Analog to Digital HUD Instrument Cluster with Touch Screen Command Center

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Abstract — **The A2D HUD and touch screen command center project is centered on the future of the driving experience. Our project delivers an innovative approach to relaying vehicle information to the driver via a dual mode instrument cluster/HUD. We implemented our design in a manner that compliments the user's driving ability and not hamper it by being a distraction. The addition of a touch screen display in the vehicle's center console adds another layer to the vehicle—driver dynamic. Careful consideration has been placed upon safety of use, cost effectiveness and real world viability.**

Index Terms — **Optical reflection, analog-digital integrated circuits, lenses, sensor systems, embedded software, visualization, graphics.**

I. INTRODUCTION

Our revolutionary automotive vehicle system, dubbed "A2D", aims to replace traditional analog dashboard components with a completely digital alternative. As the name of the product suggests, A2D will effectively convert information currently conveyed in an analog manner to digital information. It represents the future of automotive information technology, and is just another embodiment of the seemingly perpetual shift of analog being replaced by digital. This system will enable drivers to control and monitor the vehicle more easily, and will be more visually attractive than current vehicle dashboard designs. It also, aims to keep the drivers eyes on the road while using the HUD to maximize situational awareness.

A2D will consist of two major components: a HUD display which will replace conventional analog gauges and instrument clusters, and a touch screen input interface which will serve as the control mechanism for various vehicle systems. For both interfaces, ease of use is the primary concern; the HUD display should be easy and desirable to read in all lighting conditions, and the touch screen control device should be intuitive and provide the user an easy way to control the vehicle's systems in a single central location.

The technology used to implement our display is very similar to existing heads up display systems found in select high end cars. In fact, the idea was inspired by the heads up system found in the BMW 7 series flagship sedan. In that system, a projector, mounted on the top of the vehicle's dashboard, projects an image onto the windshield, directly below the driver's line of vision. While the amount of information that can be displayed is limited by the small area of the windshield that can be utilized, vital information such as the current vehicle speed, the gear the vehicle is in, and cues from the navigation system are shown. We aspire to mimic this technology, while increasing the amount of information displayed to the user and enhancing the way in which it is presented to the user. Our unit, however, will be found behind the steering wheel and will have light bars projecting data upward onto a special screen, so as to effectively implement a true digital instrument cluster. The data to be displayed will be simulated as coming from a vehicle's various sensors, sent to a microcontroller device and then relayed to the display in graphical form. Data demonstrated will include: a speedometer, a bar-based tachometer, fuel level, engine temperature, ambient and cabin temperature, odometer, and seat belt indicator. The result of the display should be an elegant display which provides the user with all the information he needs in an easy to read manner.

The touch screen display will be mounted centrally, where radio and climate controls are usually found, providing the driver a single screen from which to accurately control the vehicle's systems. From this interface, the driver will be able to control climate options, the vehicle's audio system, vehicle door locks and windows all with the touch of a finger. Additionally, it will serve as a "back up camera" screen, which will appear automatically when the vehicle is placed in the reverse gear. The user interface is designed for maximum intuitiveness, such that drivers of all age and background will be able to learn and operate it with ease. Tab buttons, located at the bottom of the screen will categorize each vehicle system, making it simple to locate and control each subsystem. The touch screen utilized is a low cost, simple to use digital solution to a previously analog setup.

II. DESIGN SPECIFICATIONS

The project fulfills the required specifications. To not exceed the production cost of $1,000 we purchased items from used automotive part distributors, relied on samples from electronics vendors, and were extremely cautious when implementing our design so as to not damage anything. To design a mobile automotive dashboard simulation, we constructed a shed-type box 48'' wide to house all the components of a real automobile. The project will allow the user to interact with the system via a gas pedal, seat mat sensor, seat belt buckle, and touch screen interface. Designing the interface for the user, the touch screen, HUD, and instrument cluster will be viewable within 160 degrees. To meet specific requirements for correct operation of the system, we purchased the correct devices and designed it accordingly.

III. DESIGN

From the start we decided to simulate the inside of a vehicles dashboard. We decided on installing a dashboard to house the touch screen and projected magnified display.

A. Simulating Vehicle Data

The data from a car will be simulated from the main controller (PIC18F4550), which will be similar to what the ECU produces for the analog instrument cluster. The HUD LCD will be controlled by the PIC18F4550 , which will take that data in and convert it to digital along with sending the information as needed to display it for the heads up display. The gas pedal will control the RPMs and speed. Information is read from each sensor and fed into the touch screen micro controller (ATMEGA328) and PIC18F4550. The Schematic for the PIC18F4550 is illustrated below.

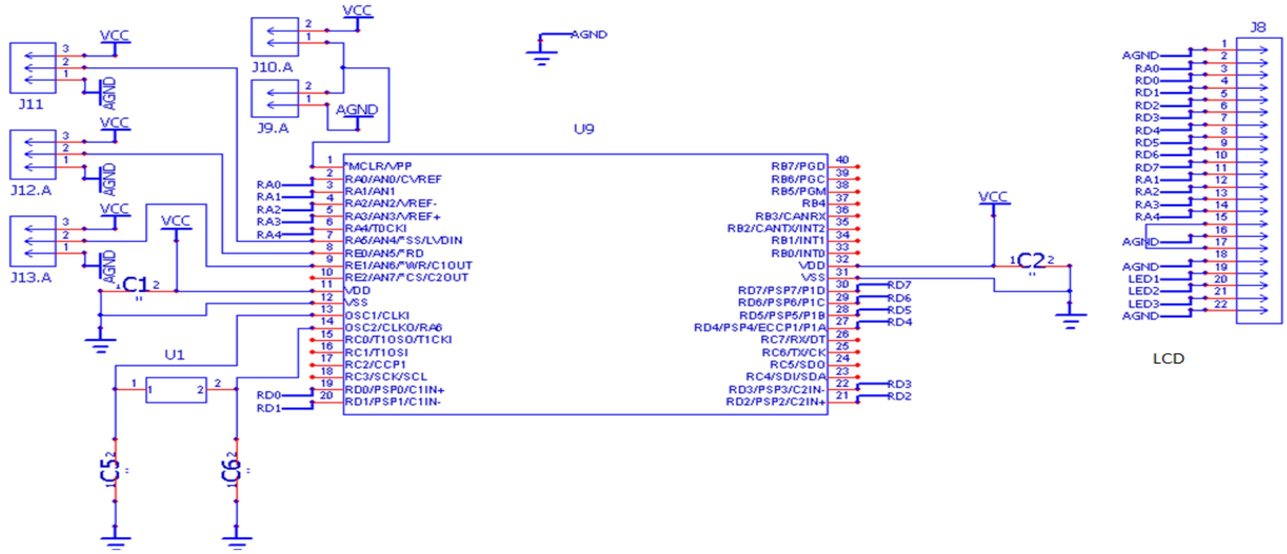

Figure 1 A detailed schematic for the PCB of the PIC18F4550 and the LCD

B. The LCD for HUD and PMD

The LCD will display the entire instrument cluster just as a digital dashboard should be represented. The user will be able to control the RPM and speed via the gas pedal. Also, the user will be able to sit down and a seatbelt symbol will occur and a seat buckle will remove the symbol on the LCD. This is the notification of a person in the driver seat, which will then tell the driver to buckle; then the driver will buckle the seat belt which will turn the seat icon off.

The instrument cluster and HUD will be a projected magnified LCD screen. A swiveling mechanism will let the user toggle between HUD mode and traditional instrument cluster mode. The traditional mode will be viewable on the swiveling mirror and the HUD will be viewed on a Plexiglas representing a windshield.

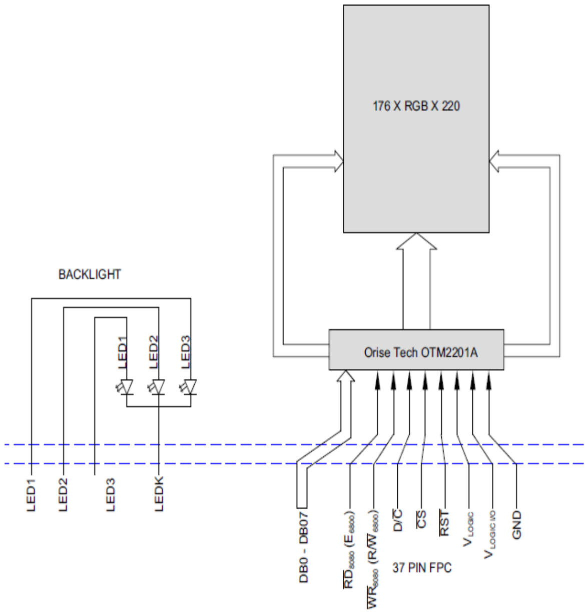

Figure 2 This figure is the LCD with its controller showing the pin connections.

C. Touch Screen Command Center

In keeping with the analog to digital theme of our project the touch screen command center will replace traditional knobs with digital representation on a touch screen device located in the center console. Data, such as ambient temperature and telemetry information will be displayed on the touch screen display. The user will also be in control of windows and locks via touch screen. The overall block diagram illustrates the flow of information and power for the project below.

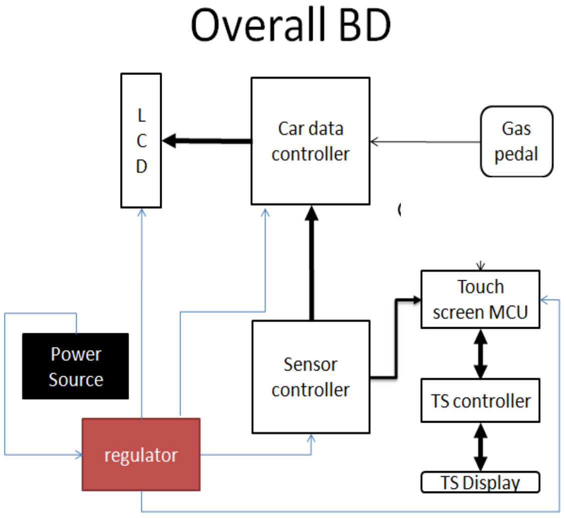

Figure 3 The overall block diagram for our project.

The project will be enclosed in a custom built box containing a dashboard and all of the components of our project. The user will only be able to view the gas pedal, touch screen, instrument cluster, and HUD. The back of the box will have an opening to view the circuits and optical devices.

IV. SIMULATION

As described before the project is enclosed in a shed-type box. The touch screen and PMD will be mounted in a real world automotive dashboard; the HUD is mounted just above the instrument cluster. The gas pedal is located where you would find the gas pedal from a typical automobile. The user will sit, as if they were driving the vehicle, in a chair provided by the group. The image below describes the simulation.

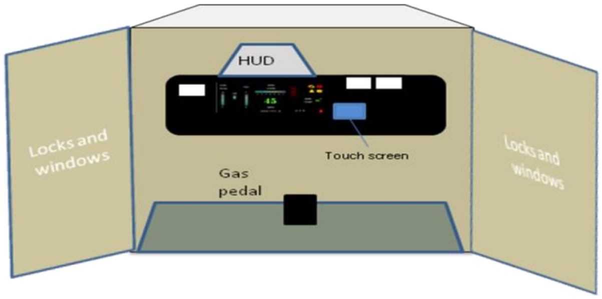

Figure 4 The front view of the simulation box.

The back of the box can be opened to reveal the electronic parts and sensors. Also, the mechanical device for the mirror rotation is located directly behind the instrument cluster, along with the optical components just below the mirror. For stability, there is a shelf to hold all of the electronic devices and optical equipment.

V. SOFTWARE

The project mainly utilizes two micro controllers to drive both the simulation as well as all graphical objects. The PIC18F4550 was programmed in MPLAB IDE using a C compiler, will be controlling the LCD screen while The ATMEGA328 was programmed in the Arduino IDE, which uses a combination of C, AVR, and the wiring language.

A. The PIC18F4550, The main micro controller

The PIC18F4550 was programmed in the C compiler, C18, offered by Microchip and the IDE was MPLAB. The PIC18F4550 accepts data from the gas pedal, occupant detection sensor, and seat belt sensor. The gas pedal and occupant detection sensor are analog signals converted digitally through the microcontroller and displayed on the LCD screen. The gas pedal uses a potentiometer to simulate speed and RPMs which the program written will display the speed and RPM bar dynamically as the user gives inputs. The occupant detection sensor and seat belt sensor will send signals to the PIC18F4550, which the program will turn on or off the seat belt indicator. The figure below shows the instrument cluster layout.

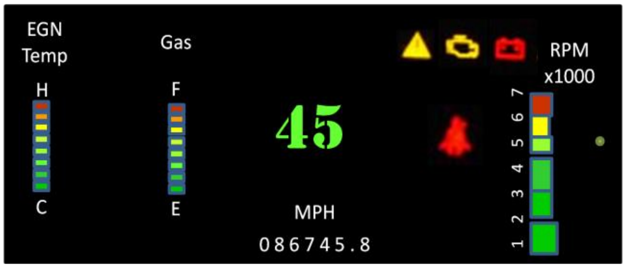

Figure 5 The layout of the intrument cluster displayed on both PMD and HUD.

We designed the background image of the instrument cluster and used a program called Image2lcd. This program converted the image into hex numbers and with the proper heading on the file, we programmed the PIC18F4550 to print the image hex number by hex number. Then as the microcontroller receives data it will update the layout background dynamically and at an extremely fast speed.

B. The ATMEGA328, the touch screen controller

The Arduino IDE provides a vast resource of libraries and header files to draw from. Included in the IDE are header files which make possible serial communication as well as GUI manipulation in a very familiar, pseudo C syntax. The ATMEGA328 serves as the bridge between the OLED and resistive touch screen which act as the simulated vehicle's command console. The touch screen controller as well as all the external sensors such as the telemetry IC and the temperature sensor IC are also handled by the ATMEGA328 through the SPI protocol. This interconnection is also represented in the block diagram seen below.

VI. ELECTRONIC COMPONENTS

A. The LCD with the PIC18F4550

The LCD and PIC18F4550 were programmed and tested on a development board. We chose the LCD screen to fit our requirement of a small, low price, and low power screen to be magnified. The inputs were realized using a potentiometer for the gas pedal, a flex sensor to detect weight on the seat and a real automobile belt buckle with a switch inside. These components will be built on the following PCB design.

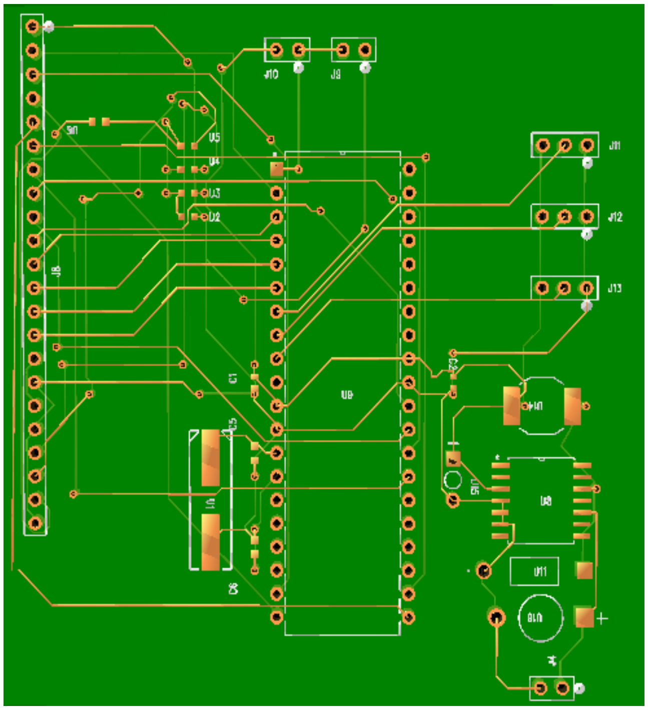

Figure 6 PCB for the PIC18F4550 with LCD, gas pedal, seat detector and seat buckle connectors.

B. The Touch Screen with the ATMEGA328

In considering the command center, careful thought went into selecting an OLED screen as well as the essential resistive touch screen. Both technologies were chosen for their tried and true reliability.

The ATMEGA328 serves to facilitate the external sensors used to determine both temperature as well telemetry. Via the I2C protocol the wiring/AVR nature of the Arduino IDE allowed us to realize our intent to be able to use the same I2C bus to accommodate more than one hardware sensor.

The touch screen controller then relays the decoded touch information received from the variations in voltages induced by a touch on the touch screen. A block diagram of the touch screen subsystem can be seen below.

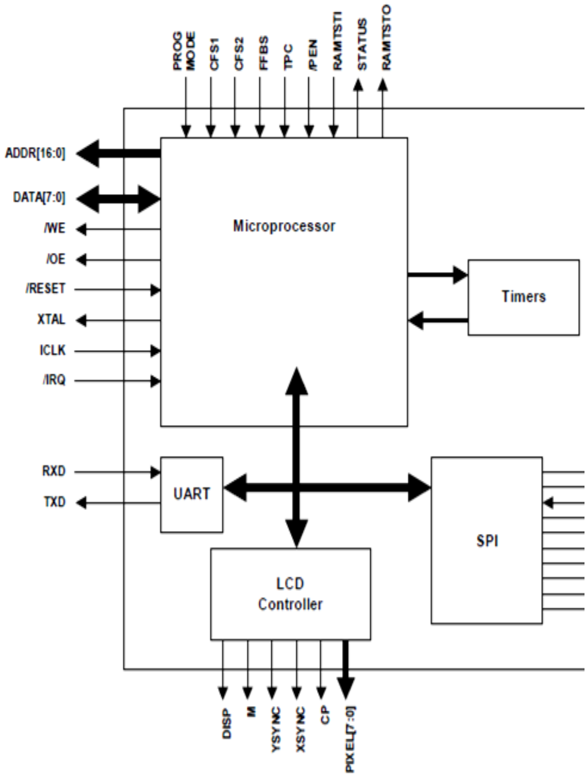

Figure 7 An overall block diagram with both the touch screen controller, GUI chip and touch screen.

C. The Sensors

The sensor subsystem designed for the project was intended to replicate typical environmental and road condition date. Typical non user dependent vehicle information such as ambient temperature and direction of travel are determined by a compass module as well as a temperature sensor.

User dependent values were also used to deliver occupant present indicators as well as seatbelt engaged lights. An overall block diagram of the sensor subsystem can illustrates the sensor hierarchy relative to the 2 micro controllers used in the project. The vehicle's velocity and acceleration are determined by a potentiometer which actuates coaxially with a drum pedal sprocket.

The specific compass module we chose was the Honeywell HMC6352. It was chosen for both cost and the feature set that it had. We determined that a 2 axis compass would be sufficient for our needs and that a 3 axis compass would only provide unnecessary pitch data.

The compass communicates to the ATMEGA328 via the I2C protocol. A schematic of a typical compass module follows. Please note that this system is a magnetic sensing system and uses this to determine the vehicle simulations approximate current heading.

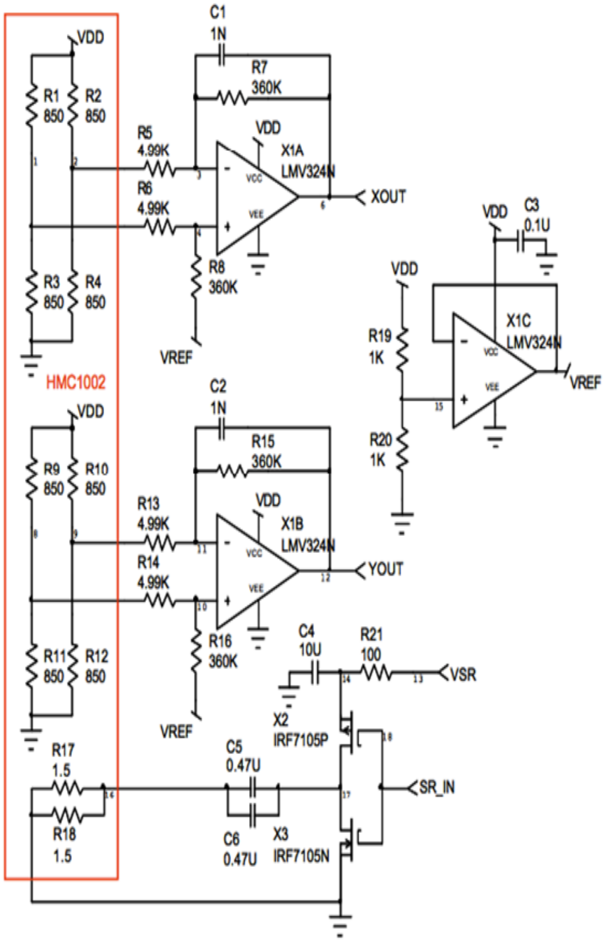

Figure 8 Figure represents a similar 2-Axis compass module used with the touch screen.

Similarly, figure 7 below is used to determine outside/ambient temperature and also communicates via the I2C protocol. The schematic below also demonstrates the interconnections of the temperature sensor as well as the LCD display used to test if proper reading were being made prior to final project integration. This will let us know how accurate this part is along with practice on how to implement it.

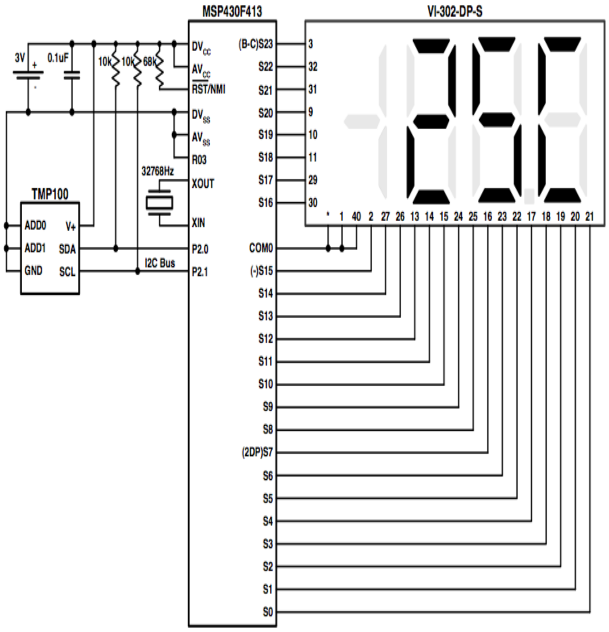

Figure 9 Interconnections of the temperature sensor as well as the LCD display used to test if proper reading are read.

An overall block diagram of the sensor subsystem illustrates the sensor hierarchy relative to the 2 micro controllers utilized by the project shown below.

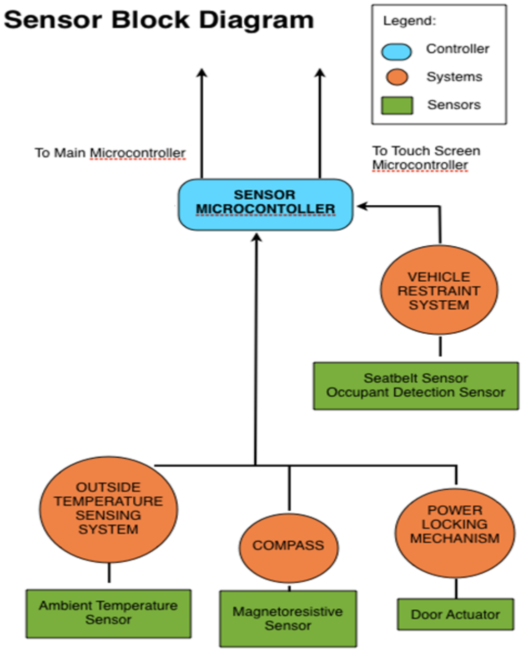

Figure 10 This figure represents the sensor hierarchy of the system relative to the micro controllers.

VII. POWER

In considering power, both of A2D's PCB's were designed such that they would be able to accept and regulate power drawn from a 12V vehicle power supply. For both practicality and transportability the project instead utilizes 9 Volt batteries to demonstrate the voltage regulating capabilities of our final circuit designs. Both PCB's were outfitted with high input regulators which stepped down to 3.3V in the case of the PIC based PCB and 5V in the case of the Atmel based PCB. A separate off board 12V power source was needed to demonstrate the integrated locking mechanism due to the high current requirement of the actuator involved in the demonstration.

VIII. OPTICAL DESIGN

As discussed in the introduction, we decided to implement a dual display for showing vehicle information. The dual "PMD" (projected magnified display)/ HUD (heads up display) was positioned inside the custom enclosure to optimize readability. As in an actual automobile, it is vital that the driver be able to read all information without diverting attention from the road. Therein lays the objective of our optical design.

The PMD image is viewed as a reflection on a small mirror, which is attached to a swiveling device used to toggle between two modes. The driver gets the option of choosing which mode is most conducive to a safe driving environment based on his or her preferences, the driving conditions, and lighting conditions. To ensure both safety and readability of the image on the mirror, a lightweight "plastic mirror" is used.

In determining the magnification achievable by the lenses we were considering, we used the magnification equation for a single lens equation shown below.

$$M = \frac{f}{f - d_o}$$

Where f is the focal length and d_o is the distance from the lens to the object.

Our heads up display attempts to perfect current automobile heads up display systems by providing a low cost alternative. Using a simple one lens design, we were able to obtain a clear image on a Plexiglas resembling a windshield. Using the thin lens formula for a single lens, we were able to obtain the optimal focal length necessary for the clearest image. Below is a diagram of our optical setup within our vehicle enclosure.

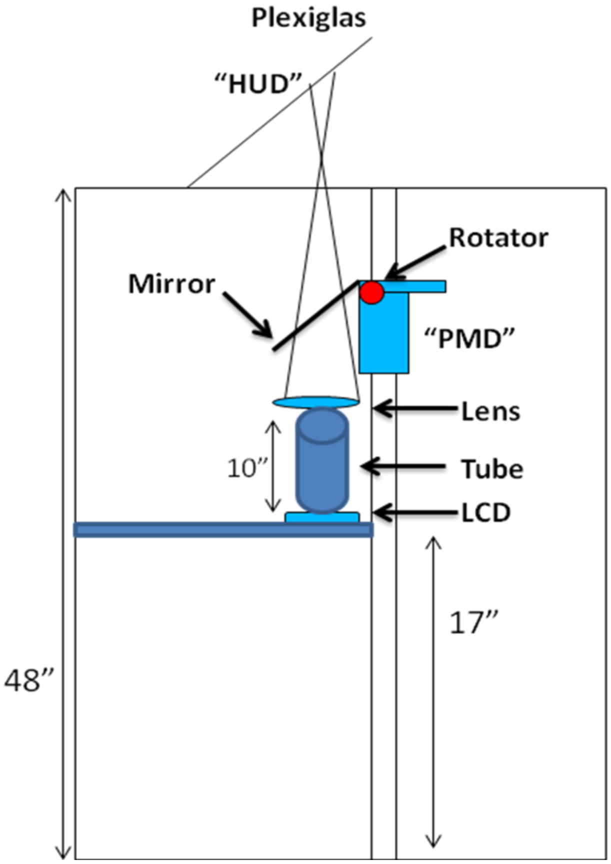

Figure 11 This figure describes the optical system.

IX. MECHANICAL DESIGN

The mechanism controlling the mirror allows the user to switch between viewing the vehicle information on the dashboard or windshield. The mechanism is made of plastic connecting pieces, which will hold the mirror and swivel. The way the mirror will stay at 45 degrees is done by having two magnets placed just right to where the device will click in place at the 45 degree angle.

The user will turn a wheel to rotate the mirror off of the magnets onto the back of the instrument cluster. The view here will be a mirror viewable by the user in place of the PMD area; therefore allowing the magnified image to pass by the mirror and appear on the windshield. The following figure shows the device.

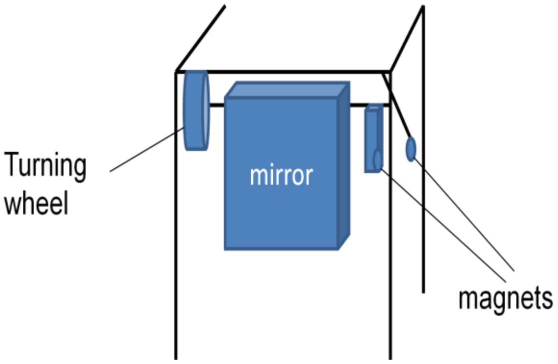

Figure 12 Mirror rotating mechanism.

X. CONCLUSION

The team has traversed a wide gamut of all engineering disciplines throughout the course of this senior design process. Electrical, Mechanical, Optical and software engineering were all needed to realize the vision we first developed. We spent a lot of time learning about each part required for our design, how to put it all together and how we plan to test it. The design is very large and will give us numerous amount of practice for the real world.

Choosing the right microcontrollers is a key factor for a large design. Utilizing a multiple microcontroller design allowed as to keep the project moving as well as avoid cross programming issues between different users. The controllers cannot mess up or fail. So thorough testing was done to prevent any system failures.

Meeting our objective and goals was important to us, We do expect to reach all of our goals, such as changing the instrument cluster into a HUD digital display unit and also having the center console being a touch screen display to control various features. The things we could have enjoyed were to actually create a handmade touch screen or even a handmade HUD system, but that seems too extreme for the time given. Our project doesn't leave us bored—not at all; it is quite extensive with a lot of fun and interesting things to create.

A few improvements to the design could be establishing the system in a real car. Unfortunately the cost is too high for our group. Also, we could have designed our system with sound. And maybe we could have added a real talking GPS system, but the compass sufficed for the demonstration.

One that we could have done differently was instead of having a collection of MCU talking together would be to have a full computer system inside. Lots of simulation projects use full computer systems, but we wanted to design our own communication and MCU's.

Another thing is that we could have done was have screens in the simulation to simulate a true a person driving experience and maybe have a steering wheel. We took different routes versus other simulation techniques. Also, meeting new people and gaining trust to collaborate on a large project is always a good thing. And since we are all new engineers, we all learn from one another and learn for the future.

What we have learned as a group is that team work, time management, accuracy, attitude and management will be the most significant aspects of our engineering career. After completing this project successfully we can conclude that we have had a piece of each of those important key features of engineering; thus giving us a real start to our upcoming lives.

ACKNOWLEDGEMENT

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BIOGRAPHIES

Chris de Guzman will be graduating from the University of Central Florida with a B.S.E.E. in December 2010. He worked at Cubic Simulations as an Electronics Technician for four years and is currently interning at Ocean Optics in Winter Park, Fl as an OEM Engineer. He plans to pursue a master's degree in business administration and obtain a PE in the future.

Jonathan Gonzalez will be graduating from the University of Central Florida in December 2010 with a B.S.E.E., after which he plans on working as a Systems Engineer. Jonathan has been employed as an intern at Lockheed Martin Missiles and Fire Control for two years where he gained valuable engineering experience.

Frank Reed Jr. will complete his B.S.C.p.E. in December 2010, from the University of Central Florida. He plans on pursuing his PhD in the electrical/computer field of engineering. He has been interested in electronics and computers for many years and plans to better the world with contributions to those fields.

Paolo F. Ronquillo will be graduating from the University of Central Florida with a B.S.E.E. in December 2010. He is currently employed by ACD Telecom in Lake Mary, Fl as a communications engineer. He plans to continue pursuing a career in the wireless communications industry after earning his degree.