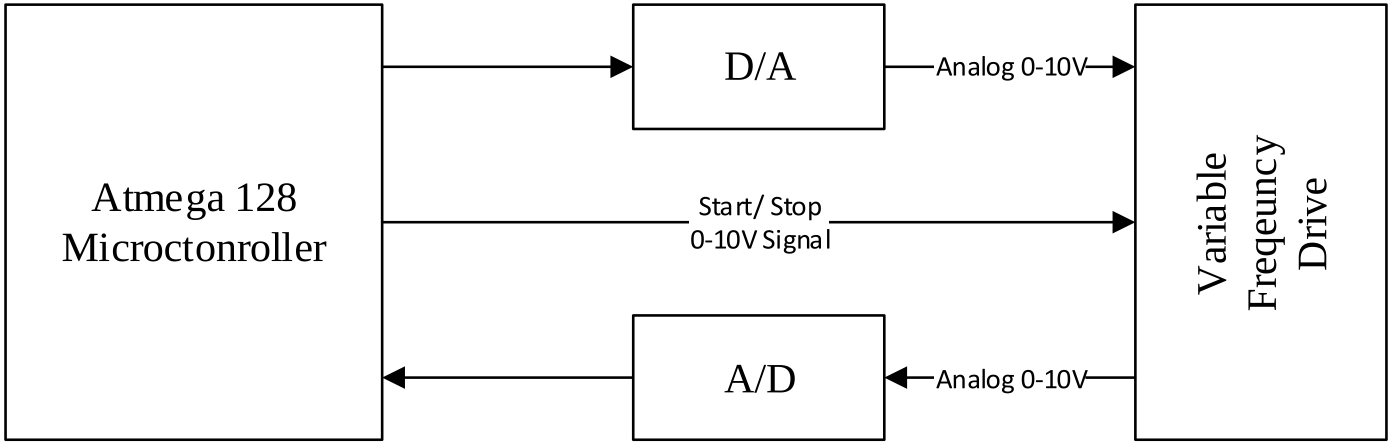
Close up of VFD System



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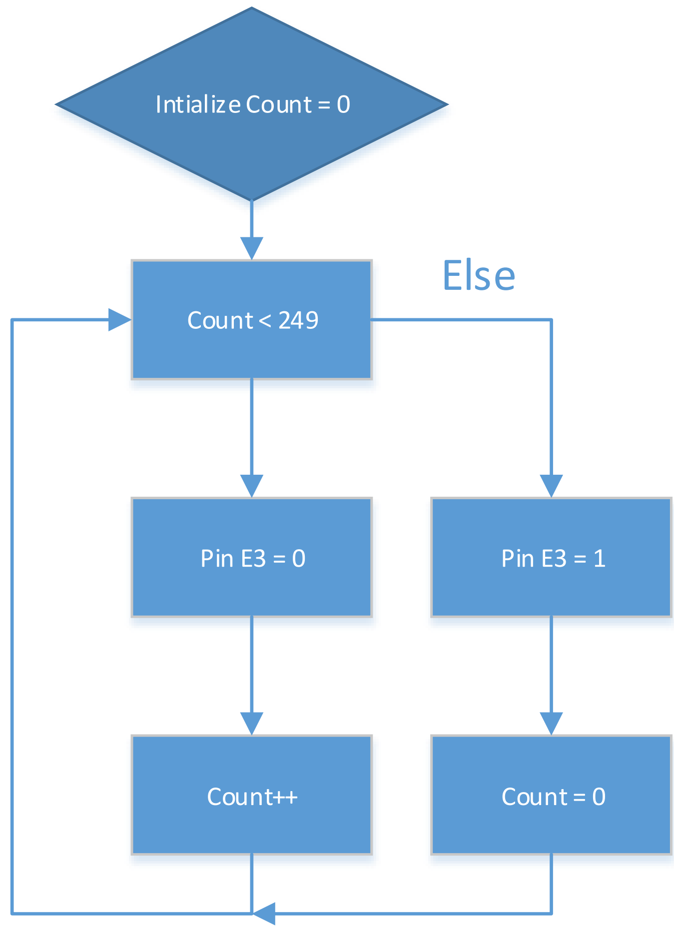
Flowchart of Internal Interrupt



[31]