# EEL 4924 Electrical Engineering Design (Senior Design)

# Final Report

26 April 2012

**Team Members:**

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**PROJECT ABSTRACT:**

Our project is an eye movement controlled wheelchair. A mounted camera will track eye movement and control a wheelchair to go forward, left or right, stop or reverse. Blinks will control start/stopping. We have included sensors on the front of the wheelchair for collision detection.

The most challenging aspects lied in finding a good way to calibrate the camera to a person's eyes without obscuring their vision, determining the eye's movement, and controlling the wheelchair's wheels for proper movement.

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## INTRODUCTION

Controlling an object with just the gaze of your eyes is something we've imagined and seen in the movies. Although mostly seen as something fun and fictional, the idea of eye controls is of great use to not only the future of natural input but more importantly the handicapped and disabled. Our project focuses on using our eyes as the controller commanding any object we see fit. The object we chose was a wheel chair however; we could have possible interfaced with a toy car, hover craft, a video game, or even an entertainment system.

People who are unable to walk and are using wheel chairs exert great amounts of energy using physical strength to turn and steer the wheels. With eyesight being their guide, the disabled would save energy and could use their hands and arms for other activities.

There are no products on the market, but there are other applications such as virtual reality using eye tracking to control the vision of the game. Eye tracking is not heavily used in mainstream products but are beginning to pick up as input to electronics become more and more natural.

The purpose of this project is to develop a wheelchair that will be controlled by the eyes of the person seated in the wheelchair. This will allow people without full use of their limbs the freedom to move about and provide a level of autonomy. The project will consist of three main parts.

The first part is the head mounted camera and laptop system that will track the camera wearer's eyes. The camera will take an image of the eyes that will be sent to the laptop where the images will be processed using the open source image processing software OpenCV. Once the image has been processed it moves onto the second part, our microprocessor.

The microprocessor will take a USB output from the laptop and convert the signal into signals that will be sent to the wheelchair wheels for movement. Also, the pressure and object detection sensors will be connected to our microprocessor to provide necessary feedback for proper operation of the wheelchair system.

The final part of the project is the motor drivers to interface with the wheelchair itself. There will be two motor drivers for each motor on the wheelchair both left and right. Each motor driver will consist of an h-bridge that will power the motor depending on the output of the microprocessor. The motor drivers will control both speed and direction to enable the wheelchair to move forward, reverse, left, or right.

## TECHNICAL OBJECTIVES

- Specifying the power requirements to our camera, micro controller, and the wheel motors
- Measuring power consumption enabling the motorized wheel chair to last for a long period during the day
- Calibrating the camera's position and stability in relation to the eyes and head
- Interfacing the camera module to the micro controller
- Designing or wiring the wheel chair hiding the electronics
- Corresponding eye movements to specific wheel chair controls

### Hardware Digital Component

Our hardware digital objective will use the MSP430 as the wheel chair controller. It will receive inputs processed from the PC, pressure sensor, sonar sensors, and the motors. From those inputs, it will output the appropriate actions such as "waking up", moving forward, steering right or left, and keeping the speed constant. Pulse width modulation will be used to control and power the motors. PWM will be able to change (and keep constant) the wheelchair's speed depending on the user's inputs.

### Hardware Analog Component

For our hardware analog objective we will bypass the wheelchair's on-board controls and drivers and design and build our own motor drivers to control the speed and direction of the wheelchair. The motor driver will receive a PWM signal from the microprocessor and amplify the signal to power up the wheel chair.

### Software Component

Our software objective will be to use OpenCV on our laptop in order to process the images obtained from the eye-tracking camera. We will develop a tracking algorithm that will allow us to determine both the position of the eye and whether or not the eye is open or closed. Once this is determined, we will send signals via USB to the UART input on our microprocessor.

## CONCEPT & TECHNOLOGY SELECTION

For the first part of our project we chose to use a USB camera for the input to the laptop. We chose this option against an IR LED circuit because our research showed that IR radiation is harmful to the human eye and not as accurate as having a camera module. Also, we chose a USB camera over a CCD because the camera is already interfaced with the laptop so we wouldn't need to interface the camera ourselves and could instead focus on other design objectives. We are using a head mounted camera as opposed to a pair of glasses in order to provide stability and some level of automatic calibration for our camera.

Using a USB camera allowed us to use a laptop running OpenCV for our image processing. Without the laptop, we would need to process the images we received in real time on a board which would be beyond the scope of this project. Another factor in this decision was that OpenCV is open source and will thus help us minimize costs.

For the next part, we chose the TI MSP430 due to its low power consumption and the fact that our digital design does not require a super powered microprocessor to connect our circuits. It provides the necessary peripherals such as the UART, PWM, and enough input/output pins to interface with a wheelchair.

For our motor drivers, we decided to use International Rectifier's (IR) gate driver and power MOSFET's since they provided the specs necessary to handle the motor's power draw. The gate driver will amplify the PWM signal of 3.3V from the MSP to a 15V PWM signal. This amplified signal will be able to switch our power MOSFET's on. The power FET's will switch the motor's power supply 24V with a PWM signal enabling us to control the direction and speed of the motor.

Lastly, we chose to retrofit an existing (non-powered) wheelchair with motors instead of buying motorized wheelchair parts in order to minimize costs. Also, we will not have to build an entire wheelchair frame. Lastly, this will provide valuable mechanical engineering experience for us when we learn about motors and learn how to assemble them with our wheelchair.

## FUNCTIONAL BLOCK DIAGRAM

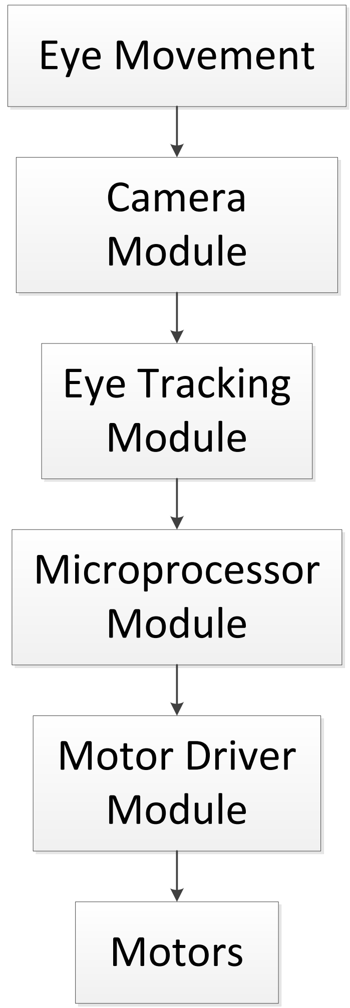


*Figure 1: Overall System Block Diagram*

## CAMERA MODULE


*Figure 2: Stabilized Helmet Fixture*

A helmet fixture was designed and built to hold the camera in place. The webcam is attached to the helmet using a flexible beam called Loc-line. The beam is attached to PVC which is zip tied to the helmet.

The webcam tracks the eye from above enabling the user to still see when controlling an object.

## Eye Tracking Module

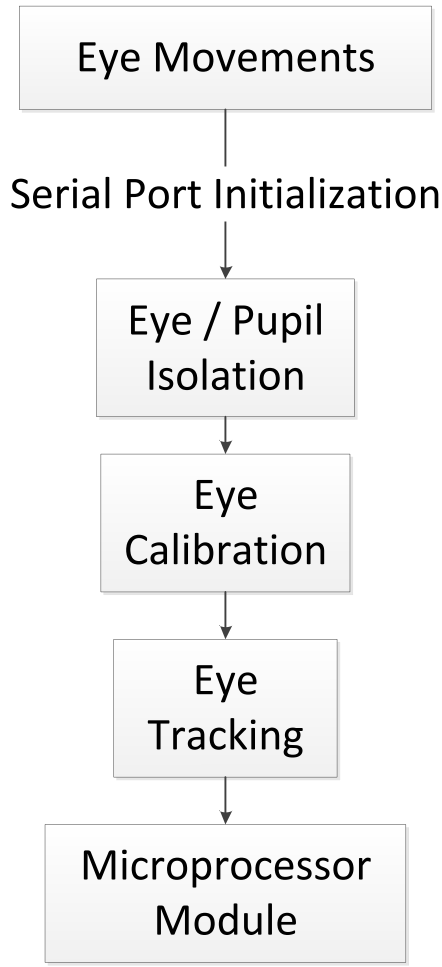


*Figure 3: Eye Algorithm Flow Chart*

Using the C++ programming language and OpenCV, an open-source image processing library, we were to develop an algorithm to track eye movements as well as eye blinks. The algorithm can be divided into three parts: isolation, calibration, and tracking. The eye tracking program will output using serial communications via Windows API's to the MSP430.

## EYE / PUPIL ISOLATION ALGORITHM

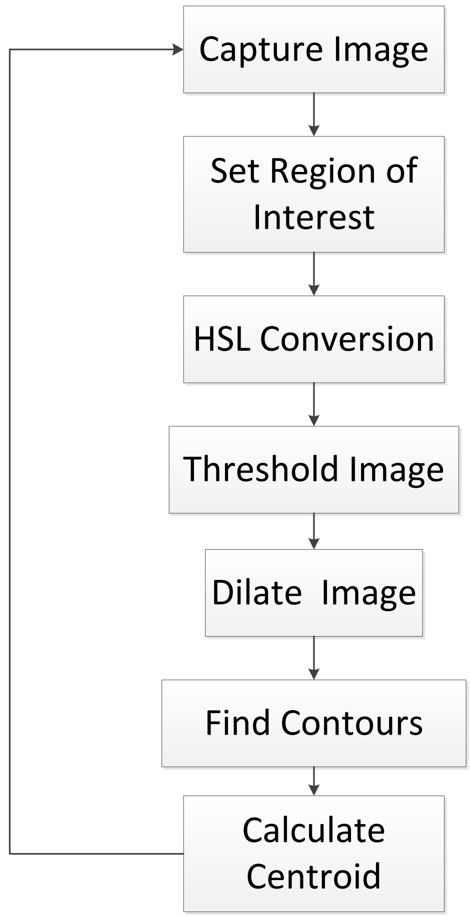


*Figure 4: Eye Isolation Algorithm Flow Chart*

In order to track eye movements, the webcam image capture will go through several image filters to determine where the eye is located.

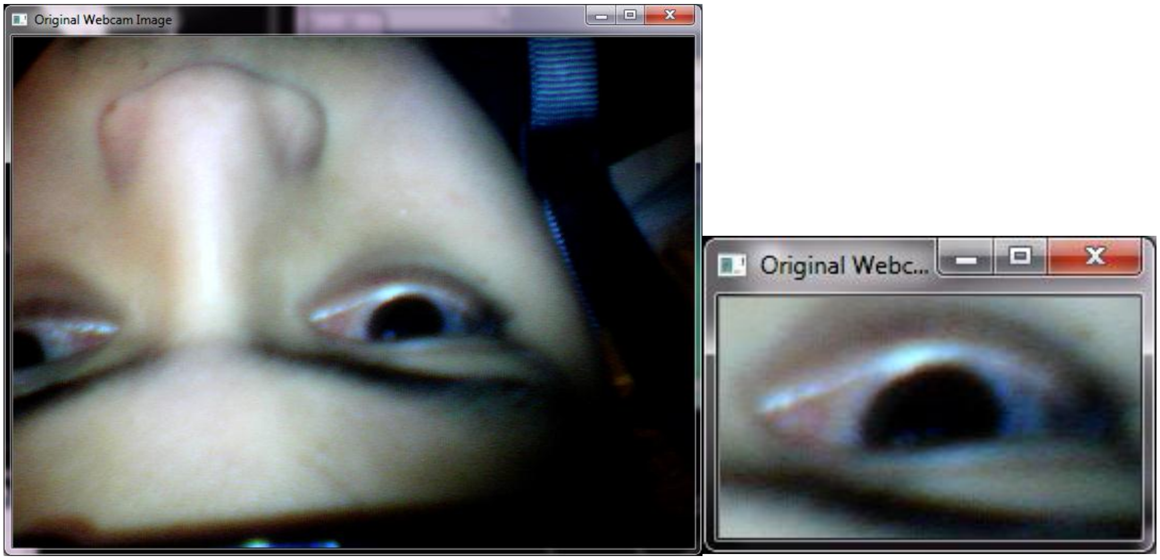

*Figure 5: Setting Region of Interest*

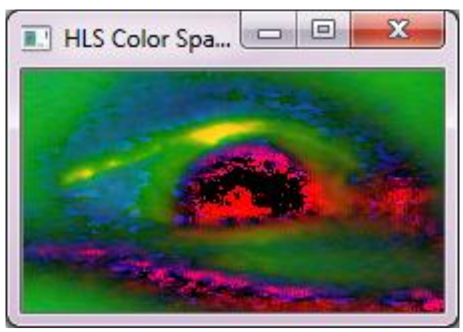

*Figure 6: HSL Color Space*

*Figure 7: Threshold (Binary) Image*


*Figure 8: Dilated Image*

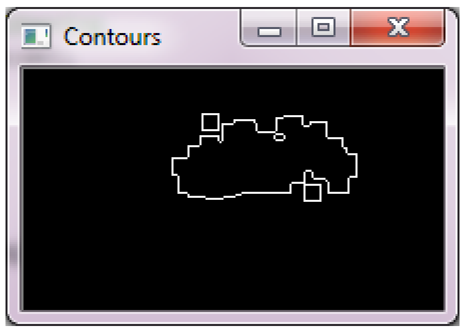


*Figure 9: Contour Image*

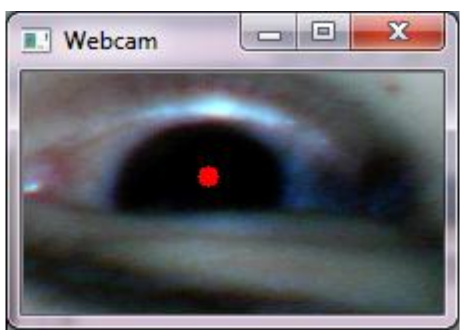


*Figure 10: Centroid*

## EYE CALIBRATION ALGORITHM

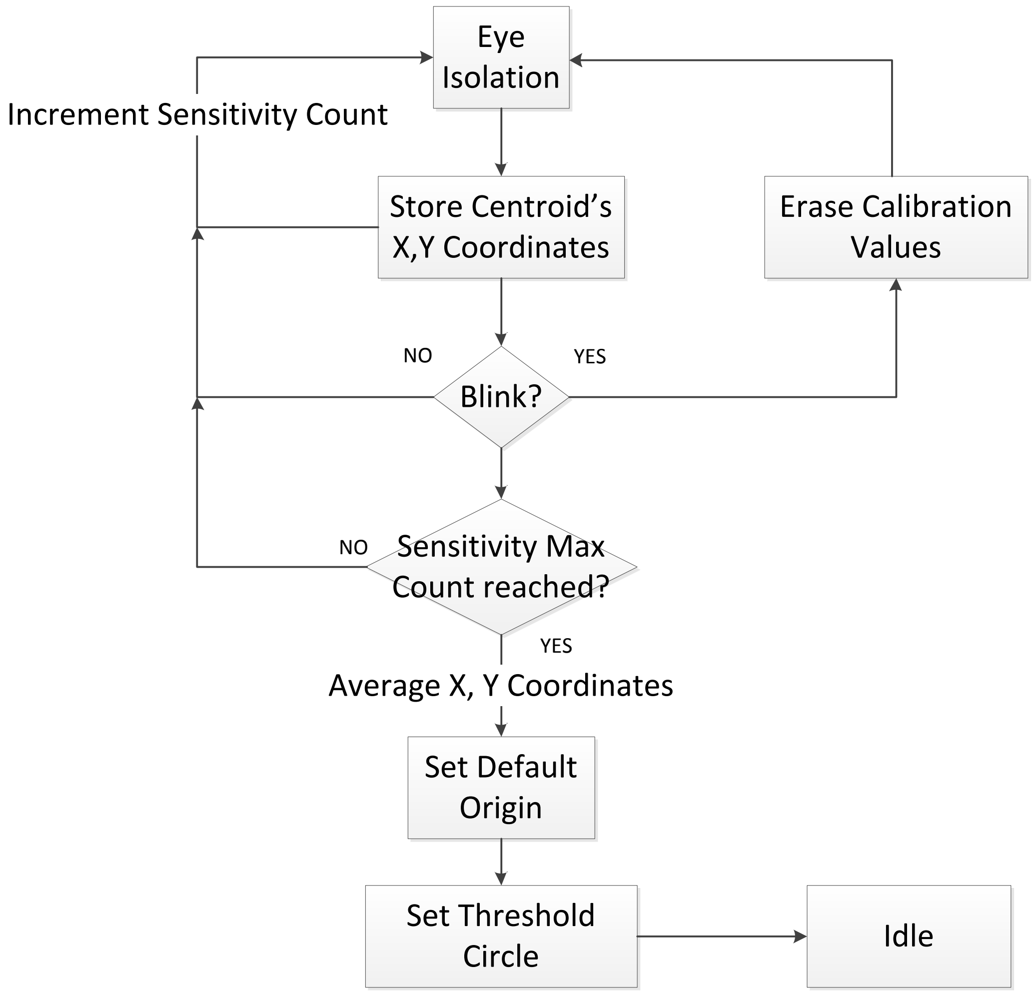


*Figure 11: Calibration Algorithm Flow Chart*


*Figure 12: Calibration Threshold*

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## EYE TRACKING ALGORITHM

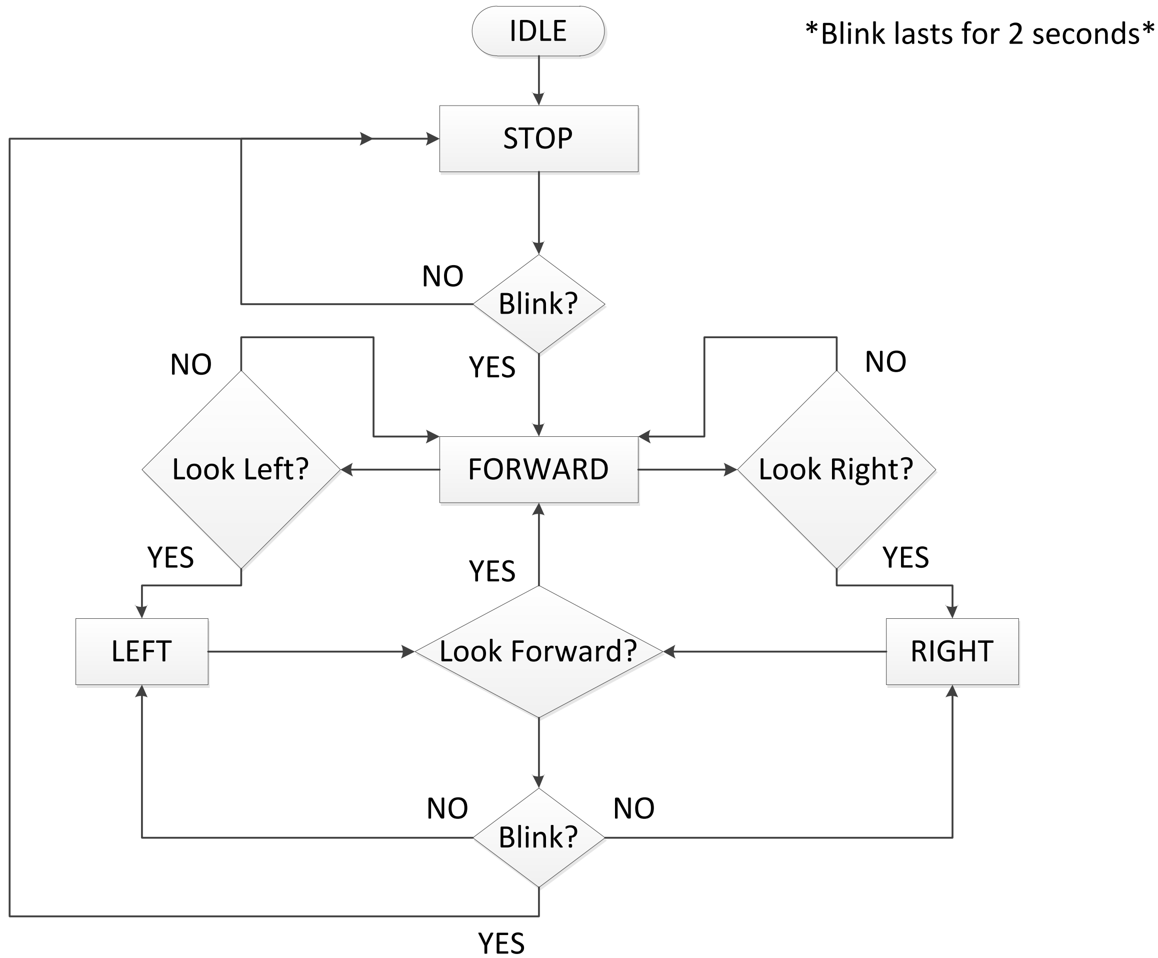



*Figure 13: Eye Tracking Algorithm Flow Chart*

## MICROPROCESSOR MODULE

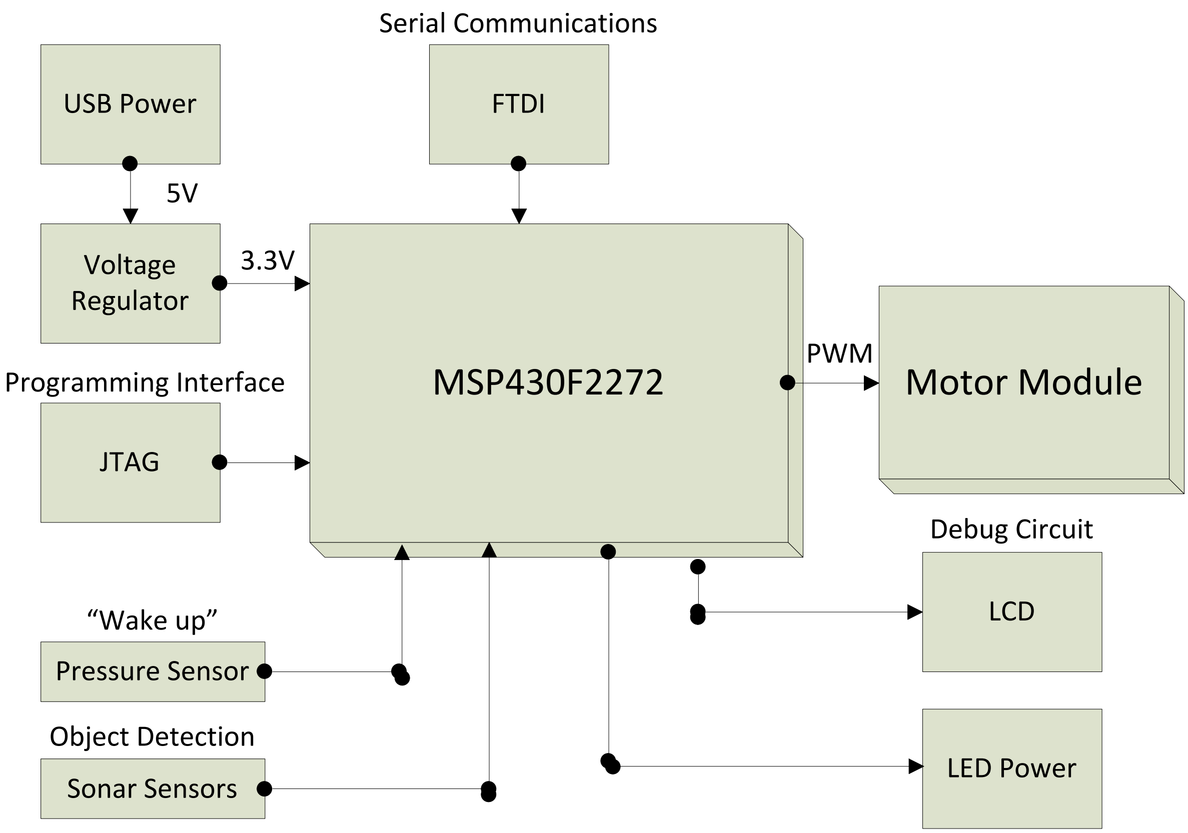



*Figure 14: Microprocessor Block Diagram*

# Final Report: EyeMove

## MICROPROCESSOR HSM

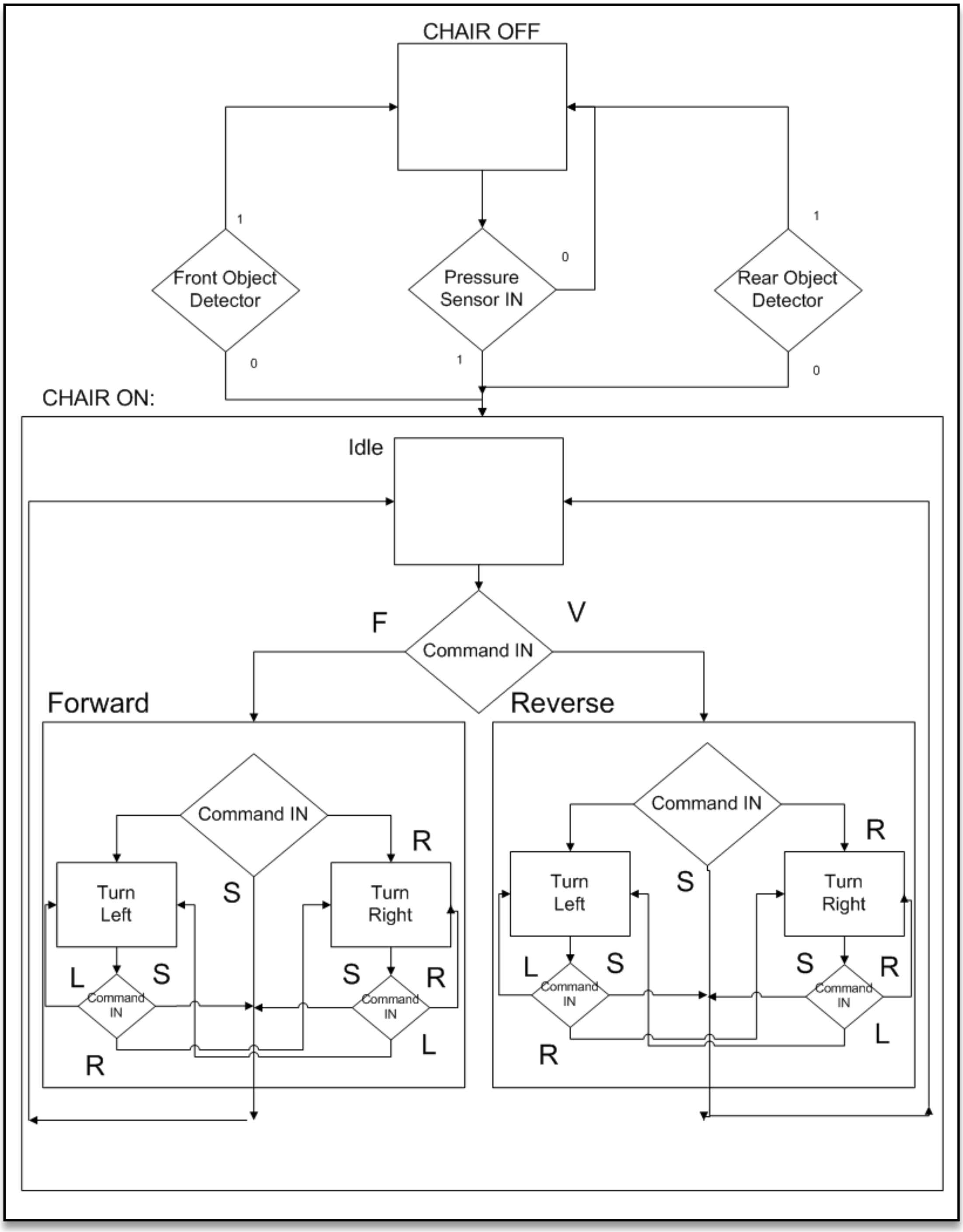



*Figure 15: HSM Flow Chart*

## MOTOR DRIVER MODULE

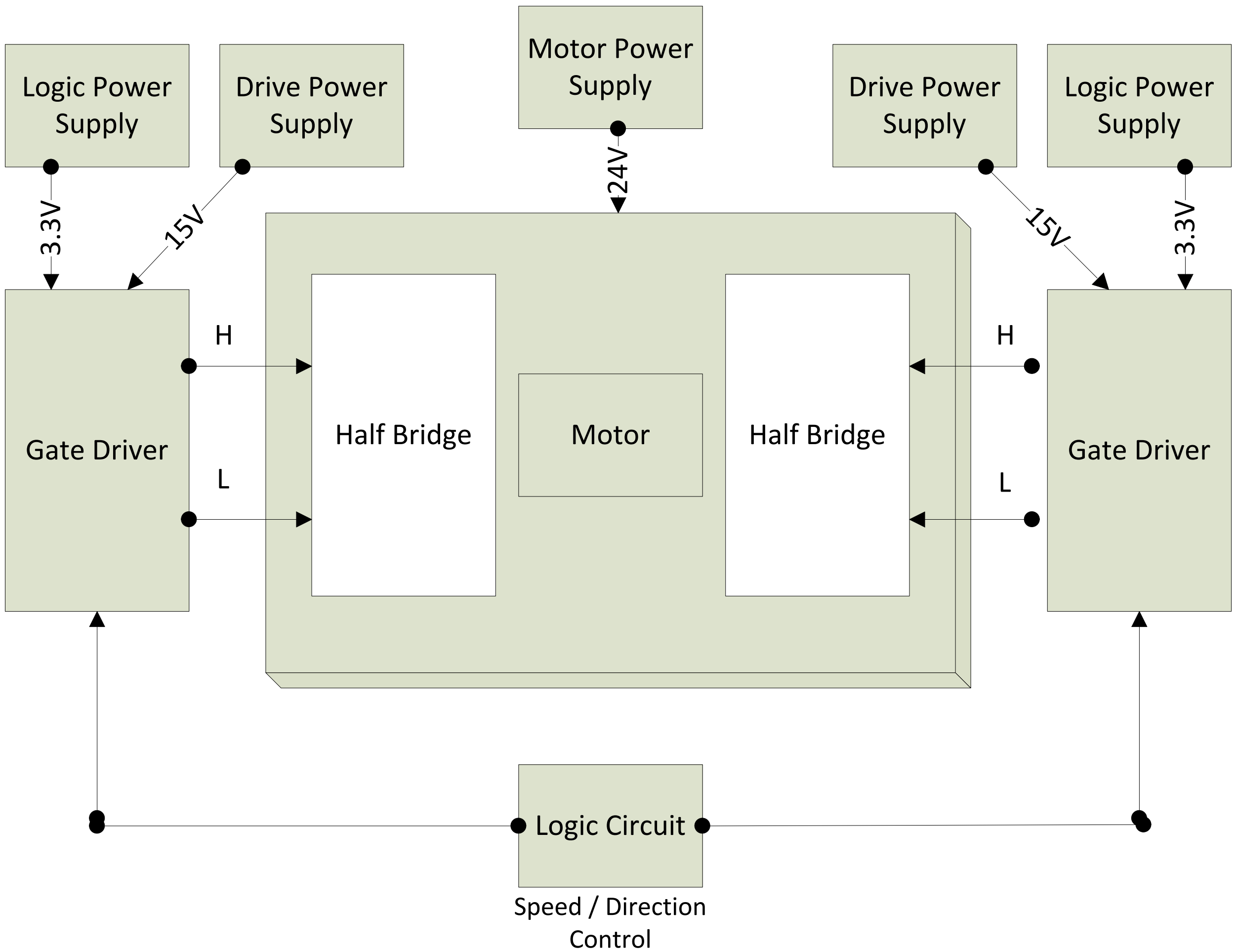
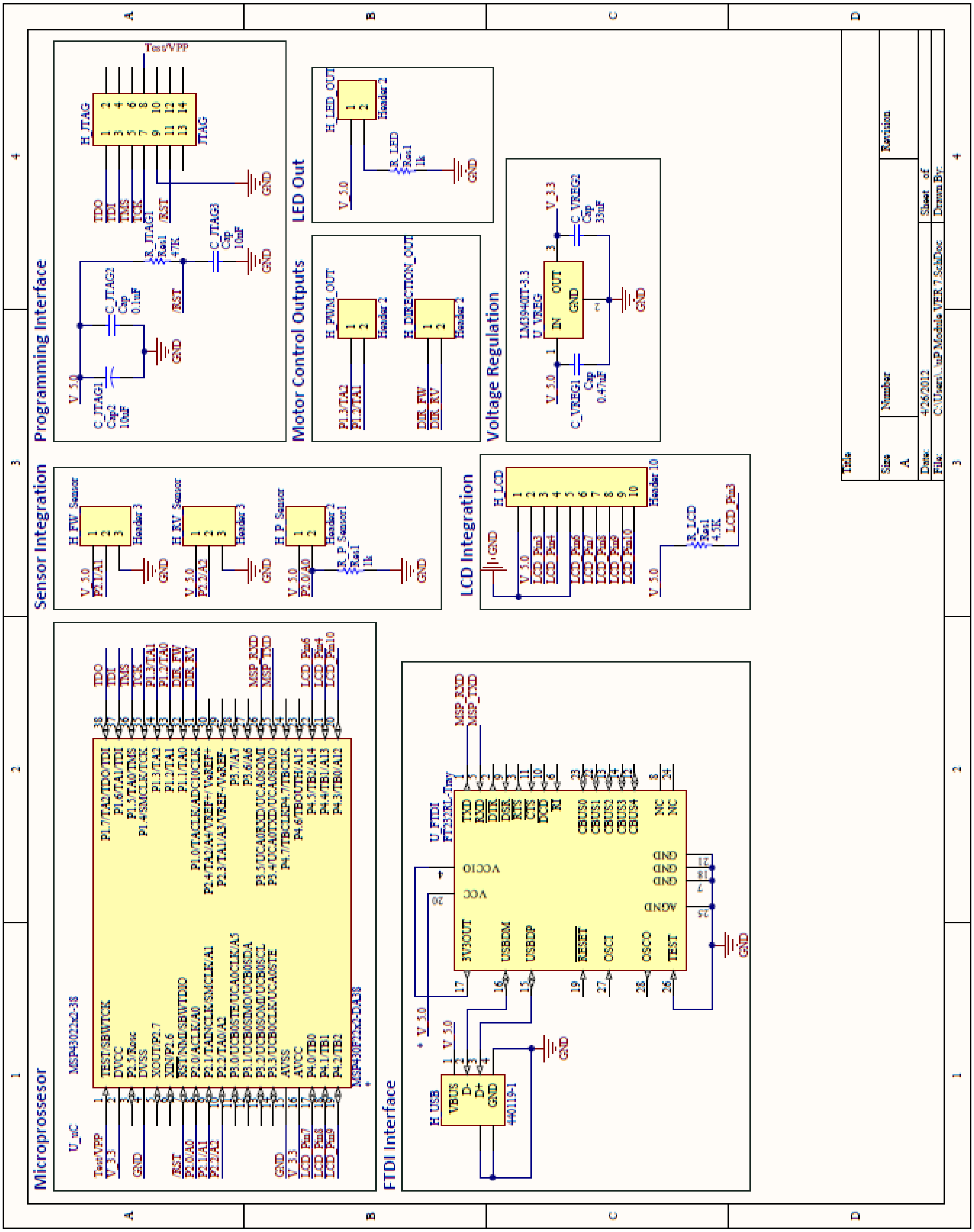
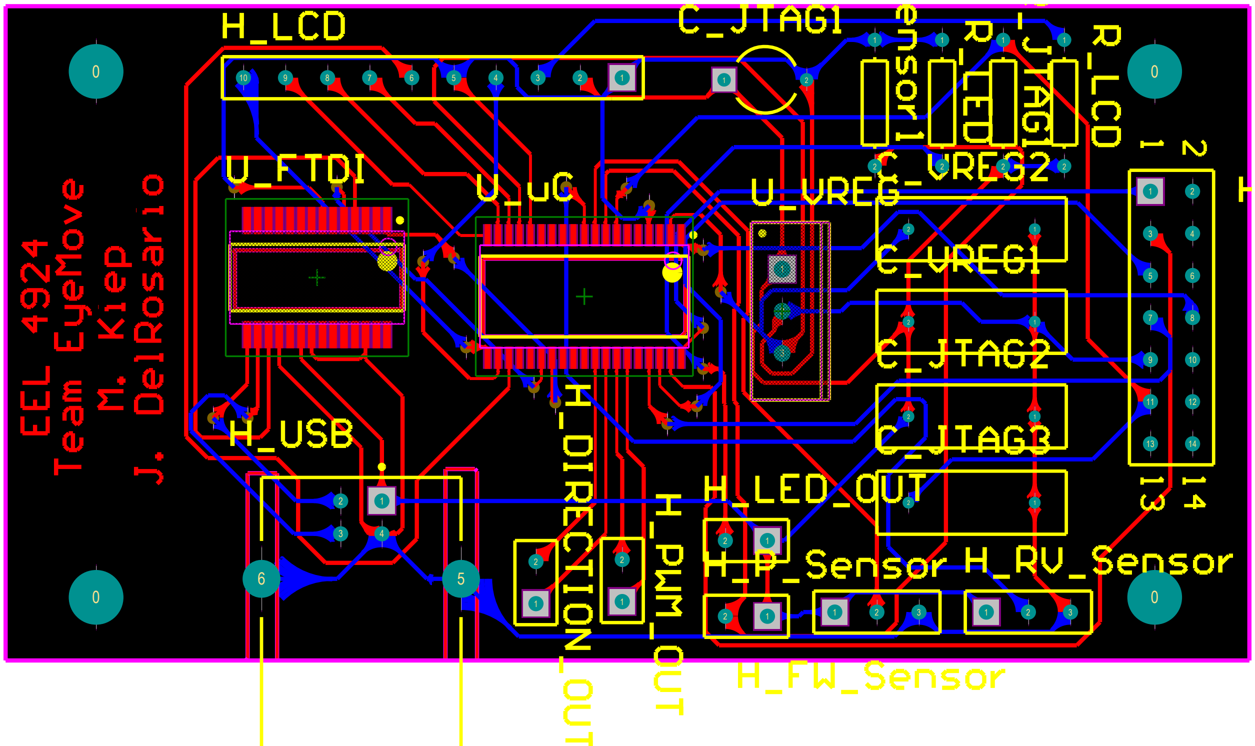


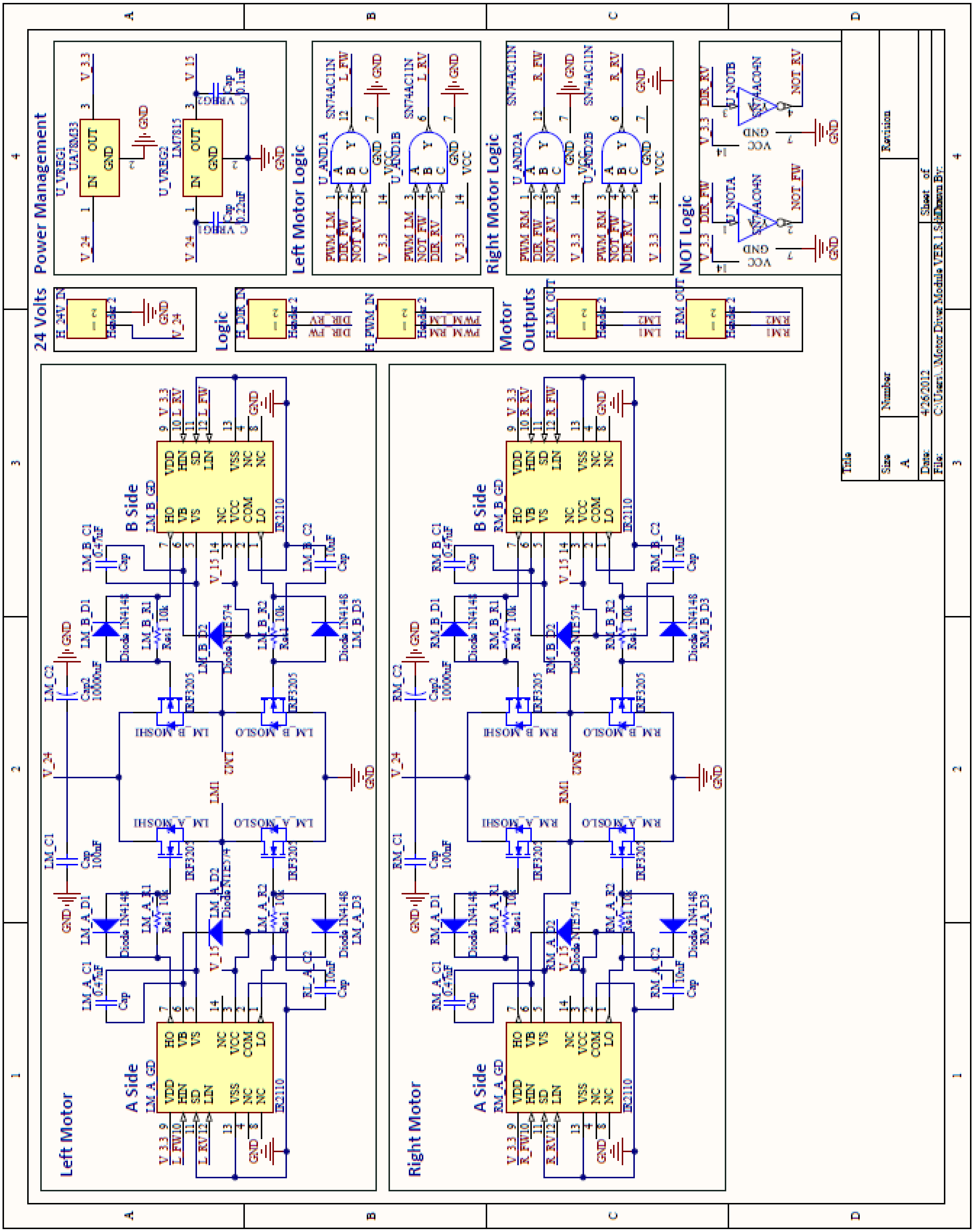

*Figure 16: Motor Driver (Left/Right) Block Diagram*

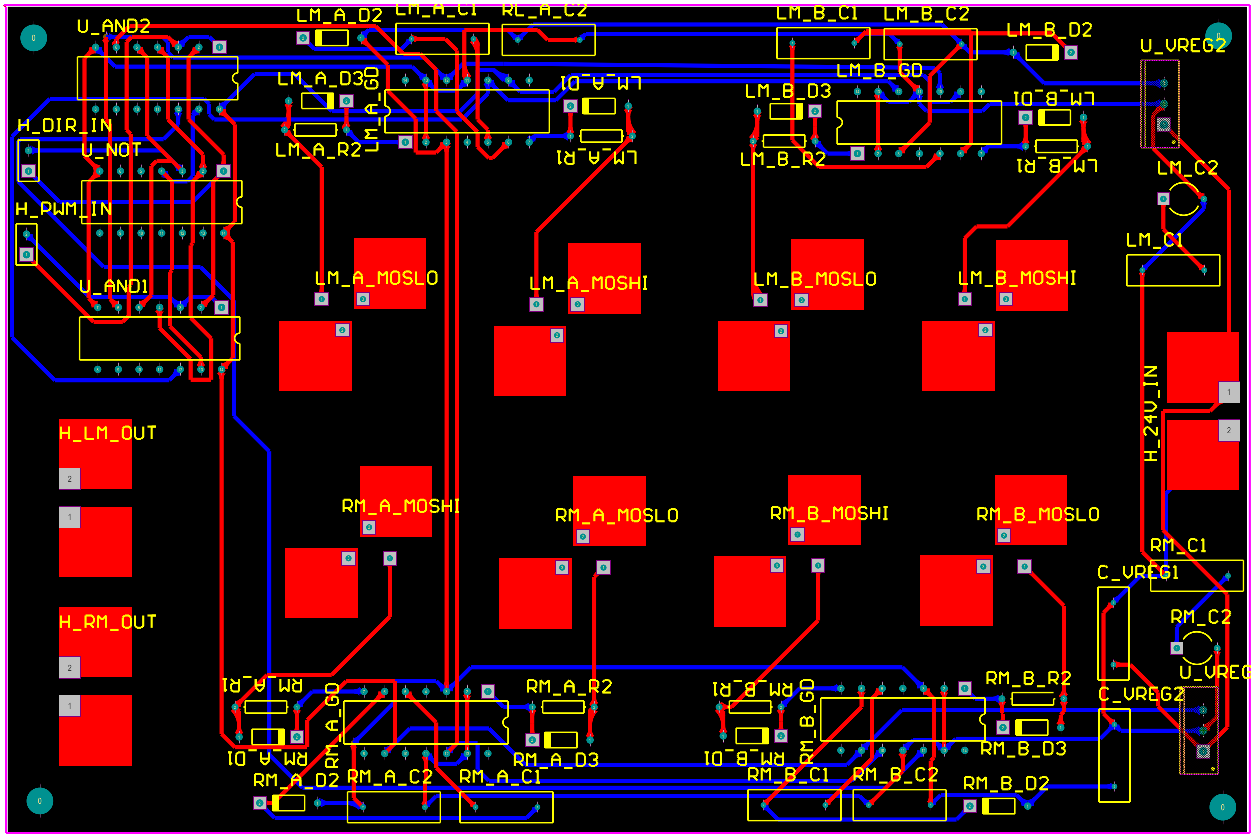
## MICROPROCESSOR SCHEMATICS & LAYOUTS




H_LCD
C_JTAG1
R_LCD
U_FTDI
U_uC
U_VREG
C_VREG1
C_VREG2
C_JTAG2
C_JTAG3
EEL 4924
Team EyeMove
M. Kiep
J. DelRosario
H_USB
H_DIRECTION_OUT
H_PWM_OUT
H_LED_OUT
H_P_Sensor
H_RV_Sensor
H_FW_Sensor

## MOTOR DRIVER SCHEMATICS & LAYOUTS




U_AND2
LM_A_D2
LM_A_C1
RL_A_C2
LM_B_C1
LM_B_C2
LM_B_D2
U_VREG2
LM_A_D3
LM_A_GD
LM_B_GD
LM_B_D3
H_DIR_IN
U_NOT
LM_A_R2
LM_B_R2
LM_C2
H_PWM_IN
LM_C1
LM_A_MOSLO
LM_A_MOSHI
LM_B_MOSLO
LM_B_MOSHI
U_AND1
H_24V_IN
H_LM_OUT
RM_A_MOSHI
RM_A_MOSLO
RM_B_MOSHI
RM_B_MOSLO
RM_C1
C_VREG1
H_RM_OUT
RM_C2
RM_A_R2
RM_B_R2
C_VREG2
RM_A_GD
RM_B_GD
RM_B_D3
RM_A_D3
RM_A_D2
RM_A_C2
RM_A_C1
RM_B_C1
RM_B_C2
RM_B_D2

## Bill of Materials

| PART | COST | QUANTITY | TOTAL |
|---|---|---|---|
| MSP430F2272 | $5.41 | 1 | $5.41 |
| USB Connector | $1.67 | 1 | $1.67 |
| FTDI FT232R | $4.50 | 1 | $4.50 |
| LM3940 | $1.75 | 1 | $1.75 |
| 33 uF Capacitor | $1.30 | 1 | $1.30 |
| 10 nF Capacitor | $0.38 | 1 | $0.38 |
| 0.1 uF Capacitor | $0.15 | 1 | $0.15 |
| 10 uF Capacitor | $0.20 | 1 | $0.20 |
| 47 k Resistor | $0.09 | 1 | $0.09 |
| LED | $2.19 | 1 | $2.19 |
| 0.47 uF Capacitor | $0.46 | 5 | $2.30 |
| 100 nF Capacitor | $0.15 | 2 | $0.30 |
| 47 uF Capacitor | $0.47 | 8 | $3.76 |
| 22 k Resistor | $0.09 | 4 | $0.36 |
| IR32-5 NMOS MOSFET | $0.60 | 8 | $4.80 |
| IR2110 Gate Driver | $6.98 | 4 | $27.92 |
| 24 V to 3.3 V Regulator | $0.60 | 2 | $1.20 |
| 24 V to 15 V Regulator | $0.60 | 2 | $1.20 |
| 1N4148 Diode | $0.06 | 4 | $0.24 |
| NTE574 Diode | $0.62 | 4 | $2.48 |
| SPST Submini SW | $3.19 | 3 | $9.57 |
| Project Box 4x2x1 | $3.19 | 1 | $3.19 |
| Project Box 7x5x3 | $6.29 | 1 | $6.29 |
| Hootoo U19-A Night Vision Webcam 12.0MP | $2.85 | 1 | $2.85 |
| Jazzy Select 14 | $300.00 | 1 | $300.00 |
| | | | |
| **TOTAL** | **$343.79** | | **$384.10** |

*Table 1: BOM*

## Distribution of Labor

| Item | Matt Kiep | Jon DelRosario |
|---|---|---|
| MSP Programming | 70% | 30% |
| OpenCV Programming | 0% | 100% |
| Camera Fixture Design | 0% | 100% |
| Wheelchair Motor Driver Design | 50% | 50% |
| Sensor Integration | 80% | 20% |
| PCB (uP, power, motor driver) Layout Design | 70% | 30% |
| PCB Construction | 100% | 0% |
| PCB Testing | 50% | 50% |
| Wheelchair/part acquisition | 50% | 50% |

*Table 2: Distribution of Labor*

# Final Report: EyeMove

## GANTT CHART

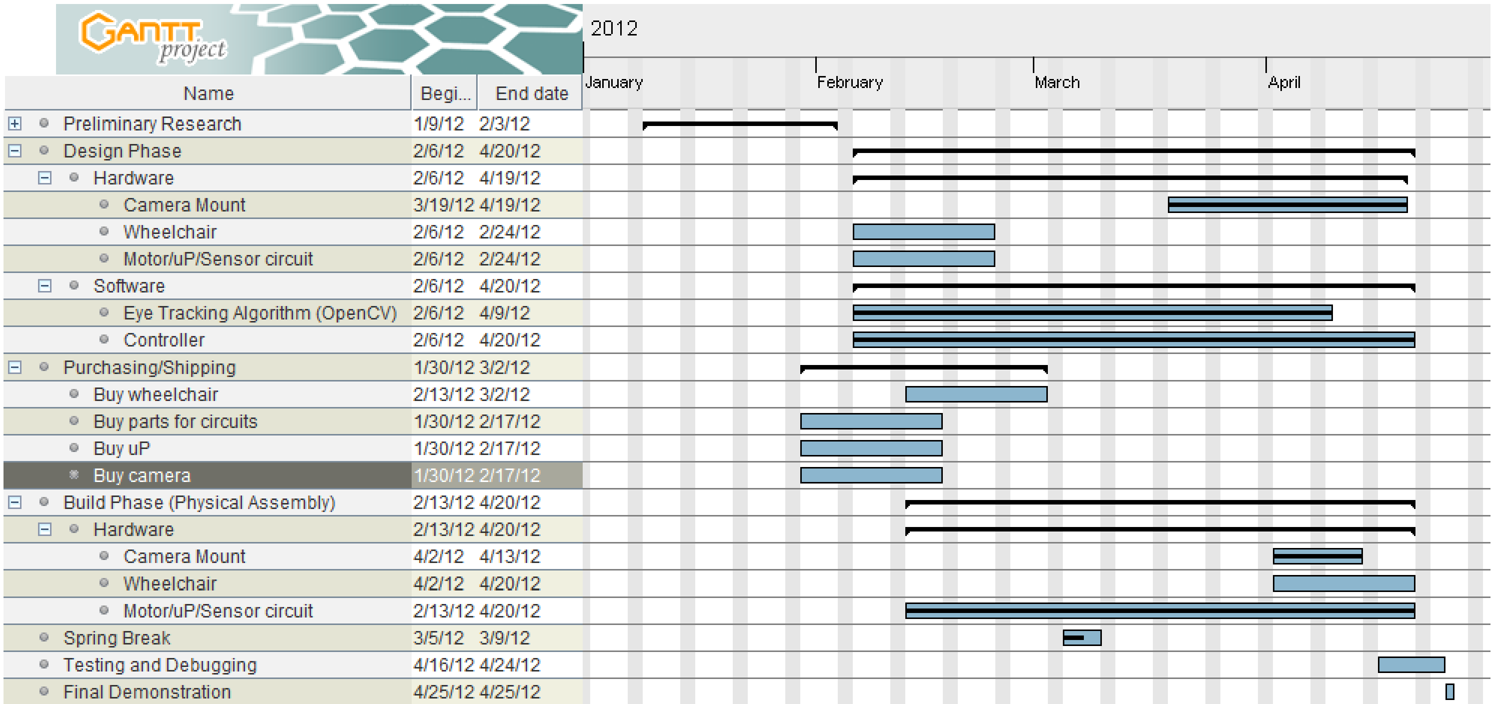



*Figure 17: Gantt Chart*

## References

*Benson, John B., Next Generation Autonomous Wheelchair Control, M.S., Department of Electrical and Computer Engineering, July, 2005.*

Eye-Controlled Wheelchair Thesis
*http://www.gavinphilips.com/projects/eyecontrolledwheelchair*

Camera Head Mount
*http://www.iod.unh.edu/Libraries/AT_Docs/Loc-Line_examples.sflb.ashx*