AERO ENGINE CONTROLS FLUID DELIVERY SYSTEM

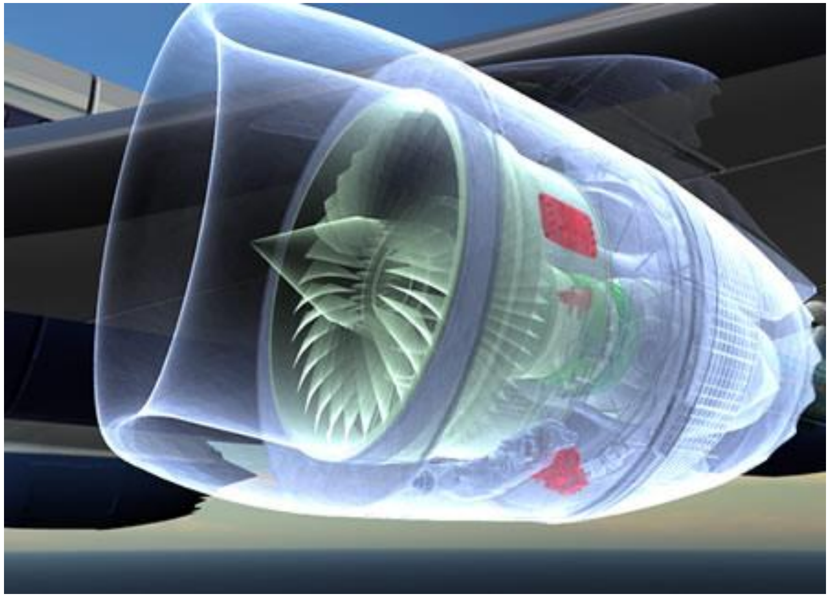
Torque Motor Subsystem

Team #21
Ross Boe
David Bostwick
Zhimin Zou

ECE 445: Senior Design Presentation
TA: Alex Suchko
April 30th, 2012

INTRODUCTION

- Motivation: IUPUI project initiative
- Objective: small scale model of a positional control system for a torque motor
    - For use in a Fluid Delivery System



http://www.aeroenginecontrols.com/Images/Page/im_AEC_NA_resized.jpg

Aero Engine Controls

http://www.aeroenginecontrols.com

FEATURES

- Reliability
- Accurate estimate of supplied fluid
- Improved control over fluid delivery
- Improved communication with higher level controller
- Dynamic positioning response
- Input dependent torque response
- PIC controller for position and torque modulation
- Extended operating voltage
- Can interface with variable types of motor drives
- Rail voltage drop performance warnings

PERFORMANCE SPECIFICATIONS

- Motor and drive circuitry handle sustained maximum power
- Angular Resolution: ±2° of input angle
- Maximum Positioning Time: 700ms
- Voltage Regulation: rail voltage is 28V ± 2V
- Current Regulation: ripple amplitude less than 0.2 A peak-to-peak

Aero Engine Controls
http://www.aeroenginecontrols.com

SYSTEM OVERVIEW

- Power Supply
- PC “EEC Interface”
- Torque Module PIC
- Drive Circuit
- Torque Motor Model
- Position feedback

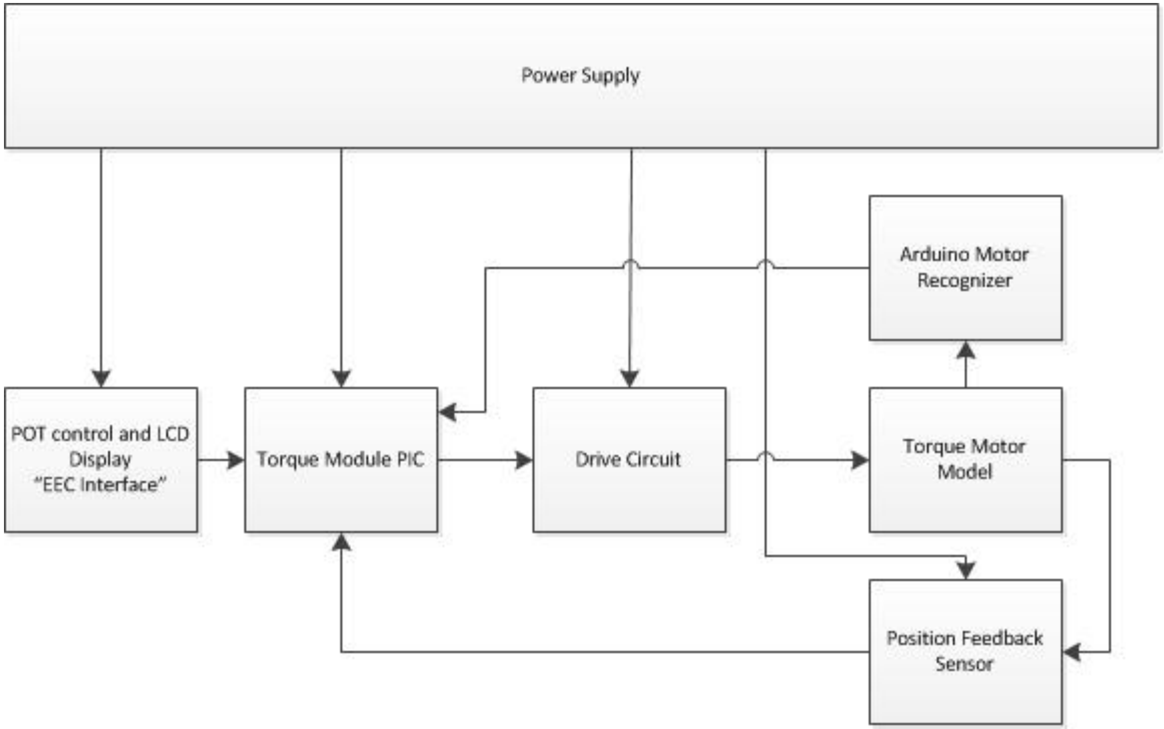


Figure 1. Torque Motor Subsystem Block Diagram

Aero Engine Controls

http://www.aeroenginecontrols.com

MODULAR DESIGN

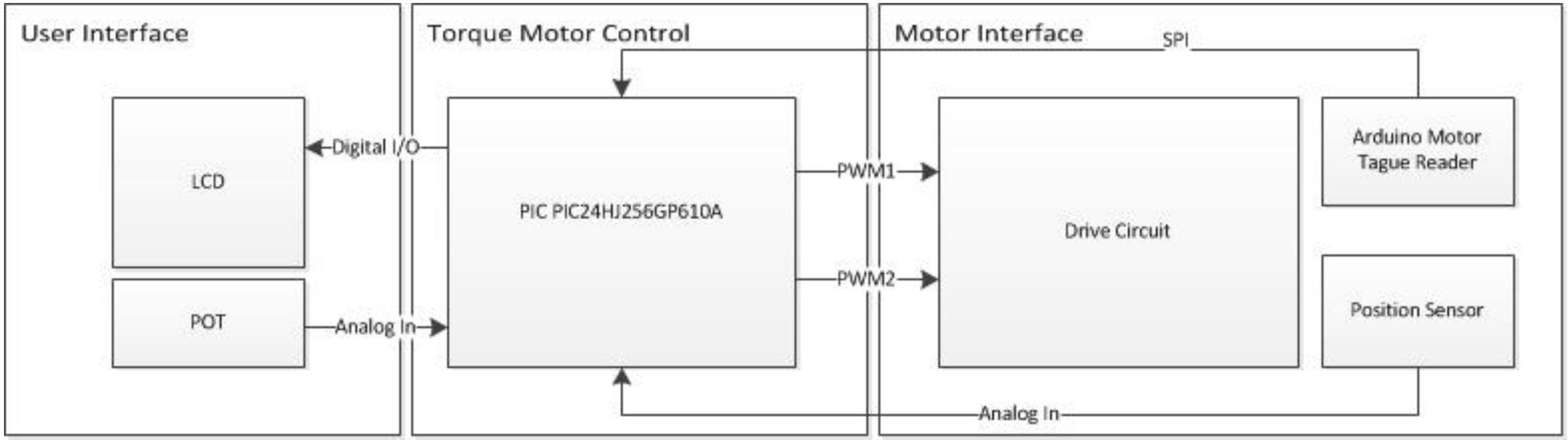


Figure 2. Torque Motor System Operation

Aero Engine Controls

http://www.aeroenginecontrols.com

MODULAR DESIGN

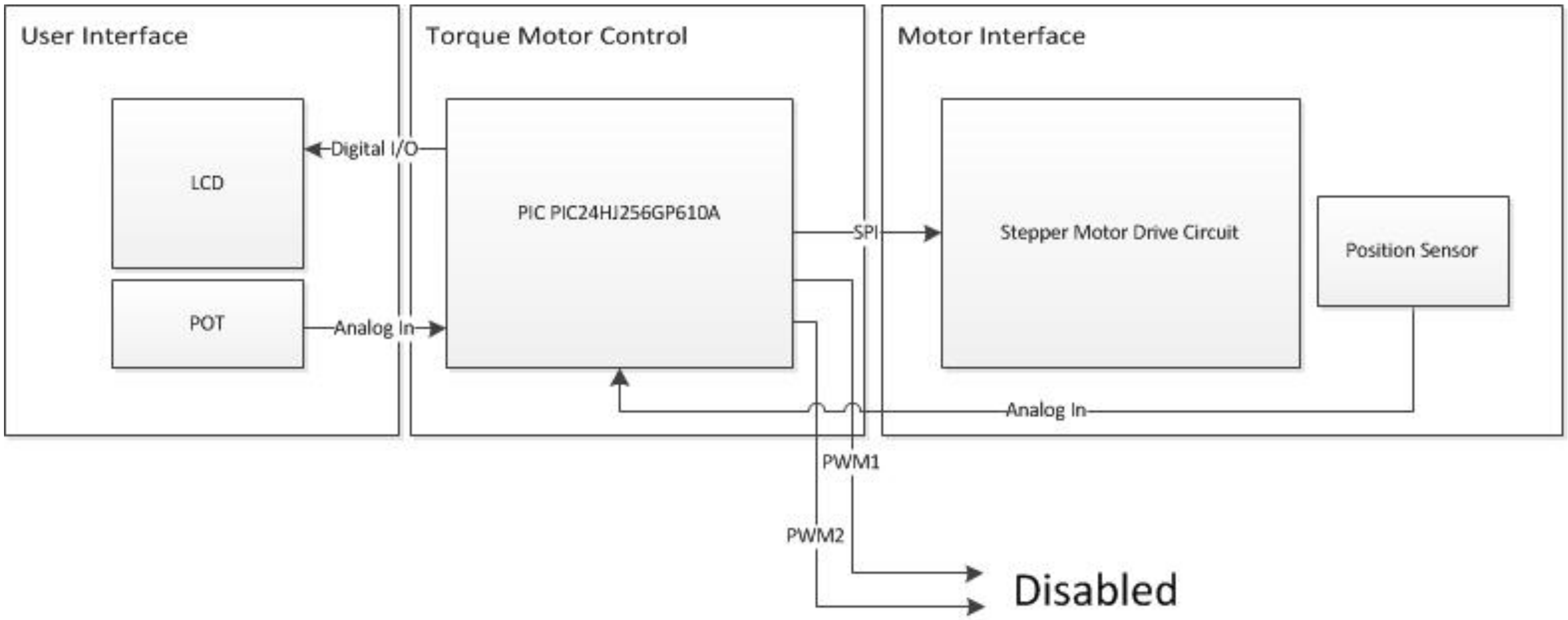


Figure 3. Stepper Motor System Operation

Aero Engine Controls

http://www.aeroenginecontrols.com

SERIAL PERIPHERAL INTERFACE (SPI)

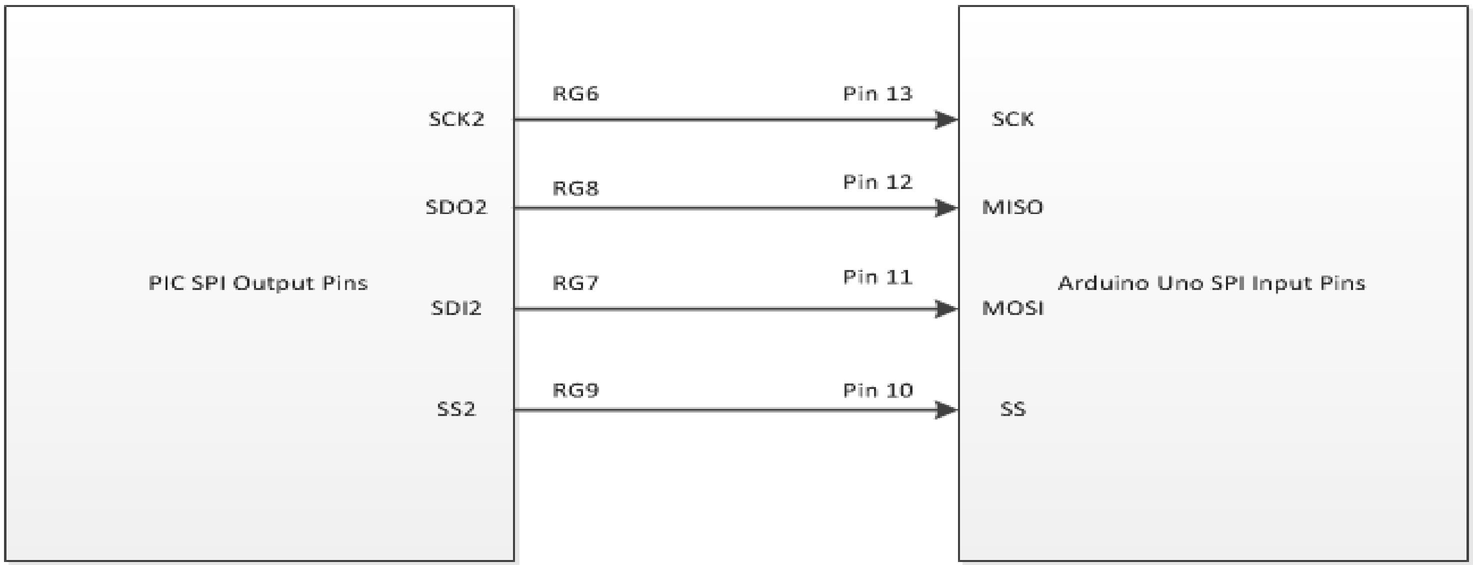


Figure 4. SPI: PIC to Arduino Master-Slave Communication

Aero Engine Controls

http://www.aeroenginecontrols.com

SERIAL PERIPHERAL INTERFACE (SPI)

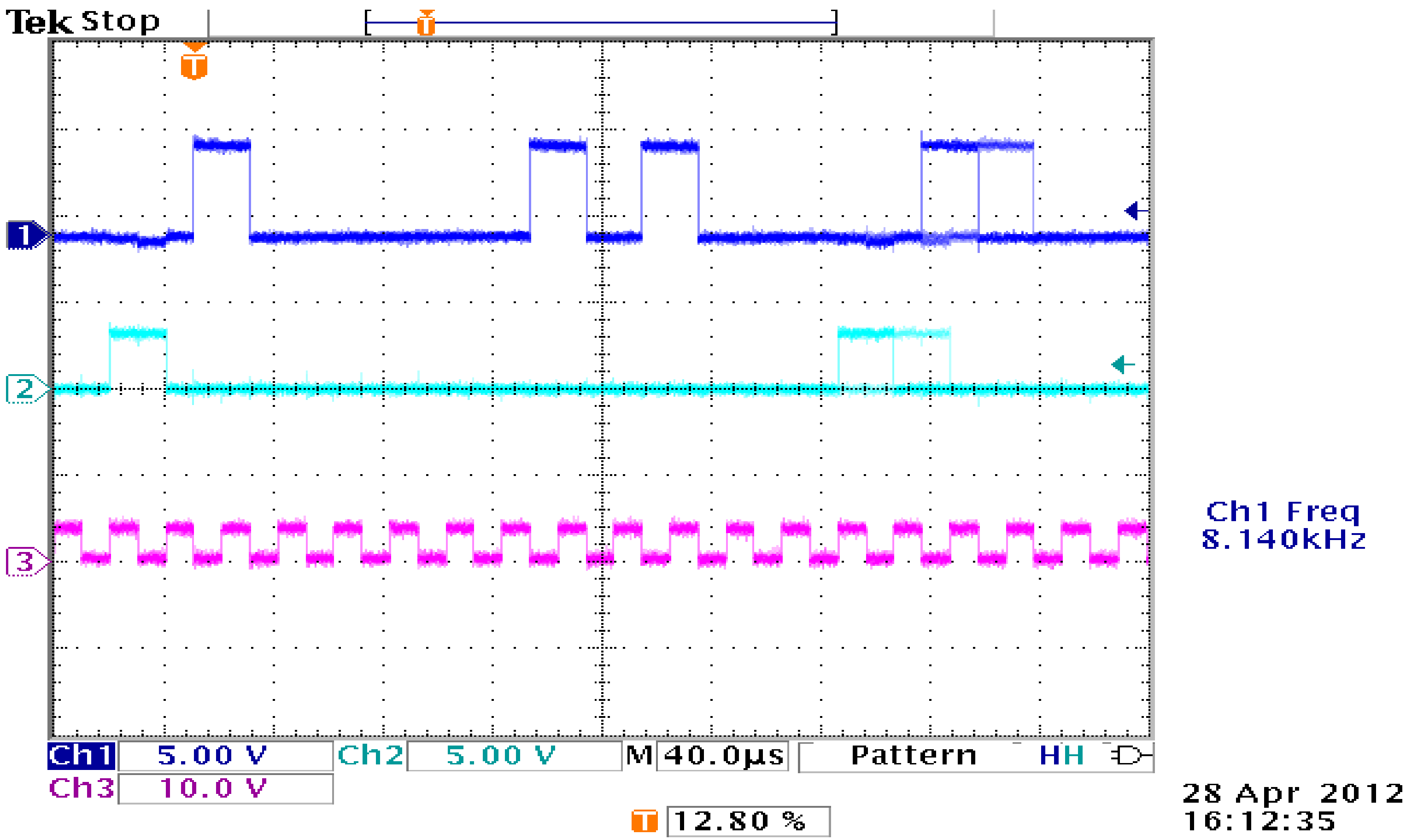


Figure 5. Arduino SPI master-in slave-out response

Aero Engine Controls

http://www.aeroenginecontrols.com

POWER SUPPLY

- Main Input: 28 V supply rail
- Buck Converters
  - 3.3 V out to power PIC
  - 5 V out powers drive circuit

Figure 6. Power Supply Buck Converter

PC "EEC INTERFACE"

- User Interface
- LCD Screen
- Potentiometer

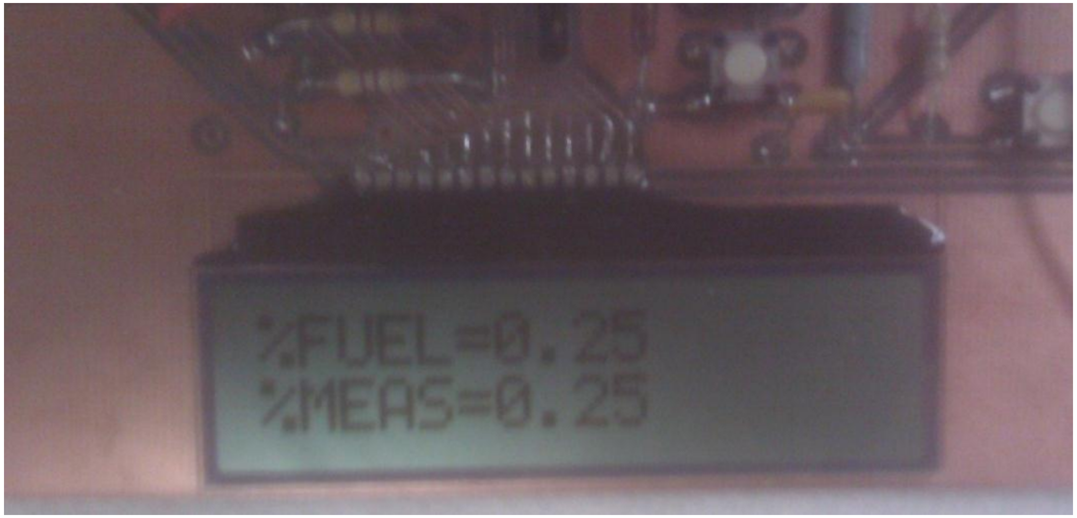


Figure 7. LCD user interface for control system

TORQUE MODULE PIC

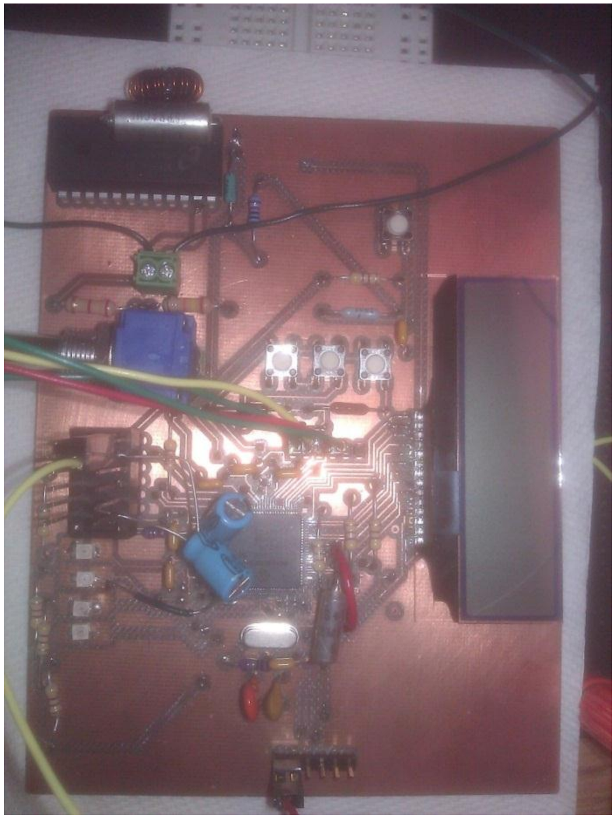


Figure 8. PIC board for the torque motor system

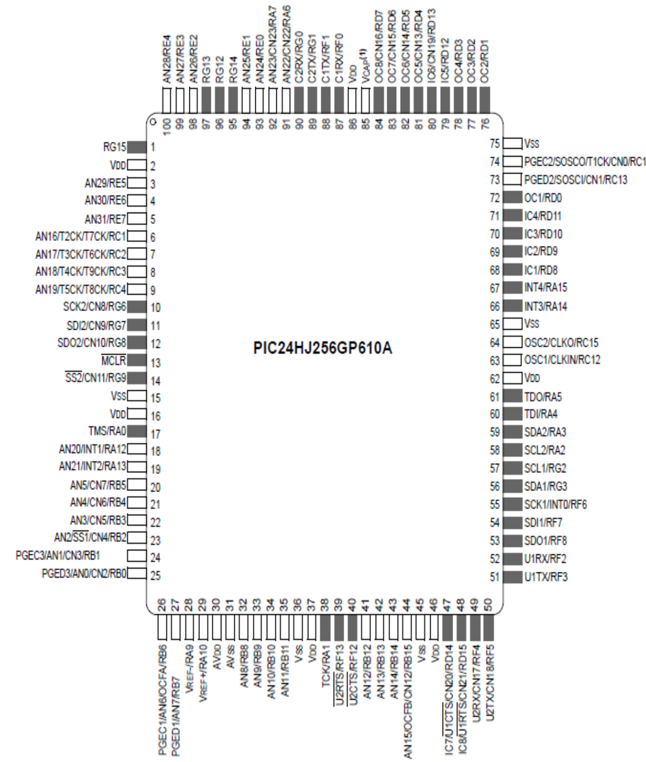


Figure 9. PIC pin out schematic

Aero Engine Controls

http://www.aeroenginecontrols.com

DRIVE CIRCUIT

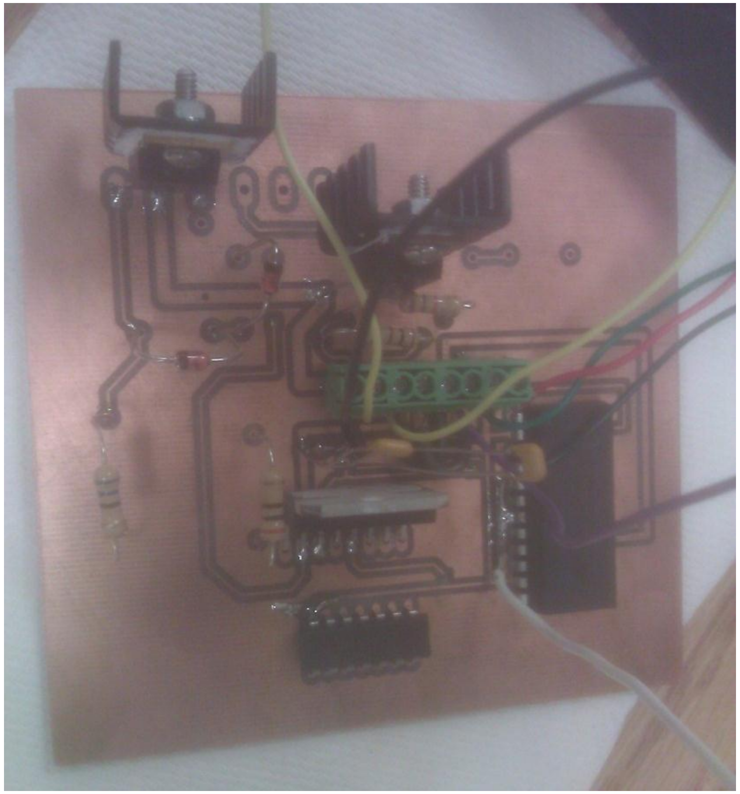


Figure 10. Drive circuit of the torque motor system

DRIVE CIRCUIT

- PMOS FET
- Zener Diodes
- DC motor modeling: inductor and resistor

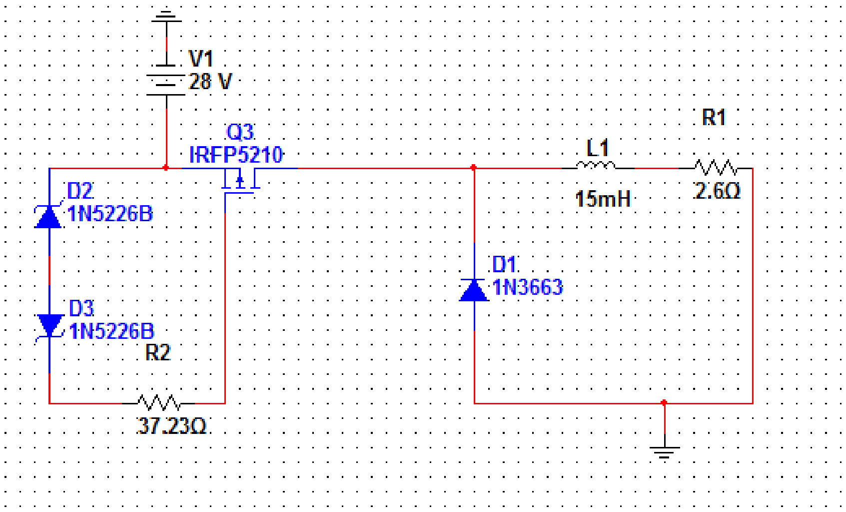


Figure 11. Drive circuit SPICE model

DRIVE CIRCUIT

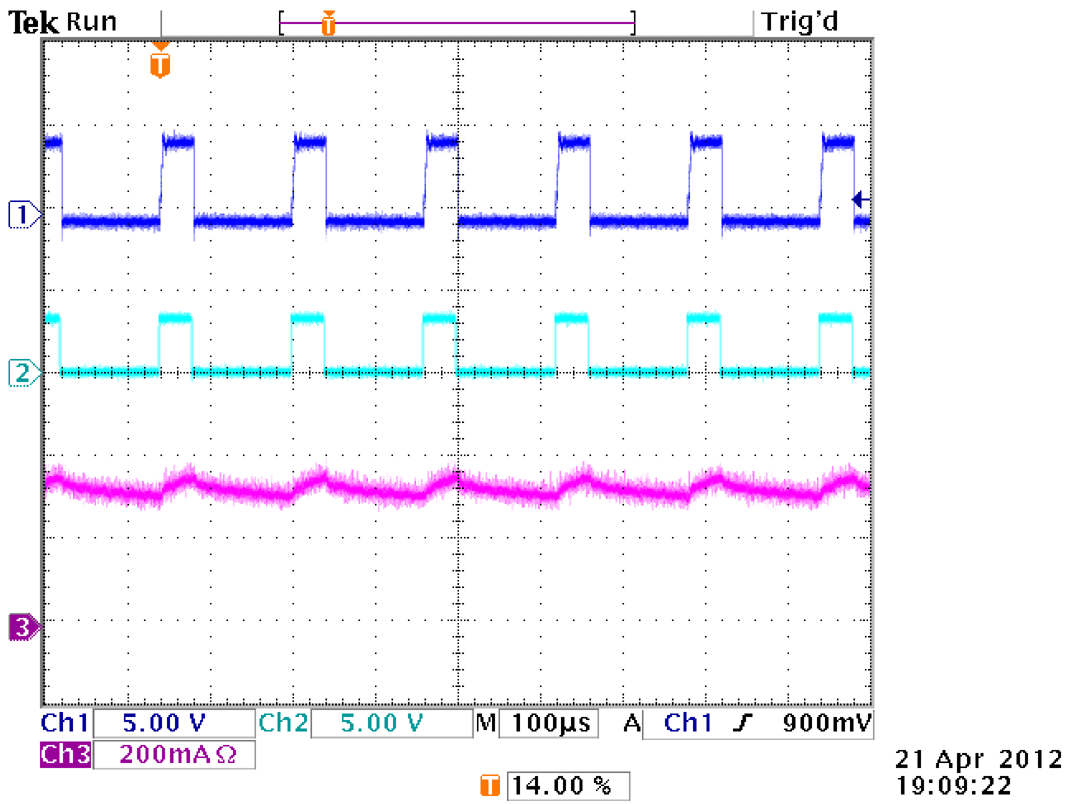


Figure 12. Drive response for input PWM with 25% duty cycle

Aero Engine Controls

http://www.aeroenginecontrols.com

DRIVE CIRCUIT

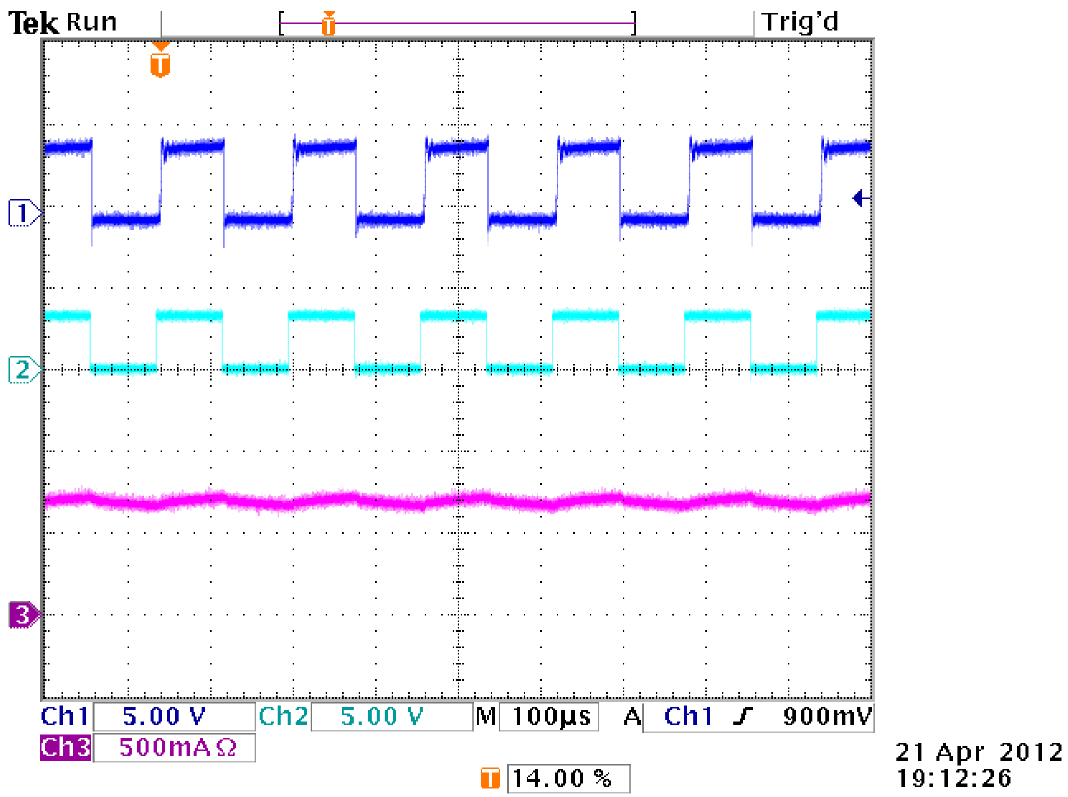


Figure 13. Drive response for input PWM with 50% duty cycle

Aero Engine Controls

http://www.aeroenginecontrols.com

DRIVE CIRCUIT

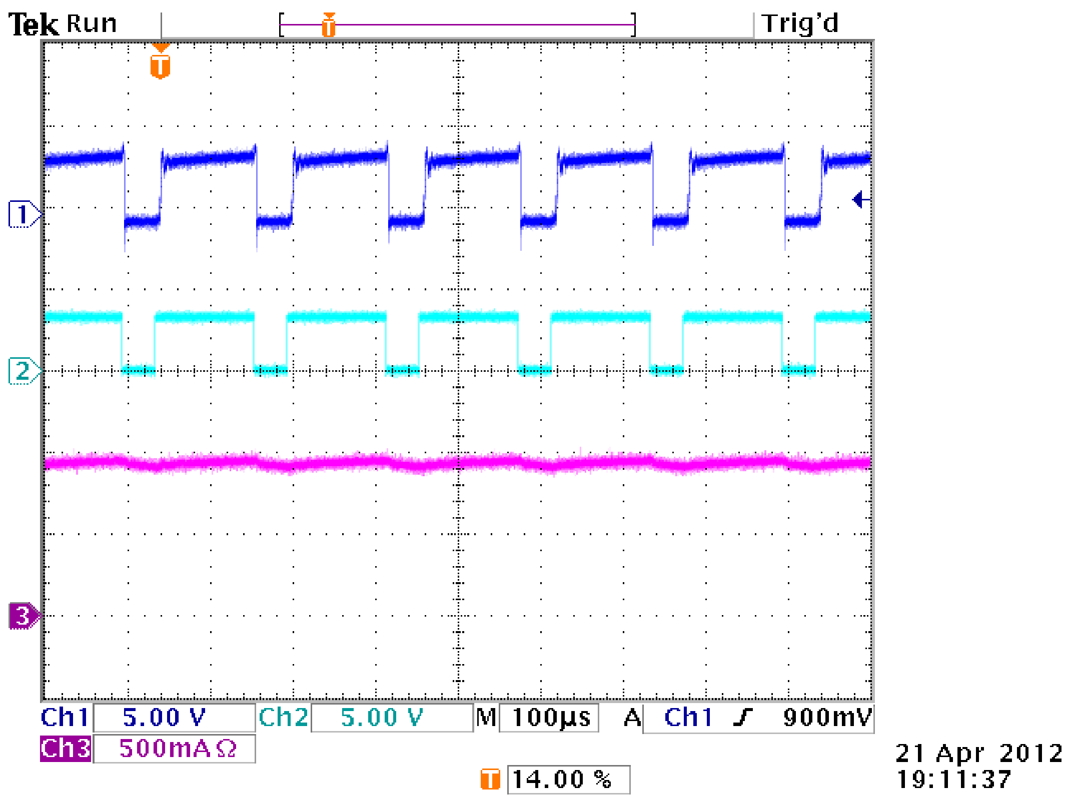


Figure 14. Drive response for input PWM with 75% duty cycle

Aero Engine Controls

http://www.aeroenginecontrols.com

TORQUE MOTOR MODEL

- Lever arm mounted on the motor shaft
- Spring models fluid pressure on a valve
- Protractor measures angular displacement of motor shaft

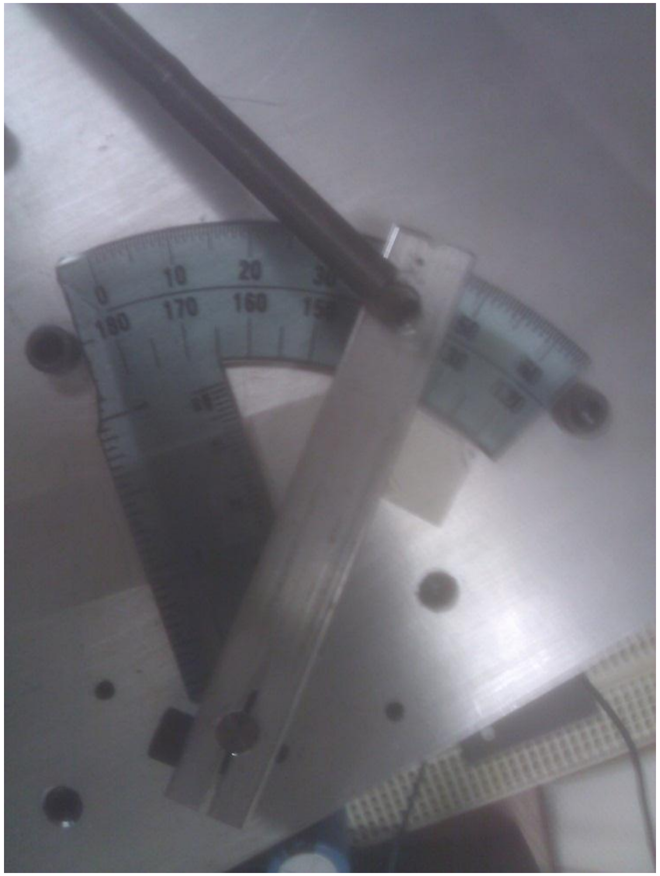


Figure 15. Torque motor module FDS dry model

MICROCONTROLLER FLOW DIAGRAM

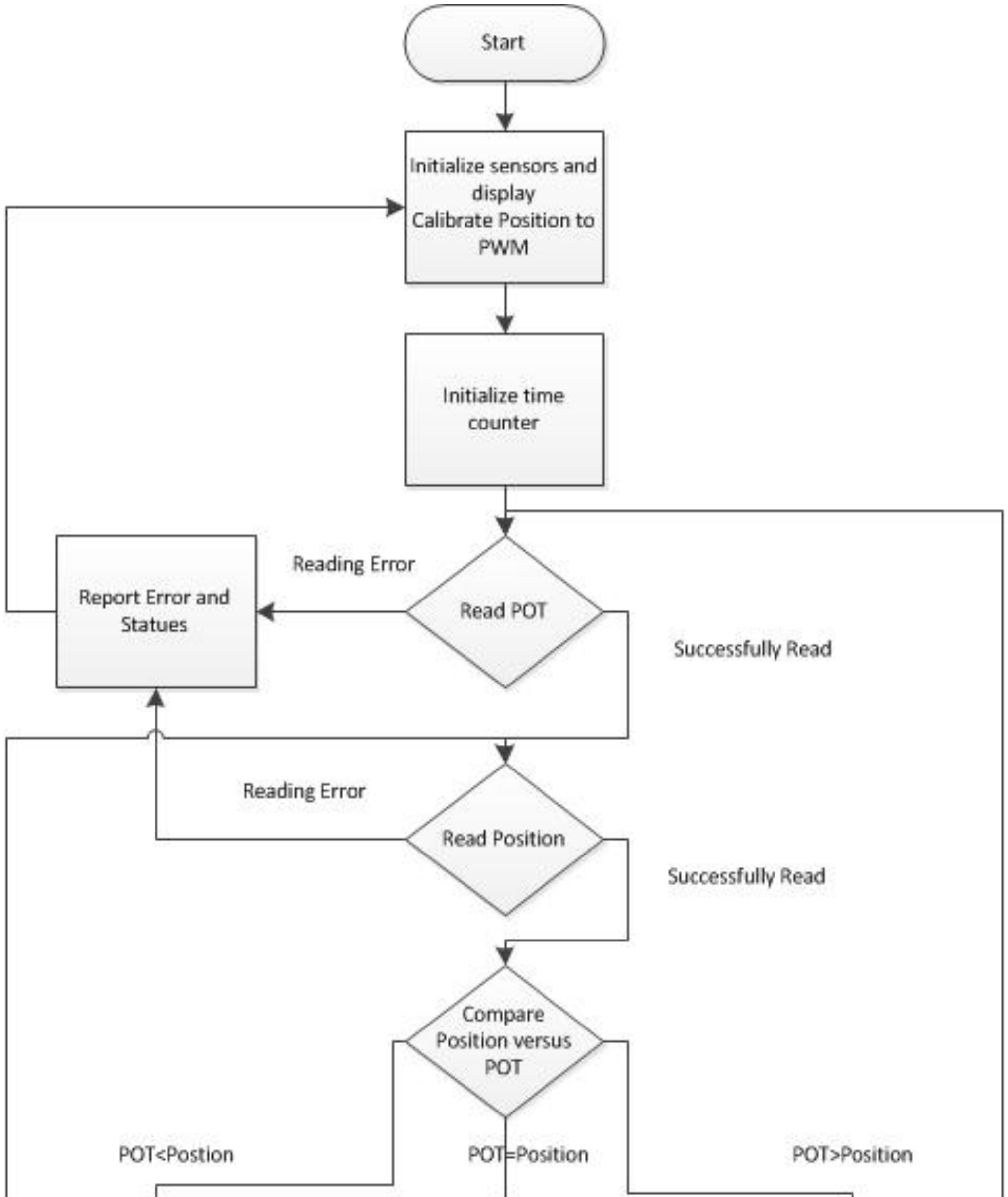


Figure 16.1. Program Flow Chart

MICROCONTROLLER FLOW DIAGRAM

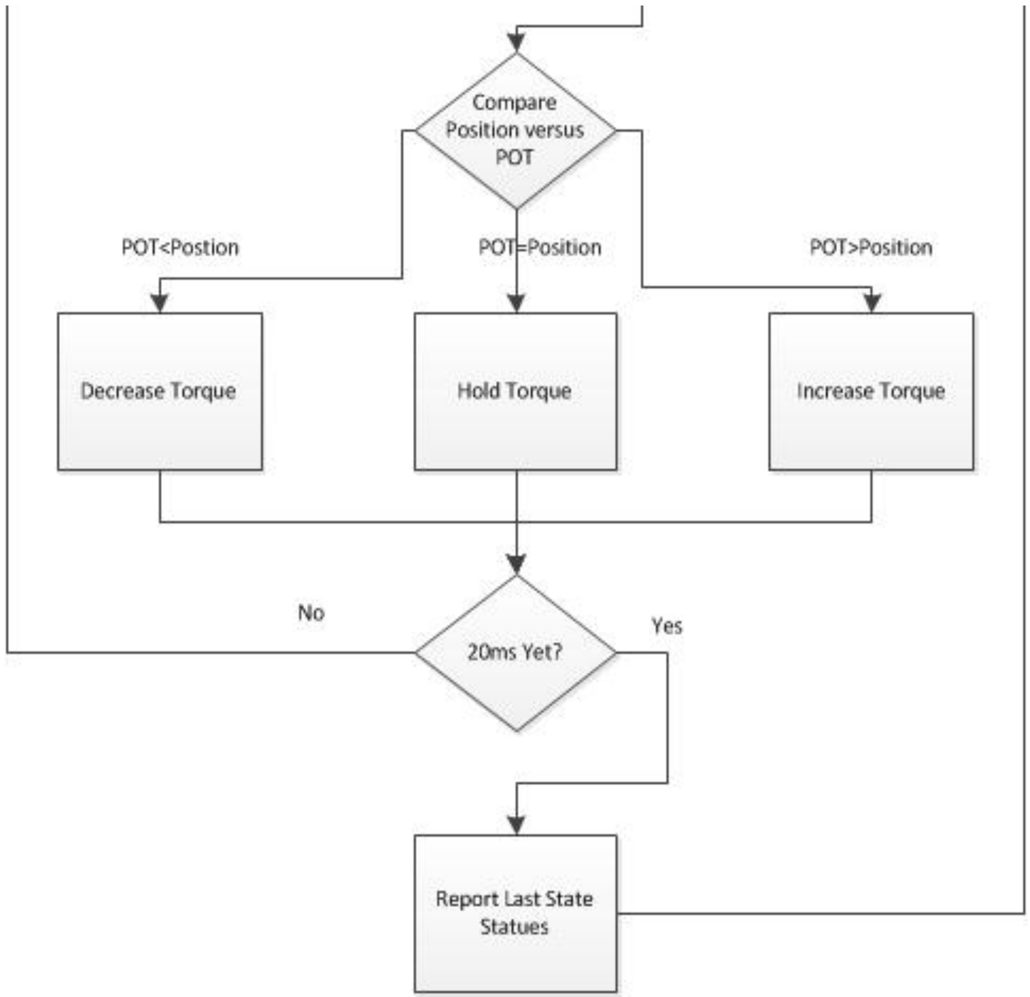


Figure 16.2. Program Flow Chart Continued

INITIALIZING LOOK-UP TABLE

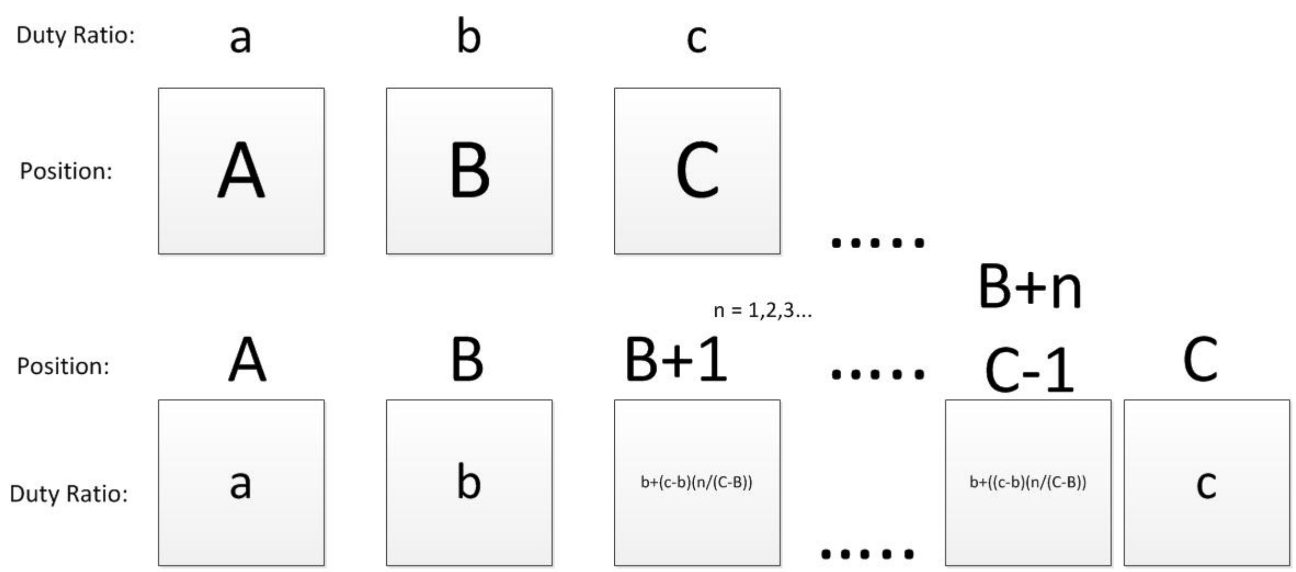


Figure 17. Averaging algorithm for positioning array

Aero Engine Controls

http://www.aeroenginecontrols.com

POSITION FEEDBACK

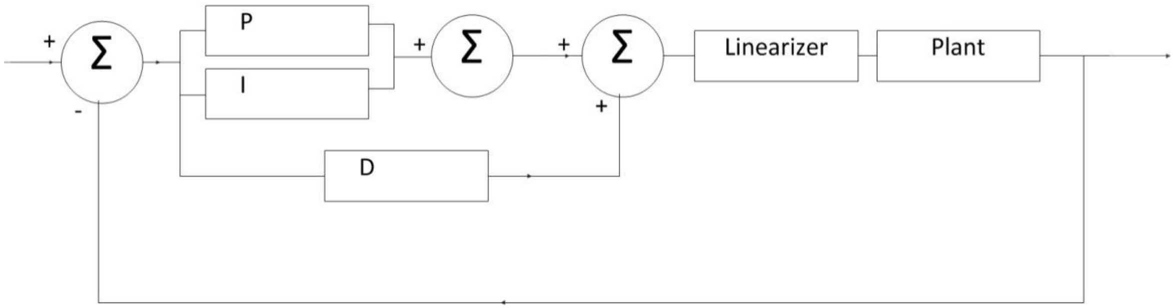


Figure 18. PI-D positioning control loop

POSITION FEEDBACK

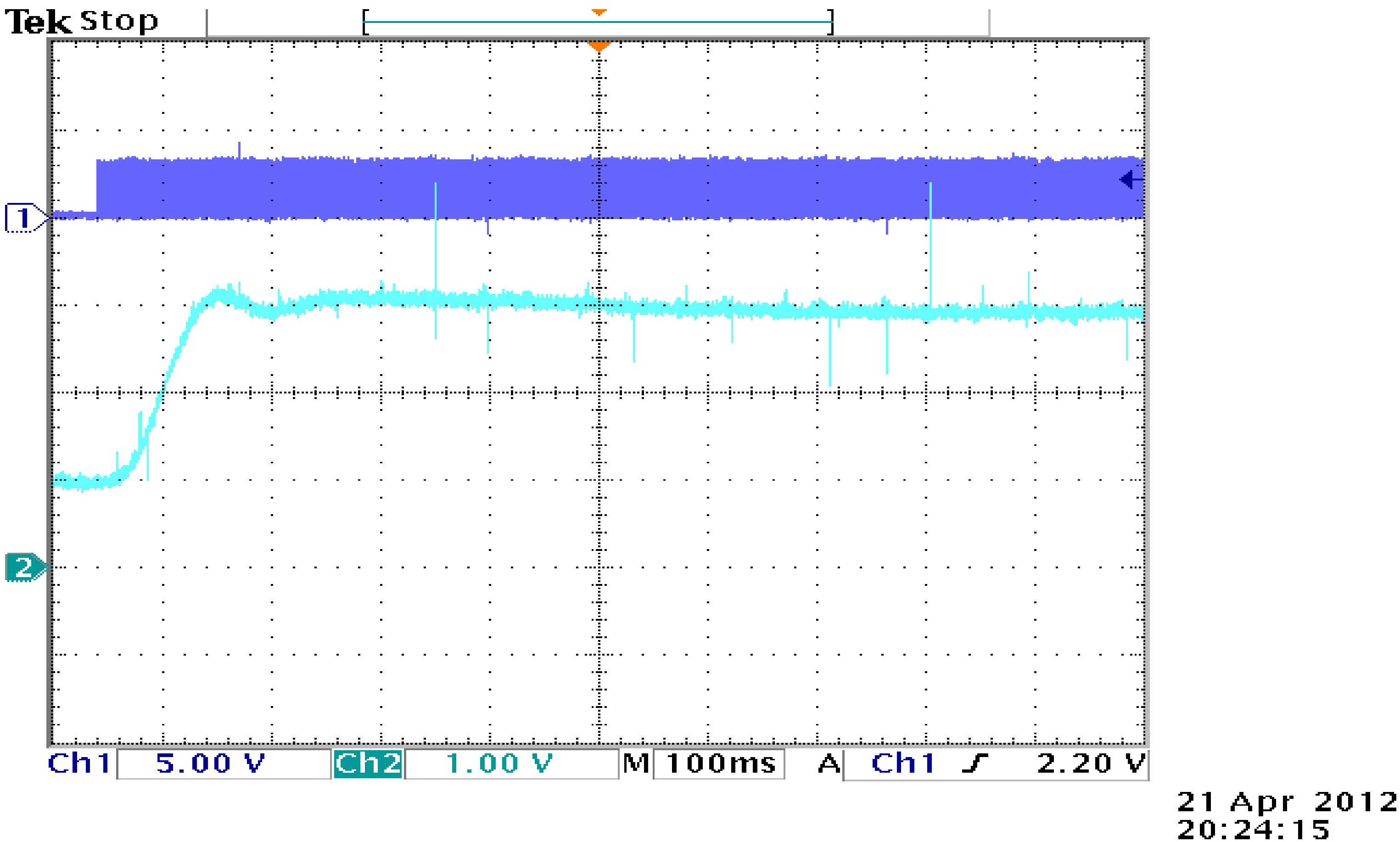


Figure 19. Motor Position Response to 50^0 input

Aero Engine Controls

http://www.aeroenginecontrols.com

POSITION FEEDBACK

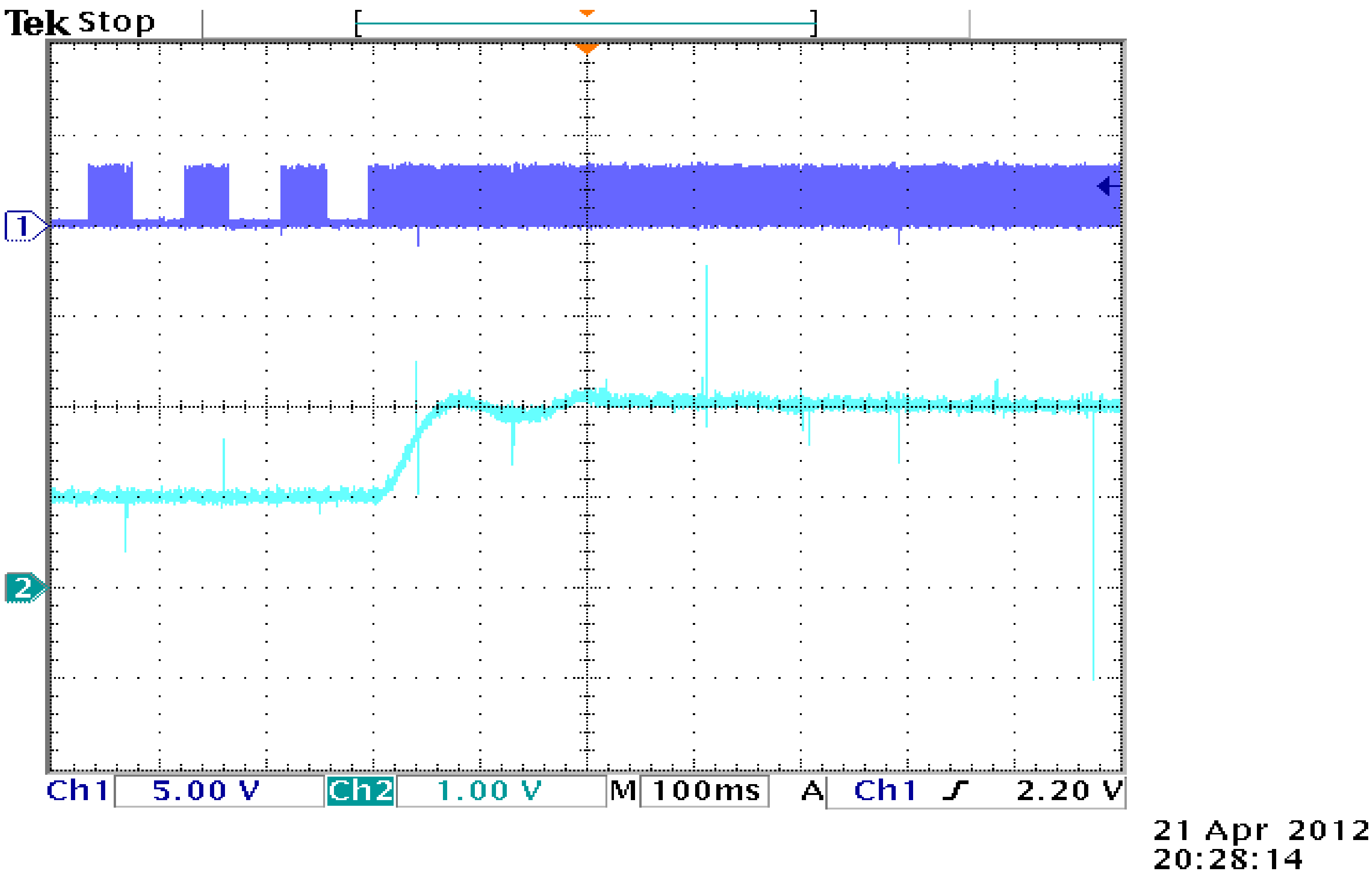


Figure 20. Motor Position Response to 44^0 input

Aero Engine Controls

http://www.aeroenginecontrols.com

DESIGN ALTERATIONS

- Reduction of hardware within drive circuitry
  - Single PMOS used in final design
    - Only one quadrant drive necessary
  - Drawback: only forward driving
    - Slower positioning time for fluid reduction positioning

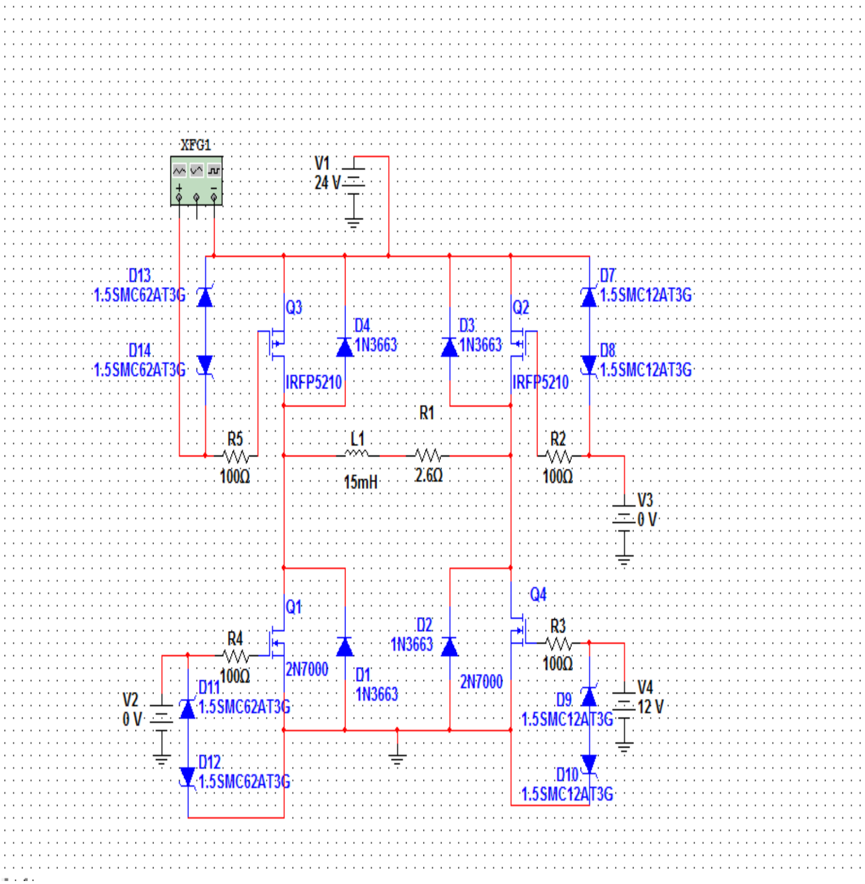


Figure 21. Original Drive Circuit for Design Review

Aero Engine Controls

http://www.aeroenginecontrols.com

ETHICAL CONSIDERATIONS

- Minimal overshoot of controller prevents fluid waste
- Safety measures and warnings given if system performance will drop due to rail voltage loss
- Accurate positioning high priority to regulate flow control
- Fast positioning needed to allow for emergency changes
- Need to comply with restrictions due to Control of Arms list; control methods for certain fluids cannot be published

Aero Engine Controls

http://www.aeroenginecontrols.com

FUTURE WORK

- Faster response time
- More intuitive control loop
- Fluid pressure sensor
- Fine tuning of the PID loop

QUESTIONS?

CREDITS AND SPECIAL MENTIONS

- Thanks to Professor Krein and the ECE 431 TA's
- Thanks to Alex, Professor Carney, and the ECE 445 staff
- Thanks to Jim Lange and AEC for providing this project and the guidance throughout the semester
- Thanks to the audience today for listening!