

**University of Central Florida
Department of Electrical Engineering and Computer Science**



A2D

**Analog to Digital HUD Instrument Cluster with
Touch Screen Command Center**

GROUP #4

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1. Introduction

1.1 Executive Summary

The A2D HUD and touch screen command center project is centered on the future of vehicle interaction. From the way a driver communicates with the vehicle to the manner in which the vehicle relays critical information to the driver, The A2D system delivers current tech solutions to both needs. The A2D HUD is a concept that stems from navy fighter jets. It is a way to relay information to the operator without necessitating a shift of gaze from the sky, or in the case of A2D, the road.

Our particular vehicular adaptation of this technology simplifies it by opting to forgo methods that require refracting mirrors. We achieve spatial depth and perception by reflecting our HUD data off a pre treated surface within the operator's line of sight. This must be done in a manner that compliments the user's driving ability and not hamper it by being a distraction.

The HUD will display critical vehicle data such as door ajar indicators, low fuel indicators, ambient temperature as well as other common indicator lights. The touch screen command center serves the main input terminal to the vehicle; as the vehicle communicates with the driver via the HUD, the driver communicates with the vehicle via the command center. The touch screen display is able to replace traditional analog controls by using digital representations of the controls users are familiar with to facilitate an optimal transition from an analog to a digital interface.

The prototype A2D HUD and command center will be implemented on a vehicle simulator and is achieved by designing 4 different sections tethered together by a main micro controller. The 4 sections are the HUD, the touch screen, our sensor system and our main vehicle simulation. The HUD, the touch screen and the sensors all communicate using the SPI communications protocol as it is a widely utilized automotive protocol. The project will account for typical driving conditions as well as typical vehicle functions such as window control and air conditioning control.

It is the intent of our design to allow 4 independent engineers to be able to work autonomously from one another by implementing 4 sections with 4 separate MCU's in order to both save time and avoid other potential pit falls of too many people working on the same aspect of the project. It is a design strategy that will create some specialization, however through careful planning and communication each engineer will be completely competent on the functions that they are not assigned to work on.

It is the intent of the A2D system to provide a peek into the future of automotive interaction. Careful consideration has been placed upon safety of use, cost effectiveness and real world viability. Although vehicular applications of this

technology is currently limited, we hope to someday see it as commonplace as power windows and car stereos.

1.2 Motivation

In our group we all fancy the digital world. Since most cars today still use analog dashboards we would like a change. So we are determined to customize the dashboard of a car to fit our digital needs. This provides a way to read your instrument cluster as easy as possible.

Also being engineers, we love numbers. So why not have everything on an instrument cluster be digital numbers and no knobs on the center console? They are easier to read and we can customize the layout all we want. And we all hate when an analog gauge goes out and we cannot read our speed or something very important, so this system will not have any problems like that.

Today a lot of touch screen devices are coming out and we are accustomed to them. Why not have it control our stereo, a/c or even our locks and windows? So we want a touch screen device for our center control system. Also, something goes out on a regular center console, it's so hard to replace. The touch screen should never go bad but if it does, you can just install another one easily.

Another big motivation for a project like this is that we chose a big project, which means lots of learning and things to do. Each member will be able to solder, program, construct and learn off of our full system. There will be an immense amount of teamwork and a good knowledge of what's in the real world.

1.3 Objectives and Goals

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.

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.

1.4 Requirement Specifications

Table 1 below represents our requirements and how they will be met.

Requirement	Requirement Deliverability
The production cost shall not exceed \$1000.00.	We shall purchase items from junk yards, try hard to get samples, and be caution when constructing to not damage parts.
The system shall be mobile and yet fully simulate the inside of a car’s dashboard.	We shall build the box 48” wide, which is suitable for a full dashboard and shall install wheels at the base.

Table 1 Requirement Specifications

Table 2 below represents our requirements and how they will be met.

Requirement	Requirement Deliverability
The system shall have the user interact with it in order to operate.	We shall design each user interaction device to activate something specifically on the display.
The system shall be able to close and clock when needed.	We shall build doors that open the box and a locking mechanism.
The system shall be ventilated and shall not let parts exceed maximum temperature.	We shall install fans to ventilate the inside of the box.
The HUD shall have a 160 degree viewing angle.	We shall build the correct device that meets this requirement.
The HUD shall utilize the RGB standard.	We shall purchase the correct device that meets this requirement.
The HUD shall display in USA format.	We shall purchase the correct device that meets this requirement.
The HUD shall have clear visibility in all lighting conditions.	We shall design the HUD to a way that meets this requirement.
The system's parts shall be powered by a car's 12v power supply.	We shall use a 12v battery and use a regulator to bring the needed voltages to each MCU.
The HUD shall have accuracy of or below 0.5%.	We shall design the chip and communication to work fast and accurate.
The HUD shall operate between -20 and 70 degrees Celsius at 95% humidity.	We shall purchase the correct device that meets this requirement.
The HUD start up time shall be within 10ms of when it receives power.	We shall purchase the correct device that meets this requirement.
The touch screen shall have a minimum of 170 degree viewing angle.	We shall purchase the correct device that meets this requirement.
The touch screen shall have a minimum of 640x480 pixel resolution.	We shall purchase the correct device that meets this requirement.
The touch screen display shall be visible in all light conditions.	We shall purchase the correct device that meets this requirement.
The touch screen shall execute all features within 100ms of user input.	We shall purchase the correct device that meets this requirement.

Table 2 Requirement Specifications

Table 3 below represents our requirements and how they will be met.

Requirements	Requirement Deliverability
The touch screen shall serve as a display for a rear mounted backup camera when the vehicle is placed in reverse.	We shall design the controller to interact with the transmission and the camera to display on command to the touch screen display.
The touch screen shall have a boot up time of less than 3s.	We shall purchase the correct device that meets this requirement.
The touch screen shall employ a graphical user interface.	We shall purchase the correct device that meets this requirement.
The sensor system shall respond to main system within 100ms.	We shall design the MCU and communication bus to operate fast and accurate.
The sensor system shall be low powered and efficient.	We shall purchase the correct device that meets this requirement.
The sensor system shall be quick responding and accurate.	We shall purchase the correct device that meets this requirement.

Table 3 Requirement Specification

2. Research

2.1 HUD Research

HUDs, or Head-up display technology has been implemented in electronic systems since its creation in the 1960's. Since their inception, the heads up display has sought to present the user with useful information in a way that does not require the user to deviate their eyesight from their usual viewpoint. As the name suggests, this technology allows to the user to simultaneously acquire crucial information and remain focused on their task. On a more literal level, as the image below shows, the user is able to keep his 'head up,' rather than looking downwards where most information displays are conventionally located.



Figure 1:HUD on a BMW 7 Series
Source: wikipedia.org : Heads up Display

In present day, heads up display systems can be found in the majority of fighter aircraft, including helicopters, and are even integrated into many commercial airlines. The systems were first integrated into automobiles by General Motors in 1988 (the Oldsmobile Cutlass Supreme being the first), and continue to be integrated into higher end vehicles, with the exception of GM vehicles. Similar to the systems in aviation, automotive heads up displays have been praised for decreasing driver distraction by providing the driver with all the critical information he needs directly in his line of sight.

2.1.1 Current Usage

Though heads up displays have been extremely successful in aircraft application, it has yet to reach the same status in automobiles. Due mostly to the cost associated with these automotive systems, HUD are found mostly in higher end vehicles, such as BMW's and Mercedes, though the American General Motors company has continued to offer these systems in some mid-priced vehicles. And even with automotive HUD systems costing upwards of \$1500 extra to install on the vehicles, the amount of data displayed has generally been limited to a few pieces of vital information; namely the current speed of the vehicle, the current transmission gear, and radio station information on some vehicles.

The use of heads up displays have now spread to commercial airline cockpits, but the majority of HUDs today remains in the cockpits of fighter aircraft. As shown in the photograph below, these displays show vital flight and combat information, so that the pilot can focus on controlling and manipulating the planes numerous systems. In the aircraft industry, the HUD projectors have been positioned in two ways: above the pilots head, and somewhere in the instrumentation cluster, projecting the image upwards (like the automotive CRT). Though both have proven effective, commercial aircraft have been known to employ over the head HUDs, while combat aircraft have maintained HUD placement below the combiner surface. Due to size and positioning constraints, automotive HUDs basically must be placed within the dashboard enclosure. Placement of the HUD unit in our project is a critical decision, due to space limitations.

2.1.1.1 Night Vision

Additionally, luxury automakers have led the way in developing night vision systems, which uses the HUD system to display the night vision image. These night vision systems, traditionally more expensive to integrate into vehicles than standard HUD's, have proven to be effective and well liked by customers. The main goal of these systems is to provide an enhanced image of the road to the driver, typically providing benefits in both seeing distance and clarity. The heads up display is not the only method which automakers have presented the night vision image, but it has proven to be the most popular due to the convenience of having the image directly on the windshield.

2.1.1.2 Automotive Application

General Motors made automotive history in 1988 when it was the first company to offer an automotive heads up display (it was offered on 50 exclusive Oldsmobile Cutlass Supreme Indy Pace Car Special Edition vehicles). The technology was not particularly embraced, and though GM continued to offer it on select vehicles, it never became widely popular.

German luxury automakers, BMW and Mercedes-Benz are known for being at the forefront of technology, and their involvement with HUD's is no exception.

2.1.1.3 Underlying Tech

According to the "Digital Avionics Handbook," written by Cary Spitzer, a typical heads up display unit consists of three components: a combiner, a projector, and a computer. The computer serves as the brain of the system, effectively generating the image which is sent to the projector unit. The projector shines the image onto the combiner, the medium on which the image is seen by the user. Projection units can be located above or below the computer, though in automobiles they have been integrated into the dashboard, projecting light upwards onto the windshield. The 'combiner' unit, for the purpose of vehicles, is almost always the windshield, directly in front of the operator of the vehicle. Depending on the vehicle and the angle at which the user is viewing the image from, variations in HUD components are necessary to produce images the user can clearly see and utilize to their advantage. Such variations include curved 'combiner' surfaces, multiple mirrors in between the projector unit and the combiner, and different types of light emitting technology.

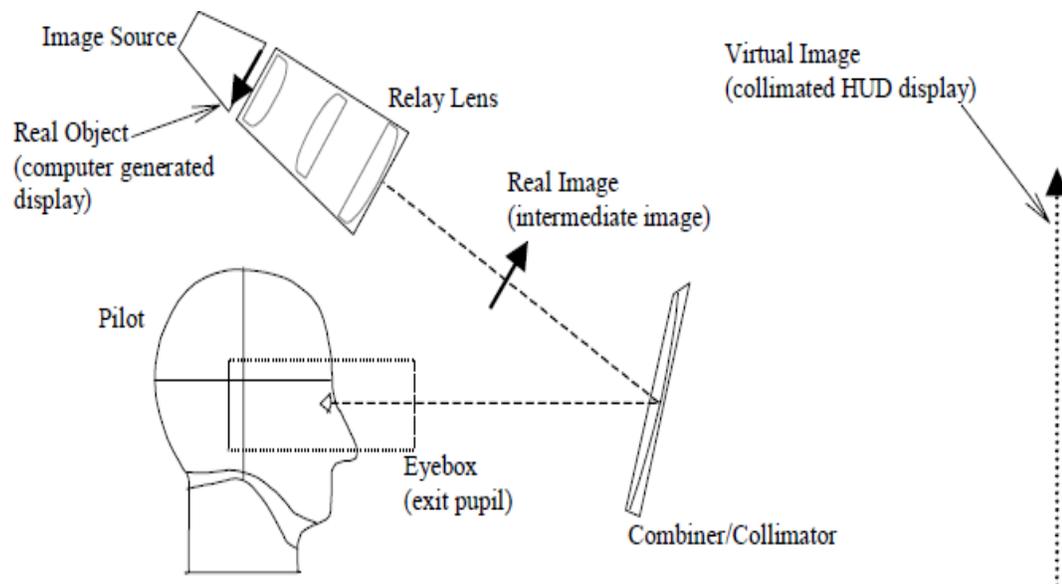


Figure 2:HUD Optical System

Permission pending from Robert D. Brown, Rockwell Collins Flight Dynamics

2.1.1.4 Computer

Heads up display computer components, particularly in automobiles and aircraft, receive vast amounts of information from the vehicle's sensors, perform calculations and conversions, and then relay data to the projector to be displayed in a graphical form. Because their main function is processing and computing, they must be able to handle large amounts of data constantly being fed in from the vehicle. These computers are usually dual independent redundant systems, and are integrated with aircraft systems so as to allow connectivity onto various data buses.

2.1.1.5 Combiner

The combiner, in the context of this project, is the glass onto which the image is reflected on. Due to the fact that the glass is transparent, measures must be taken to reduce the negative effects of certain factors like sunlight and water. Vehicles with HUD systems usually have special windshields that allow the image to be reflected effectively. Rugate coating, for example, is a common technique used, especially in avionics HUDs, to make the HUD image particularly easy to see. A thin film coating, applied to the combiner surface, reflects the HUD data, while simultaneously allowing a clear view through the combiner to the outside world. According to research conducted by Thales Optical, this technique of reflecting HUD light off a special coating:

- only reflects CRT wavelengths
- has a high photopic transmission
- weighs approximately half that of equivalent holographic combiners
- is extremely rugged, environmentally and temperature stable coating
- is low cost
- does not suffer from 'flare' images

The following chart demonstrates how particular wavelengths are transmitted.

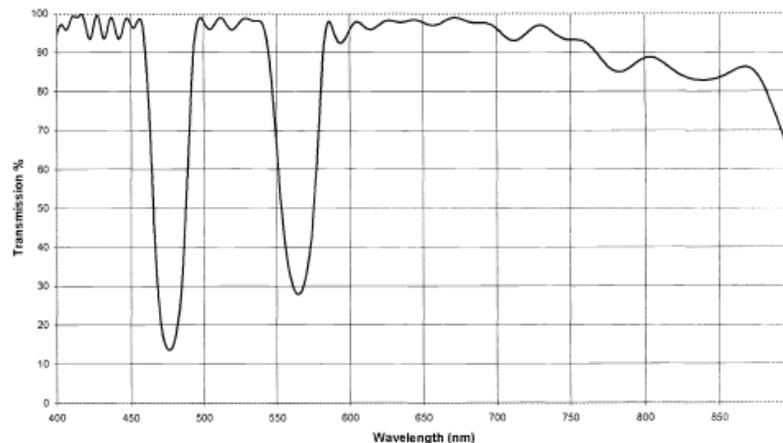


Figure 3: Certain wavelengths are transmitted
Permission pending from Thales Optics

2.1.1.6 Projector

There have been three utilized light sources used for projection in HUDs: CRT, LCD, and laser/waveguide technology. CRT, or Cathode Ray Tube technology is still the predominant projection type found in HUDs today, though advances are being made to implement more efficient technology. An interesting fact is that an LCD based projector uses the same HUD optics (combiner and relay lens) as the CRT, but typically consists of liquid crystal micro displays, a rear projection unit, an illuminator, a digital LCD drive board, low voltage power supply and lamp ballast. LCD displays are essentially area array light switches and require an external source of linear polarized light. These may be back-lit or front-lit, depending upon their application. The type of backlight utilized in HUD has been a source of debate amongst engineers.

The HUD projector is by far the largest component of the HUD system. And because of its size, it is typically set deep into automobile's dashboard. Precisely curved mirrors are then used to bend and reflect the image produced by the projector onto the combiner, above. The science and engineering behind the mirrors and their curvature are essential to producing the clearest HUD image and are implemented in higher end projectors such as the one seen below.



Figure 4:A CRT projector

Permission pending from Robert D. Brown, Rockwell Collins Flight Dynamics

2.1.1.7 Reflective HUD

Reflective HUDs do as their name suggests, reflect light off a surface. This type of system may use a beam splitter element, or may inject the light at a small angle to reflect it through a projection optic to form the image.

There are various LCD devices which can be used with this configuration. Spatial light modulators are the most common. A liquid crystal layer is built over

a mirror and when the liquid transmits, the cell reflects as demonstrated in the following diagram.

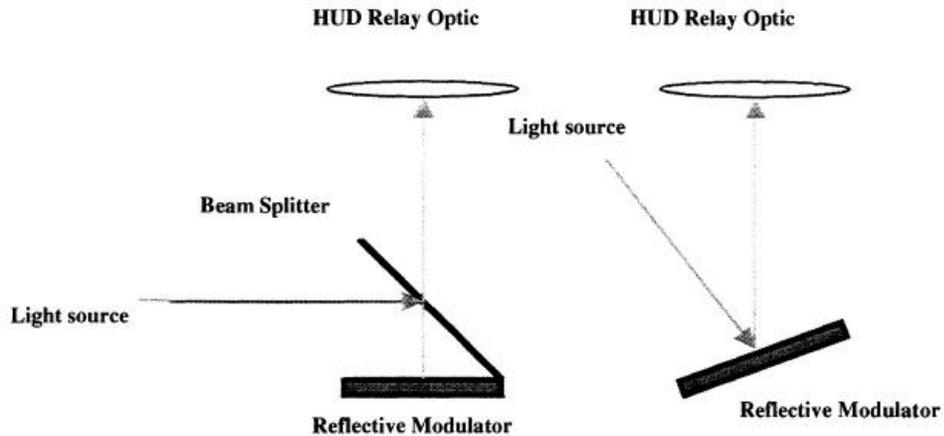


Figure 5: Reflective system schematic
 Permission pending from Christopher T. Bartlett, BAE Systems

With a mirror, linear polarized light will be transmitted to the LCD, which then modulates the light intensity by manipulating the polarization of the light reflected off each pixel, which goes to the polarizing mirror to be analyzed. This mirror reflects light polarization rotated perpendicular to the input and projects it into the relay optic.

2.1.1.8 Transmissive HUD

Transmissive HUDs essentially implement a powerful backlight placed behind a transmissive LCD coupled to an optical relay.

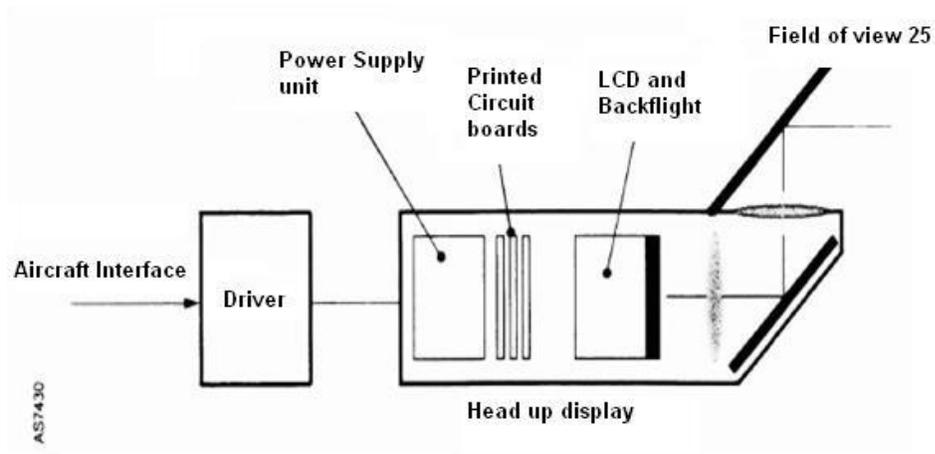


Figure 6: Figure scheme of the LCD HUD
 Permission pending from BAE Systems

For this design, a monochrome LCD with no color filters is necessary. The transmission of these displays are about 20%, and are by no means uniform.

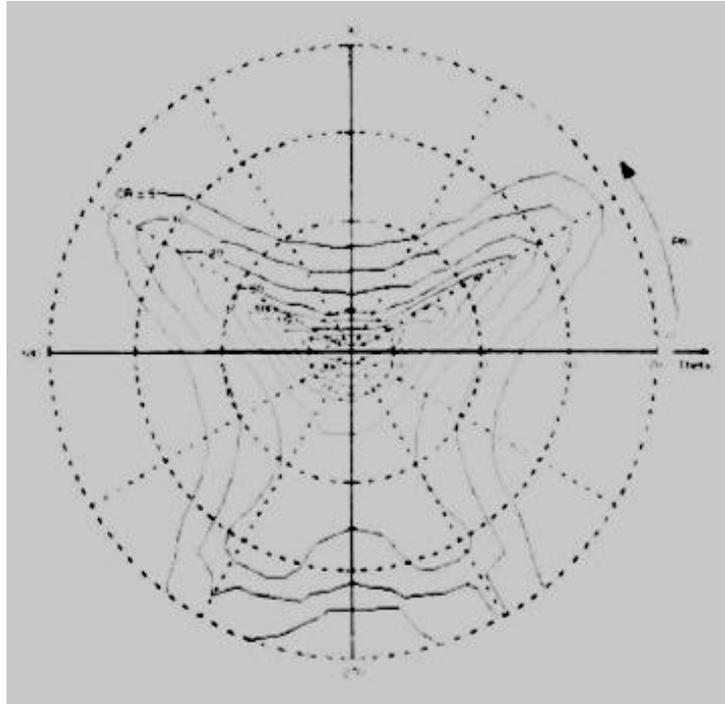


Figure 7: Polar plot of a typical LCD
Permission pending from BAE Systems

In an ideal system, the light should not diverge more than a few degrees. For this setup, the two backlights that offer the best solution are the LED matrix and RF light. The LED has proven to yield the best results, while using standard green LEDs in a matrix. Fifty to one hundred LEDs are needed to adequately illuminate the LCD, with one of the major issues being divergence. To combat this, the lamp should be positioned far back to allow special optics to be inserted.

2.1.2 Cost and Other Limitations

Perhaps the biggest factor hampering widespread automotive adoption of heads up technology is the cost associated integration into everyday vehicles. Though cost is not a major concern with military application of these systems, in the consumer world, cost is often the prime deciding factor for potential customers. And though HUD technology is convenient and has been proven to be safer than conventional information systems, automakers have yet to find cost effective ways of incorporating them into non-luxury models. When considering the cost of these systems it is important to consider each component separately, as prices for each component may differ greatly.

Engineering concerns include the physical size of the computer and the projector, and its placement within the vehicle for optimal viewing angle. While this has remained a major concern for engineers, powering HUD systems is also a source of concern. HUDs, particularly CRT based HUDs, are notorious for using considerable amounts of energy.

2.1.3 Advanced HUD Concepts

As the next generations of electric and hybrid vehicles are developed, vehicle systems will become more sophisticated as well. Since one of the chief concerns of electric vehicles remains to be the weight of the vehicle, automakers will naturally strive to reduce weight in all possible vehicle systems. Naturally, HUD breakthroughs could provide a lighter alternative to conventional instrument clusters. The Holographic Optical Waveguide is one such example of a future technology which may eventually be employed in HUD systems. BAE electronics has been in development of the Holographic Optical Waveguide, a revolutionary new optical technology which dramatically reduces size and mass. This technology is basically a way of moving light without the need for a complex arrangement of conventional lenses. This is made possible by embedding within the substrate a specially designed hologram which has carefully tailored set of optical properties. The image (or light waves) is constrained to follow a path through the substrate. As these waves pass through the substrate, the hologram is programmed to allow some energy to escape in a carefully controlled manner reforming the image that was injected into the substrate. At the same time the hologram design modifies the image geometry such that the user views it as a full size conformal image precisely overlaid on his outside world view. Furthermore this image is maintained over a very large exit-pupil giving the user great flexibility in the installation of the display.

2.2 Touch Screen Research

2.2.1 Touch Screens

The most prevalent touch screen technologies today are resistive touch screens and capacitive touch screens. Most applications that closely resemble the A2D touch screen interface would more than likely choose to utilize the more graphically appealing capacitive technology.

While resistive technology touch screens do not have as sharp of a picture, they are however, the most accessible and available of all the existing technologies. Their availability as well as the maturity of the technology ensures a wide variety of available controllers and other assorted components.

For the touch screen command center, since it is meant to be an automotive application, the GUI interface as well as the size of the screen must be conducive to operation while driving a vehicle. With this in mind, both the size and sensitivity of the equipment become compelling factors when choosing components. Other

important characteristics are those dealing with how the selected parts interact with the rest of the system. The communications protocol of the devices must all be compatible with all other portions of the project. Other than communications the way the parts impact the systems power system also plays a critical role meaning that the power requirements of each component must be closely scrutinized.

The aforementioned touch screen technologies all have their strong and weak points when taken in reference to our project. First, capacitive touch screens offer the most visibility outdoors which is important to us as the screen will be operating in daylight 50% of the time. This technology also boasts higher image resolution as well as having high sensitivity. However, these come at the cost of a higher price tag than a comparable resistive unit as well as being more susceptible to the elements. Resistive screens on the other hand offer us size which makes interacting with the unit much easier while driving.

When considering parts we decided to confine ourselves to the 2 most common and available technologies as it would make it easier to make deadlines and milestones as well as having a larger resource of information that is associated with a mature technology.

That being said, we considered several models with varying sizes, touch tech as well as prices and appearances during the course of our product research. Keeping in mind the criteria discussed here and in the design specifications we took each part and put them up against our initial specs of what we thought we needed

2.2.1.1 Capacitive Touch Screens

The Capacitive screens below were considered for their size, availability, power rating as well as their communications protocols and their maximum resolution.

The 3M5520-ND is a capacitive touch screen and its performance measured by accuracy, resolution and light transmission can be found below.

System Performance	
Light Transmission	91.50%
Input Method	finger touch
Accuracy	>99% of true position
Resolution	1024X1024
Linearization	Factory linearized
Tail Connection	solderless design

Table 4 Performance Specs for 3M5520-ND

This next table deals with the touch screen's power consumption as well as the communications protocols which it employs

Electronics	
Communication	USB, Serial, USB HID Digitizer
Dimensions	8inch diagonal
Operating Current	USB:75mA Serial 85mA
Sleep Current	<500uA
Power Connection	USB: 5Vdc @ 75mA Serial: 5-12Vdc @ 85mA
Connectors	5-pin locking AMP (touch section) 5-pin Molex (COM side)
ESD	8KV contact, 27KV air
Point Speed	200pps
Minimum Touch Time	5.4ms
MTBF	>700,000 hours

Table 5 Electronics Specifications

The dimensions of the entire screen as well as the dimensions of its actual operating area are illustrated in the diagram below. We noted that the size of the screen was acceptable. The 3M5520-ND is available on digikey.com for \$108.00 and it is available now.

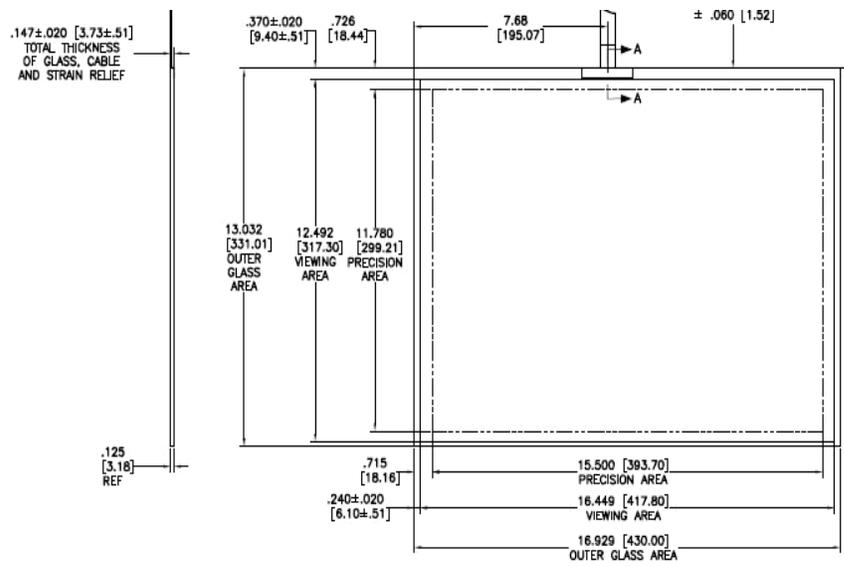


Figure 8: Screen dimensions
Permission pending from Berquist Electronics.

The 3M5522-ND is another capacitive screen from 3M. Like before we determined what its electronic and physical parameters were in order to determine if the part was right for us. It is a 12 inch capacitive touch screen making it much larger than the previously discussed 3M screen. Its system performance is outlined in the table below.

System Performance	
Light Transmission	91.50%
Input Method	finger touch
Accuracy	>99% of true position
Resolution	1024X1024
Linearization	Factory linearized
Tail Connection	solderless design

Table 6 3M5522-ND System Performance

As with the previous model, the 3M522-ND electronic components and power needs are outlined in the table below.

Electronics	
Communication	USB, Serial, USB HID Digitizer
Dimensions	12 inch diagonal
Operating Current	USB:75mA Serial 85mA
Sleep Current	<500uA
Power Connection	USB: 5Vdc @ 75mA Serial: 5-12Vdc @ 85mA
Connectors	5-pin locking AMP (touch section) 5-pin Molex (COM side)
ESD	8KV contact, 27KV air
Point Speed	200pps
Minimum Touch Time	5.4ms
MTBF	>700,000 hours

Table 7 3M5522-ND Electronics

As far as integration into the A2D command center the real challenge is in interfacing using USB which none of A2D's members are fully knowledgeable in. That considered we consider the touch screen's size to be a great asset. The screen's dimensions are shown in the figure below.

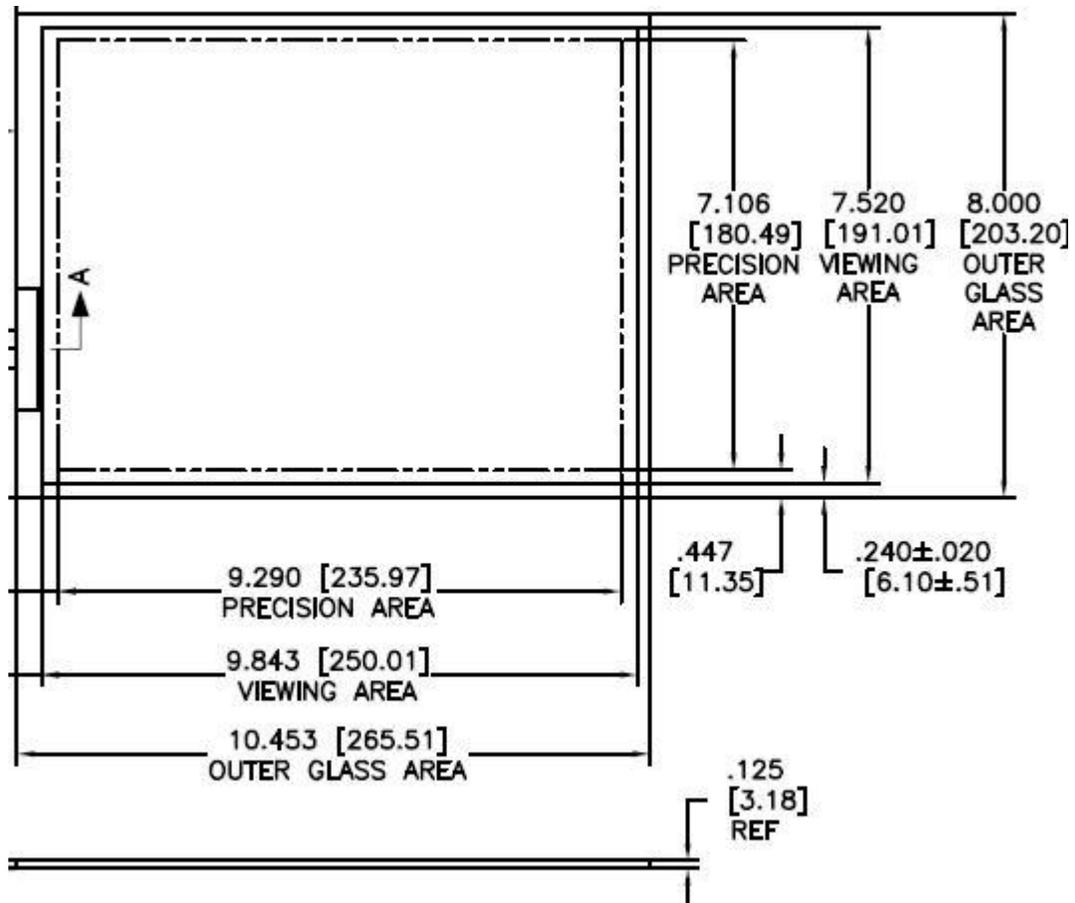


Figure 9:12inch 3M is proportional to its 8 inch counterpart
 Permission pending from Berquist Electronics

It is important to note that when considering these screens as the potential main user input, that controllers are often packaged with the screen making them almost proprietary rather than interchangeable and adaptive to other manufacturers.

The face of the screen is glass making it more susceptible to cracks and scratches. Though capacitive screens are more susceptible to outside elements, it is ultimately its cost and complexity that makes it an ill fit for our particular project. We find that due to the availability and cost of resistive screens that it is a much better choice as the A2D command center touch screen.

There is however more than one type of resistive touch screen. The 4 wire and the 5 wire variants all have their strong and weak point naturally and all of those will be discussed in the sections to follow. Resistive screens though are, in general, more resistant to outside elements at the cost of course of a lower screen resolution. The 3M5522-ND is available now and costs \$170.00

2.2.1.2 5-Wire Resistive touch Screen

The 5 wire resistive touch screen is quite similar to its 4 wire cousin. In considering this technology for our project the main task was to determine whether or not the increase in durability and functionality was great enough that it justified the leap from the 4 wire tech. Durability aside, other factors considered were again, cost and availability. Although these screens are cheaper than capacitive screens they are still more expensive than 4-wire screens and, as was said before, therein laid the challenge of determining whether or not we were getting marginal returns on our investment.

The first 5-Wire considered is the BER251-ND from Bergquist; an 8 inch diagonal viewing area model. This screen is appealing because of its availability and its common interface options make integration into the system less of a challenge.

This particular model is a screen only therefore we must consider the housing it will sit in for both protection as well as aesthetic purposes. Its screen dimensions and physical size are shown in the following figure.

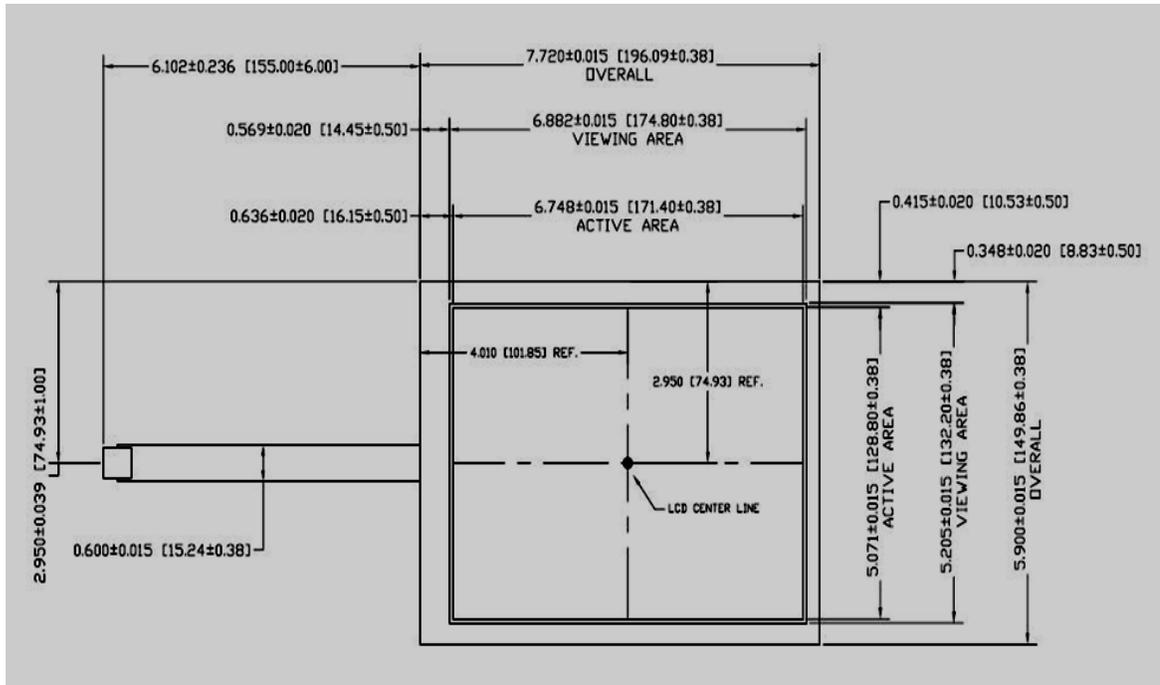


Figure 10: Viewing and Active area of screen
Permission pending from Berquist Electronics

The screens dimensions are within the limitations set forth in our spec sheet. The screens environmental operating range are show in the table below.

	Specification	Remarks
Operating Temperature	-10° C ~ +70° C	
Storage Temperature	-40° C ~ +80° C	
Constant Temperature/ Humidity	70° C/ 80% RH/ 500 Hrs.	Tested at ambient temperature after cycle
Thermal Shock	-40° C ~ +80° C 60 min/cycle/100 times	Tested at ambient temperature after cycle
Chemical Resistance	Acetone, methylene chloride, methyl ethyl ketone, isopropyl alcohol, mineral spirits, unleaded gasoline, diesel fuel, antifreeze, vinegar, coffee, tea, cooking oil, most commercial cleaners including laundry detergent, and ammonia based glass cleaners	10 minutes at room temperature

The screen's durability as well as its electrical operating range are shown in the following tables

Durability

	Specification	Remarks
Activations	35 Million	
Activation Force	≤50g Stylus	
Top Film Hardness	3H	ASTM D3363
Tail Bond Strength	>13 lbs	Straight Tail Pull

Electrical Specifications

	Specification	Remarks
Operating Voltage	5.5V or Less	
Insulation Resistance	≥ 20 MΩ at 25 V(DC)	
Electrostatic Protection	20 discharges at 15Kv	EN 61000-4-2

Table 8 BER251-ND durability and electrical specifications

The BER251-ND from Bergquist is available now from Digi-Key for \$52.50

The next 5-wire model considered is the Bergquist BER248-ND. After much time on Digi-Key we learned that this particular brand was very widely used in many controller and micro controller sample designs leading us to believe that it compatibility would not be an issue and that system integration support resources would be plentiful. This particular model was a 12 inch model which is highly desirable in our application because it makes interacting with it while driving much easier. The screen's dimensions are shown below.

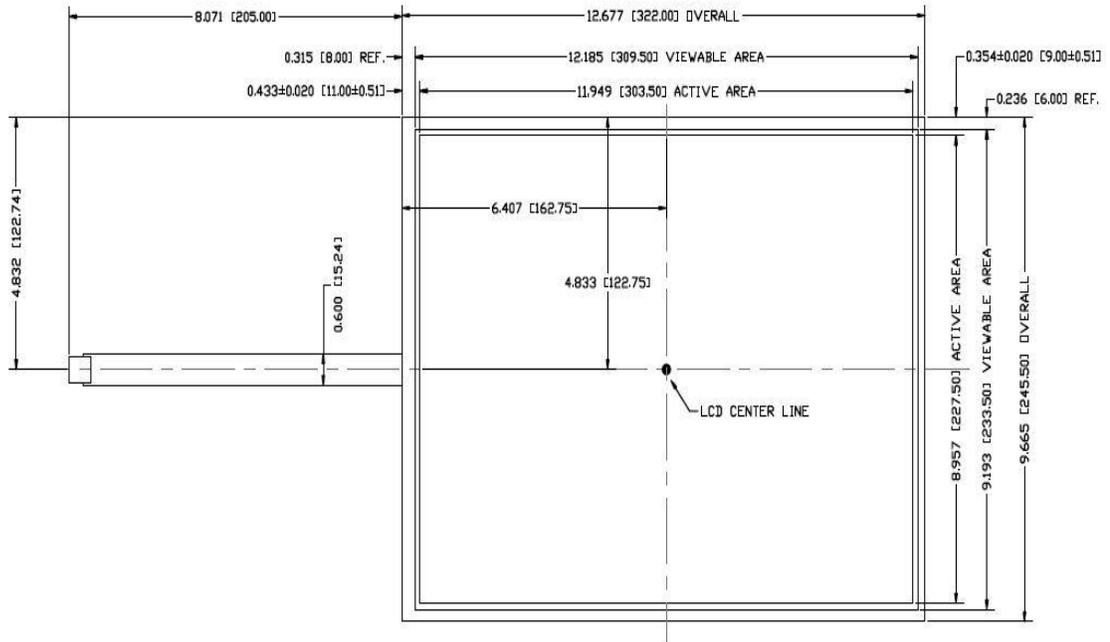


Figure 11: The Bergquist BER248-ND touch screen
 Permission pending from Berquist Electronics

Other than the dimensions being within our specifications of what would fit in a car console it is important to note that this screen introduces the idea of anti-glare treatment to improve direct sunlight operating conditions and visibility in said conditions as well as the obvious reduction in glare. The touch screen's electrical and technical specifications are enumerated in the following tables:

	Specification	Remarks
Overall Dimensions	10.680" x 8.100", 271.27mm x 205.74mm	+/- .020", +/- .50mm
Overall Thickness	.087", 2.2mm	+/- .008", +/- .20mm
Viewable Area	9.956" x 7.535", 252.87mm x 191.40mm	+/- .020", +/- .50mm
Active Area	9.798" x 7.378", 248.87mm x 187.40mm	+/- .020", +/- .50mm
Nominal Glass Thickness	.073", 1.85mm	

Table 9 BER248-ND dimensions

The screen's environmental operating range is as follows.

	Specification	Remarks
Operating Temperature	-10° C ~ +70° C	
Storage Temperature	-40° C ~ +80° C	
Constant Temperature/ Humidity	70° C/ 80% RH/ 500 Hrs.	Tested at ambient temperature after cycle
Thermal Shock	-40° C ~ +80° C 60 min/cycle/100 times	Tested at ambient temperature after cycle
Chemical Resistance	Acetone, methylene chloride, methyl ethyl ketone, isopropyl alcohol, mineral spirits, unleaded gasoline, diesel fuel, antifreeze, vinegar, coffee, tea, cooking oil, most commercial cleaners including laundry detergent, and ammonia based glass cleaners	10 minutes at room temperature

Table 10 BER248-ND environmental operating range

The screens durability and electrical operating range are shown below

Durability

	Specification	Remarks
Activations	35 Million	
Activation Force	≤50g Stylus	
Top Film Hardness	3H	ASTM D3363
Tail Bond Strength	>13 lbs	Straight Tail Pull

Electrical Specifications

	Specification	Remarks
Operating Voltage	5.5V or Less	
Insulation Resistance	≥ 20 MΩ at 25 V(DC)	
Electostatic Protection	20 discharges at 15Kv	EN 61000-4-2

Table 11 BER248-ND durability and electrical operating range

The touch screens power consumption and operating range fall safely within the specifications and therefore passes our initial screening of the unit. The 5-wire technology however must perform much better than 4-wire to justify its higher price tag and scarcer availability. Similarly sized 4-wire options are evaluated in the following section to gauge its performance vs. like sized 5 wire screens. The BER248-ND is available now and costs \$87.00

The main difference we found between these two similar technologies is the 5-wire is touted as being more resistant to outside forces such as the environment or rough day to day handling i.e. .with a finger. Since this is a unit which is the main input into the system, this is a major selling point for us and something we wished to investigate further. That said, the durability criteria is something added to the analysis of the 4-wire resistive models. The first 4-wire model we researched was the BER278-ND and it was to be directly compared to the 8 inch

5 wire model. As with other models the touch screen has 4 wire connections and its dimensions and viewing area are also carefully outlined below.

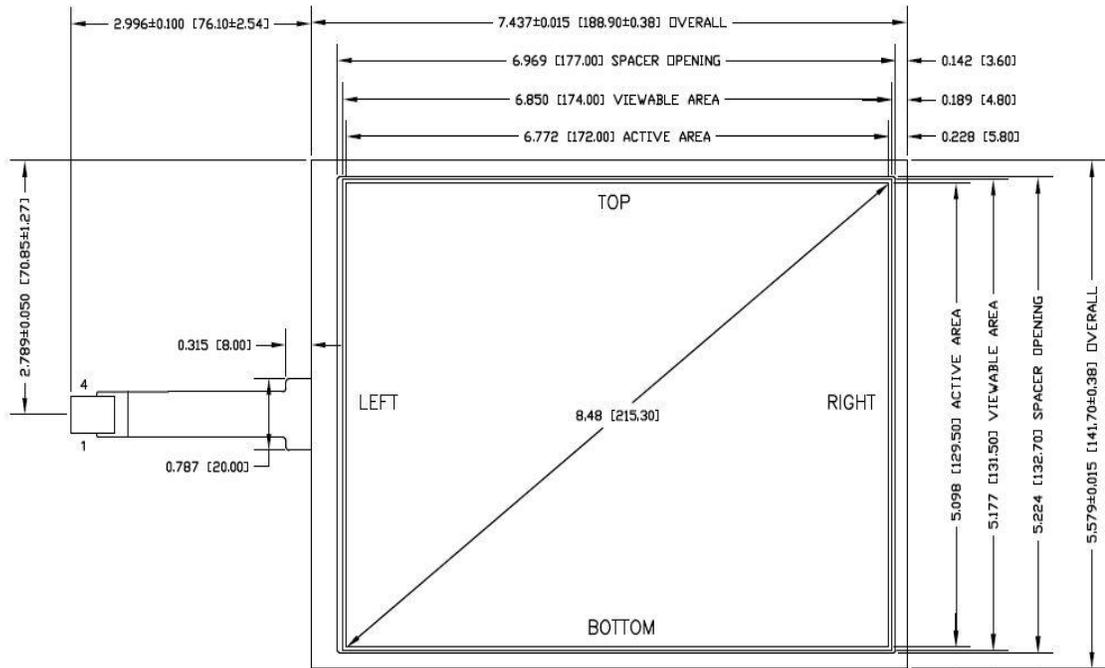


Figure 12: BER278-ND dimensions
Permission pending from Berquist Electronics

As with the other models, nothing about the physical design leads us to believe that there would be any physical limitations associated with this particular model. This models electrical and technical data are now compiled along with durability specifications to better contrast it with more expensive 5 wire models. The screen's dimensions are outlined in the following table.

Mechanical Dimensions and Construction.

	Specification	Remarks
Overall Dimensions	7.437" x 5.579", 188.90mm x 141.70mm	+/- .020", +/- .50mm
Overall Thickness	.075", 1.9mm	+/- .008", +/- .20mm
Viewable Area	6.850" x 5.177", 174.00mm x 131.50mm	+/- .020", +/- .50mm
Active Area	6.772" x 5.098", 172.00mm x 129.50mm	+/- .020", +/- .50mm
Nominal Glass Thickness	.063", 1.6mm	

Table 12 BER278-ND dimensions

The environmental operating range is shown below

Environmental Specification

	Specification	Remarks
Operating Temperature	-10° C ~ +60° C	
Storage Temperature	-40° C ~ +80° C	
Constant Temperature/ Humidity	70° C/ 80% RH/ 500 Hrs.	Tested at ambient temperature after cycle
Thermal Shock	-40° C ~ +80° C 60 min/cycle/10 times	Tested at ambient temperature after cycle
Chemical Resistance	Acetone, methylene chloride, methyl ethyl ketone, isopropyl alcohol, mineral spirits, unleaded gasoline, diesel fuel, antifreeze, vinegar, coffee, tea, cooking oil, most commercial cleaners including laundry detergent, and ammonia based glass cleaners	10 minutes at room temperature

Table 13 BER278-ND environmental operating range

The screen’s durability and electrical specifications are shown in the following tables.

Durability

	Specification	Remarks
Activations	10 Million	
Activation Force	≤82g Stylus	
Top Film Hardness	3H	ASTM D3363
Tail Bond Strength	>13 lbs	90° Tail Pull

Electrical Specifications

	Specification	Remarks
Operating Voltage	5.5V or Less	
Insulation Resistance	≥ 10 MΩ at 25 V(DC)	
Electostatic Protection	Withstands 15KV air discharge	EN 61000-4-2

Table 14 BER278-ND durability and electrical operating range

The BER278-ND is available now and costs \$50.00

The next model of 4 wire is selected to be compared to the like sized 5 wire model. It is the 12 inch Bergquist BER280-ND. What is most desirable about this screen is simply the real estate made available to the user. Screen sizes such as this make no look operations much easier and safer while operating a motor vehicle.

The touch screens physical appearance as well as detailed physical measurements are noted to determine compatibility with the proposed application. Its dimensions are seen below.

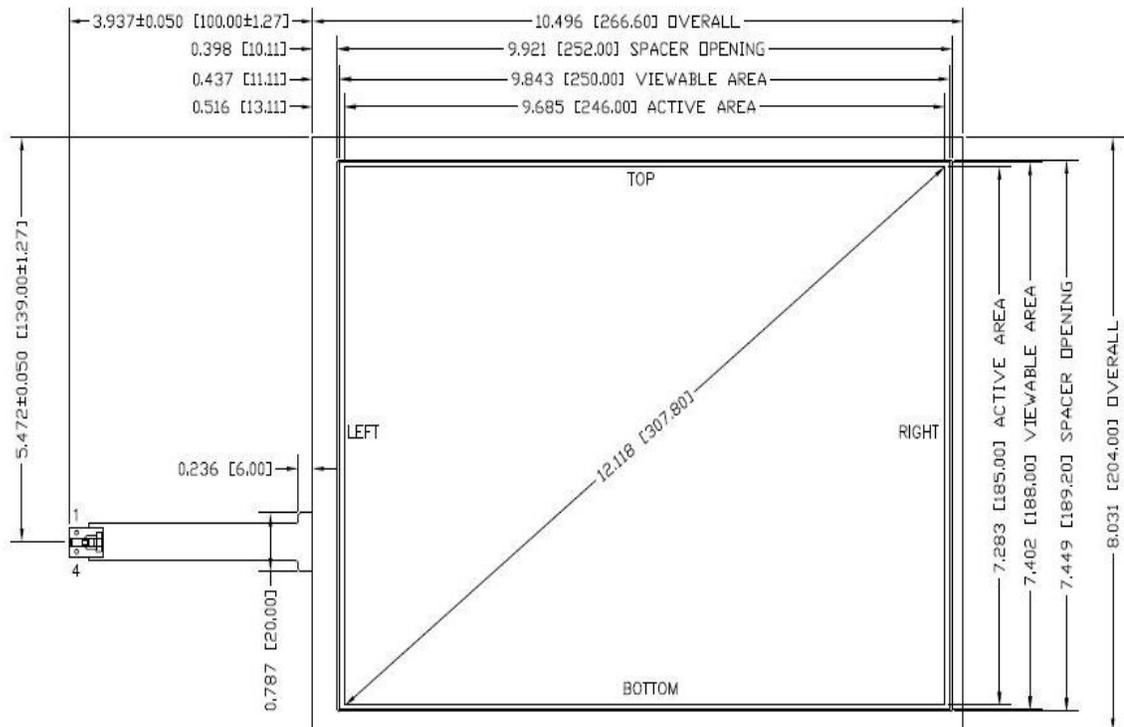


Figure 13: Dimension of the 12 inch Bergquist BER280-ND
Permission pending from Berquist Electronics

While being one of the largest screens it is still safely within the limits of a common vehicle console. Noted next are the screens technical, electronic and durability specifications as well as its optimal operating range and conditions.

Mechanical Dimensions and Construction.

	Specification	Remarks
Overall Dimensions	10.496" x 8.031", 266.60mm x 204.00mm	+/- .020", +/- .50mm
Overall Thickness	.083", 2.1mm	+/- .008", +/- .20mm
Viewable Area	9.843" x 7.402", 250.00mm x 188.00mm	+/- .020", +/- .50mm
Active Area	9.685" x 7.283", 246.00mm x 185.00mm	+/- .020", +/- .50mm
Nominal Glass Thickness	.071", 1.8mm	

Table 15 BER280-ND construction

The following table outlines the screens environmental operating range

Environmental Specification

	Specification	Remarks
Operating Temperature	-10° C ~ +60° C	
Storage Temperature	-40° C ~ +80° C	
Constant Temperature/ Humidity	70° C/ 80% RH/ 500 Hrs.	Tested at ambient temperature after cycle
Thermal Shock	-40° C ~ +80° C 60 min/cycle/10 times	Tested at ambient temperature after cycle
Chemical Resistance	Acetone, methylene chloride, methyl ethyl ketone, isopropyl alcohol, mineral spirits, unleaded gasoline, diesel fuel, antifreeze, vinegar, coffee, tea, cooking oil, most commercial cleaners including laundry detergent, and ammonia based glass cleaners	10 minutes at room temperature

Table 16 BER280-ND environmental operating range

The following tables outline the screens durability as well as its electrical operating range

Durability

	Specification	Remarks
Activations	10 Million	
Activation Force	≤82g Stylus	
Top Film Hardness	3H	ASTM D3363
Tail Bond Strength	>13 lbs	90° Tail Pull

Electrical Specifications

	Specification	Remarks
Operating Voltage	5.5V or Less	
Insulation Resistance	≥ 10 MΩ at 25 V(DC)	
Electrostatic Protection	Withstands 15KV air discharge	EN 61000-4-2

Table 17 BER280-ND durability and electrical operating range

Having considered the screens we also investigated the controllers and other parts needed to integrate the touch screen as a successful input device into our project. The two main components needed to integrate the screen into our system were the touch screen controller and a method of implementing a GUI interface onto the touch screen.

2.2.2 Touch screen Controller

When investigating the touch screen controller, the parts considered were recommended by the manufacturer of Berquist touch screens. Therefore without much hesitation it was decided that due to its inherent compatibility with a wide range of touch screens as well as an impressive array of implemented applications that group 4 would employ Burr-Brown/Texas Instruments touch screen controllers. The parts were available but more importantly available as free samples in all available pin packages.

The Burr-Brown TSC2200 is widely regarded in our research as a reliable and cost effective touch screen controller. It accurately represents the x-y coordinates of where the user touches and relays this information to the main controller for processing. The touch screen controller must perform exceptionally well in a motor vehicle application because the user will often use it without using their eyes. Touch must be accurately represented in order to perform the task that is actually desired.

As the TSC2200 is openly marketed in TI's vehicle applications catalog we are confident that its power consumption is well within the bounds of our spec sheet. The TSC2200 is available now and is also available for free sample ordering from the TI website at no cost to the group.

The 4 x and y pins are connected directly to the 4 leads of a 4 wire touch screen and determine exactly where the user has touched. This chip is therefore, obviously made to interact with a 4 wire resistive touchscreen.

2.2.3 Graphical User Interface.

The GUI is the heart and soul of any touch screen based user interface. It is the manner in which the machine will communicate to the user just exactly what portion of the screen will activate what. In order to implement a fully realized GUI we searched for and found the Amulet technologies' AGB46LV01-QC-E GUI OS chip. This particular graphics controller has a graphics library which contains enough GUI elements to create a very succinct UI while also taking load of the main micro processor because it has its own on board processor designed to do just that.

It is packaged as an 80-Pin QFP and would present a challenge to hand solder. However upon further investigation of our on campus resources it was discovered that the design lab has capabilities of soldering such a package onto a printed circuit board.

A few key features of this chip are:

- A dedicated GUI chip frees up the microprocessor
- HTML based GUI creation (drag and drop)
- Operated independent of the processor

Some Requirements include:

- It requires a 3.3V power supply
- Serial Flash memory
- Asynchronous SRAM
- A crystal/clock of up to 20MHz

2.3 Simulation Research

2.3.1 Discussion of vehicle implementation versus simulation

One part of our research is figuring out if we should use an actual car or simulate a car to represent our modifications to the dashboard. We need to look at a few features for the two ways to build our project. One important thing is cost. For college students cost may be the most influential factor unless your group has a sponsor. Availability and complication of design also play an important role in a senior design project. To compare the two options we will research the three features for each situation and decide the best result.

First off, cost. Cost is quite important because our group does not have sponsor, so we need to decide between buying a used car and simulating the inside of the car. For purchasing a used car we found out that there are many for around \$500, via craigslist.org, but this does not include any of our design purchases. These design purchases will include the microcontrollers, sensors, HUD, touch screen, and rear camera used for demonstrating our project. Now, for simulating a car we can assume we will use the same design purchases above plus the following additional things: another microcontroller to simulate the data of a car, two real instrument clusters, equipment to represent locks and windows, equipment to represent stereo and air conditioning unit, and finally something to hold it all together. Thus, if these extra design purchases come out to be significantly cheaper than buying a used car, then simulating will be considered the choice for our design. To research on parts for the simulation we ended up visiting a few pull and pay junkyards along with checking out prices for the simulation box at Home Depot. Thanks to junkyards, getting the extra equipment will be easy and cheap. For presentation ability we can build a shed type box to simulate a car like surrounding. The following table represents price comparison we've researched of simulation extra cost versus the \$500 used car purchase.

Extra Simulation purchases	
2x instrument cluster	\$25
shed box	\$100
fans	\$10
Window and locks	\$20
simulation controller and development board	\$50
LEDs	\$10
gas pedal	\$10
total	\$225

Table 18 Extra simulation purchases on top of design purchases.

As for availability, they both seem to be available right now, but which will be less of a hassle to get? For purchasing a used car off of craigslist we would have to decide whose name gets to be on the title. We would have to decide where the car will be kept. Buying a used car seems to be a big hassle. For the simulation all we need to do is pick a place to build it. The parts are accessible in many places and we can go pick out the pieces together or individually. We can build it together or also individually. Lastly, there are no legal issues putting this together. This seems to be the most logical choice.

Finally, we look at complication of design. Here we looked at how hard it is to design this in a car and how hard it is to simulate it. The biggest thing is how the car talk to its components. Cars today have many controllers to run everything but the main one is the engine control unit. This maintains various activities for the engine and its main purpose is to get the lowest emissions possible and best millage. Another important control unit is the transmission unit and this has many inputs that we need such as the vehicle speed. For our project we would need to tap into each of these controllers to gather data. This can be a very challenging and time consuming thing because none of us are car mechanics. Also, any mistakes done to the car may jeopardize the whole project. As far as simulating the project we can make our own ECU and TCU data, where we will use one controller to simulate the car's data that is being fed throughout the car, in our case through our simulator. This makes it easier to control and safer to use. Thus, the simulator is easier to use and we get to be as creative as we want when putting it together.

The choice is obvious; we will be simulating a car's dashboard for this project. We will build a shed-like box that will open and display analog instrument cluster, digital instrument cluster, windows and locks, touch screen controlling a fan and stereo, gas pedal, transmission control, rear camera and tire pressure. The simulated data and controllers will be hidden behind the presented surface, but can be displayed upon request.

2.3.2 What data is in a car and what will we simulate:

Inside a car there are many control units collecting and transferring data at all times. The data is transferred through the vehicle data bus called the CANbus. There are two main controllers in a car, the transmission control unit and the engine control unit. Looking at these control units we can figure out what is necessary to replicate for our simulation. The following table represents the input of the engine control unit.

ECU inputs			
<u>static analog inputs:</u>	<u>dynamic analog inputs:</u>	<u>static digital inputs:</u>	<u>dynamic digital inputs:</u>
v batt	engine knock	ignition switch	vehicle speed
engine temp		acc-a/c-heater-brakes-lights	camshaft speed and pos
air temp		throttle idle pos	crankshaft speed and pos
manifold abs pressure		diagnostic mode	oil pressure sensor
max air flow rate			
exhaust oxygen			
throttle position			

Table 19 ECU inputs of a normal car.

Table 20 shows the outputs of a typical ECU.

<u>ECU outputs</u>		
<u>static digital drive outputs:</u>	<u>dynamic digital driver outputs:</u>	<u>static analog outputs:</u>
fuel pump	fuel injectors	regulated voltage/current sensor
check engine light	ignition coils	dynamic analog outputs
a/c cutout relay		idle speed control servo
EGR solenoid		
purge canister solenoid		
diagnostic code readout		
fan relay		

Table 20 ECU outputs of a normal car.

The transmission control unit controls the following inputs and output.

Inputs-	Outputs-
vehicle speed sensor wheel speed sensor throttle position sensor turbine speed sensor kick down switch brake light switch traction control switches cruise control trans fluid temp sensor	shift lock shift solenoids torque converter clutch Engine control unit pressure control

Table 21 Typical transmission control unit I/Os.

Since we will not have a real car to tap into these controllers we will simulate the data using a controller with at least eight outputs. For the instrument cluster we will simulate the gas amount, vehicle speed, RPMs, engine temperature, oil pressure and mileage. The main controller will replicate the crankshaft speed for simulating the RPMs. Also it will replicate the oil pressure sensor and engine temperature sensor for simulating those two. The main controller will also replicate the vehicle speed sensor for simulating the miles per hour along with the fake gas pedal. The gas amount and mileage will be set amounts from the main controller, which will be displayed on the HUD.

2.3.3 Car data development board research:

There are several key factors when choosing a controller. Some factors include communication and I/O requirements, memory requirements, and even processing requirements. Since we are not using an operating system our memory can be carefully managed within the compiler which means we can reduce the memory and processing requirements. This leaves the communication and I/O factor to be very important.

First off, we need to determine the I/O buses. As we determine the I/O we can also make note what data will be physical and what will be simulated. The inputs of the controller will be the gas pedal, transmission buttons and touch screen controller, which are all physical. There are six virtual outputs going to the HUD controller from the car data controller, they are the gas amount, speed, RPMs, mileage, oil pressure and engine temperature. We need at least a controller with 3 inputs and 6 outputs.

What we will do next is find a development board to practice on. This will help us decide what chip best fits our requirements for the car data controller. Also, it will help on deciding how it will communicate and what kind of memory we need.

We know that this controller talks to the HUD controller, but we need to determine if we want the communication to be analog, serial, Ethernet, parallel data buses, shared memory, or some other kind of bus. If we choose serial, parallel, or memory mapped we can lump the I/O together in the same bus, for example all six of the outputs to the HUD controller are one bus. This will affect the minimum of required I/O ports needed for this controller.

Now that we have an idea about the I/O ports, we can start to think about which processor and compiler we need for this function. A good idea is to use a freeware compiler to program on, such as a C compiler. Two specific development boards come to mind when regarding freeware compiler, the ARM and the PIC. The Arduino board has an AVR processor in it and uses a wire base language to program it. As far as programming the architecture of the board, freeware would be a better choice, since have experience using the language. There are other ways to program the chip on many boards and most companies give software to help microcontroller programmers.

Below are three development boards in discussion about what specific features they have. Choosing the cheapest to learn from is probably the key factor of choosing one, since it will not be in our final design. Of course it will meet the requirements, the three were chosen based on that.

ARM development board

Let's get into some development boards for the ARM processor. One board called NXP LPC2468 Development Board with arm7 chip has some really good features. Its data sheet describes the board is ideal for multi-purpose communication applications. It has very fast processing speeds up to 72MHz, which is most likely more than enough.

As you can see the board is fully capable of handling our design. There is another good feature about this board and that is the JTAG interface that the ARM supports. This means you can use the program LabVIEW, which can port LabVIEW software right onto the ARM chip. The LabVIEW guide, I found online, talks about the basic steps to design on an ARM chip, they are as follows:

“A general process for incorporating a new ARM target follows these basic steps:
Porting the RTX Real-Time Kernel
Integrating the Real-Time Agent module for debugging
Creating the target in LabVIEW and incorporating the Keil toolchain
Developing peripheral and I/O drivers”
(LabVIEW Embedded for ARM Porting Guide)

The tutorial continues with specific steps taken to incorporate an evaluation board along with a guideline for each process that applies to any target. The cost for the LPC 2468 is \$105.00 including shipping from eBay.

PIC Development board

The USB development board, PIC18F4550, offers a quick and easy way to program the chip. It offers software to where the user can program in C for the compiler. The Microchip ICD2 feature allows a lot of flexibility and the infinite amount of resources because of the C programming. This board has a whopping 35 I/O's available for use, using the standard IDCC connections.

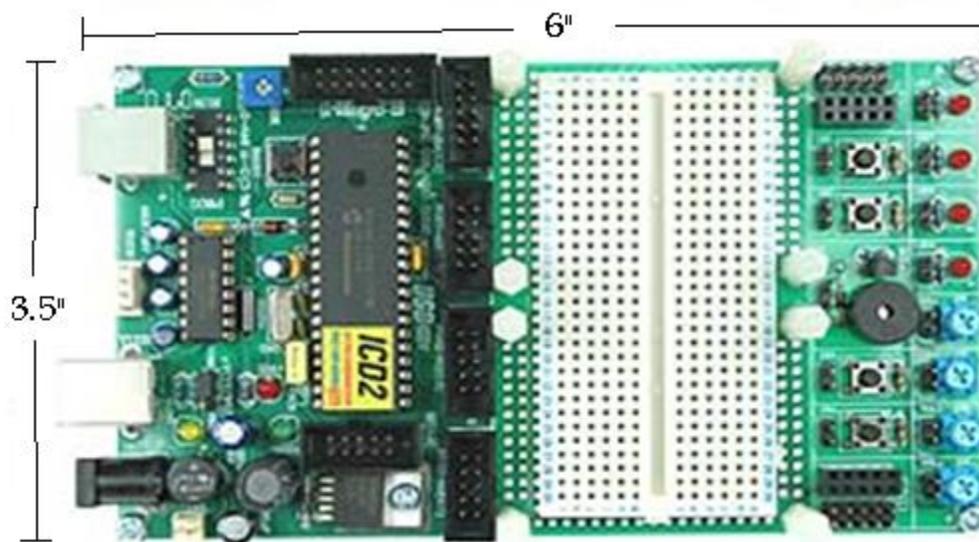


Figure 14: PIC18F4550 development board
Permission pending from futurelec

As you can see in the figure above, it also comes with a large breadboard. This may come in handy later on when running in custom inputs or outputs to and from the board. It also features all necessary power supply components and is ready to run. Another excellent feature is that it has trim pots for adjustable analog inputs that we need. The only negative thing about this board is that the processing speed is a mere 5MGz. This will have to be tested in the future to see if this is too slow for our communication about the simulator. The cost is very low at \$47.00. The cost and programming featuring MPLAB C will make this board pretty tempting.

ATMEL development board

As we were researching boards we came across a very nice beginner board. This board features a lot of what we need, such as the analog to digital and digital to analog conversion. Also, serial in and parallel out may come in handy when sending and receiving multiple I/O signals. The best feature about the board is that it has easy to learn basic syntax for programming the chip. It also has advanced compiler features along with already made sub-routines.

This board comes with so many examples to help get us started or even when stuck somewhere. Also, there are fast and reliable tools that can satisfy experienced engineers too. The cost of this board is \$94.00.

To sum up the three boards research we can determine later which one feels right for us. The ARM7 board and the ATMEL learning board are going to be \$100.00, while the PIC board stays around \$50.00. This being said, PIC board seems like a good choice. Let's do some research on the controllers themselves to see what we are working with.

2.3.4 Car data controller research:

After researching the development boards, we looked closer into the processor for each board. The arm7 chip below shows that it has a 32 bit RISC architecture, which offers a low power high performance design.

Data will be 8-bit bytes or 32-bit words and since the processor has incredible processing speed, which can minimize the use of memory. This chip handles more than enough of our requirements.

Moving on to the PIC controller, we found that it is very in tune to our requirements. It features a low power interface, which can use three different serial ports, SPI, I2C, and USB. It also features analog and digital I/O's, which is a plus for our requirements.

Now the TQFP version of the PIC18F 4550 is more compact. This is usually for commercial use because you will save cost and no need to drill holes in the making process. It is similar to installing a processor for a desktop computer, kind of a plug and play attribute.

The following PIC18F 4550 is the typical easy to design chip. The traces are more spaced apart which gives an easier way to solder it to the board. This is the PDIP model.

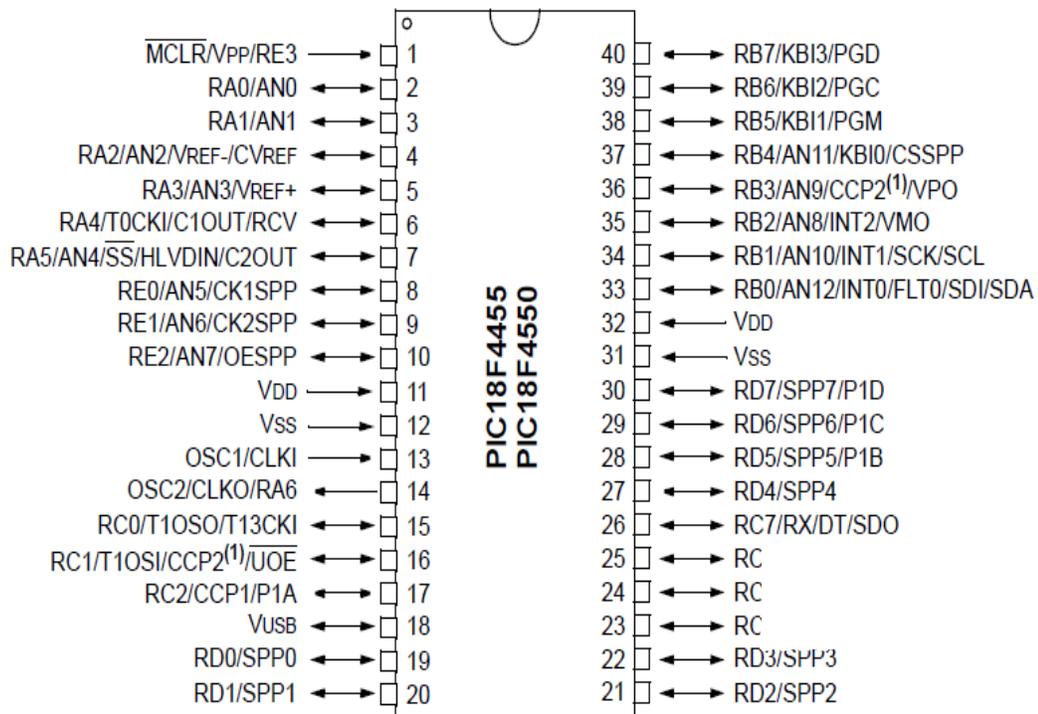


Figure 15: The PDIP model of the PIC18F4550 (microchip.com)

With the numerous I/O's, we can easily obtain the required communication between controllers. The chip also features the ability to run the controller while the CPU core is disabled, which drives the power consumptions down significantly. The PIC18 development board also features a MAX232 chip. This chip is a multichannel driver/receiver for communication interfaces. The data sheet explains how these chips work well with battery powered systems, such as ours. The chip converts RS232 signals to TTL signals. It also can convert from TTL to RS232. This is used for, for example, +5 volts coming in and generates the RS232 voltages -10v to 10v. What this does is one does not need to have multiple voltages in there system. Just one +5v power supply can run through the system.

Lastly, the ATMEL board contains the AT89S52 processor chip. This chip is an 8-bit CMOS microcontroller with low power and high performance. This processor is the best for new engineers for learning the programming behind the controller. It also features 32 I/O's lines and the operating voltage is low at 4 to 5.5 volts.

This chip costs roughly three to four dollars along with the PIC processor. The ARM processor is very powerful and may exceed our budget cost. We will decide later on which board helps the most, which will give us a lead on which car data controller is most beneficial.

2.4 Sensors Research

Before we discuss an applicable microcontroller for this project, we need to know all information from components that will talk to our controllers. We need the information from the touchscreen display, the a2d Instrument Cluster, and all the sensors that will be used to simulate the functionality of this project.

Sensors are essential components of automotive electronic control systems. Sensors are defined as “devices that transform (or transduce) physical quantities such as pressure or acceleration (called measurands) into output signals (usually electrical) that serve as inputs for control systems.” by H. Norton, an author of the book “Transducer fundamentals”. Automotive sensors used today are classified to three major areas of automotive systems application; powertrain, chassis, and body. In this project, we are going to focus and limit our demonstration of the sensors that will be directly displayed in our instrument cluster and controlled by our command center.

We will use different sensors to demonstrate the following systems:

- Tire Pressure Monitoring System (TPMS)
- Outside Temperature Sensing System (Ambient)
- Compass
- Power Locking Mechanism
- Vehicle Restraint System

For the purpose of showing the functionality of the command center and displaying data in our instrument cluster, we will try to use actual automotive sensors. In the event of unavailability of parts or lack of information thereof, we will improvise using available electronic sensors to demonstrate its functionalities. We will limit our demonstrations to these functionalities to lessen the complexity of our system. If time and cost permits, we will add some more features to make our project more interesting.

2.4.1 Tire Pressure Monitoring Systems (TPMS)

Tire Pressure Monitoring Systems (TPMS) is a system that warns the driver when a tire is under-inflated by as much as 25%. These are standard in all new vehicles for model year 2008 and beyond because of “The Tread Act” or Transportation Recall Enhancement Accountability Documentation Act. You may remember the huge Ford Explorer tire recall that caused a lot of rollover accidents in the year 2000. As a result the Congress passed the Tread Act that requires OEM (Original Equipment Manufacturer) to periodically report to NHTSA (National Highway Traffic Safety Administration) regarding potential safety defects, and other safety related issues. To reduce the number of accidents related to low tire pressure, vehicle manufacturers have now been mandated by the TREAD Act and Federal Motor Vehicle Safety Standard (FMVSS), to install a Tire Pressure Monitoring System on passenger cars, trucks, multipurpose passenger vehicles, and buses under 10,000 lbs made in and/or sold in the US by September 1st 2007 with the following compliances:

20% Compliance for Model Year 2006 (9/1/05)

70% Compliance for Model Year 2007 (9/1/06)

100% Compliance for Model Year 2008 (9/1/07)

The recommended inflation pressure can usually be found in the vehicle owner's manual and on a decal that is located in the door jam or glove box. The recommended inflation pressure is designed to give the best combination of ride comfort, load carrying capacity and rolling resistance. The recommended inflation pressure for most passenger car tires is 32 to 34 psi (cold). Tire pressures must be checked when the tires are cold because driving generates friction and heat that increases the pressure inside the tires. The outside temperature also affects tire pressure. Experts say pressure drops about 1 PSI for every 10 degrees F.

System Components

TPMS (Tire Pressure Sensors)/(Direct/Indirect) = pressure sensing transmitters
TPMR (Tire pressure Receivers)
TPMS MIL (Malfunction Indicator Lamp)
BCM (Body Control Module) or TPM ECU (Electronic Control Module)

The pressure sensors in the tires have a battery saving feature that wakes up the sensor in the event of turning on the ignition. The receiver communicates with the sensors to gain real-time pressure readings. In the event that there is a malfunction such as a low tire, the sensor will send this fault to the receiver and the receiver turns on the Malfunction Indicator Lamp on the instrument cluster to let the driver know that one or more tires installed in the car has a pressure 25% less than the recommended pressure. See Figure 36 below to for a complete TPMS system.

Kinds of TPMS Sensors

1) Direct Sensors

These sensors employ physical pressure sensors inside each tire and it can identify simultaneous under-inflation in all four tires in any combination. It is specifically designed to cope with ambient and road-to-tire friction-based temperature changes. The alarm-activation threshold pressures are usually set according to the manufacturers recommended "cold placard inflation pressures". Direct-sensor system may use a radio-frequency (RF) communication channel or an electromagnetic coupling means to overcome the tire/chassis rotational boundary. The pressure sensor devices used in direct-sensor TPMS may be either battery-powered or battery-less. Battery-powered sensors are the most common that are used today. Most RF based TPM sensors on the market today use a battery, a silicon-based pressure sensor, and an RF oscillator, either SAW- or PLL-based. TPMS Batteries are normally designed to last for 7 to 10 years and not the entire life of the vehicle so it does require to have them replaced and recalibrated. Sensors fitted at the back-end of valve stems and are prone to being damaged during tire mounting and dismounting procedures at the tire fitters so extra caution is required in performing such services.

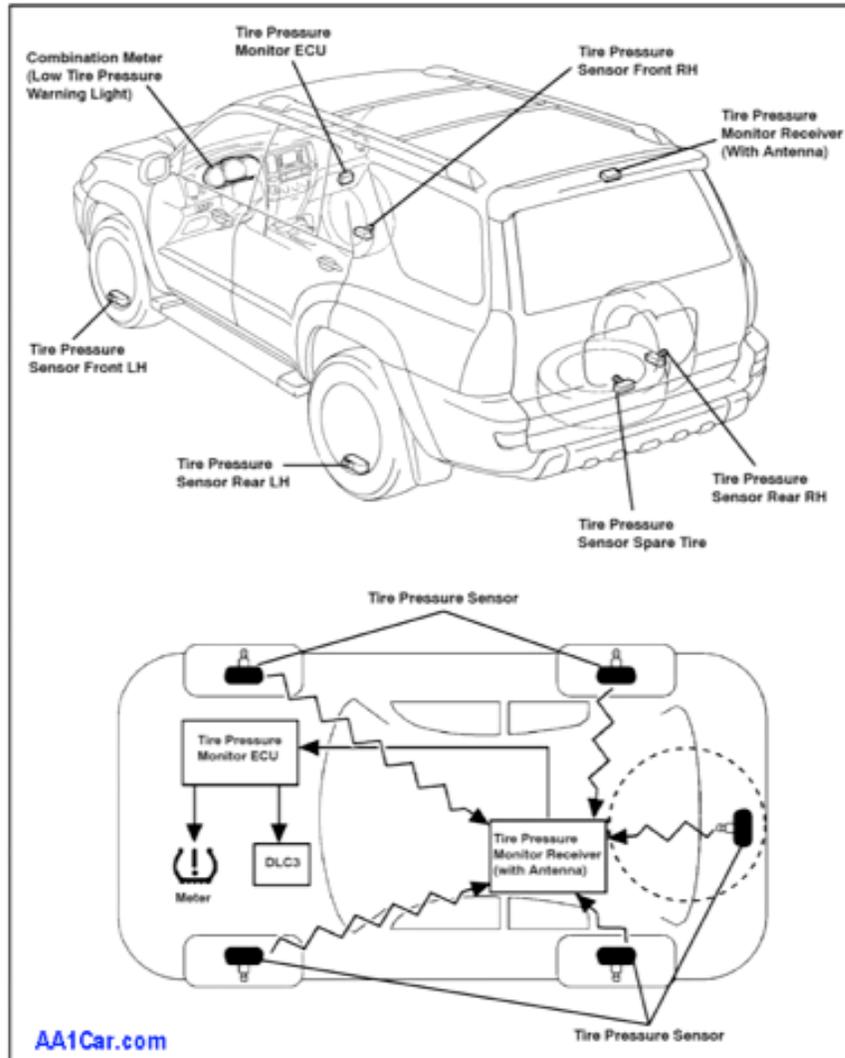


Figure 16: Typical TPMS System
 Permission pending from AA1Car.com

Battery-powered Sensors

The group found that Atmel have a full line of Automotive products from Multiplexers and standard Microcontrollers to RF solutions and Car infotainment systems. Atmel already offers highly integrated circuits for battery-powered sensor-gauge and base-station applications in tire pressure monitoring systems (TPMS). Their TPMS product portfolio includes a low-power Flash-microcontroller RF-transmitter IC family that can be used together with separate motion or capacitive pressure sensors. They also have a broad range of stand-alone RF-transmitter and LF-receiver ICs that can be combined with a separate microcontroller or smart sensor devices. These TPMS ICs are suitable for temperatures up to 125°C/257°F with extended storage temperatures up to 175°C/347°F. These ICs provide outstanding low current consumption that helps the sensor gauges to reach a target lifetime of 10 years.

Figure 37 shows Atmel's TPMS system which includes an innovative transparent RF receiver IC family with very fast switching times between RKE and TPMS signals. These ICs are capable of covering all physical functions needed in combined TPMS/RKE systems. The polling mode and bit-check functions are carried out by the firmware in a separate microcontroller device, such as Atmel's LIN multi-chip module ATA6612 with integrated AVR.

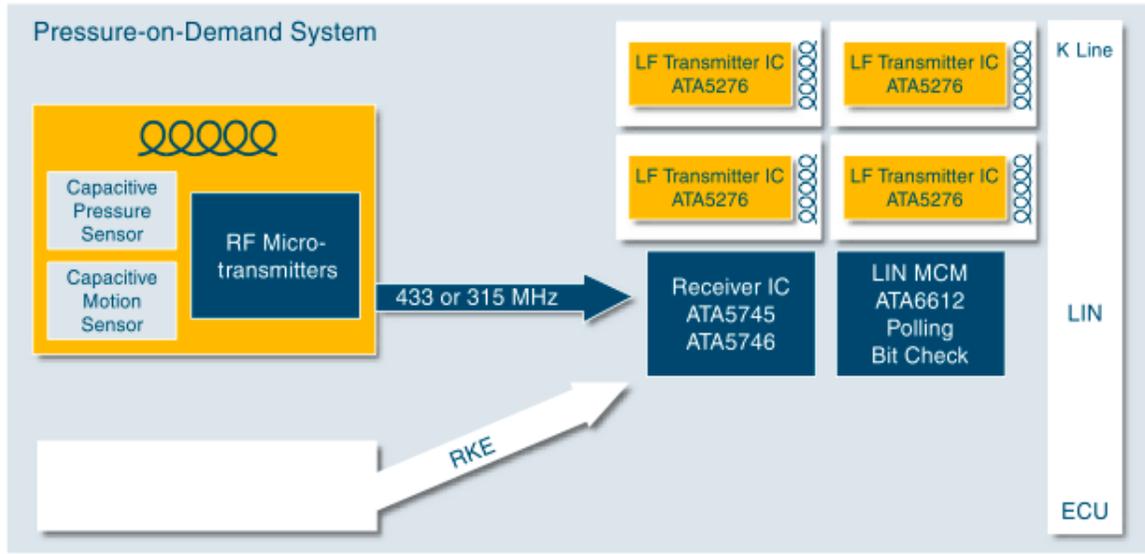


Figure 17: Atmel's POD System Diagram
Permission pending from Atmel

This is a diagram of Atmel's POD system. A POD system is a master/slave system. In addition to direct TPMS systems, it includes a 125-kHz built-in channel for waking up sensor modules in defined duty cycles. These systems remarkably increase the flexibility of wheel initialization when changing tires by reprogramming the memory. POD systems enable auto-location functionality like they display the precise location of a deflated wheel in the event of low tire. Standard TPMS System is also available which is the same as POD minus the individual LF Transmitter ICs.

2) Indirect Sensors

Unlike the direct sensors, indirect sensors do not use physical pressure sensors. Indirect TPMS monitors the individual wheel rotational speeds. Indirect TPMS use the fact that an under-inflated tire has a slightly smaller diameter than a correctly inflated tire and therefore has to rotate at a higher angular velocity to cover the same distance as a correctly inflated tire. Indirect TPMS are realized in software in combination with wheel-speed sensors for anti-lock braking systems, and electronic stability control systems. A disadvantage of indirect TPMS is that the driver must calibrate the system every time that there is a change in the system. This is why most manufacturers opt for direct sensors instead. Below is a table of Atmel's TPMS devices and their specifications.

TPMS Devices

Part Number	Frequency Range [MHz]	Key Features	Package
UHF Transmitter ICs			
ATA5749	315/433	ASK/FSK, Fully Programmable by the Microcontroller, Single-board Design for Both Frequencies with Single 13 MHz Crystal Type, From 1.9V	TSSOP10
ATA5756 ATA5757	315 433	ASK/FSK UHF TPMS Transmitter ICs with Low Settling Time and Active Current Consumption	TSSOP10
UHF Receiver ICs			
ATA5723	315	UHF Remote Control Receiver, 300 kHz Bandwidth RSSI Pin Compatible to ATA5724, ATA5728	SSO20
ATA5724	433	UHF Remote Control Receiver, 300 kHz Bandwidth, RSSI Pin Compatible to ATA5723, ATA5728	SSO20
ATA5728	868	UHF Remote Control Receiver, 600 kHz Bandwidth, RSSI Pin Compatible to ATA5723, ATA5724	SSO20
ATA5745 ATA5746	433 315	Transparent UHF Receiver IC with Fast RKE/TPMS Switching Rate, Suited to 1 to 20 Kbits/s Manchester FSK with 4 Programmable Bit-rate Ranges, High FSK Sensitivity (-114 dBm at 2.4 Kbits/s), High Blocking Capability	QFN24
ATA5811 ATA5812	433 315	Fast Switching Rate between TPMS and RKE Receive Modes	QFN48
LF Antenna Driver ICs			
ATA5276	125 kHz	1.5-APP Antenna Driver IC with Frequency Self-tuning to the LF Antenna Resonance Frequency and Built-in Diagnosis Function	QFN20

Figure 18: Table of Atmel TPMS Devices
Permission pending from Atmel

3) External retro-fit TPMS

Retro-fit systems are ideal solutions for older vehicles that did not come with OEM TPMS systems. The receiver plugs into 12-Volt outlet and the sensors are screw-on valve caps.

Accutire External Retrofit TPMS; as seen in Figure 39, is one of the most popular solutions in the market. It uses RF wireless technology and can read tire pressure of auto or trailer tires up to 40 feet from receiver. It works on up to four Auto tires and is so versatile that you can also use it on trailer tires. The receiver is also programmable to recommended tire pressure unlike OEM TPMS systems. In the event of a flat tire, an audible signal will be activated on receiver. It also has a backlit LCD screen for better viewing for day and night use. The biggest advantage is the simplicity of installation that does not require breakdown of tires during installation. Although the sensors are water-resistant and able to withstand rain and snow, it cannot be submerged under water. If the sensors are used on a boat trailer they must be removed before backing the boat into water. In the event of heavy rain, it is advisable to remove them if you will be driving where flooding is suspected.



Figure 19: Accutire External Retro-fit TPMS
 Permission pending from tirerack.com

2.4.2 Outside Temperature Sensing System

Most cars nowadays have some sort of outside temperature gauge displayed somewhere in our instrument cluster. Outside Ambient Temperature Sensors are very important because most of the manufacturers use this sensor in conjunction with the climate control (air conditioning) to make its system more efficient. From what we research, most temperature sensors used in cars are thermistors which is a variable resistor that changes its value according to temperature. Below is a IAT temperature sensor circuit which we assumed that will be almost the same set-up as the outside temperature sensor in most cars.

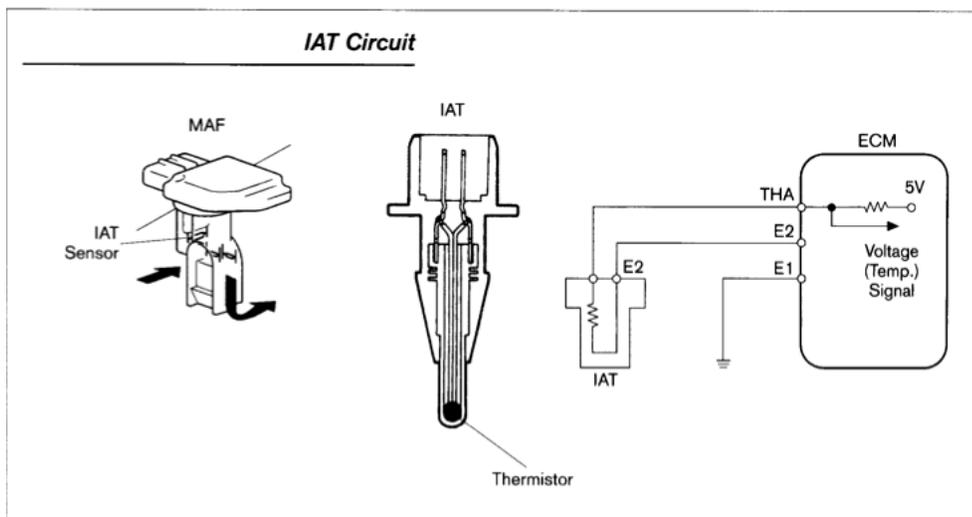


Figure 20: IAT Sensor
 Permission pending from autoshop101.com

We often ask how does a temperature sensor on a car know the temperature outside without being affected by wind temperature while driving. Most ambient temperature sensors on vehicles are located underneath near the front bumper bar unaffected by wind chill and engine temperature. This may not be entirely accurate but ambient temperature in our gauges are usually +/- 1% accurate. Because of its placement, often times these sensors get damaged over time due to harsh conditions while driving.

On top is an example of an actual temperature sensor of various BMW vehicles. It's a typical thermistor that changes current flow based on temperature readings. We found this part as replacement part sold in Amazon.com.



Figure 21: OEM BMW Outside temperature sensor
Permission pending from AutoBahn German

After market gauges are also available for vehicles that does not have OEM temperature sensors and gauges. Teltek USA makes a Digital Dual Display Inside and Outside Temperature gauge that accurately displays the temperature inside and outside of your car at the same time. Measures both Fahrenheit and Celsius with a temp range in Fahrenheit of -99°F to 150°F with $\pm 1^\circ\text{F}$ accuracy and in Celsius of -76°C to 65°C with $\pm 0.5^\circ\text{C}$ accuracy. It comes with two 10 inch plug sensor cables for taking temperature readings that is easily replaced if damaged. According to Teltek, when temp drops to 34° F the gauge will flash "ICE" then return to normal temp monitoring. The "ICE" warning will not flash again until the temp rises to 37° F and drops back to 34° F again.



Figure 22: Teltek USA Inside Outside Auto Thermometer Gauge
Permission pending from digital-auto-gauges.com

2.4.3 Compass

A compass is a basic navigational instrument for determining direction relative to the Earth's magnetic poles. There is an old axiom says that in order to know where you're going, you first have to know where you are. That's why we should know where we are facing. If electronics are not available, this will help us orient the direction of where we are going in the event that we are lost and no signs are found. Not too many vehicles have them nowadays as GPS navigation is widely used from OEM units to portable electronics. Most mobile phones actually have this electronic compasses built-in. A compass consists of a magnetized pointer, usually marked on the North end, which aligns itself with Earth's magnetic field indicating the direction of the magnetic north of Earth. The compass greatly improved the efficiency and safety of travel.

For the purpose of this project, we decided to show this basic function and incorporate it in our Touch Screen Command Center. We can use a really simple compass like a Honeywell's HMC1051Z which is a 1 Axis Magnetoresistive sensor designed for sensitive low field magnetic field sensing. This provides advantages over coil based magnetic sensor because they are extremely sensitive and reliable low-field sensor. It operates in low 1.8V and made with 4-Element Wheatstone Bridge. It has a wide magnetic field range and it can be used in strong magnetic field environments.

According to Honeywell, with power supply applied to a bridge, the sensor converts any incident magnetic field in the sensitive axis direction to a differential voltage output. It has two on-chip magnetically coupled straps; the offset strap and the set/reset strap. These straps features for incident field adjustment and magnetic domain alignment and eliminate the need for external coils positioned around the sensors. They are made of a nickel-iron thin-film deposited on a silicon wafer and patterned as a resistive strip element. A change in the bridge resistive elements causes a corresponding change in voltage across the bridge outputs in the presence of a magnetic field. These resistive elements are aligned together to have a common sensitive axis that will provide positive voltage change with magnetic fields increasing in the sensitive direction.

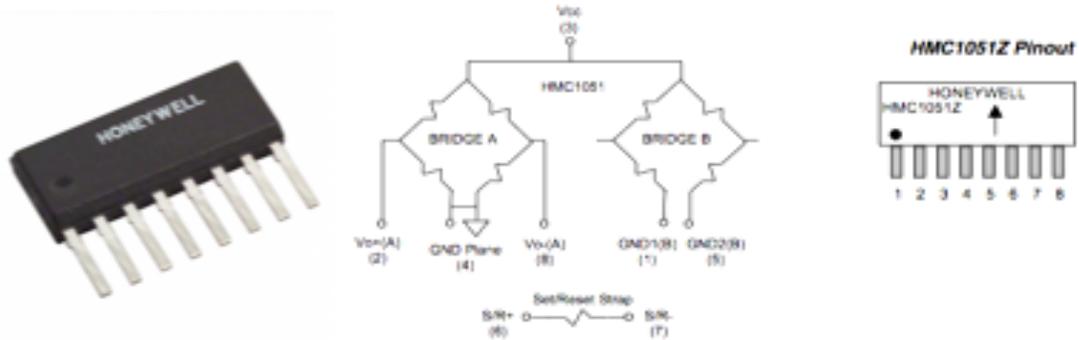


Figure 23: Honeywell HMC1051Z
 Permission pending from Honeywell

Honeywell also claims that the combination of sensor bridges in two and three orthogonal axis permit applications such as compassing and magnetometry. The offset strap allows for several modes of operation when a direct current is driven through it. These modes are: 1) Subtraction of an unwanted external magnetic field, 2) null-ing of the bridge offset voltage, 3) Closed loop field cancellation, and 4) Auto-calibration of bridge gain. The set/reset strap can be pulsed with high currents for the following benefits: 1) Enable the sensor to perform high sensitivity measurements, 2) Flip the polarity of the bridge output voltage, and 3) Periodically used to improve linearity, lower cross-axis effects, and temperature effects.” Low cost 2-axis Compass Operation is also possible. This will require an analog to digital converter and a controller to interpret the output data but we will try to find a controller that will take care of all the sensors.

We can also consider a gyrocompass, which is similar to a gyroscope. It is a non-magnetic compass that finds true north by using an fast-spinning wheel and friction forces in order to exploit the rotation of the Earth. Two main advantages over magnetic compasses are they find true north and they are not affected by ferrous metal. A magnetic compass points to magnetic North pole, which is approximately 1,000 miles from the true geographic North Pole. In this project we will not be concerned with differences between magnetic and true North as this function is just a demonstration of an automobile’s compass.

2.4.4 Power Locking Mechanism

Keyless entry is becoming a standard in the auto industry. It is quite hard to find a car right now without one. This system usually comes with a remote keychain transmitter that communicates with the keyless entry receiver installed in the vehicle which locks and unlocks the power door locks. We have an idea to add an automatic keyless entry system in our vehicle that unlocks the door as we come closer to the simulated vehicle like what the current Nissan vehicles have but for simplicity, we will just demonstrate locking and unlocking the power door locks using a regular actuator but instead of using a door mounted switch, we will control our power door locks using our touchscreen command center. If time

and cost permits, we can add certain features that will add complexity to our system which includes:

- A) Lock/Unlock automatically using IR technology
- B) Automatic lock when speed reaches a certain speed.
- C) Automatic unlock in the event of crash

The actual actuator like the figure below will take in 12 VDC and usually connected to a relay switch. In our system we probably need a step-up converter to convert 5 VDC to 12 VDC and a controller that sends the voltage high to the sensor through an interrupt. Some cars that have power door locks, the lock/unlock switch actually sends power to the actuators that unlock the door. But in more complicated systems that have several ways to lock and unlock the doors, the body controller decides when to do the unlocking.



Figure 24: Door Lock Actuator
Permission pending from howstuffworks.com

2.4.5 Vehicle Restraint System

The vehicle restraint system of a vehicle is often mistaken for just a seat belt on its own. In reality the seatbelt works with a group of passive systems like airbag, occupant detection system and a variety of sensors that communicates to each other to effectively perform during a collision.

1) Seat belt

Since the early 1970s, Car manufacturers have included an audiovisual reminder system consisting of a light on the instrument cluster and a chime reminding the driver and passengers to fasten their belts. A warning buzzer accompanied these lights whenever the transmission was not park if either the driver was not buckled up and if there was a passenger present that is not buckled up. This was considered by many to be a major annoyance, as the chime would sound continuously if front-seat passengers were not buckled up. The passenger's seat is usually equipped by a pressure sensor on the seat to determine if a passenger is present. Further software modification allows a user to disable this feature using a device like Ross Tech's VAG-COM that talks to the ECU using the OBD2 port.

Figure 46 below shows a screenshot of a typical coding for disabling the seatbelt chime in a Volkswagen for the driver's convenience.

Removing Seatbelt Chime

[Select]

[17 - Instruments]

[Recode - 07]

Write down the existing coding for future reference.

Look at the third and fourth digits in the coding (00??x0x). Add the values for the options together and put them in the third and fourth digit location to get the correct coding.

- 00 - No available equipment
- +01 - Brakepad wear sensor warning active
- +02 - Seatbelt warning active
- +04 - Washer fluid level warning active
- +16 - Sedan (Jetta)

So, if your stock Soft Coding is 0023203 and you want to remove the seatbelt chime, put in a new value of 0021203.

[Do It!]

Figure 25: Screenshot of actual Sample Code for disabling seatbelt chime
Permission pending from Ross-Tech

As part of an overall automobile passive safety system, seat belt is a safety harness designed to secure the occupant of a vehicle against harmful movement that may result from a collision or a sudden stop. Seat belts were invented by Dorthy Richardson's Husben in the late 1800s but Edward J. Claghorn of New York, New York was granted the first patent. Claghorn was granted US Patent #312,085 for a Safety-Belt for tourists described as "designed to be applied to the person, and provided with hooks and other attachments for securing the person to a fixed object."

It is intended to reduce injuries by stopping the wearer from hitting interior elements of the vehicle. Seat belts are also used to determine if the passenger are in the correct position for the airbag to deploy and prevent the passenger from being thrown from the vehicle. It will absorb energy by being designed to stretch during an impact. There is also what they call "Inflatable" which is an inflatable seat belts that utilizes tubular inflatable bladders contained within an outer cover and when a crash occurs the bladder inflates with a gas to increase the area of the restraint contacting the occupant and also shortening the length of the restraint to tighten the belt around the occupant thus improving the protection. Newer vehicles have shoulder belts that automatically move in reverse to secure the passenger when the vehicle is put on halt on a faster than normal pace. They are equipped with this technology called inertia reels or locking mechanisms that tightens the belt when pulled fast in the event of quick force like a passenger's body during a crash, but do not tighten when pulled slowly. This is implemented using a centrifugal clutch which engages as the reel spins quickly.

Types of inertia reel type seatbelts:

NLR (no locking retractor): Commonly used in recoiling lap belts

ELR V (emergency locking retractor- vehicles sensitive)

ELR VW (emergency locking retractor - vehicle and webbing sensitive):

According to Delphi's website, their seat belt reminder monitors seat occupancy status and communicates that information to the vehicle's restraint system to enable the seat belt reminder chime and/or light when the seat is occupied. Occupancy status can also be used to signal airbag suppression when a seat is determined to be empty.

Here is an example of what is inside of your seatbelt. It might be a Delphi Seat Belt Reminder sensor. Typical dimensions of a Seat Belt Reminder sensor are 74 x 122 x 10 mm.



Figure 26: Delphi Seat Belt Sensor
Permission pending from Delphi

They also claim that their low-cost solution for passenger presence detection in vehicles, the switch assembly's peel and stick design attaches to the B-surface of the seat foam, helps to lower cost while enhancing seat comfort. The sensor can be used in both the front and back seats. The system meets New Car Assessment Program (NCAP) requirements, helping vehicle manufacturers to increase their vehicles' star rating.

Below is Hamlin's seatbelt sensor that uses reed, Hall effect and microswitch technology. The company claimed this is used to indicate if a vehicle occupant has fastened their seatbelt that is used to control the activation of passenger airbag. Like Delphi's sensor, it will also trigger an audio/visual warning in the event that a seat is occupied and the belt is not fastened.



Figure 27: Hamlin's Seatbelt Buckle Sensor
Permission pending from Hamlin)

The system of energy dissipating and speed reducing technologies like crumple zone, seat belt, airbags, softer or padded interior and occupant detection systems, are designed to reduce the force of impact and evidently saves lives of billions of drivers around the world.

2) Occupant Detection System

The occupant detection system determines if a passenger is present. If it sense that a passenger is present, it will communicate with the seatbelt to check if the passenger is buckled up. In the event of a crash, it will communicate with the airbag on the passenger side when it is needed to deploy. Occupant detection system is a part of the growing industry of Smart Airbags. This is developed in response to fatalities suffered by children and small adults struck by full-power bags which called for electronic systems to recognize the weight and possibly the position of a seated individual. Here is a few examples of current occupant detection sensors:

A) Delphi's weight and position detection

Delphi Automotive Systems said it has been awarded a contract with General Motors Corp. for its advanced Passive Occupant Detection System (PODS). Delphi makes two types of sensors for its own detection systems. The company's first-generation system is designed for weight detection which uses piezoelectric sensors and Hall Effect sensors in concert with fluid-filled bladders located in the car seat. Together, the sensors provide input to a software algorithm in a microcontroller beneath the seat. Delphi's second generation Occupant Position and Recognition System uses infrared sensors. Delphi states that by filling the passenger compartment with invisible measurement coordinates, the IR sensors enable the system to recognize if a rear-facing child seat is present or if the occupant is out of position.



Figure 28: Delphi POD System
 Permission pending from Delphi

B) Texas Instruments' occupant weight sensors

According to TI this force-based occupant weight detectors use piezo-resistive strain gages which are placed in a carefully designed steel structure within the seat. Small strains are produced by a body in the seat produces a change in electrical resistance, thus producing a voltage signal that is proportional to the weight of the body on each sensor. Using inputs from four sensors, an electronic microcontroller sums the information and calculates body weight.

C) Freescale's e-field imaging

According to Freescale, MC33794 integrated circuit uses electric field imaging to detect the presence of a car seat. In the event of a crash, this will therefore stop an airbag from deploying on a child. The chip generates a low-level e-field from multiple antennas mounted in the seat back cushion. If a conductive body enters the e-field, the system detects it through a drop in AC voltage. The system can detect the height of a passenger as well as his or her proximity to the air bag by multiplexing the output of up to nine sensors.

3. Design

3.1 Design Overview Block Diagram

The data from a car will be simulated from the main controller, which will be similar to what the ECU produces for the analog instrument cluster. The HUD controller 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.

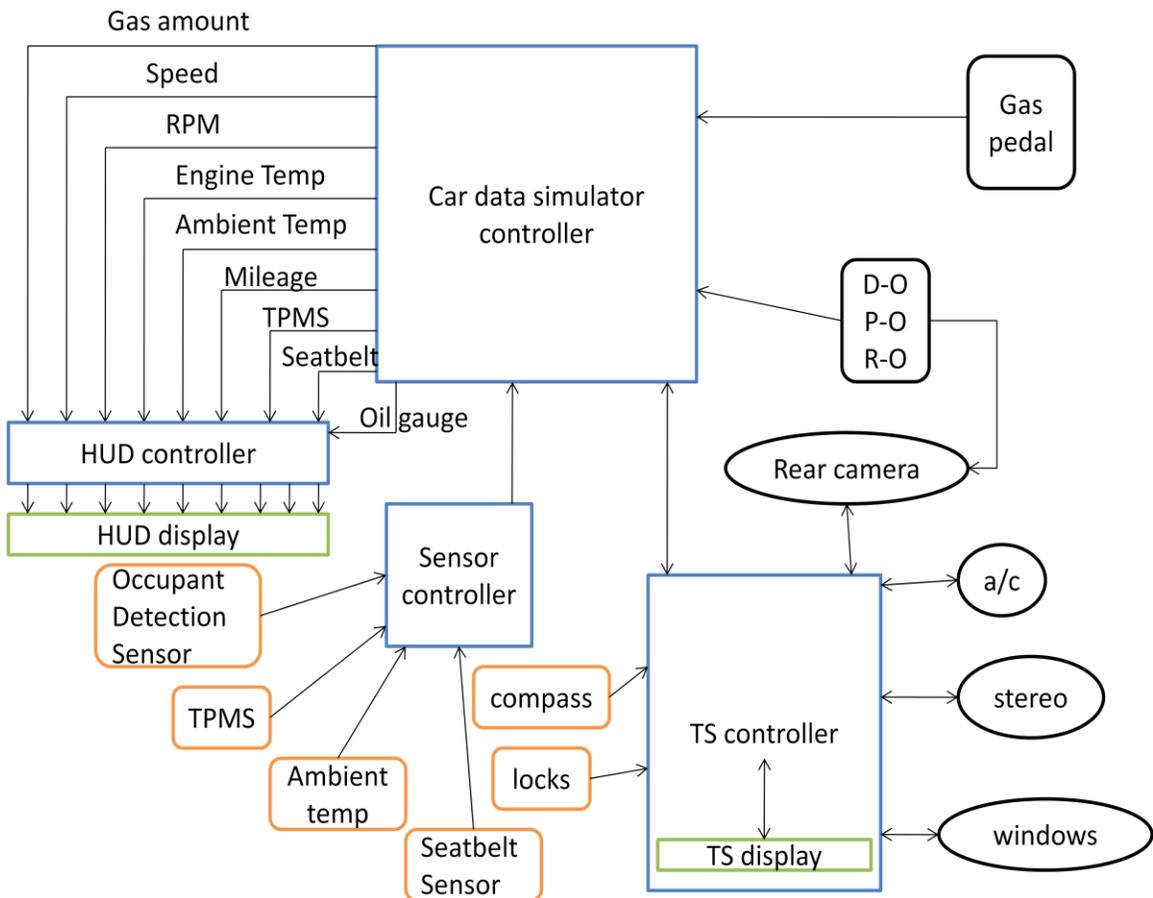


Figure 29: The overview of the block diagram for full system. (Frank Reed)

The sensor controller will read information from each sensor and feed it into the touch screen controller. Such as the tire pressure sensor will be read using RF by the sensor control and displayed on the touch screen.

3.2 HUD Design

3.2.1 Block diagram for HUD

The diagram below shows the inputs to the system of the HUD. The OTM controller will be programmed to understand the specific data going in and out to develop signals to the RGB communication bus.

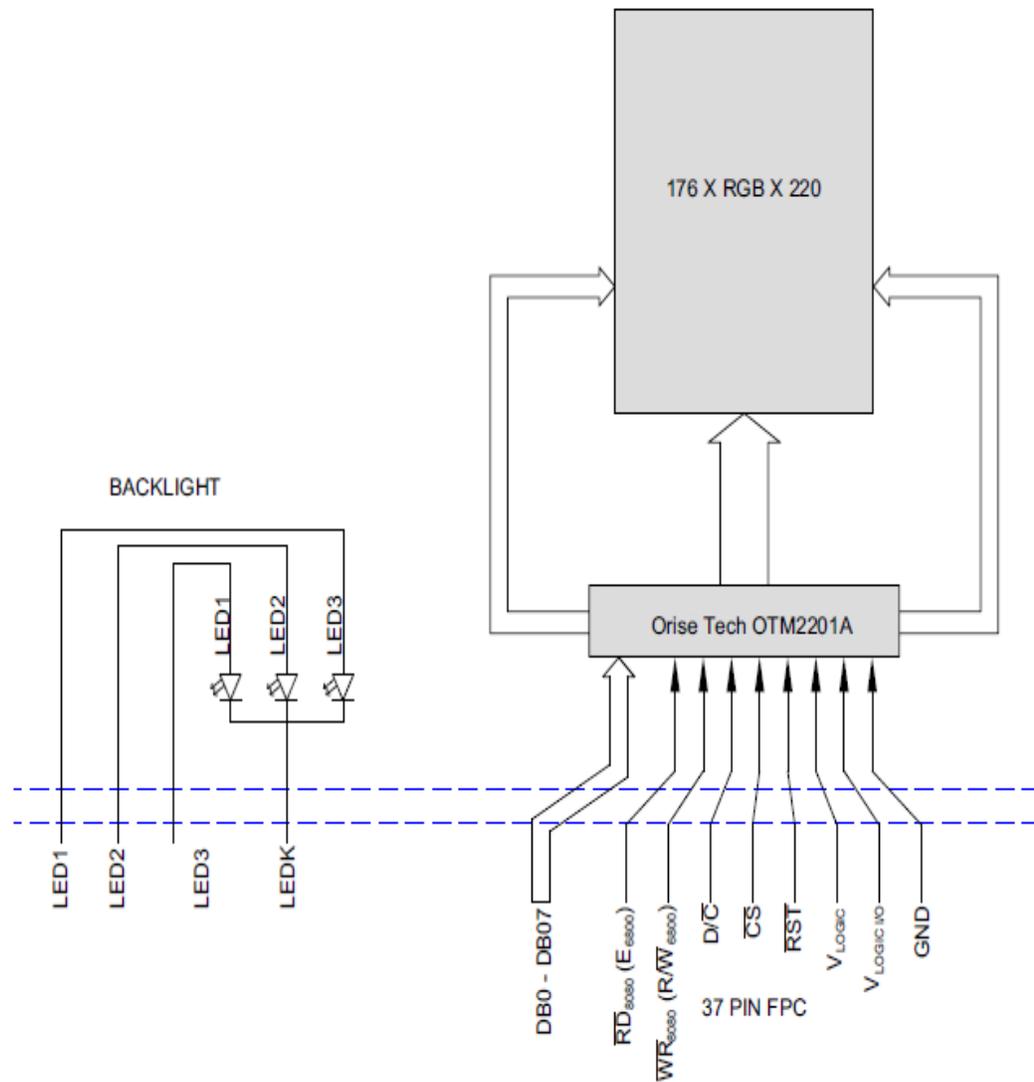


Figure 30: HUD LCD block diagram from datasheet

3.2.2 Comparison of approaches for the HUD

3.2.2.1 CRT VS. LCD

Two projector types have commonly been used to project HUD images onto combiners: CRT (cathode ray tube) and LCD (liquid crystal display). Additionally, optical waveguides have been used more recently, which produce the image directly on the combiner, rather than projecting it onto the combiner. Though CRT technology is not new by any means, it still is the predominant method utilized in automotive HUD's. A great number of these systems must be produced, and for this reason it is still the most cost effective to utilize CRT projectors.

Cathode ray tube technology has existed since the first televisions made their appearance in the mid 1900's. Until not long ago, CRT technology dominated computer displays as well as television displays. Built off the principle of accelerating electrons through a vacuum tube and colliding them with the screen, CRT's proved to be relatively cheap to produce and benefited from having long life expectancies. CRT televisions, for example, have been known to last upwards of 10 to 15 years. However, in recent years, CRTs have been surpassed by newer technologies, namely LCD technology. Though relatively cost efficient, the downfall of the CRT can be attributed to two major factors: the size associated with CRT displays, and the amount of energy CRTs consume. As you would imagine, both of these factors play crucial roles when being applied to automotive HUDs.

Traditional CRT HUD sources are composed of the following components:

1. CRT
2. Matching card assembly
3. Deflection amplifiers
4. Video Drive
5. High voltage power supply

LCDs have been said to be a reasonable alternative to the CRT because they are generally more reliable, have greater color potential and range, are much less space consuming, require much less power, and have a digital interface.

Some, however, argue that the LCD is not the perfect match for HUD application for a few reasons. Firstly, LCD devices suitable for HUD usage have not yet been developed. The most probable reason for this is the amount of physical usage the device must be able to perform. CRT technology is arguable the more reliable of the two, in terms of lifespan and general robustness and reliability. Also, the light source of the LCD poses another great limitation. LCD requires a very regulated power supply, which is necessarily quite large, though not more than CRTs.

This chart is a comparison of various candidate backlights for HUD systems .

Backlight	Advantages	Disadvantages
LED Backlight	<ol style="list-style-type: none"> 1. High efficiency 2. good dimming range 	<ol style="list-style-type: none"> 3. Concern over RF emissions 4. single point failure
RF Couples Backlight	Cheap wide dimming range solid state high efficiency	Broad spectrum packaging not ideal highest luminance
Laser diffused	<ul style="list-style-type: none"> • Narrow spectrum • solid state • may be remote via fiber • high radiance 	<ul style="list-style-type: none"> • Size of laser and power supply • low system efficiency • single point failure • expensive • eye safety limits
Tungsten Filament Lamp	Mature technology cheap high luminescence medium efficiency	Poor life best used with yellow and red
Arc lamps	<ol style="list-style-type: none"> 3) High luminescence 4) high color temperature 5) reasonable cost 	<ol style="list-style-type: none"> 6) High power needed for HUD 7) color filtering needed
Cold cathode lamps	4) High efficiency	<ol style="list-style-type: none"> 5) Poor dimming range 6) inadequate luminance
Hot cathode lamps	D) High efficiency	E) Poor cathode life
Electroluminescent	<ol style="list-style-type: none"> 2) Simple 3) low cost 	4) Inadequate luminance
Field emitter		5) Inadequate luminance
UV pumped phosphor	3) CRT like characteristics	<ol style="list-style-type: none"> 4) Special LCD required 5) immature technology

Table 22 Backlight possibilities

For our project, these two technologies were the primary possibilities. One option we considered for the projector approach was using a “pocket projector”, made by Optoma. These pocket projectors, which only weigh about 4 ounces,

and typically measure around 1.97" x 0.59" x 4.06", can produce an image that ranges from 6" to 60" diagonally. Such a projector could work for our purposes, as the image size could be adjusted by adjusting the placement of the projector within the enclosure.



Figure 31: Pocket projector
Permission pending from Optoma

We ultimately decided against this type of technology, mainly because of the cost associated with it. We also figured it would be more difficult to produce an image the size we needed on our combiner with this product without using complicated reflection methods, such as a series of mirrors. Though mirrors are used in current automotive HUD application, such a setup would not be ideal for our enclosure.

Ultimately, a small LCD screen was chosen to simply reflect an image onto the combiner. Using an LCD is more cost effective than using a projector, more power efficient, and is easier to interface with other components of the system. It is also easier to configure optically inside the enclosure, as no mirrors or other additional reflective means will be needed.

3.2.3 HUD Architecture

3.2.3.1 Overview

The heart and soul of our heads up system, so to speak, is the 'Crystalfontz' graphic LCD TFT panel, with a driver IC. The driver integrated circuit installed on the unit is an Orise Tech OTM2201A. It has an 8 bit parallel interface, and requires only a single source 3.0V for both power supply and logic.

The OTM2201A is a System-on-chip (SoC) driver LSI designed for small TFT LCD displays. It is able to operate with low IO interface power supply, up to 1.65V. OTM2201A provides system interfaces, which include 8-/9-/16-/18-bit parallel interfaces and serial interface (SPI), to configure system. The system interfaces can be used to configure system, as well as access RAM at high speed for still picture display. In addition, the OTM2201A incorporates 6, 16, and

18-bit RGB interfaces for picture movement display. The OTM2201A also supports a function to display eight colors and a standby mode for power control consideration. Here are some of the main features of the controller:

- 1 . One-chip solution for amorphous TFT_LCD
- 2 . Supports resolution up to 176xRGBx220
- 3 . Built in 87120 bytes internal RAM
- 4 . Line inversion AC Drive/frame inversion AC drive
- 5 . Interfaces
 - 68-series high-speed interfaces to 8-, 9-, 16-, and 18-bit parallel ports
 - 80 series high-speed speed interfaces to 8-, 9-, 16-, and 18-bit parallel ports
 - Serial Peripheral Interface (SPI)
 - Interfaces for moving picture display
 - 6-, 16-, and 18-bit RGB interfaces
6. Diverse RAM accessing for functional display

See schematic section for schematic of the OTM2201A.

Since our needs are for a moving motion picture display, the external interface (RGB interface) is the most suitable.

3.2.3.2 Programming

One of the advantages utilizing the Crystalfontz graphic LCD is the integrated controller. Predefined graphic TFT driver libraries are used to develop the GUI to be presented on the LCD. Crystalfontz recommends the following library sources: easyGUI, RAMTEX, Micrium, en.radzio.dxp.pl, and Segger. Our preference is to use an open source library of some sort, so as to avoid any costs related to a special development environment and/or library use.

Programming the heads up display LCD involves manipulating simple graphics, such as bars, lines, numbers, and possibly other geometric objects. Our plan is to use the following types of graphical elements for the each instrument cluster component:

Display element	GUI used
Speedometer	Large numbers, like seven segment display
Tachometer	Large color bar
Ambient temperature	Small numbers
Tire pressure monitor	Small color bar
Fuel level	Small, single color bar
Odometer	Small numbers
Oil Temperature	Small numbers
Safety restraint indicator	Small icon (on or off)

3.2.4 Components for the HUD

For the heads up display projector device, we selected an LCD display from “Crystalfontz,” which includes an integrated microcontroller and numerous parallel interfaces. We opted to go with a graphic LCD display, for obvious reasons. The LCD is back lit, and is fairly bright which is a necessity for a HUD projection device. Perhaps the biggest selling point of this LCD device was the integrated microcontroller with integrated drivers. This design eliminated the need to program a separate controller to take care of the graphics and drivers.



Figure 32:CFAF176220M-T LCD screen Source Datasheet.

This LCD has the following specs:

176xRGBx220 TFT consists of a TFT panel, a driver IC, an FPC (Flexible Printed Circuit) tail, and an LED backlight.

Module Dimensions

- Active Area is 50.8 mm (2.00") diagonal, width and height 31.68 (W) x 39.60 (H) mm (1.25" (W) x 1.56" (H)).
 - Overall module dimension with FPC *unfolded* is 38.40 (W) x 68.80 (H) x 3.50 maximum (D) mm (1.51" (W) x 2.71" (H) 0.14" (D)).
 - Overall module dimension with FPC *folded* is 38.40 (W) x 52.20 (H) x 3.50 maximum (D) mm (1.51" (W) x 2.06" (H) x 0.14" (D)).
- Requires only a single source 3.0v for both power supply and logic.
 - 8-bit parallel (8080) interface.
 - Driver IC is Orise Tech OTM2201A or compatible controller.
 - Transmissive display with LED backlight (edge-lit three white LEDs).
 - Display light pixels on a dark colored area (any color combination) or invert for dark colored pixels (any color combination) on a light area.
 - 12:00 o'clock Viewing Angle.
 - Wide temperature operation: -20°C to +70°C.
 - RoHS compliant.

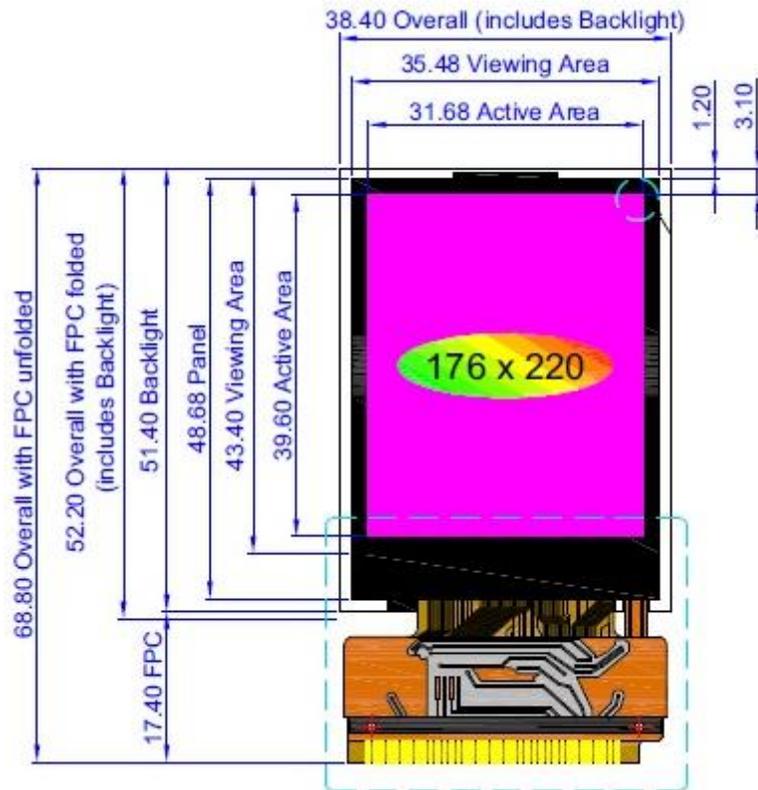


Figure 33:CFAF176220M-T Source Datasheet.

For the combiner surface we chose to use curved glass with a plastic reflective coating. Similar to automotive and aircraft HUD systems, the coating make viewing the image easy in all lighting conditions. We are currently actively searching for a combiner glazing or coating solution, and are leaning towards using coating technology from Saflex, a company that specializes in automotive HUD windshield glazing. The coating will be applied to a curved glass, which we will acquire from a vehicle windshield.

3.3 Touch Screen Design

Implementing a center mount approach, it is our intent to mount the touch screen about the middle of the vehicle simulator's dashboard in a similar fashion to the Lexus sedan pictured below.



Figure 34:Lexus Sedan's full dashboard, viewing center console
Permission pending from Lexus

To ensure that the screen will be easily accessible the Bergquist BER280-ND 12 inch 4 wire resistive touch screen will be used in conjunction with the TI/Burr-Brown TS2200 touch screen controller. The GUI interface will be provided by the amulet technologies' GUI OS chip dubbed AGB64L. This particular chip will handle all the graphics for our interface and operate independently of the main controller.

3.3.1 Touch Screen Block Diagrams

The block diagram below is a high level view of how the GUI chip interfaces with the display and touch screen.

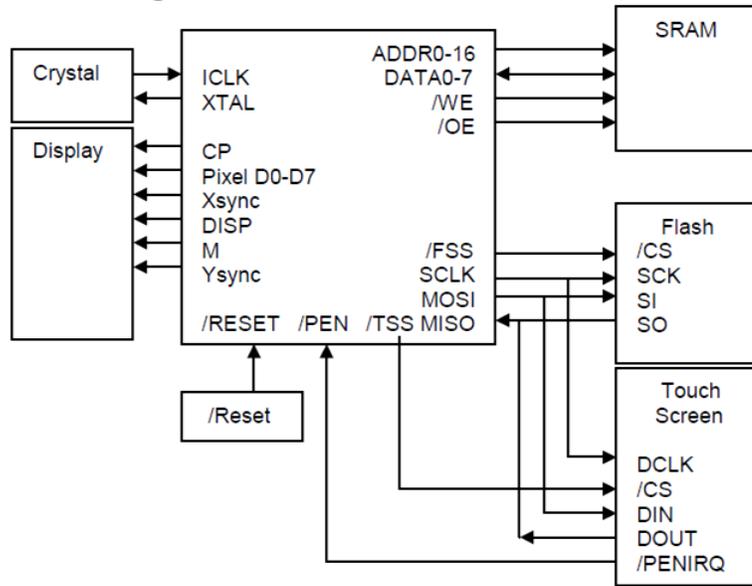


Figure 35: Schematic Diagram for Touch Screen
Permission pending From Pryxis

The GUI chip outputs to the touch screen as well as receives input in order to relay to the touch screen controller. Using the SPI communications protocol the chip is set up as such:

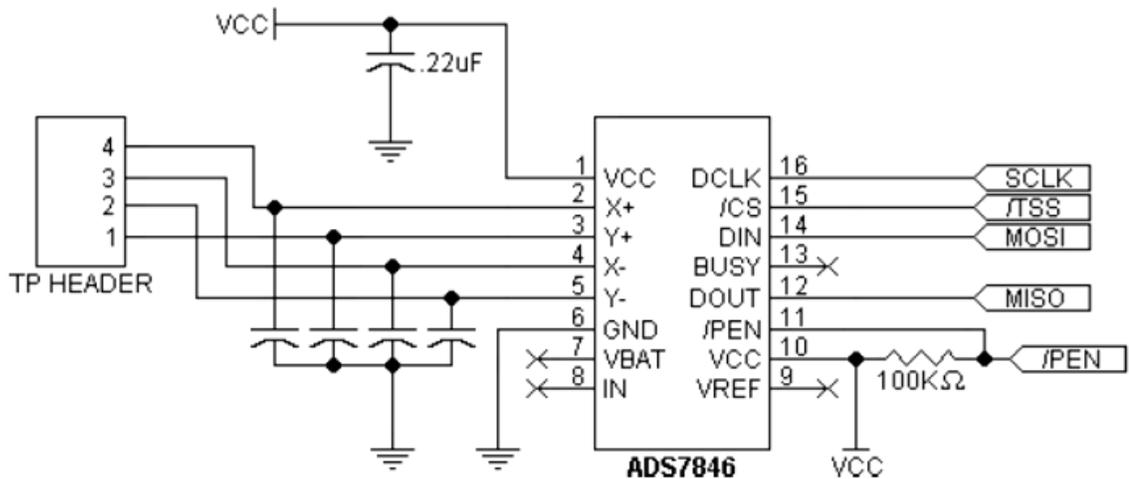


Figure 36: Schematic Diagram for Touch Screen
Permission pending From Texas instruments

Where the 4 noise reducing capacitors may or may not be needed. The ADS7846 touch screen controller is used to interpret the data from the touch screen into x and y coordinates which corresponds to a subroutine to be executed from our main program. An overall block diagram with both the touch screen controller, GUI chip and touch screen can be seen below:

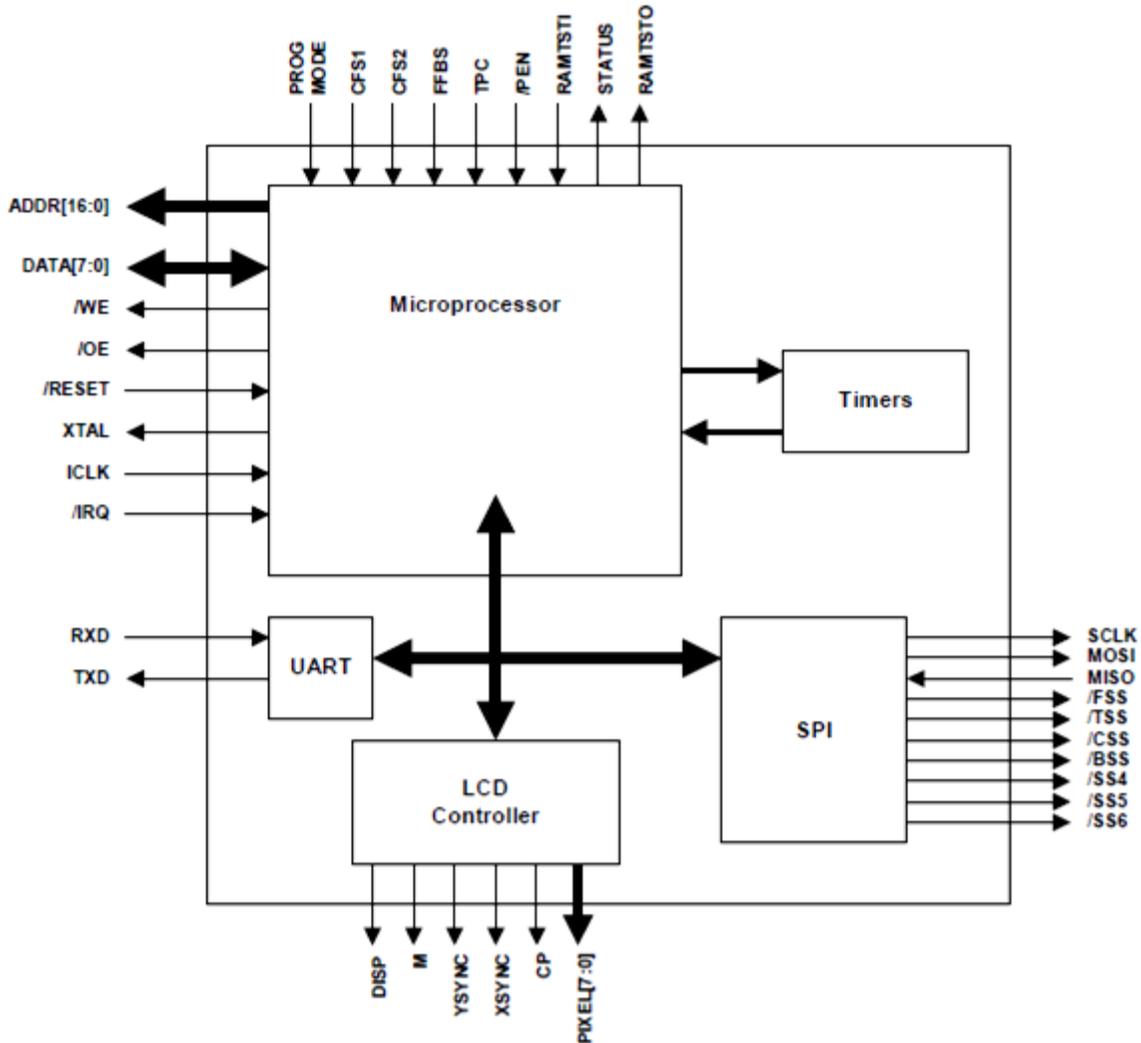


Figure 37: Schematic Diagram for Touch Screen
Permission pending

Please note the touch screen is interfaced with the LCD controller and that this particular diagram communicated with the rest of the design via the SPI protocol, which was chosen due to its wide utilization in the automotive industry. This will help communication between them.

3.3.2 Comparison of Approaches

3.3.2.1 Capacitive vs. Resistive (4/5 Wire)

The 2 main approaches to be taken when designing a touch screen interface are the capacitive and resistive routes. Within the resistive route a 4-wire and 5-wire option also exists. When first considering the capacitive screen it is immediately noted that the capacitive technology is much more expensive and not as readily available. Capacitive screens are constructed with glass that, while more durable, is also much more expensive to repair or replace in the event of an accident.

Cracks in a glass screen can impair operation and visibility. Barring any coating on the surface, the glass fragments also pose a harmful threat to those that choose to interact with the shattered screen.

While still not fully operable when damaged, Resistive touch screens have the benefit of having a cheaper price tag and in an environment where the device is used daily and exposed to assorted abrasives for durability alone the resistive models tend to come out ahead. Comparisons within the resistive family highlight a different thing. Since the technology is so similar with one being more expensive than the other, the aspect of diminishing returns comes into play. For an application such as ours, is the added investment of funds into a 5 wire system justifiable compared to the throughput we would obtain from a similarly sized 4 wire model?

To determine this we observe the durability specifications of both 4 and 5 wire screens and determine that although the 5 wire systems perform better under durability the practical application of this fact is not optimal per our application. Whether or not a screen has the ability to power cycle 4 million times vs 5 million is irrelevant as most vehicles do not have a lifespan that would compare to one such as that.

3.3.2.2 Mounting Options

Another point of comparison was size as this would ultimately determine the location of our control center. Smaller screens had more possible locations while larger models ultimately had to be mounted center mass under the central air vents of a vehicle. When selecting where to place the screen, it is important to remember that the driver must be able to access and at times clearly see the display. Suffice it to say, this eliminates the in glove box method of mounting as it would be a dangerous feat to attempt to operate the screen while driving.

The Lexus sedan pictured above displays several different possible options as well as different sizes and locations that would theoretically be available. Obviously we wouldn't put it in the glove box; we want it definitely to be in the center.



Figure 38: Lexus Touch Screen comparison
Permission pending from Lexus

Yet another approach was to utilize an in dash method of mounting which would save on room and minimize the impact of having the touch screen in place because it can be safely tucked away when not in use. This also serves as a theft deterrent in cars as it hides itself from the prying eyes of would be thieves.



Figure 39: CD receiver touch screen device
Permission pending from Meritline.com

3.3.2.3 Color vs. Monochrome

Another consideration was the resolution and color capabilities of the screen. As it is, after all, a vehicle application, it is a reasonable assumption that aesthetics must be considered during the design phase. Therefore when considering monochrome vs full color screens it is important to note whether or not they are capable of rendering the desired clarity and detail.

While a monochrome screen such as the one pictured below would perform the tasks it needed to with no issue.



Figure 40: Monochrome screen
Permission pending from meritline.com

The following screen is much more suited for a vehicle application because it adds to the vehicles aesthetics rather than detracting for it. In a product that is designed for a vehicle that one must also consider the needs and tastes of as many people as possible.



Figure 41: Touch screen for vehicle
Permission pending from meritline.com

Communications Protocols

Although several were available, due to our lack of knowledge on the matter we picked a protocol which was an industry standard and possessed a wide library of resources that would help us in our design. The SPI protocol is an industry standard serial communications protocol which has been around long enough that finding assistance should not prove to be too challenging.

Determinations

Because across the board, power demands as well as physical dimensions were so very similar, component choices came down to cost, availability, durability and cost effectiveness. Also considered were its aesthetics as well as its communications protocols, which is ultimately what will tie the system together. For these reasons the touch screen technology A2D will utilize is the 4-Wire resistive type utilizing anti glare technology for optimum performance in direct sunlight conditions as well as additional protection from scratches and fingerprint resistivity which adds to the overall aesthetics of the vehicle.

3.3.3 Touch Screen Architecture

The GUI chip is programmed using the proprietary HTML compiler provided by amulet technologies.

This allows near drag and drop design capabilities for GUI layout planning and design. The TI/Burr-Brown components are all programmed in C. These parts include the touch screen controller and the MCU for the touch screen section.

- Other than the GUI chip, all programming is open source compiler driven
- Full system integration via SPI is not necessary until the individual Touch Screen section is operational
- Autonomy from the main micro controller due to the onboard MCU on the GUI chip from amulet tech.

Upon touch screen system completion, it is then integrated with the rest of the project using the SPI communications protocol.

3.4 Simulation Design

3.4.1 Simulation block diagram:

The following block diagram shows a simplistic version of the full system overview. This diagram shows the communication buses between each controller and each input or output.

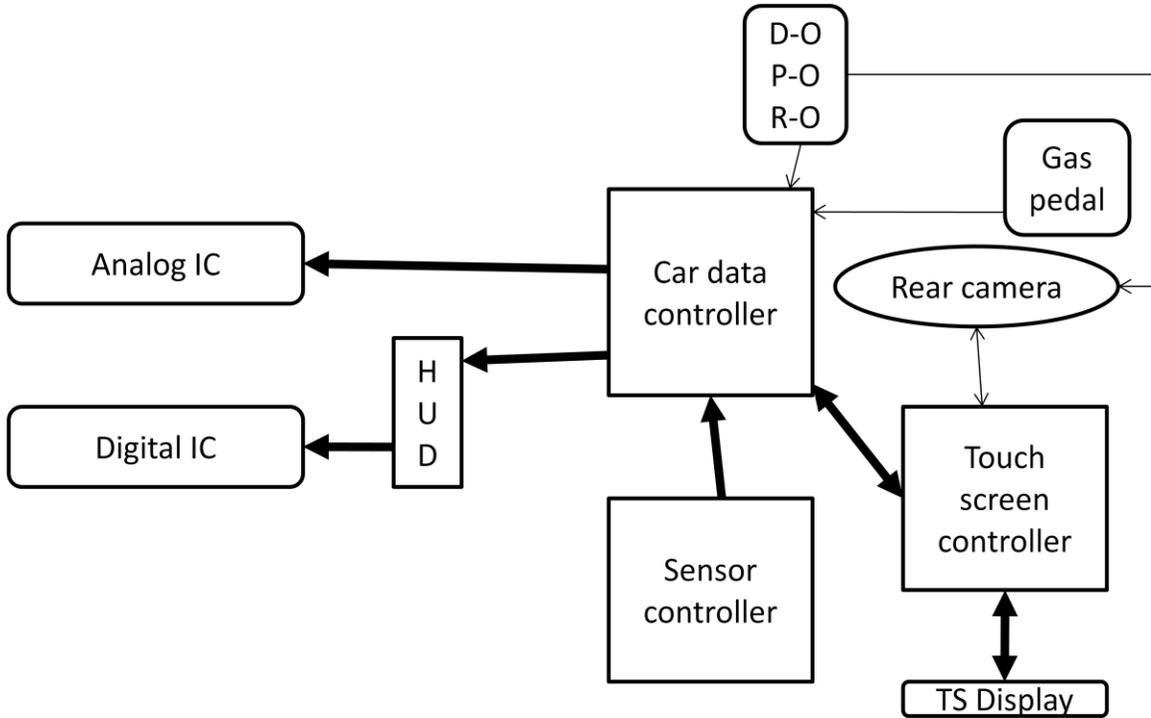


Figure 42: Simulation Block Diagram (Frank Reed)

3.4.2 Simulation design:

There are many ways we can construct a simulated dashboard. The way we want to design it would be to build a box to display each featured item. The display box will be mobile but very strong. It will require the user to interact just as if it was a car. The model includes two real car instrument clusters and a transmission like D-P-R area. Also to complete the simulated dashboard we have a touch screen center console to control the windows and locks. There is also a tire pressure sensor and rear view camera that displays on the touch screen. The user can also use a gas pedal to simulate RPMs and speed.

The following image represents the closed 3D view of our full simulation box. The box will measure four feet wide, four feet tall and two feet deep. This will give us the most room for displaying all of our features.

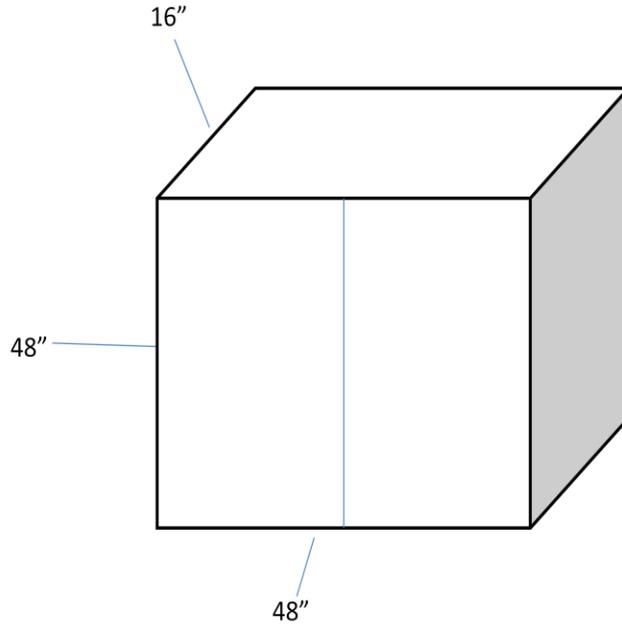


Figure 43: Outside view of the simulation box, with dimensions. (Frank Reed)

The top of the box view shows it split across the whole box. This is because we will have the controllers and wires hiding behind the front, so when the user is viewing our modifications it will be less cluttered.

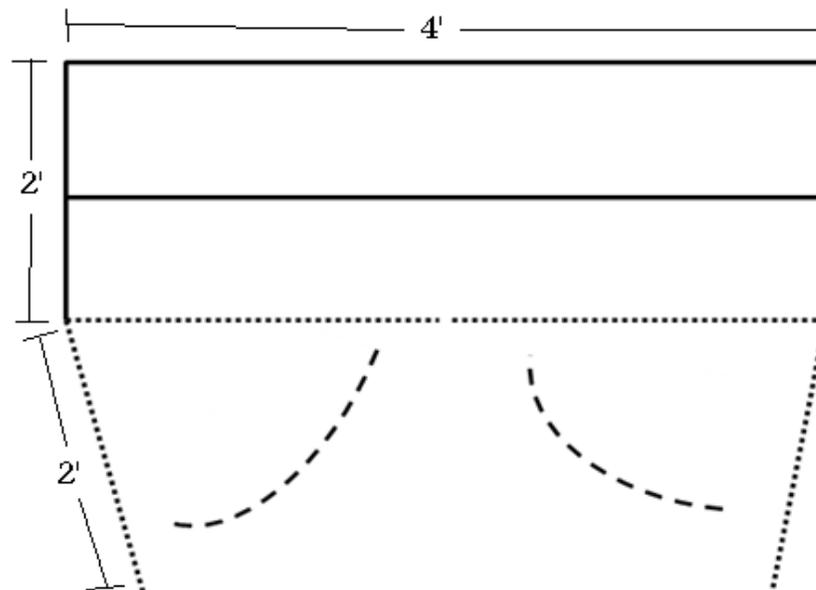


Figure 44: Top view of the simulation box. (Frank Reed)

The size is pretty close to a real life car, as measured before was a 1995 Honda Dx coupe, which the dashboard measured to be 50" across. This means we have enough room to simulate a full length dashboard to acquire all of our specifications.

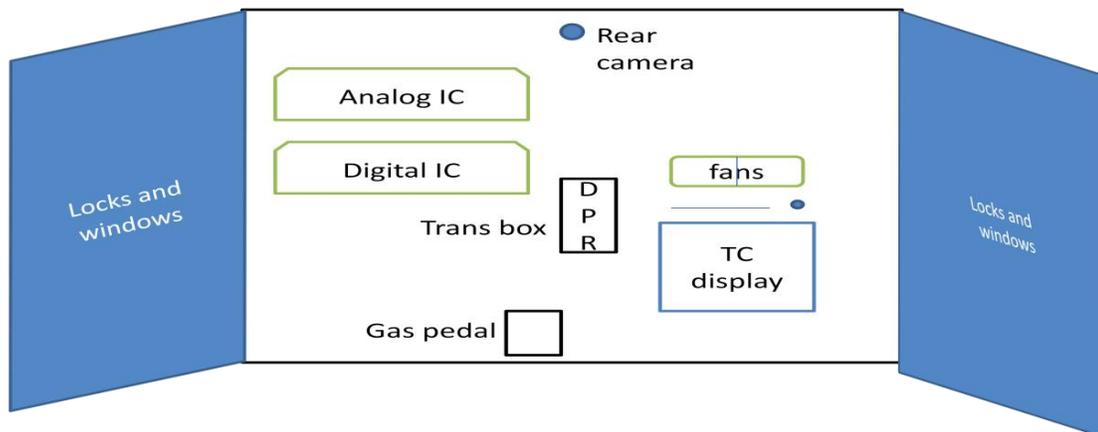


Figure 45: Front user view of simulation box, showing featured components. (Frank Reed)

The box may be mobile with wheels attached to the bottom. Along with a few simulated features such as the a/c will be simulated with fans. The radio may be simulated with just LEDs showing power on or off. The windows will be simulated the same, but the locks may be more realistic. There will be a real tire with a tire pressure sensor inside and will demonstrate that is really works on the touch screen display.

3.4.3 Car Data controller comparison

After researching a few controllers that meet the required design specifications for the simulation of car data, we came across the three development boards to practice on. The three boards included the ARM, PIC, or ATMEL chip. The ATMEL board is really good for beginners, but the PIC board is half the price. The ARM board may exceed our requirements far more than we need. That leaves the other two boards to discuss. The PIC board offers a feature that the ATMEL board doesn't, a breadboard. This will allow us to practice on certain I/O connections needed for our simulation.

The following is a table of certain features regular to micro controllers and the three controllers in comparison. As you can see, the PICF18 4550 is a very strong and independent controller. We plan to use this controller in our final design.

	PIC	ATMEL	ARM
architecture	8 bit	8 bit	32 bit
Internal and external oscillator	yes	yes	yes
Analog to digital	yes	Yes	Yes
Digital to analog	yes	Yes	Yes
I/O	35	32	35+
Low power modes	many	Yes	few
pins	40	40	64
Flash memory	32K bytes	8K bytes	32K bytes+
eeprom	256 bytes	256 bytes	256 bytes +
sram	2048 bytes	No	2048 bytes +
MSSP	I2C, SPI	I2C	I2C, SPI
Compiler	C, MPLab	Own software	JTag
Price of chip	\$4.47	\$3.53	>5
Price of development board	\$47	\$94	\$105

Table 23 Comparison of the PIC, ATMEL, and ARM processors

3.4.4 Car Data Programming

After deciding on using the PIC board we looked in how the processor is compiled. There are many free compilers for the PIC18 family. The PIC18 chip can use a program called MPLab, which allows the chip to be programmed in C. For academic use, MPLab offers students a special free version. This free version has limited but still amazing features.

The PIC is also good because it requires few external components, which is probably why the development board is half the price and half the size of the other two microprocessors we've researched.

The IDE editor seems to be straightforward to use and learn. We find this software to be very fortunate for our design experience. The following figure is an example of the student version MPLab.

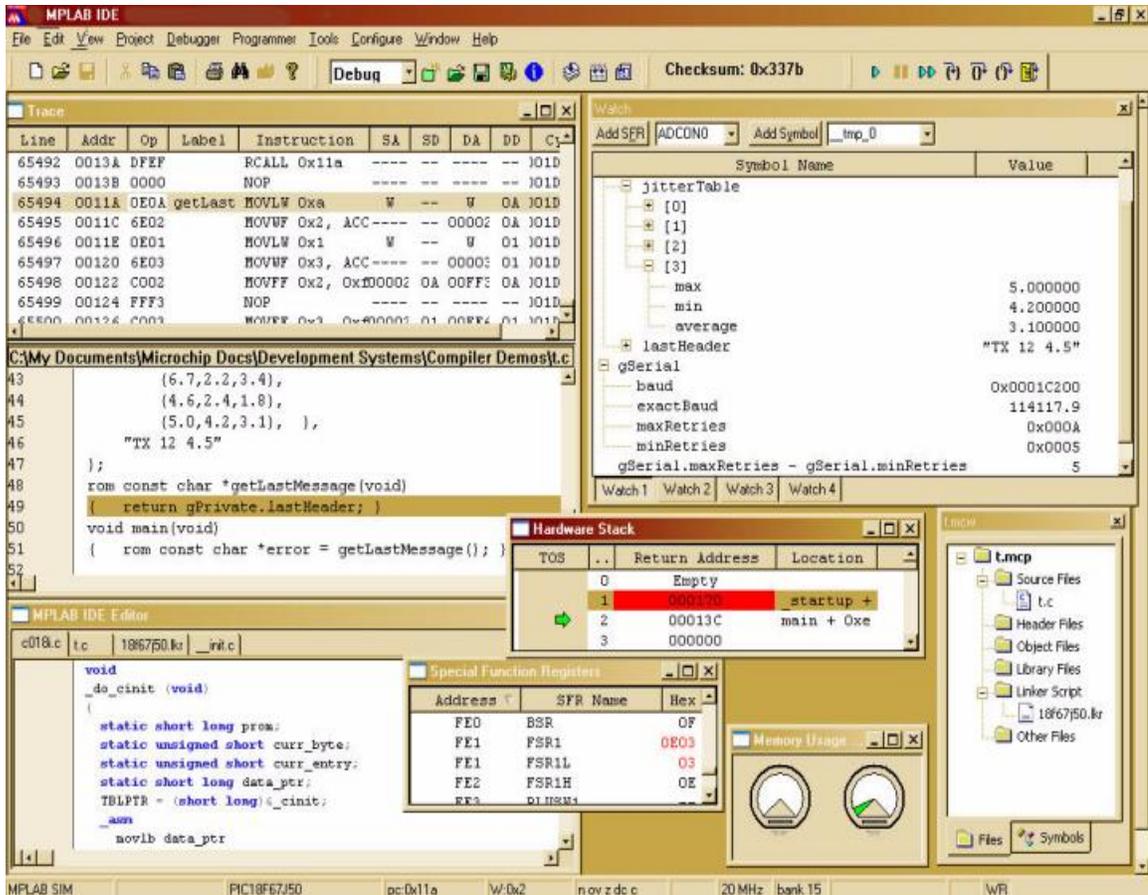


Figure 46: MPLab for academia use
Permission pending from Microchip

3.4.5 Car Data Schematic

The PIC18 will be powered by a +5v coming from a regulator. The regulator converts the 12v battery we will be using into the 5v we need for each of the controllers. The 12v battery will be rechargeable and simulates the car battery. The schematic shown below expresses the PIC18F 4550 connected to ground, regulator and the I/O pins.

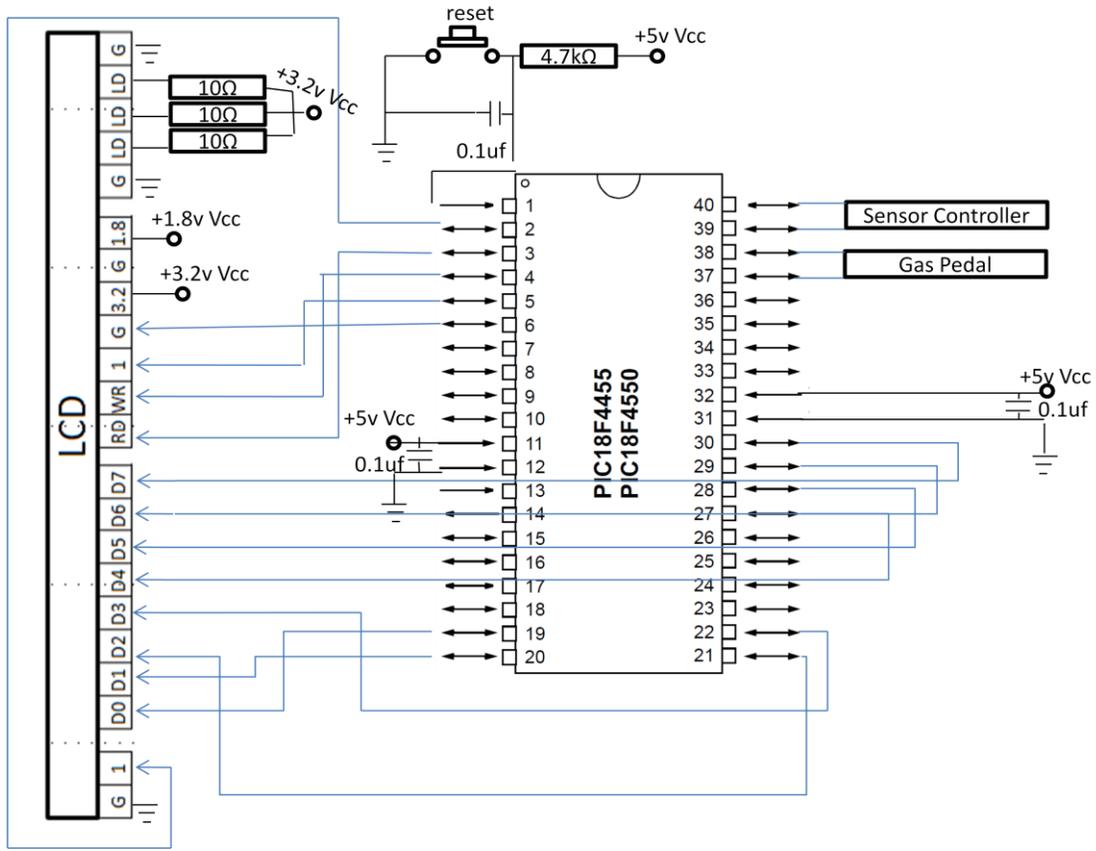


Figure 47: Schematic view of the PIC18F 4550 with inputs and outputs (Frank Reed)

A full schematic will be derived when group gets parts after testing and programming.

3.5 Sensors Design

3.5.1 Sensor Block diagram

The Sensor Systems are made up of five different systems that usually implemented in a normal vehicle. These inputs will be incorporated in our simulator to have the same feel and functionality of a real vehicle. Sensor Systems will be demonstrated using actual automotive sensors or simulated if parts may become unavailable.

Sensor Block Diagram

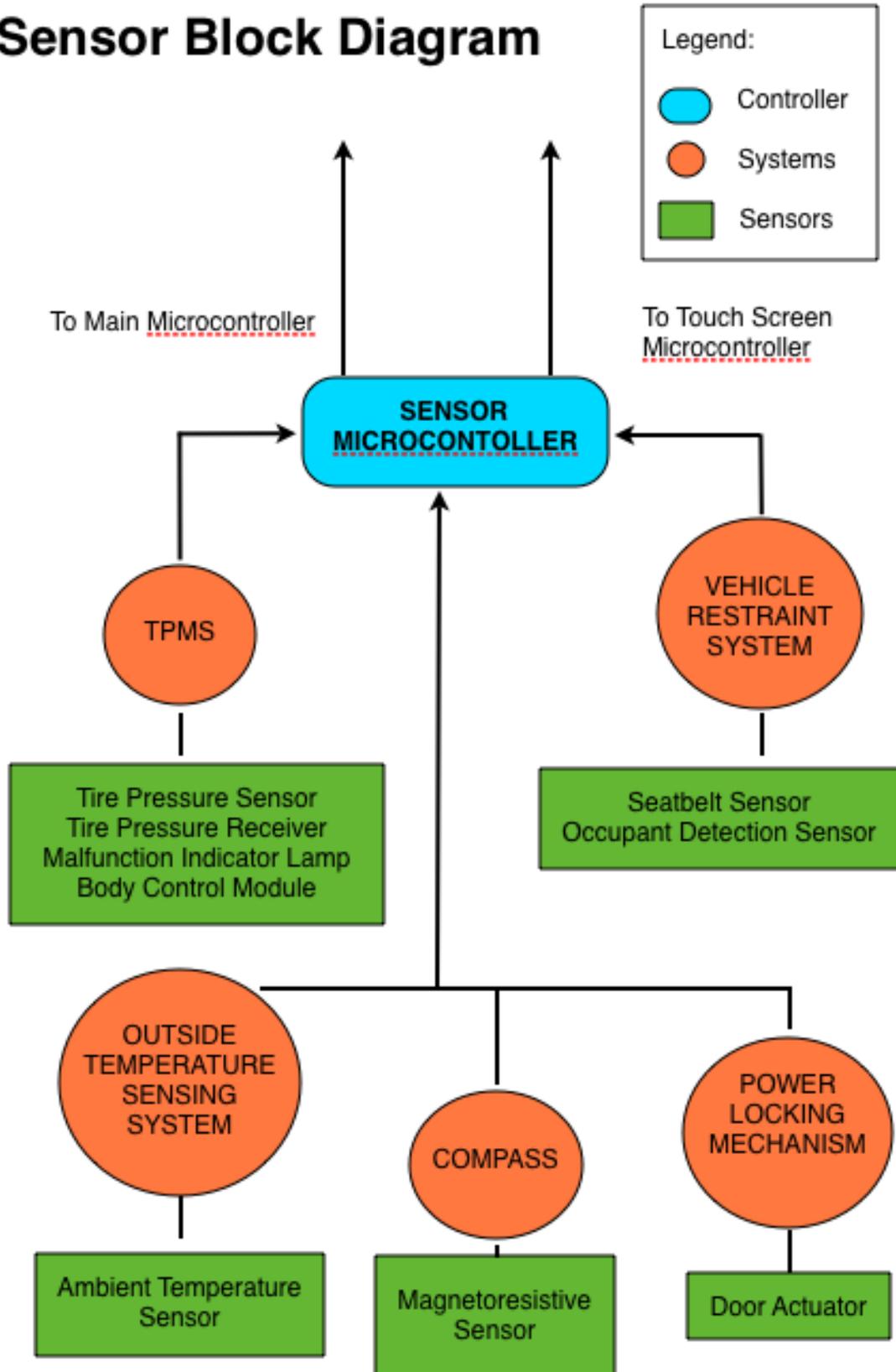


Figure 48: Block diagram of the sensors system. (Chris de Guzman)

The Tire Pressure Monitoring System is composed of tire pressure sensor, tire pressure receiver, Malfunction Indicator Lamp, and Body Control Module. This system will connect to the Sensor Microcontroller to translate its data and pass it on to the Main Controller.

Together with the TPMS, the Vehicle Restraint System will also connect to the Sensor Microcontroller and also transmit data to the Main Controller. This system is composed to the seatbelt sensor and Occupant detection sensor which works together to perform this functionality.

Lastly, the Outside Temperature Sensing System is connected to the Sensor Microcontroller. The data from the temp sensor will be in digital and will be translated by the sensor controller. This data will be transmitted to the Main Microcontroller also. Every sensor data that is transmitted from the sensor controller to the main controller will be displayed in our A2D HUD Instrument Cluster.

There are two systems that are connected to our Touch Screen Microcontroller, the Compass which is a 2-axis magnetoresistive sensor and Power Locking Mechanism which is a door actuator. The Compass will only transmit data to the Touch Screen controller while the Power Locking Mechanism system will receive data from the touch screen controller.

3.5.2 Comparison of approaches for the sensors

We will compare different sensors to demonstrate the following systems:

- Tire Pressure Monitoring System (TPMS)
- Outside Temperature Sensing System (Ambient)
- Compass
- Power Locking Mechanism
- Vehicle Restraint System

3.5.2.1 Tire Pressure Monitoring Systems (TPMS)

Direct Sensors vs. Indirect Sensors

Most TPMS in new cars nowadays use direct sensor because is simple and effective. Direct sensors employ physical pressure sensors inside each tire and it can identify simultaneous under-inflation in all four tires in any combination while indirect sensors do not use physical pressure sensors. Instead Indirect TPMS monitors the individual wheel rotational speeds. It uses the fact that an under-inflated tire has a slightly smaller diameter than a correctly inflated tire and therefore has to rotate at a higher angular velocity to cover the same distance as a correctly inflated tire. Direct-sensor system may use a radio-frequency (RF) communication channel or an electromagnetic coupling means to overcome the tire/chassis rotational boundary while Indirect TPMS are realized in software in

combination with wheel-speed sensors for anti-lock braking systems and electronic stability control systems. One of the disadvantage of a direct TPMS are the sensors fitted at the back-end of valve stems and are prone to being damaged during tire mounting and dismounting procedures at the tire fitters so extra caution is required in performing such services. Another one is most direct TPMS sensors are battery-powered and may need maintenance and replacement while direct TPMS are mostly connected to the vehicles power source. Lastly, most direct TPMS does not calibration and programs by itself when users rotate their tires while in Indirect TPMS the driver must calibrate the system every time that there is a change in the system. This is why most manufacturers opt for direct sensors to use in their TPMS instead.

Battery-powered vs. Battery-less

The pressure sensor devices used in direct-sensor TPMS may be either battery-powered or battery-less. Battery-powered sensors are the most common that are used today. Most RF based TPM sensors on the market today use a battery, a silicon-based pressure sensor, and an RF oscillator, either SAW- or PLL-based. TPMS Batteries are normally designed to last for 7 to 10 years and not the entire life of the vehicle so it does require to have them replaced and recalibrated. Clearly, Battery-less TPMS would be ideal as it does not need battery and/or maintenance every 7 to 10 years. According to wikipedia, a new generation of battery-less TPMS is being developed by two companies using quite different technologies Transense is promoting a SAW-based technology. and VisiTyre is using an electromagnetic close-coupling technology to effectively eliminate the sensor battery and make the TPMS maintenance free. VisiTyre battery-less TPMS also eliminates the need for any "Learn Tools" to register new sensor positions after wheel rotation and workshop procedures. Transense had licensed its technology to several automotive companies but it is not yet commercially available for OEM passenger vehicles.

Real TPMS vs. Simulation

The group found that Atmel have a full line of Automotive products including its own applications in tire pressure monitoring systems (TPMS). Their TPMS product portfolio includes a low-power Flash-microcontroller, RF-transmitter IC family that can be used together with separate motion or capacitive pressure sensors. Finding the parts for Atmel's system is relatively easy because they conveniently put them together. The hard part is implementing them and configuring them to work together. We are still trying to figure out how to package a capacitive pressure sensor to a tire valve together with board design running on a battery. On the other hand, simulating this system is fairly easy. We can use proximity sensors to simulate the under inflated or "low tires". We can install the sensor at the back of the tire. When air is let out through the valve stem, the tire will decrease in size and will trigger the proximity sensor and display a fault light in our a2d Instrument cluster.

Information about OEM TPMS is hard to find. The group did not find enough details to implement and use existing systems. OEM or replacements are also very expensive. TPMS Sensors are already more than \$70 per sensor. OEM Receivers and transmitters are obviously a lot more than the sensor. The Accutire External Retro-fit TPMS is \$89 which is more than what the group is willing to spend for such a small part of the project. We have to realize that the main idea in this project is to replace an analog gauge with a digital HUD instrument cluster with touchscreen display. The only reason we have a TPMS in the project because new vehicles comes with it and is typically “displayed” in the instrument cluster. Simulating this function will not only be sensible but also cost less.

3.5.2.2 Outside Temperature Sensing System

Digital Temp Sensor vs. Analog Temp Sensor

Temperature sensor will be needed to show the ambient temperature in our a2d instrument cluster. The main difference between digital and analog is functionality and cost. They both will measure temperatures from -55°C to $+125^{\circ}\text{C}$ (-67°F to $+257^{\circ}\text{F}$) and even operate at the same 3.0V to 5.5V at the same level of $\pm 2.0^{\circ}\text{C}$ accuracy. Digital cost more that is around \$5.00 and analog cost around \$1.00. This is because digital sensors usually come with a converter (analog to digital / temperature to digital), memory (temp register), and logic control. These functionality are usually handled by a separate ic although some microcontroller have this capability.

Texas Instrument TMP100 vs. Maxim DS1822

These sensors are both digital with similar capabilities. Their resolution is the same up to 12-Bits and is user selectable, measure temperatures from -55°C to $+125^{\circ}\text{C}$ (-67°F to $+257^{\circ}\text{F}$) and even operate at the same 3.0V to 5.5V at the same level of $\pm 2.0^{\circ}\text{C}$ accuracy. They both come with a converter (analog to digital / temperature to digital), memory (temp register), and logic control (I/O). The main difference between these two is the interface on how they would communicate. TI uses a I²C two-wire serial interface and Maxim uses 1-wire interface. Lastly, these two have a completely different packaging. TI uses a SOT23-6 surface mount packaging while Maxim uses a TO-92 through-hole mount packaging.

Surface-mount vs. Through-hole

According to wikipedia, the main advantage of Surface-mount technology(SMT) over the older through-hole technique is they use smaller components therefore smaller “realty”. Fewer holes need to be drilled through and simpler automated assembly. SMD(surface-mount device) is easier and faster to be placed by automated machines than a through-hole component. They are capable of placing more than 136,000 components per hour. Components can be placed on

both sides of the circuit board using SMD but through-hole can not as the wire goes through the board. SMD also have a lower resistance and inductance at the connection which leads to better performance for high frequency parts. SMD parts generally cost less than through-hole parts as through-hole is becoming scarcer.

The main disadvantage of SMD is the manufacturing processes for SMDs are much more sophisticated than through-hole boards, rising the time of setting up and initial cost for production. Manual prototype assembly or component-level repair is more difficult given the very small sizes and lead spacings of many SMDs. SMDs can't be used with breadboards, requiring a custom PCB for every prototype. SMDs' solder connections may be damaged during rework as pads are known to lift up out of the PCB.

3.5.2.3 Compass

Gyrocompass vs. Magnetic Compass

Gyrocompass has two main advantages over a magnetic compass. First is it finds the true north which is the direction of Earth's rotational axis as opposed to magnetic north. Secondly, they are far less susceptible to external magnetic fields.

1,2 and 3 Axis Magnetic Sensors

1 Axis Magnetic sensors like HMC1051 are used for simple magnetic field sensing applications such Magnetic Anomaly Detectors (MADs), Magnetometers, switch or a latch. A similar circuit to the compass application can be implemented using one, two, or three magnetic sensors. It can also be used as a current sensor with thermistor element performing a temperature compensation function. 2 Axis Magnetic sensors like HMC1052 are ideal for low cost 2-axis compass. The basic principle of two-axis compassing is to orient the two sensor bridge elements horizontal to the ground (perpendicular to the gravitational field), orthogonal to each other, and to measure the resulting X and Y analog output voltages. With the amplified sensor bridge voltages near-simultaneously converted to their digital equivalents, the arc-tangent Y/X can be computed to derive the heading information relative to the X-axis sensitive direction. 3 Axis Magnetic sensors are like 2 axis magnetic sensor plus one like HMC1053. They are usually used for sensing the magnetic field in three axis. A good example of application of this sensor will be for airplane use. The third sensor is used for tilt sensing. Here is a list of Honeywell's Magnetic sensors with corresponding application, size, and price.

Design Criteria for HMC Components			
Application	Size (Small/Smaller/Smallest)	Price (Low/Lower/Lowest)	Performance (Good / Better / Best)
General Compassing	HMC1022/1043/1042, 1052	HMC1043/1022, 1042/1052	HMC1052/1022,1042/1002
Compassing- Automotive			HMC1052/1042/1022
Compassing- Hand Held, GPS			HMC1052/1022/1042, 1043
Attitude Reference	HMC1002/1022/1043, 1042	HMC1002, 1043/1022/1042	HMC1042/1022/1002, 1043
Metal Detectors	HMC1021S/1041Z/1042, 1052	HMC1021S, 1041Z/1042/1052	HMC1021S, 1041Z, 1052/1042
Vehicle/Traffic Detection	HMC1021S/1041Z/1052	HMC1041Z/1021S/1052	HMC1052 /1041Z, 1021S/1001
Current Sensing	HMC1021S/1042/1052		
Vertical (Z- axis) Sensing	HMC1001, 1021Z, 1051Z/ 1041Z	HMC1001/1051ZL, 1051Z/ 1021Z, 1041Z	HMC1051Z, 1051ZL/1021Z, 1041Z/1001
Position Sensing	HMC1501, 1512	HMC1512/1501	HMC1501,1512

Figure 49:Honeywell’s Magneto resistive Components Application Matrix
Permission pending from Honeywell

HMC1022 vs. HMC1042 vs. HMC1052

From the information gathered from above, the group opted for a 2 Axis Magnetic sensor for a simple two-axis compass. The specifications for these sensors are very close and would suffice for the application we are aiming for.

Here is a table of specification for these sensors that we can use in selecting our sensors.

	HMC100X	HMC102X	HMC104X	HMC105X	Units
Sensitivity*	3.2	1.0	1.0	1.0	mV/V/Gauss
Field Range**	± 2	± 6	± 6	± 6	Gauss
Field Resolution**	27	85	120	120	µGauss
Linearity (± 1G)	0.1	0.05	0.05	0.05	% FS
Supply Voltage (typ.)	5 - 12	5 - 25	1.8 - 25	1.8 - 25	Volts
Set/Reset Current	3.0	0.5	0.5	0.5	Amps
Offset Strap Coil Constant	51	4.6	10	10	mA/gauss
Orthogonal Axis Alignment	1.5	1	<0.01	<0.01	Degree
Cross Axis Effect	0.5	0.3	0.3	3	%
Size	12.7 x 7.3 x 2.5	10 x 3.9 x 1.5	3 x 3 x 0.8	3 x 3 x 0.8	mm
Board Area (2 Axis)	128	60	10	10 - 15	mm ²

Figure 50:Honeywell’s Magnetoresistive Components Specification Matrix

3.5.2.4 Power Locking Mechanism

Door Lock Types

According to the 12volt.com, there are 6 types of door locks namely Single wire systems, 3 Wire Negative, 3 Wire Positive, 4 Wire Reversal, 5 Wire Alternating +12V DC, and Vacuum Type door lock types.

In Single Wire System there may be one, two, or three wires in the harness and only changes in voltage or resistance on one wire to lock and unlock. Some of these will open a circuit to lock and ground a wire to unlock while others will show a difference in resistance to ground or positive 12V DC during lock or unlock or both. In 3 Wire Negative, there are three wires in the harness like the 3 Wire positive. The difference is one wire has continuity to ground at all times for negative and one wire has constant +12 V DC at all times. Another wire only shows continuity to ground during lock and +12 V DC at rest. The last wire only shows continuity to ground during unlock and + 12 V DC at rest. In 3 Wire Positive, another wire only shows (+) 12 V DC during lock and ground at rest. The last wire only shows (+) 12 V DC during unlock and ground at rest. 4 Wire Reversal have four wires in the harness. One wire has constant (+) 12 V DC at all times. Another wire has continuity to ground at all times. A third wire reads nothing at rest, and +12V DC during lock and continuity to ground during unlock. The fourth wire reads nothing at rest, and ground during lock and +12V DC during unlock. 5 Wire Alternating +12 V DC, there are four, five, or six wires in the harness. One or two of the wires has constant +12 V DC at all times. One or two of the wires has continuity to ground at all times. Another wire reads continuity to ground at rest, and +12V DC during lock. The last wire reads continuity to ground at rest, and +12V DC during unlock. Last is the Vacuum Type which has no external switch and it has three wires. One wire always shows continuity to ground. Another always shows constant +12 V DC. The third wire changes, reading continuity to ground or +12 V DC depending on the position of the door locks.

The more wires there are, the more complicated a system can be. Power Lock mechanism systems depend on the manufacturer's design and features. Every system is made up of actuators and relay switches.

3.5.2.5 Vehicle Restraint System

Seat belt

1) Types

Lap Seat belt is an adjustable strap that goes over the waist which is normally found in older cars or rear middle seats. Passenger aircraft seats also use lap seat belts to help prevent injuries while still allowing passengers to adopt a brace position. In automobiles, this type is less safe than the three-point harness.

Three-point are the most common in vehicles nowadays. This is similar to the lap and sash belts, but has one single continuous length of belt. It helps spread out the energy of the moving body in a collision over the chest, pelvis, and shoulders therefore the safest way to buckle up in non-competition type vehicles. Belt-in-Seat (BIS) is a three-point where the shoulder belt attachment is to the backrest of the seat, not to the B pillar. Five-point harnesses are the safest but most restrictive than most other seat belt types. They are typically found in child safety seats and in racing cars. The lap portion is connected to a belt between the legs and there are two shoulder belts, making a total of five points of attachment to the seat. Six-point and seven-point harnesses are also available but will not be discussed because they only apply to racing and/or aerobatic aircraft and will not be considered for this project.

2) Delphi Seat Belt Sensor vs. Hamlin's Seat Belt Buckle Sensor

Delphi claims advantages over competitors:

- Lower cost and better performance than A-surface solutions
- Stable performance over a wide temperature and humidity range
- Short development cycle – existing design suitable for majority of applications
- Well established relationships with seat manufacturers worldwide
- More than 10 years of outstanding performance with B - surface technologies Engineering and manufacturing localized in region to meet customer needs

Delphi also claims that their low-cost solution for passenger presence detection in vehicles helps to lower cost while enhancing seat comfort. The switch assembly's peel and stick design attaches to the B-surface of the seat foam. The sensor can be used in both the front and back seats. The system meets New Car Assessment Program (NCAP) requirements, helping vehicle manufacturers to increase their vehicles' star rating.

Hamlin's seatbelt sensor which uses reed, Hall effect and microswitch technology. The company claimed this is used to indicate if a vehicle occupant has fastened their seatbelt that is used to control the activation of passenger airbag. Like Delphi's sensor, it will also trigger an audio/visual warning in the event that a seat is occupied and the belt is not fastened.

Occupant Detection System

1) Delphi vs. TI vs. Freescale

Delphi Automotive Systems advanced Passive Occupant Detection System (PODS) makes two types of sensors, piezoelectric sensors and Hall Effect sensors. The company's first-generation system is designed for weight detection which uses in concert with fluid-filled bladders located in the car seat. Delphi's

second generation Occupant Position and Recognition System uses infrared sensors. Delphi states that by filling the passenger compartment with invisible measurement coordinates, the IR sensors enable the system to recognize if a rear-facing child seat is present or if the occupant is out of position. TI force-based occupant weight detectors use piezo-resistive strain gages which are placed in a carefully designed steel structure within the seat. Small strains are produced by a body in the seat produces a change in electrical resistance, thus producing a voltage signal that is proportional to the weight of the body on each sensor. Freescale, MC33794 integrated circuit uses electric field imaging to detect the presence of a car seat. The chip generates a low-level e-field from multiple antennas mounted in the seat back cushion. If a conductive body enters the e-field, the system detects it through a drop in AC voltage.

3.5.3 Components for Sensors

Based on the comparison of approaches, these are selected parts the group has decided to use in our project.

3.5.3.1 Tire Pressure Monitoring System (TPMS)

The group has decided to use a direct sensor for the TPMS. We found that this is going to be the simplest and most effective way to demonstrate TPMS in our project. The disadvantages of a direct sensor; prone to being damaged during installation during mounting and dismounting and battery exhaustion, would not be a problem in this case. We would try to make a sensor that will go outside of the tire like the external retro-fit by Accutire and as for the battery lifetime, we think that 10 years will be long enough for this project. We would try and implement the real TPMS system using Atmel's system. It will involve a lot of system integration and firmware programming but hopefully we would have enough time to do so. In the event of insufficient time and cost, we would opt for simulating this system by using a reed switch as a proximity sensor that will produce an interrupt when the tire reaches a certain level of being "low".

3.5.3.2 Outside Temperature Sensing System (Ambient)

Digital would be an ideal Temperature sensor as it is simpler and has fewer components to integrate. The cost might be higher but it would be irrelevant as we are only building one. Through-hole mounting will be ideal in our project because it is going to be easier to solder to our PCB (printed circuit board). Every component will be put on by hand and not by pick and place machines. Both TI TMP100 and Maxim DS1822 have identical specifications and capabilities built into these digital temp sensors. We would prefer the DS1822 because of through-hole mount packaging but we would also consider the TMP100 as this surface mount component is still solderable by hand.

3.5.3.3 Compass

We would definitely go for a Magnetic Compass instead of a gyrocompass because we don't need to find the true north. Magnetic north will suffice the need of vehicle navigation. For compassing, the group will need a 2-axis Magnetic sensor for 360 degrees compassing. 1-axis would only be use for magnetic field detection and 3-axis is usually for compassing with tilt compensation and z axis which is height. For automotive purposes, we would use HMC1022 which is a 2-axis Honeywell Magnetic Sensor for compassing. It is small, well priced, and best performance compared to HMC1052 and HMC1042. The specification for these sensors are very close and would suffice for the application we are aiming for but the HMC1022 is the only one that comes in a SOIC (Single Outline Integrated Circuit) package which is a surface-mount that will be easier to solder compared to HMC1042's and HMC1052's PLCC (Plastic Leaded Chip Carrier) which needs a socket to be installed on to a PCB.

3.5.3.4 Power Locking Mechanism

As for door lock type, we would go for the simple single wire systems to minimize the complexity of this system. The group does not need to demonstrate multi-functionality that multi-wire system can implement but would consider such types if cost and excess time is available.

3.5.3.5 Vehicle Restraint System

Even though three-point harnesses are the most common type of seatbelt, the group will use a lap seatbelt to simply demonstrate the "click" we would get to achieve the purpose of being "buckled up". We could use either Delphi's seatbelt sensor or Hamlin's SeatBelt sensor. Both are simple enough to be implemented. It all depends on the availability and support informations we could get from these manufacturers as enough information like datasheets and user guide are not available from their websites. If all fail, simulating the sensors with reed switch and hall-effect sensors will be our last choice of implementation.

We would also demonstrate the occupant detection to enable the seatbelt reminder for the passenger. Delphi's, TI's and Freescale's systems are all complex enough to be a project itself as it involves measurement coordinates and complicated algorithms to implement their systems. We are in search of a simple flex sensor or may be a pressure or force sensor that will be integrated to work with our seatbelt sensor. Any interaction of from these sensor should trigger the seatbelt to enable during use.

4. Prototype

4.1 HUD Prototype

4.1.1 HUD Parts Acquisition

During the design portion of our project, the group decided that we would be very proactive about acquiring parts by the cheapest means possible. Apart from electronic components, which were ordered through various websites online, the rest of the parts were acquired through searching local venues for parts we could use for our purpose.

Acquiring the physical instrument cluster like the picture below was a point of debate in the group. We debated buying an instrument cluster from automotive dealerships, and even finding one at a local junk yard. Eventually, we decided to procure the instrument cluster from a junk yard. By choosing this option, it allowed us the chance to search and see many various clusters, and pick out the one that would best suit our needs. As our project is titled A2D (Analog to digital), we obviously needed a cluster that had minimal digital components.



Figure 51: This instrument cluster, from a Geo Storm, is similar to what we need.

The physical enclosure in which the HUD is encased is made out of wood, and constructed by the group. A special stand of some sort will likely be needed to place the HUD on, and will most likely also be wood. The combiner, the surface onto which the HUD data is displayed, will likely be acquired in the same manner as the instrument cluster, from an auto junkyard or salvage yard. Though this may be the case, the special reflective coating that will be attached to the combiner glass will be acquired from a specialized company that produces these coatings for HUD application.

4.1.2 HUD Build Strategy

4.1.2.1 Optics

The chief objective of the HUD in our project is to present the user with a clean, easy to read display in a convenient format, while reducing eye strain and distraction associated with conventional instrument clusters. Therefore, the main thing we kept in mind when designing this system was the LCD's placement position and luminosity were going to influence how the display looked to the user. The engineering challenge then encompassed finding the optimal values for the following factors: position of the HUD within the enclosure, combiner surface shape and material, and the brightness of the display.

Naturally, just as in current automotive HUDs, our combiner surface must be curved, so as to not the distort the image. If the surface were flat, the image would appear distorted, especially around the edges of the image.

An important factor to note about the design is that existing HUDs, especially in the automotive sector, have been known to make the digital image appear ahead of the windshield, directly above the street ahead. Due to the constraints of our design choice (i.e. the HUD being inside a close enclosure, in which the user looks *into* it), our HUD image will not appear as though it has depth past the combiner surface. Instead, it simply reflects onto the combiner glass surface, therefore producing a simulated heads up display experience, so to say.

As one of the objectives of the HUD display was to make it visible from various distances, careful consideration was put into how to insure the HUD is visible from close as well as far distances. Large, colorful bars and numbers are utilized to present data, as these are far easier to read than traditional gauges and needles. The HUD image should also be visible from various angles, though we will not consider too many. In automotive application, the driver is the only user of the system, and thus the only one who needs to see it clearly. Thus, the standards for viewing angle are not as strict as those for viewing distance. The CFAF176220M-T LCD we chose is convenient because it has a 12:00 o'clock viewing angle.

The following image is similar to the appearance we wish to emulate in our heads up design.



Figure 52: Sample appearance on how we want our HUD displayed
Permission pending from www.motorcycle-usa.com

4.1.2.2 Circuit Design

An advantage of the LCD chosen for our HUD system is the built in graphics controller (schematic included in schematic section). For this reason, circuit manipulation is minimal, and mainly limited to the data connection with the main controller. Since the primary goal of the HUD is displaying data, data I/O is by nature the only concern of the HUD.

4.2 Touch Screen Prototype

4.2.1 Prototyping the Touch Screen

In order to implement the touch screen design, The GUI chip must be programmed using the proprietary HTML compiler provided by amulet technologies.

This allows near drag and drop design capabilities for GUI layout planning and design. The TI touch screen controller, as well as the TI micro controller that is implemented by the touch screen section, are both coded in C. The touch screen controller is specifically designed to interface with 4 wire resistive touch screens and have 4 pins corresponding to positive and negative x-y coordinates. Noise filtering capacitors may be needed at the 4-wire input terminal of the TS controller depending on the systems overall sensitivity to noise.

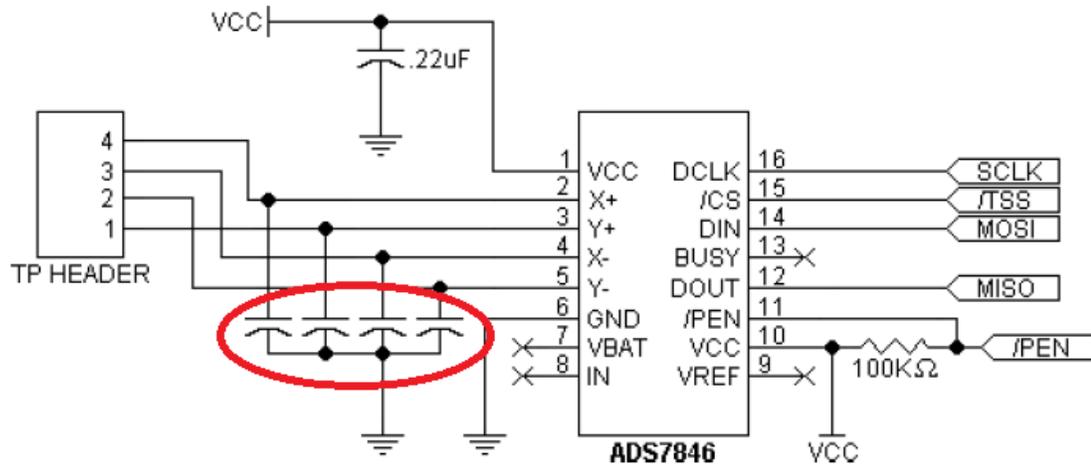


Figure 53: Schematic of the touch screen interfacing with the touch controller.
Photo source permission pending

The schematic above demonstrates the interaction of the touch screen to the controller, however the design may grow depending on the need for LED backlighting and contrast control. The IC's are surface mount chips and demand specialized equipment. Therefore careful planning has gone into determining the optimal pin package for this section of the project. The TTSOP package has been selected for the TS controller while the QFP configuration was selected for the GUI chip. These were selected for their compatibility with available resources as well as wide availability of instructional and supplemental materials.

4.2.2 Parts Acquisition: Touch Screen

The Main touch screen GUI chip is on order from Digi-key. Several parts from TI have been ordered and shipped as of August 2nd 2010. These parts include, but not limited to microprocessors as well as several models and variations of touch screen controllers in case our main choice proves problematic.

TI order sheet:

The following tables show parts on order.

TI Sample Request # 1154429

Part number/Description	Status
MSP430F4132 - 16-Bit Ultra-Low-Power MCU, 16KB Flash, 512B RAM, 10-bit ADC, USCI, Analog Comp, 56 I/Os, LCD Driver MSP430F4132IPMR	1 of 1 part(s) Shipped 02 Aug 2010
MSP430F415 - 16-Bit Ultra-Low-Power Microcontroller, 16kB Flash, 512B RAM, Comparator, 96 Segment LCD MSP430F415IRTD	1 of 1 part(s) Shipped 02 Aug 2010
MSP430F4152 - 16-Bit Ultra-Low-Power MCU, 16KB Flash, 512B RAM, 10-bit ADC, USCI, Analog Comp, 56 I/Os, LCD Driver MSP430F4152IPM	1 of 1 part(s) Shipped 02 Aug 2010
MSP430F4250 - 16-Bit Ultra-Low-Power MCU, 16kB Flash, 256B RAM, 16-bit Sigma-Delta A/D, 12-bit D/A, LCD Driver MSP430F4250IRGZT MSP430F4250IDLR	1 of 1 part(s) Shipped 02 Aug 2010 1 of 1 part(s) Shipped 02 Aug 2010
MSP430F4260 - 16-Bit Ultra-Low-Power MCU, 24kB Flash, 256B RAM, 16-bit Sigma-Delta A/D, 12-bit D/A, LCD Driver MSP430F4260IRGZT MSP430F4260IDLR	1 of 1 part(s) Shipped 02 Aug 2010 1 of 1 part(s) Shipped 02 Aug 2010
MSP430F4270 - 16-Bit Ultra-Low-Power MCU, 32kB Flash, 256B RAM, 16-bit sigma Delta A/D, 12-bit D/A, LCD Driver MSP430F4270IDLR	1 of 1 part(s) Shipped 02 Aug 2010

Figure 54: Part request, ordering sheet 1.

TI Sample Request # 1154425

Part number/Description	Status
TSC2200 - Programmable 4-Wire Touch Screen Controller with 12-Bit 125KHz ADC and Keypad Interface TSC2200IRHB TSC2200IPW	5 of 5 part(s) Shipped 02 Aug 2010 5 of 5 part(s) Backordered 17 Aug 2010 est.
ADS7842 - 12-Bit, 4-Channel Parallel Output Sampling Analog-to-Digital Converter ADS7842E ADS7842EB	5 of 5 part(s) Shipped 02 Aug 2010 5 of 5 part(s) Shipped 02 Aug 2010
TPA3001D1 - 20-W Mono Class-D Audio Power Amplifier (TPA3001) TPA3001D1PWPR	5 of 5 part(s) Shipped 02 Aug 2010

Figure 55: Part request, ordering sheet 2.

The Bergquist 12 inch touch screen is priced at \$70.00 dollars and is also available now from digi-key.

4.3 Simulation Prototype

4.3.1 Simulation Box and Controller Part Acquisition

Table 24 and Table 25 below represent the acquired parts to construct the simulation for project presentation and Microcontroller used.

Part	Availability(Y/N)	Lead Time (days)	VENDOR	Cost
Particle Board	Y	0	Home Depot	\$40
Metal screws	Y	0	Home Depot	\$5
Metal hinges	Y	0	Home Depot	\$6
2x4 plywood	Y	0	Home Depot	\$4
Simpson Strong Tie (holds wood together)	Y	0	Home Depot	\$10
Instrument cluster	Y	0	J&B U Pull & Pay	\$15
Fans	Y	0	Personal	\$0
LEDs	Y	0	Vendor Electronix Corp.	\$10
Gas pedal	Y	0	J&B U Pull & Pay	\$5
Rear camera	Y	0	Clover (BC329)	\$3

Table 24 Parts for simulation

As we can see, the group is able to get all parts required to construct the simulation.

Part	Availability(Y/N)	Lead Time (days)	VENDOR	Cost
PIC18F4550 USB Development Board + BB	Y	0	Futurlec	\$40
PIC18F4550-I/P	Y	0	MICROCHIP	\$0
Pickit 2	Y	0	Newark	\$30
Wires,capacitors, resistors	Y	0	digikey	\$0

Table 25 Microcontroller development tools

4.3.2 Simulation Box Prototype

From looking at the design of our simulation, we elaborated into a fine prototype. The following image is the “x-ray” of the top view of our simulation box. The figure above shows two sections, user view and closed off. User view is the only part the user can see, which is shown after you open the doors in the front.

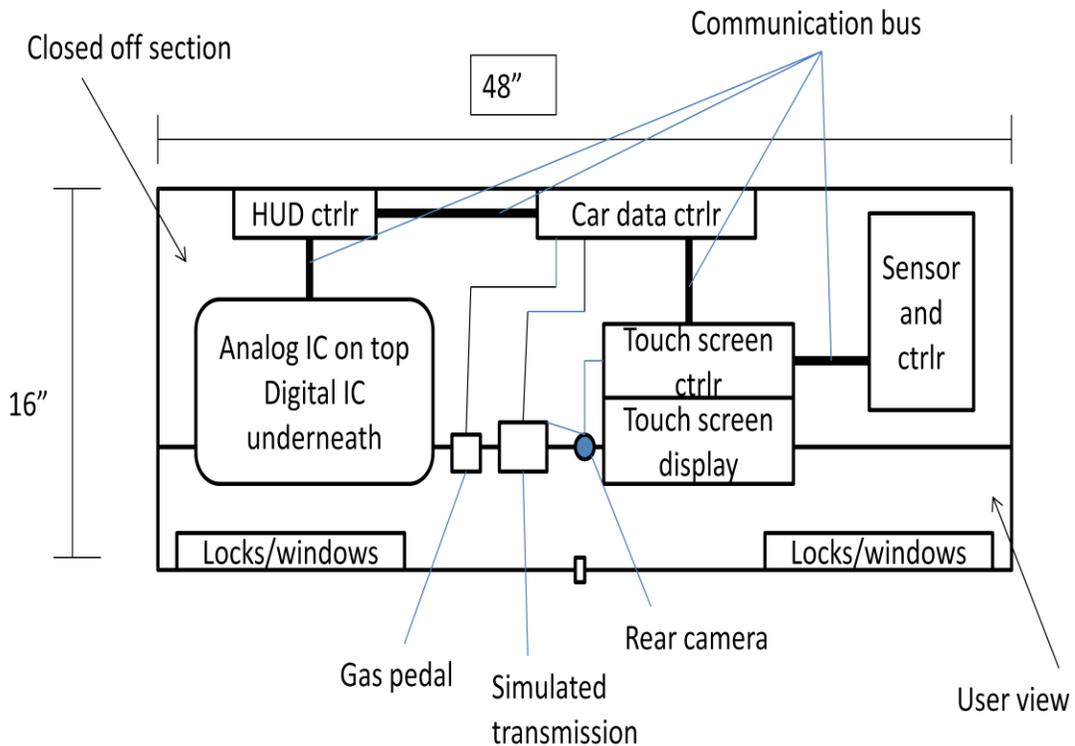


Figure 56: Top “x-ray” view of simulation box. (Frank Reed)

The user view will demonstrate the analog instrument cluster and right below it, for comparison, there will be the digital HUD instrument cluster. The user will also be able to see a gas pedal at the bottom and a “button” transmission. The view of the rear camera will show up when the user presses the “R” on the transmission. Also, there is the touch screen in the center console, including the stereo and a/c. On the side doors, the user will see the windows and locks.

What the user does not see is the closed off section. As you can see in the same figure above, all of the controllers, boards and wires will be hidden in the closed off section. The space provided for the closed section must be large enough to hold the controllers with the communication bus, along with the depth of the instrument clusters use. Also, there must be enough room between the locks/windows and the displays in user view section so there is no damage to either one. We will have to test to see if 16” is large enough for all the gadgets going into this box.

The simulation box will be hand crafted with wood and screws. We will be using $\frac{3}{4}$ inch particle board at \$29.00 each. The wood will be held together by metal angle brackets and screws, which should cost no more than \$15.00. Four metal hinges for the opening doors and a two by four base will be made to hold the thing upright. Those two will cost no more than \$15.00. And for the inside objects we will purchase smaller screws to hold them to the wood, should be only \$5.00 more. The total cost for the simulation box should be no more than \$100.00, which is what we planned on spending.

4.3.3 PICF18 Prototype

To start simple we will use the development board with the PICF18 4550 on board. Using MPLab to program the chip we will use the buttons and LEDs on board to verify the code works. This will let us get used to programming the PICF18 using MPLab. The PICF18 has an option for an external oscillator and internal oscillator. For the beginning prototype we will use the internal oscillator and for final we will use an external one because the internal may be too slow. Inside the chip is a MUX connecting to the CPU.

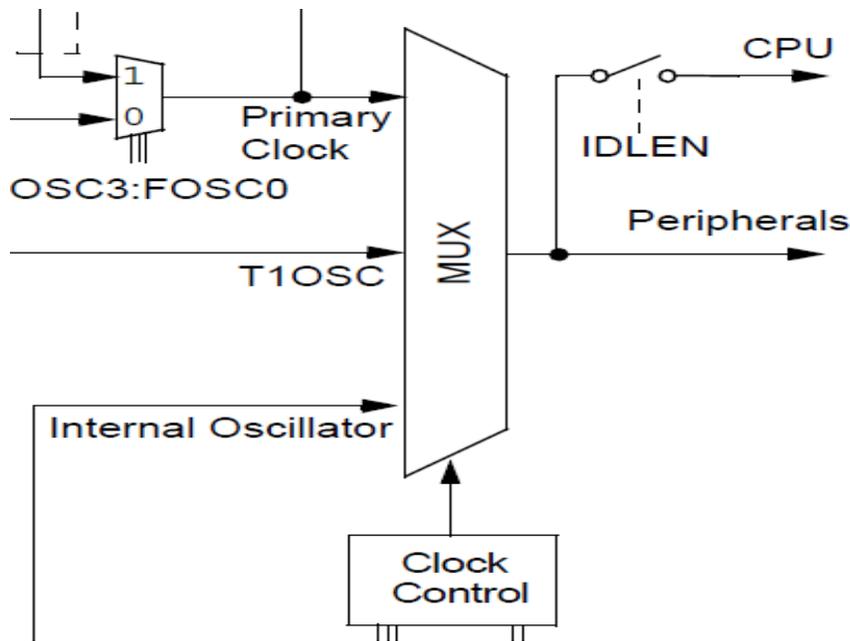


Figure 57:Clock configuration for PICF18
 Permission pending, microchip.com

The MUX will choose between the different clock options we have. So for our first try at this board we will use the internal oscillator for the CPU clock. For power we will use the 7 Vdc power supply. After the power supply is connected and the chip programmed, we will add some inputs. We will connect the gas pedal through a digital input pin. The transmission and touch screen controller will also connect to a digital input pin.

After we get the development board working, we can start working on the real prototype. Using a bread board before soldering would be the best idea. The PIC processors don't need external memory devices or anything major. Now, having the bread board, we will insert the PICF18 4550 and continue with the same program from development board, using the internal oscillator. After the chip is in place we will connect the same inputs onto the breadboard. This time, for power, we will use a 12v rechargeable battery with a 5v regulator. This will power the breadboard and its components. We will design it very close to how the development board is designed, but with a lot less features. The following image is a sample of the "Hello World" design on a breadboard.

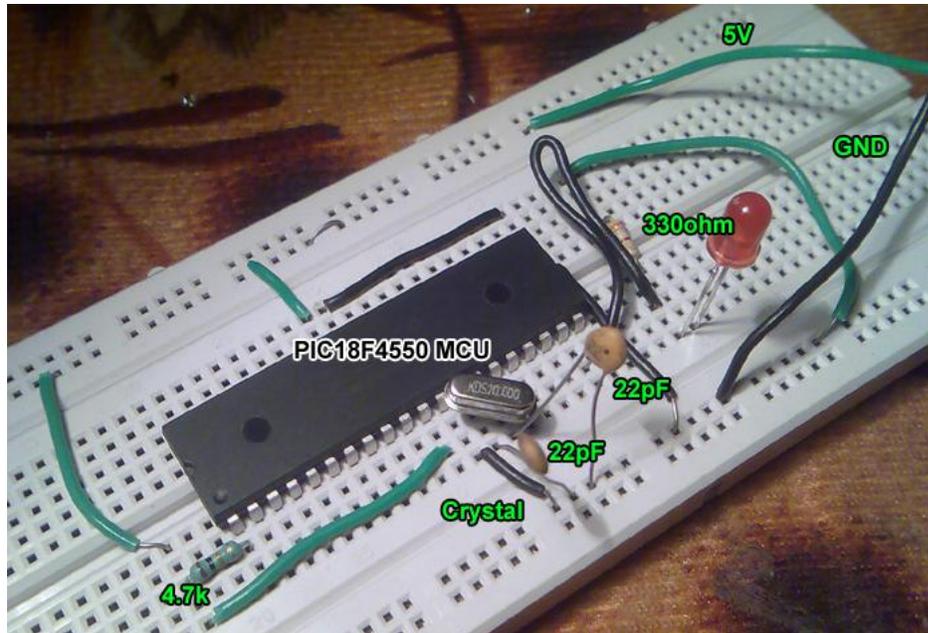


Figure 58: Simple LED blinking “Hello World” using the PIC18 4550
Image approved by creator, Avinash Gupta

This sample really helps in beginning the breadboard design. In his schematics he has his external crystal oscillator. We will program the internal one and try that first. We will prove that we have a working prototype before switching to an external oscillator to make sure we know how to get it to run.

4.4 Sensors Prototype

4.4.1 Parts Acquisition

The following table shows various parts for our tire Pressure Monitoring System (TPMS).

Part #	Availability(Y/N)	Lead Time (days)	VENDOR	Cost(\$)
ATA5276	Y	0	Digikey	7
ATA5746	N	N/A	Digikey	7
ATA6612	N	N/A	Digikey	7
ACCUTIRE Ext.TPMS	Y	0	Tirerack	80

Table 26 Tire Pressure Monitoring Systems

As we can see, the group faces a problem of gathering and system set-up by Atmel as it is out of stock from Digikey and anywhere else. The group will try to

contact Atmel about the parts and will find a replacement in the event of obsolescent. We will also look for an alternate company that implements the same system.

The Maxim DS1822 is not available from Digikey but we are not sure if this is available from other vendors. We will investigate its availability and search for replacement

This table shows two possible parts for our temperature sensing system.

Part #	Availability(Y/N)	Lead Time (days)	VENDOR	Cost(\$)
TMP100	Y	0	Digikey	2.63
DS1822	N	0	Digikey	4.38

Table 27 Outside Temperature Sensing System (Ambient)

Honeywell’s magnetic sensors are available in digikey. We are going to use HMC1022 because of its IC packaging. The HMC1042 and HMC1052 are only listed for reference.

Part #	Availability (Y/N)	Lead Time (days)	VENDOR	Cost(\$)
HMC1022	Y	0	Digikey	17
HMC1042	Y	0	Digikey	17
HMC1052	Y	0	Digikey	17

Table 28 2-Axis Compass

Any door-lock actuator will suffice in our project. The group will strive to find the lowest cost and simplest actuator we can find. Amazon has the lowest cost so far.

Part #	Availability (Y/N)	Lead Time (days)	VENDOR	Cost(\$)
2-wire	Y	0	Amazon	5
3-wire	Y	0	Amazon	5
5-wire	Y	0	Amazon	5

Table 29 Door Actuators

The group need to contact Delphi and Hamlin to inquire about purchase. They usually deal with big automobile manufacturers as their products are usually for OEM use. We will update this document once we find some concrete information from the manufacturer. The last two sensors are for Occupant Detection. These are flex and force sensors that can be integrated wit our seatbelt sensor.

Part #	Availability (Y/N)	Lead Time (days)	VENDOR	Cost(\$)
DELPHI	Y	TBD	DELPHI	N/A
HAMLIN	Y	TBD	HAMLIN	N/a
FS-L-0095-103-ST	Y	0	Digikey	12.95
FLEXIFORCE 30056	Y	0	Digikey	20

Table 30 Occupant Detection System

4.4.2 Build Strategy for Prototype

Sensor Systems

For the purpose of showing the functionality of the command center and displaying data in our instrument cluster, we will try to use actual automotive sensors. In the event of unavailability of parts or lack of information thereof, we will improvise using available electronic sensors to demonstrate its functionalities. We will limit our demonstrations to these functionalities to lessen the complexity of our system. If time and cost permits, we will add some more features to make our project more interesting.

A) Tire Pressure Monitoring System (TPMS)

Due to the cost of the current TPMS systems and unavailability of information about them, the group will try to make our own TPMS system. We will find a full system like Atmel's TPMS for simplicity and ease. If parts are unavailable, we will try to find a similar system. If we fail to find a replacement, we will opt to simulate the system. We plan to use reed switch as proximity sensors to simulate the under inflated or "low tires". We can install the sensor at the back of the tire. When air is let out through the valve stem, the tire will decrease in size and will trigger the proximity sensor and display a fault light in our a2d Instrument cluster.

B) Outside Temperature Sensing System (Ambient)

In the event that we cannot find an actual temperature sensor on a used car, we will use a component such as TI TMP100. This is one of the simplest temperature sensors we found from our research that provides an impressive

accuracy. Since this system is temperature, it would probably best if we place this away from any heat generating circuit in our PCB to eliminate any error that may occur. Worst case scenario, we can install a small fan to compensate for the real-time ambient temperature.

C) Compass

In our sensor board, we will use a Honeywell HMC1022 2-axis magnetic sensor. It will be connected to a 12-bit Analog-Digital converter and a controller. Compass will be displayed at the touch screen command center.

D) Power Locking Mechanism

During the trip to the junkyard, we will try to find an old functional door with actuator and relays in it. If we can't find one with actuator and relay, the group will purchase them and wire them up like a regular system. The actuator will be controlled via data or control line from the Touch Screen Command Center.

E) Vehicle Restraint System

The group will plan to take a trip to a used car parts store and will try to find an old seatbelt assembly. In the event of unavailability of parts and/or information, we will attempt to contact the Delphi and Hamlin about their sensor which will be installed on the actual seatbelt we acquired from the junkyard. There is a possibility that we won't be able to acquire these parts so in this case, the group will try to simulate these two vehicle restraint systems.

For the seatbelt assembly, we can use any proximity sensor or magnetic switch. When both parts (female and male parts) of the seatbelt come in contact and fastened, it may complete or disconnect a circuit depending on our design. A perfect sensor for this application will be a reed switch as it does not require external power, can be used up to 200V, and it is made for automotive applications. According to Wikipedia a reed switch is an electrical switch operated by an applied magnetic field. It has a pair of contacts on ferrous metal reeds in a hermetically sealed glass envelope. The contacts may be normally open, closing when a magnetic field is present, or normally closed and opening when a magnetic field is applied. The switch may be actuated by a coil, making a reed relay or by bringing a magnet near to the switch. Once the magnet is pulled away from the switch, the reed switch will go back to its original position.

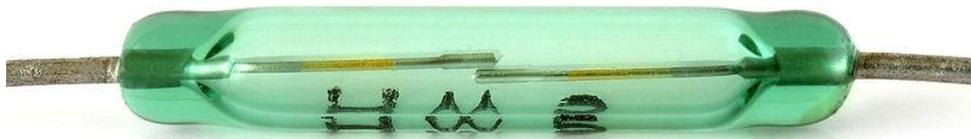


Figure 59: Reed Sensor
Permission pending from Wikipedia

We had a tough time on finding parts that can simulate our Occupant detection system. If we think about the function of this system, we need some sort of pressure sensor or weight sensor that will be simple enough to alert the ecu that a passenger is present on the seat. We are not concern about the weight or the height of our passenger. We just need to have a detector if indeed we have a passenger. Most of the pressure sensor in Digi-Key is for air pressure and force detector only limited to the two sensors next page.

Once we acquired any of this sensors, we will attach it underneath the seat to act like a switch to enable our passenger light on the a2d instrument cluster and would not turn off until the seatbelt sensor is engaged.



Figure 60: FlexForce Sensor
Permission pending from Parallax Inc.

This sensor is very limited as it detects pressure only up to 25 lbs. According to Parallax, this will allow you to demonstrate the resistive nature of the sensor with a resistor/capacitor discharge time measurement circuit; no correlations to weight are made. The Flexiforce has an ideal output for A/D conversion - 0V is no force and 4.2V is 25 lb. Their website does not have a lot of information on how their sensors work. The group will pursue a call to get more information about their product.



Figure 61:Spectra Symbol FS Flex Sensor
Permission pending from Spectra Symbol

This sensor is like FlexForce but their datasheet actually have a suggested circuit for a high or low output depending on the voltage of the output needed. Variable Deflection Threshold Switch” uses an Op amp to use the flex sensor as a switch without going through a microcontroller.

Other applications like using FIR(Far-Infrared Ray) Camera and other capacitive occupant system were considered but decided that these will be more complex than we wanted to use for such a simple demonstration.

We are aware that implementing the proper system might be ideal but time constraint and budget will be a factor. In the event of obtaining a sponsorship and excess time, we might attempt to implement the real Vehicle Restraint system. For now, the main goal is to get an output from this sensor and be able to display them on our HUD display.

5. Testing

5.1 HUD Testing

5.1.1 Testing the HUD

Now that the LCD components have been tested individually, it is time to integrate it into the enclosure. For the HUD to be completely functional, the LCD display must display the data properly, and projector displaying the image as clearly as possible onto the combiner. This means that a visual inspection of the optical clarity of the image will be done to ensure that it is as clear as possible. The picture should be clear and easy to read and understand.

5.1.2 Testing the Data Connection

Before inserting the HUD system into the enclosure, we will first connect it to its data source, the main controller, to make sure the data connection is working properly. As the controller sends data over the serial connection, the LCD should render the appropriate graphics correctly, displaying the simulated data being sent from the controller. If this is not the case, the connection, or the method in which the data is being transferred, need to be evaluated.

Using various user methods of data input (gas pedal, switches), the LCD should at this point be correctly simulating a digital instrument cluster. Notes will be made about the smoothness and the realism of the display. The digital instruments should not exhibit any sudden, jerky movements. Such activity may indicate issues with the software or possibly with the data.

5.1.3 Testing the Optical Setup

Once the data connection is sound, the next challenge is to test the visual clarity of the HUD display once it has been inserted into the enclosure. The success of the HUD can be completely judged on how easy it is to see and read, and so it is absolutely critical that the visibility and clarity of the display be right on. To test this, we will use various individuals not involved with the project to view the display from various angles and present their input, regarding the clarity of the display. We will then use this feedback to modify and adjust optical or placement

issues which affect the HUD image. Similar to existing HUDs, the true test for the effectiveness of an HUD is the reaction it elicits to its users.

5.1.4 HUD Testing – Other

Once the HUD is up and working cooperatively with other systems, it will be time to expose the HUD to other test factors. A true measure of any HUD, and one of the main engineer concerns is its liability and longevity. These systems are expected to function properly for years, as they are very expensive and exclusive. For that reason, the HUD will be put to prolonged usage to insure that it is able to handle rigorous and constant use.

HUDs, particularly in automotive application, are expected to perform equally well in all types of lighting conditions. To test this, we will subject the display to both dark conditions (viewed in a completely dark environment) and bright conditions (bright room). This will not only test the strength of the display backlight, but also the effectiveness of the combiner, as well as the film applied to the combiner. For the surface to be a successful screen, the display will be visible in all lighting conditions.

5.1.5 Prototype Testing: HUD

Testing the heads up display instrument cluster will entail rigorous testing of the LCD display by itself (i.e. not in the enclosure). The LCD unit will not be connected to the main controller, and therefore all the inputs will be simulated through the software. Ideally, this exercise will verify that the programming is sound, before introducing outside data.

Initially, each particular field to be displayed will be tested one by one. The speedometer and tachometer will be compared individually against the simulated throttle input. We will make sure that the tachometer precisely mimics its direct relationship to the input pedal signal. Likewise, we will independently test the speedometer display to insure that the longer the throttle signal is active, the higher the speed should rise.

In the same manner, the rest of the instrument cluster components will be verified by varying each input signal from the main controller. If everything is working properly independently, testing will proceed to applying all the inputs, in different combinations. The temperature display component, tire pressure component, gas level component and odometer should be displaying the sample data coming in from the software. The main purpose of this testing is to identify any bugs to be found in the programming of the visual components. It is essential at this point that all the data is displaying properly, so that when it is connected to the main controller we know that it should technically work if the data is being properly taken in.

5.2 Touch Screen Testing

To ensure proper operational status of the touch screen command center, the GUI elements must accurately recreate the desired events in the system. Once the MCU, TS controller and GUI chip have all been programmed and the 4-Wire touch screen has been connected to the 4 terminals of the controller we must ensure that the simulation program is running properly.

Though several methods are available, a “printf” approach is implemented to ensure that what should execute is indeed what is happening. By first tying each button of the GUI to an LED light, this ensures that the separate functions are mapped to the correct buttons on the touch screen. Once we ensure proper paths between command and action are in place we must then test for true functionality.

- We must ensure that the touch screen responds quickly and accurately to a users’ gloved or ungloved hand. This is yet another reason resistive technology was used rather than capacitive
- We must ensure that the GUI elements are mapped to the appropriate functions of the simulator
- We must ensure that the project power supply is adequate to provide full functionality to all aspects of the touch screen, including optimal brightness and viewing angle as well as touch responsiveness.
- We must ensure that sudden jolts of power will not cause harm to the selected components
- We must ensure that the screen will be visible in all lighting conditions
- We must perform touch tests in order to determine if too much pressure is required to activate GUI elements.

A successful prototype test will result from a prototype which delivers fast accurate response to touch, will all conditions visibility. The prototype must fully operate on the supplied voltage and all controls and GUI elements must be accurately mapped to the correct controls and functions.

5.3 Simulation Testing

5.3.1 Simulation Testing

The first part of testing for the simulation would be to test for space. As we determine the size of each controller, we will measure up against the available space. The largest thing would be the instrument cluster. This must be able to have enough room for the back of it to not damage any controllers and also to no damage itself when doors are closed.

We will then test the temperature of inside the user section and closed off section. This is vital for the closed off section because every electronic part must not exceed its maximum temperature. We will take precaution and use airflow throughout the simulation box.

The box must be sturdy enough to hold when the doors are opened. We will test the strength of the hinges and the weight difference between the doors and body. The system shall not collapse and we will test this by adding extra forces in all areas to find any flimsy potential area.

5.3.2 PIC18F4550 Testing

During the prototype construction we will do various tests. It is wise to test quite a bit throughout your development. This is because if you finish a product without testing, and there is something wrong with, then it will be very difficult to debug and fix. At the beginning of learning how to program the PIC18 on the development board we will run tests to see if we can even get code to work. The development board has LEDs and buttons to verify if the code works. Another thing is to get the oscillator to clock correctly. After these tests with the development board, we can test specific inputs into the development board.

After verifying the programmed chip works we can now test on a breadboard. We will connect the chip and install the firmware via USB. We will run the simple "Hello World" version with LED's to test if the chip works. If the simple test works on the breadboard we will program the chip for testing the inputs and outputs. Since we have the working code from the prototype we can add the gas pedal, transmission, and touch screen inputs.

To test the outputs we will program the chip on the development board to create these outputs from the inputs and internal data. To test if the outputs worked we will measure the voltages coming out of each individual pin out, which represent the signals to the HUD controller. If the output works to specifications then we can test on a breadboard.

The final testing of the PIC18 will be done fully on a breadboard. The input and output requirements will be met before any PCB construction.

5.4 Sensors Testing

5.4.1 Tire Pressure Monitoring System (TPMS)

We will use only one tire for this system just demonstrate its functionality. A normal cold-tire have a pressure of around 35 psi. We will inflate our tire at 35 psi and confirm with a commercial tire pressure gauge. Our TPMS system will be designed to trigger the "low tire" display in our a2d instrument cluster at 29.75 psi which is 30% less than the cold reading of 35 psi. This will be as close as the current TPMS system used nowadays. We need to let some air out pinching the tire valve and deflate the car to less than 29.75 psi. In this event, the "low tire" warning signal should be lit on our cluster. Next we fill our tire using our portable compressor to 35 psi and reconfirm with our tire gauge. Once we fill more than 30 psi of air, the warning light should now turn off.

5.4.2 Outside Temperature Sensing System (Ambient)

Our Temperature system is an “always on” system that continuously measure ambient temperature. We observe our a2d instrument cluster for the measured temperature and we can use a thermometer or other temperature monitoring device to confirm its precision and function.

5.4.3 Compass

Like our temp sensor, our compass system is always on. We should observe the direction of the magnetic field depending on where our sensor is facing. Read the information from the Touch Screen and verify data using a real compass.

- Power Locking Mechanism

This system will be controlled by our Touch Screen Command Center. The touch screen will have a lock and unlock button on the screen. When the lock button is pressed, the door actuator should engaged and the door will become locked. Next we should press the unlock button and door lock should disengage and the door should unlock.

5.4.4 Vehicle Restraint System

This system is comprised of the seatbelt and the occupant detection sensor. In normal operation without a passenger, the seatbelt light will be off. The light will be lit when a passenger sits down on the seat, this will activate the occupant detection sensor. Now it will wait for the seatbelt sensor to engage. The light will remain lit until the seatbelt is engaged. If the seatbelt is engage, the seatbelt light will go out.

6. Design Summary

6.1 Overview

Our system design was significantly, but intentionally, affected by our decision to implement separate micro controller for each subsystem and tie them all together using a main controller. This design helps to prevent interdependence between components and allows one engineer to plan without hindering or directly affecting someone working on a parallel section of the project. The project overview, which can be seen in the following diagram:

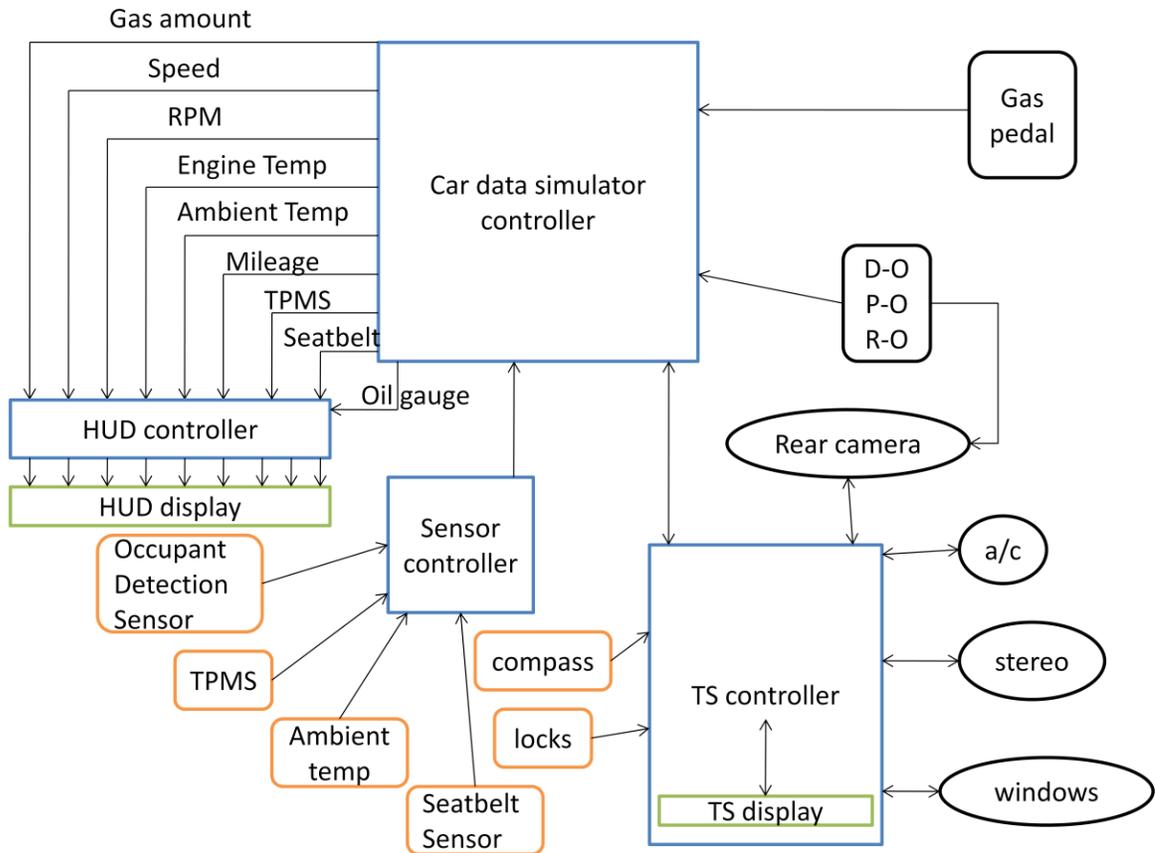


Figure 62: The overview of the block diagram for full system. (Frank Reed)

Demonstrates how the sensor controller receives a signal from each sensor and feeds it into the touch screen controller. Each sensor would then feedback information to the main controller and display the results to either the HUD display or the touch screen display

6.2 HUD

When considering available technologies for the HUD, CRT's, backlight projectors and LCD's emerged as front runners due to their price, availability and the maturity of the technology. The maturity directly correlates to available support and availability of supporting design components. When implementing an LCD HUD which we ultimately decided to the following block diagram is a good representation of how said system would be laid out

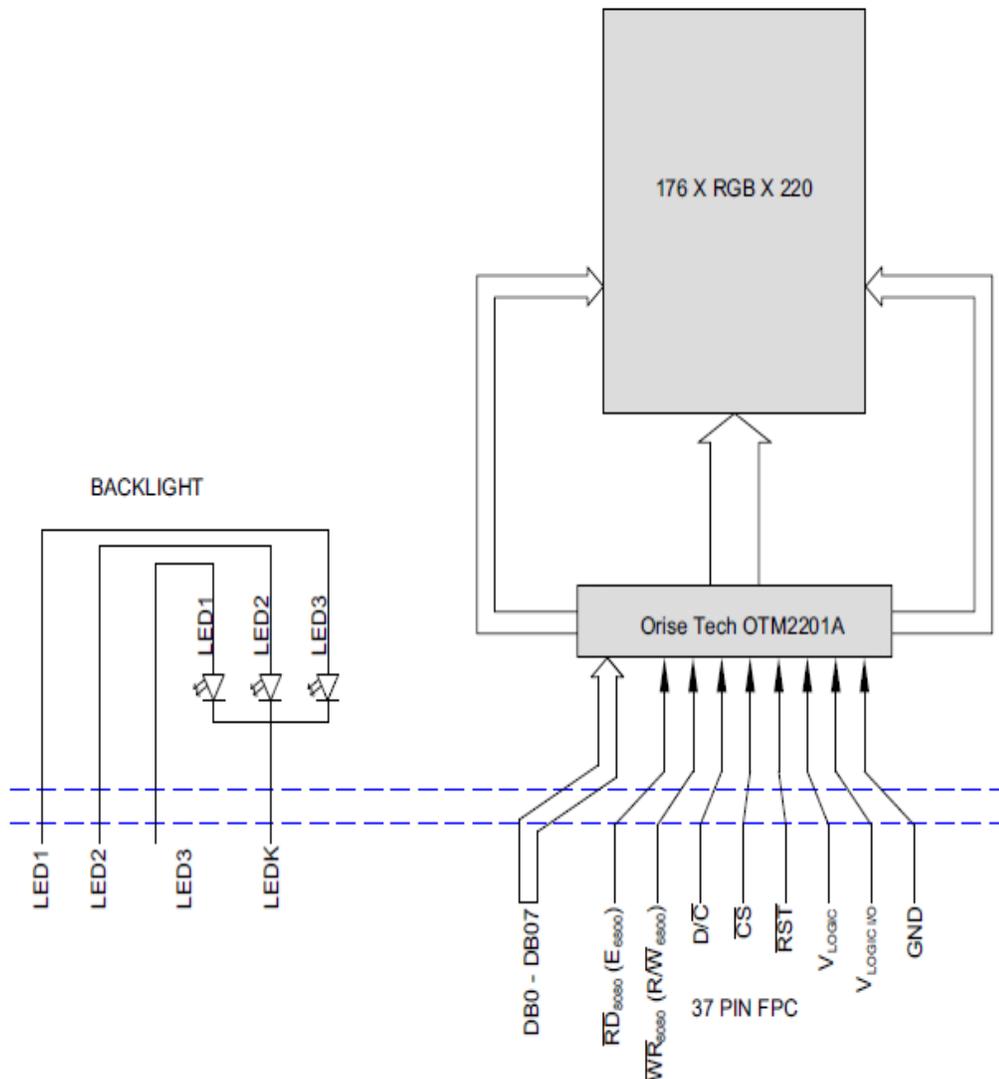


Figure 63:HUD LCD block diagram.

The diagram above shows the inputs to the system of the HUD. The OTM controller will be programmed to understand the specific data going in and out to develop signals to the RGB communication bus.

Another consideration was the backlighting approach which would enable use in daylight conditions. Ultimately, complexity, cost and availability caused us to select the more available LCD options and we believe this will be a long term decision we will not regret.

After determining the HUD technology we were going to implement we needed to find the heart and soul of our heads up system, so to speak. We found it in the 'Crystalfontz' graphic LCD TFT panel, with a driver IC. The driver integrated circuit installed on the unit is an Orise Tech OTM2201A. It has an 8 bit parallel interface, and requires only a single source 3.0V for both power supply and

logic. The OTM2201A designed for small TFT LCD displays. It is able to operate with low IO interface power supply, up to 1.65V. OTM2201A provides system interfaces, which include serial interface (SPI), to configure the system. The system interfaces can be used to configure system, as well as access RAM at high speed for still picture display.

One of the advantages utilizing the crystalfontz graphic LCD is the integrated controller. Predefined graphic TFT driver libraries are used to develop the GUI to be presented on the LCD. Crystalfontz recommends the following library sources: easyGUI, RAMTEX, Micrium, en.radzio.dxp.pl, and Segger. Our preference is to use an open source library of some sort to avoid any costs related to a special development environment and/or library use.

Our plan is to use the following types of graphical elements for the each instrument cluster component:

Display element	GUI used
Speedometer	Large numbers, like seven segment display
Tachometer	Large color bar
Ambient temperature	Small numbers
Tire pressure monitor	Small color bar
Fuel level	Small, single color bar
Odometer	Small numbers
Oil Temperature	Small numbers
Safety restraint indicator	Small icon (on or off)

Table 31 Graphical elements

For the heads up display projector device, we selected an LCD display from “Crystalfontz,” which includes an integrated microcontroller and numerous parallel interfaces. Perhaps the biggest selling point of this LCD device was the integrated microcontroller with integrated drivers. This design eliminated the need to program a separate controller to take care of the graphics and drivers.

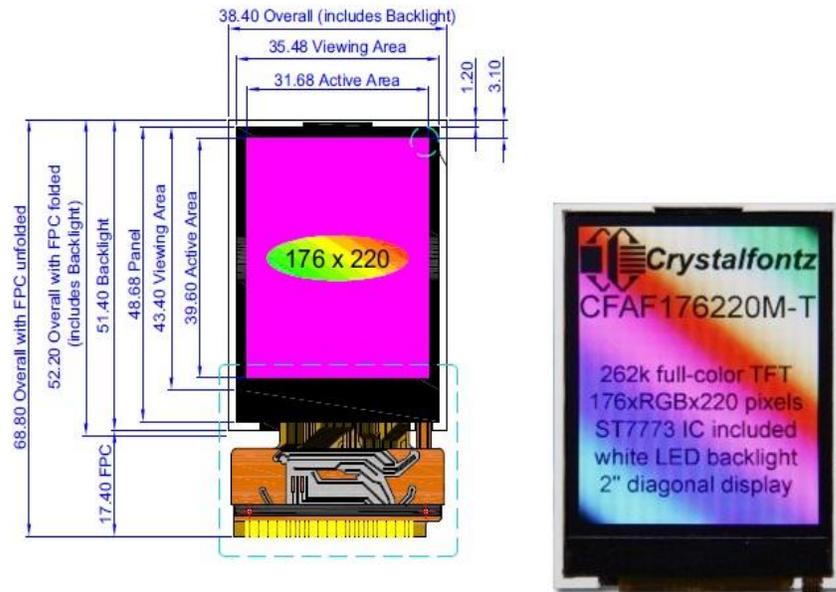


Figure 64:CFAF176220M-T Source Datasheet

For the combiner surface we chose to use curved glass with a plastic reflective coating. Similar to automotive and aircraft HUD systems, the coating make viewing the image easy in all lighting conditions. We are currently actively searching for a combiner glazing or coating solution, and are leaning towards coating technology from Saflex, a company that specializes in automotive HUD windshield glazing.

6.3 Touch Screen

When considering the touch screen command center, the 2 main approaches to be taken when designing a touch screen interface are the capacitive and resistive routes. Within the resistive rout a 4-wire and 5-wire option also exists.

Because across the board, power demands as well as physical dimensions were so very similar, component choices came down to cost, availability, durability and cost effectiveness. Also considered were its aesthetics as well as its communications protocols which is ultimately what will tie the system together. For these reasons the touch screen technology A2D will utilize is the 4-Wire resistive type utilizing anti glare technology for optimum performance in direct sunlight conditions as well as additional protection from scratches and fingerprint resistivity which adds to the overall aesthetics of the vehicle.

To ensure that the screen will be easily accessible the Bergquist BER280-ND 12 inch 4 wire resistive touch screen will be used in conjunction with the TI/Burr-Brown TS2200 touch screen controller. The GUI interface will be provided by the amulet technologies' GUI OS chip dubbed AGB64L.

The GUI chip outputs to the touch screen as well as receives input in order to relay to the touch screen controller.

Where the 4 noise reducing capacitors may or may not be needed. The ADS7846 touch screen controller is used to interpret the data from the touch screen into x and y coordinates which corresponds to a subroutine to be executed from our main program. An overall block diagram with both the touch screen controller, GUI chip and touch screen can be seen below:

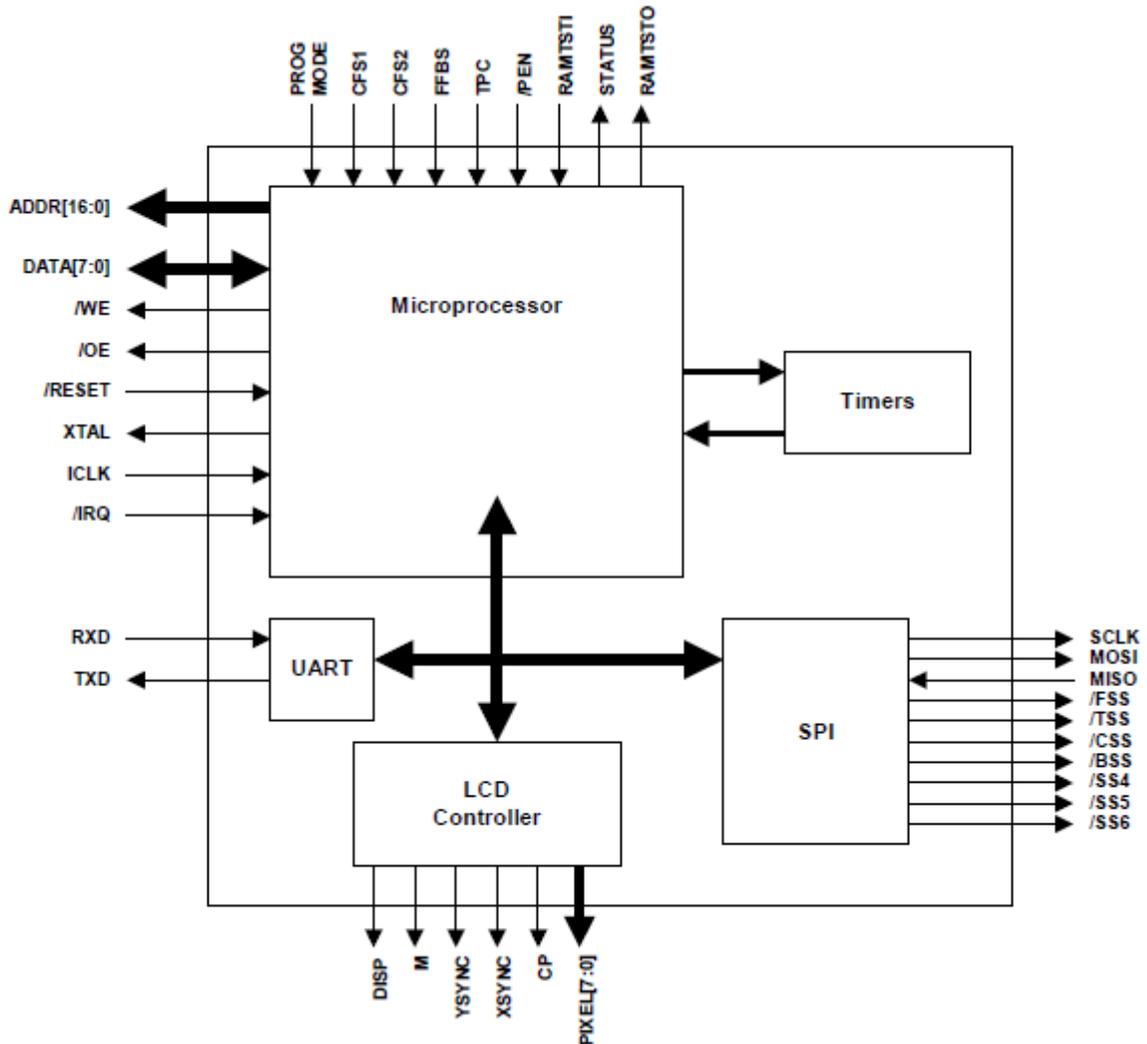


Figure 65: Touch screen Block diagram
Permission pending

Please note the touch screen is interfaced with the LCD controller and that this particular diagram communicated with the rest of the design via the SPI protocol which was chosen due to its wide utilization in the automotive industry.

6.4 Simulation

The physical design of the simulator will be that of a diorama type presentation of a vehicle dashboard encased in a cabinet enclosure for easy transportation and maximum use of space. The model includes two real car instrument clusters and a transmission like D-P-R area. Also to complete the simulated dashboard we have a touch screen center console to control the windows and locks. There is also a tire pressure sensor and rear view camera that displays on the touch screen. The user can also use a gas pedal to simulate RPMs and speed.

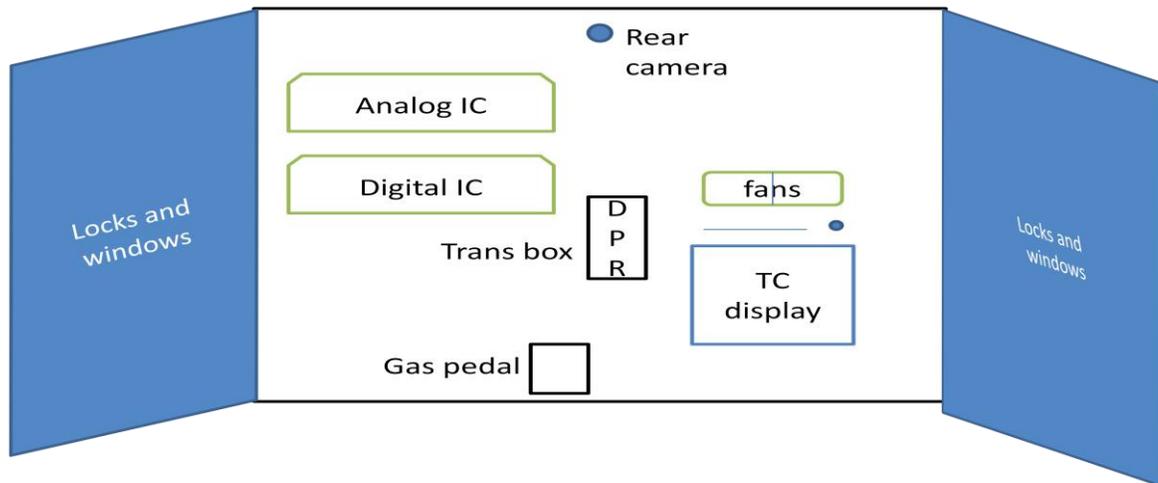


Figure 66: Front view of the sim box showing the featured objects. (Frank Reed)

The box may be mobile with wheels attached to the bottom. Along with a few simulated features such as the a/c will be simulated with fans. The windows will be simulated the same, but the locks may be more realistic. There will be a real tire with a tire pressure sensor inside and will demonstrate that is really works on the touch screen display.

After researching a few controllers that meet the required design specifications for the simulation of car data, we came across the three development boards to practice on. The three boards included the ARM, PIC, or ATMEL chip. The ATMEL board is really good for beginners, but the PIC board is half the price. The ARM board may exceed our requirements far more than we need.

We decided on using the PIC board and looked in how the processor is compiled. The PIC18 chip can use a program called MPLab, which allows the chip to be programmed in C. The following figure is an example of the student version MPLab.

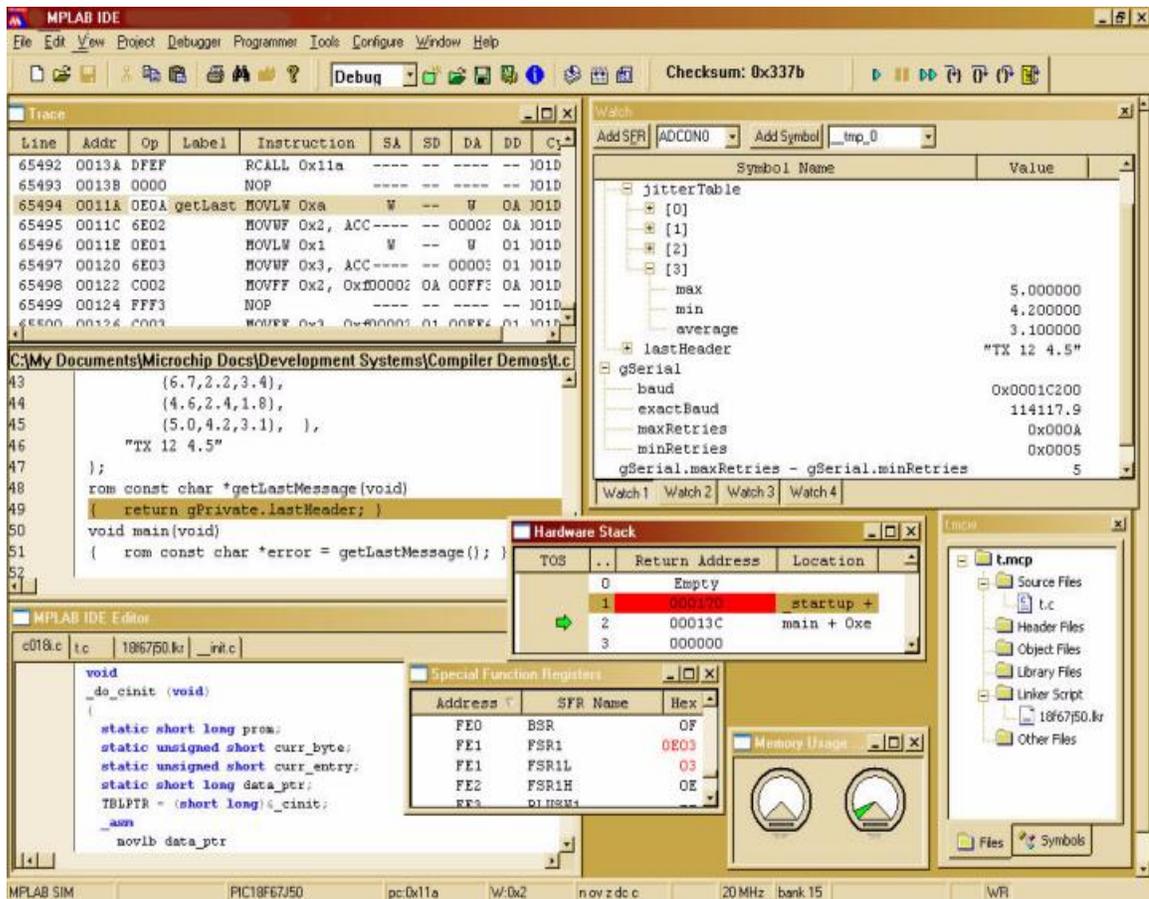


Figure 67: MPLab for academia use
Permission pending

The PIC is also good because it requires few external components. The PIC18 will be powered by a +5v coming from a regulator. The regulator converts the 12v battery we will be using into the 5v we need for each of the controllers. The 12v battery will be rechargeable and simulates the car battery.

6.5 Sensor System

Moving onto the sensor system, the Sensor Systems are made up of five different systems that are usually implemented in a normal vehicle. Sensor Systems will be demonstrated using actual automotive sensors or simulated if parts may become unavailable.

Sensor Block Diagram

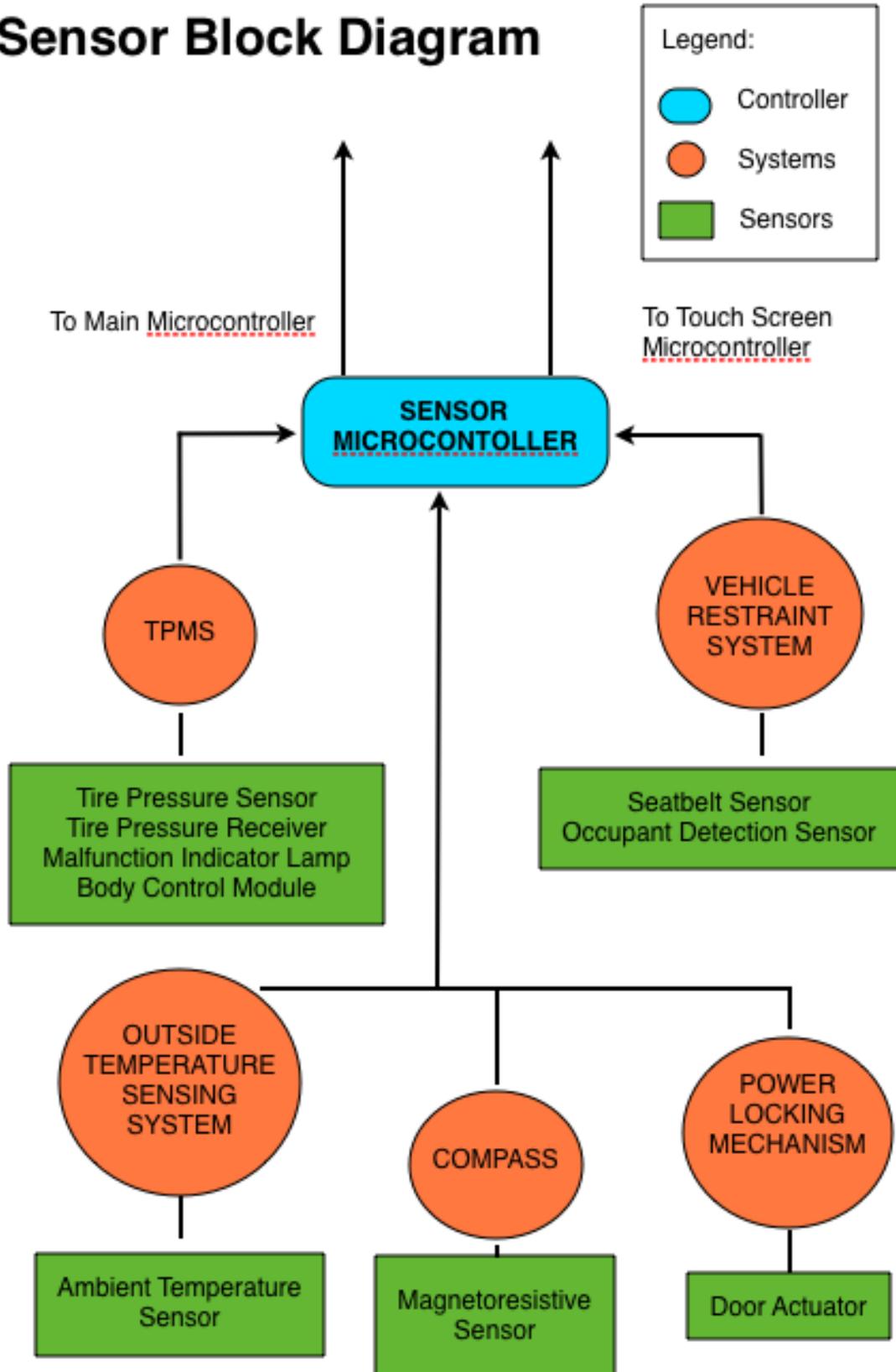


Figure 68: Block diagram of the sensor system. (Chris de Guzman)

To conclude the sensor section, listed below is the group's decisions on which of the presented technologies to use in our design:

TPMS

The group has decided to use a direct sensor for the TPMS. We found that this is going to be the simplest and most effective way to demonstrate TPMS in our project.

Temperature sensor

Digital would be an ideal Temperature sensor as it is simpler and less components to integrate. The cost might be higher but it would be irrelevant as we are only building one simulator. We would prefer the DS1822 because of through-hole mount packaging but we would also consider the TMP100 as this surface mount component is still solderable by hand.

Compass

For automotive purposes, we would use HMC1022 which is a 2-axis Honeywell Magnetic Sensor for compassing. It is small, well priced, and best performance compared to HMC1052 and HMC1042.

Power Locking Mechanism

As for door lock type, we would go for the simple single wire systems to minimize the complexity of this system. The group does not need to demonstrate multi-functionality that multi-wire system can implement but would consider such types if cost and excess time is available.

Vehicle Restraint System

We could use either Delphi's seat-belt sensor or Hamlin's seat belt sensor. Both are simple enough to be implemented. It all depends on the availability and support we could get from these manufacturers as not enough information like datasheets and user guide are not available from their websites.

To conclude our design summary, it is important to re-emphasize the sectional nature of our approach. In choosing to tackle these subsystems of our project separately, we are able to better isolate potential issues and avoid having to "pick up" where others have started from. By implementing separate MCU's for each section, we are able to finish subsystems free of dependence from the rest of the project.

7. Budget and Finances

7.1 BOM (Billing of Material)

The following table summarizes parts the group utilized for testing and development of the project.

Qty	Item	Cost
1	Pickit2 + Dev Board	\$60.00
1	1995 850 Volvo Instrument Cluster	\$10.50
1	arduino duemilanove (Dev board for ATmega328 MCU)	\$28.45

Table 32 Budget – Testing and Development

The chart below summarizes electronic components used for the project, and their prices.

Qty	Item	Cost
1	3.5" OLED display + 3.5" 4-wire resistive Touch Screen + ATMEGA 2560 graphics processor	170.00
1	TI ADS7846 Controller	FREE
1	PN CFAF176220M-T Controller/LCD combo	\$28.10
1	ATMEL ATA5276 IC XMITTER TPM	\$4.95
1	ATMEL ATA5745 IC RX UHF	\$3.48
1	ATMEL ATA6612 MCU W/ LIN	FREE
1	TI TMP100 Temp Sensor	FREE
1	Honeywell HMC1022 2-Axis Magnetic Sensor	FREE
1	PIC18F4550	FREE
1	ATmega 328 MCU Samples	FREE
1	20M Hz crystal	\$0.28

Table 32 Budget – Component

The following chart details other miscellaneous items used to construct the project.

Qty	Item	Cost
1	3.5" OLED display + 3.5" 4-wire resistive Touch Screen + ATMEGA 2560 graphics processor	170.00
1	TI ADS7846 Controller	FREE
1	PN CFAF176220M-T Controller/LCD combo	\$28.10
1	ATMEL ATA5276 IC XMITTER TPM	\$4.95
1	ATMEL ATA5745 IC RX UHF	\$3.48
1	ATMEL ATA6612 MCU W/ LIN	FREE
1	TI TMP100 Temp Sensor	FREE
1	Honeywell HMC1022 2-Axis Magnetic Sensor	FREE
1	PIC18F4550	FREE
1	ATMega 328 MCU Samples	FREE
1	20M Hz crystal	\$0.28

Table 33 Budget – Other items

7.2 Financing

The project will be financed by the group members if sponsorship was not acquired. Total cost will be divided equally between the four group members. Total amount of \$459.97 is an estimated cost and will be flexible to go above or below as some parts maybe acquired as “sample”. If some parts may become unavailable or “out of stock”, the group will search for replacement with equal or same value and function.

Note:

The following parts are not final. These are basic information we have on hand based on the idea of our project. Adjustments in the hardware and software design will be implemented during the design stage of the project.

8. Project Milestone

Below is our planned Project milestone for both Semesters from May 2010 to December 2010. As we can see, 75% of the research & design needs to be completed by the end of the Summer semester which is on August 2010. Further design will be needed as we test our project during the Fall semester. By November 2010, our project should be 94% done and operational. Next page is a more detailed description of the phases of our project separated by month.

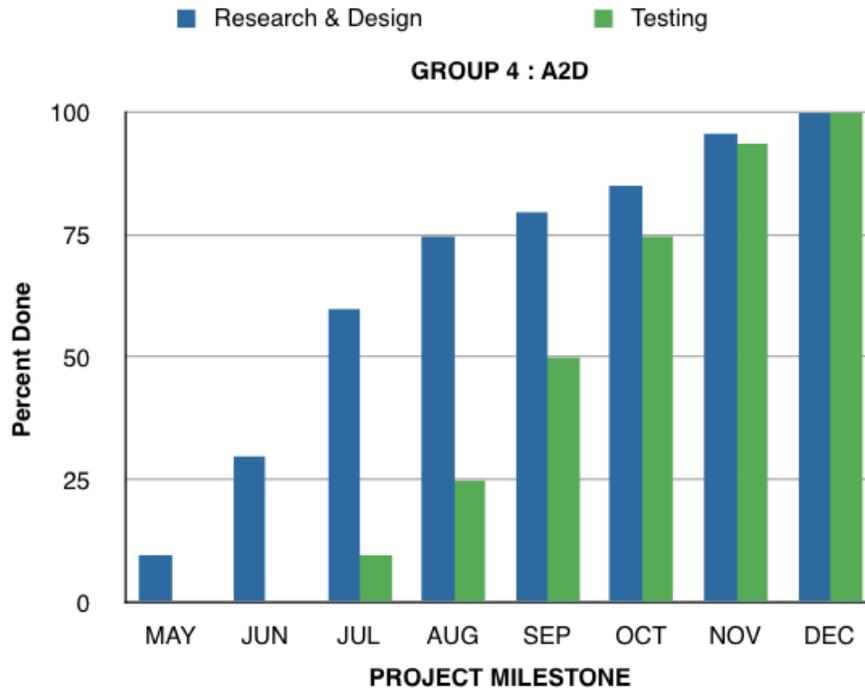


Figure 69 Project Milestone

SUMMER 2010 & FALL 2010

MAY

-group meeting and brainstorming ideas about project.

JUNE

- finalize project idea. Turn in Initial Project and Group Identification Document. Research automobile's instrument cluster output and decide if project will be done on a real automobile or a simulator. Start research on HUD and controllers for command center.

JULY

- more research. Design prototype. Need specific hardware and software information to be utilize by this month. Senior Design 1 paperwork should be almost finished by the end of the month.

AUGUST

- SD1 paperwork is done and ready to submit before August 4th. Start ordering parts during break. Parts should be on hand by middle of the month. Begin preliminary testing of individual parts. Finalize board design for hud display, command center, and sensor. Submit to board manufacturer to be made.

SEPTEMBER

- start building tested parts and integrate them as a system. Document testing and redesign. Research issues and reevaluate theory.

OCTOBER

- system integration should be halfway done at this time. Rework bugs and redesign. Final Documentation of the group should be almost ready at the end of the month excluding final test.

NOVEMBER

- majority of the design should be working at this time. Work on Final documentation of the project. Final testing should be done at the second or third week of this month.

DECEMBER

- project should be 100% tested and working at the first week of this month. Final documentation ready and proof read. Practice for final presentation.

9. Conclusion

At this point in the project we have learned how to become a team. 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. Having different ones communicating at all times is hard enough, but remembering that this design could deal with a vehicle. The controllers cannot mess up or fail. So thorough testing will be done to prevent any downfalls.

Meeting our objective and goals is important to us, but nothing is set in stone before the project research is even started. 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 will have to do.

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 simulation a person driving and maybe have a steering wheel and a seat.

Overall our project will be fun and very interesting. 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. As for the future of this project we will get started early by ordering and collecting parts. The sooner the better, would be best for testing purposes.

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<http://extremeelectronics.co.in/microchip-pic-tutorials/hello-world-project-with-pic-microcontroller-part-ii/>
<http://www.winpicprog.co.uk/>

<http://www.farnell.com/datasheets/73827.pdf>

<http://extremeelectronics.co.in/microchip-pic-tutorials/tutorial-0-getting-started-with-microchip-pic-microcontrollers/>

<http://www.aliexpress.com/product-fm/289974404-XL600-51-MCU-development-board-8051-study-kit-on-board-ISP-wholesalers.html>

http://www.futurlec.com/PIC18F4550_Board_Technical.shtml

<http://www.microchip.com/>

<http://zone.ni.com/devzone/cda/tut/p/id/6994>

http://cgi.ebay.com/ws/eBayISAPI.dll?ViewItem&item=300442861781&rvr_id=&rlp=1_263602_263622&UA=WVF%3F&GUID=ab0156171290a0b452e3dfd3ffde6228&itemid=300442861781&ff4=263602_263622

<http://chiphacker.com/questions/1107/avr-vs-arm-vs-others>

http://en.wikipedia.org/wiki/Electronic_control_unit

<http://www.cartechautoparts.com/instrument-cluster/>

<http://www.eetimes.com/design/embedded/4017937/Designing-a-Vehicle-Instrument-Panel-Cluster-151-A-Case-Study>

10.2 Permissions

senior design project Inbox | X

★ **frank reed** Our group would like to use the NXP LPC2468 development board image for our s... 4:32 PM (1 hour ago)

★ from **MDFLY** <questions@mdfly.com> [hide details](#) 5:45 PM (1 minute ago) ← Reply ▼

to frank reed <frankereed@gmail.com>

date Mon, Jul 26, 2010 at 5:45 PM

subject Re: senior design project

Hi,
No problem.

Regards

2010-07-26

www.MDFLY.com

frank reed
2010-07-26 13:32:40
questions
senior design project

Our group would like to use the NXP LPC2468 development board image for our senior design project documentation. We were wondering if we can have permission to use pictures and data from your website for non-commercial use.

Thank you, Frank.

senior design project Inbox | X

★ ● **frank reed** to avinash [show details](#) 3:37 PM (9 hours ago) ↩ Reply ▾

Our group would like to use the simple LED "Hello World" project for the PIC18F 4550 image for our senior design project documentation. We were wondering if we can have permission to use pictures and data from your website for non-commercial use.

Thank you, Frank.

↩ Reply → Forward

★ **AVINASH GUPTA** to me [show details](#) 11:40 PM (1 hour ago) ↩ Reply ▾

Hello,

Ok, you can use them. But don't forget to give credits somewhere in the document.

Regards
Avinash Gupta.
[eXtreme Electronics](#)

★ ● **frank reed** to technical [show details](#) 4:27 PM (18 hours ago) ↩ Reply ▾

Hello Technical Support of Futurlec,

Our group would like to use the PIC18F4550 USB Development Board image for our senior design project documentation. We were wondering if we can have permission to use pictures and data from your website for non-commercial use.

Thank you, Frank.

↩ Reply → Forward

★ from **sales** <sales@futurlec.com> [hide details](#) 4:08 AM (7 hours ago) ↩ Reply ▾

to frank reed <frankereed@gmail.com>
date Tue, Jul 27, 2010 at 4:08 AM
subject RE: senior design project

Hi Frank,

Yes, this is okay, many thanks for asking.

Best Regards
Alan
Sales Manager
www.futurlec.com

[Get The Latest Copy of Silicon Chip Direct from Futurlec](#)

Photo permission: HUD

Full view

Jon G.
To rdbrown1@rockwellcollins.com

7/16/10
Actions

Dear Robert,

This message is to request permission to use three images taken from: "High Resolution LCD Projector for Extra Wide Field of View Head-Up Display". I am an electrical engineering student at the University of Central Florida working on my senior design project, which incorporates HUD technology heavily. The figures requested are: figures 1,3, and 4. Thank you for your time on this issue!

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Your E-mail Address	<input type="text" value="credeguzman@knights.ucf.edu"/>	<i>*required</i>
Verify your E-mail	<input type="text" value="credeguzman@knights.ucf.edu"/>	<i>*required</i>
First Name	<input type="text" value="chris"/>	<i>*required</i>
Last Name	<input type="text" value="de guzman"/>	<i>*required</i>
Company	<input type="text"/>	
Title	<input type="text"/>	
Department	<input type="text"/>	
Mailcode	<input type="text"/>	
Address	<input type="text"/>	
City	<input type="text"/>	
Country	<input type="text" value="United States"/>	
State/Province	<input type="text" value="Florida"/>	
Zip Code	<input type="text"/>	
Phone	<input type="text"/>	
Message	<p>To Whom It May Concern,</p> <p>My name is Chris de Guzman. I am an Electrical Engineering student at the University of Central Florida. We are doing a Senior Design Project and we would like to ask for permission regarding the use of your image in our documentation. I captured the picture of the POD system and seatbelt sensor. Please let me know if this is ok.</p> <p>Thank you very much for your consideration.</p> <p>Chris de Guzman UCF EE Senior</p>	<i>*required</i>

Submit →

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□ **Bill Ozinga** [Add to contacts](#)
To chris de guzman

On Aug 1, 2010, at 10:25 PM, chris de guzman wrote:

To Whom It May Concern,

My name is Chris de Guzman. I am an Electrical Engineering student at the University of Central Florida. We are doing a Senior Design Project and we would like to ask for permission regarding the use of your image in our documentation. Attached is the image that we are asking permission of use for.

Thank you very much for your consideration.

Chris de Guzman
UCF EE Senior
<tpms_accu_extretro_accutiretpms_l.jpg>

Chris,

That would be fine.

Bill

Bill Ozinga | Webmaster

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□ **Larry Carley** [Add to contacts](#)
To Cre de Guzman

That's fine. Just be sure to include a link to the AA1Car.com website.

Thanks.

Larry
www.aa1car.com

--- On **Mon, 8/2/10, Cre de Guzman <credeguzman@knights.ucf.edu>** wrote:

From: Cre de Guzman <credeguzman@knights.ucf.edu>
Subject: Re: Permission for use of Image
To: "Larry Carley" <aa1car@yahoo.com>
Date: Monday, August 2, 2010, 3:35 PM

Larry,

I believe that after this project has been implemented, the final paper will be posted to the school's senior design website for reference to the next batch of students. I hope this is fine as it is for educational purposes only.

Thank you for your consideration.

chris de guzman
(407) 928-7427

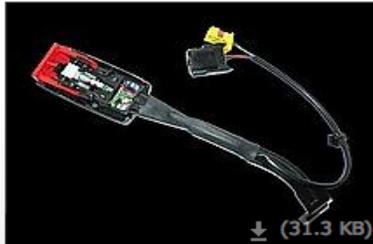
sent from iPhone

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□ **chris de guzman**
To sales@digikey.com

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Chris de Guzman
UCF EE Senior

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□ **chris de guzman**
To media@howstuffworks.com

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Chris de Guzman
UCF EE Senior

❏ **chris de guzman**
To sales@digital-auto-gauges.com

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Chris de Guzman
UCF EE Senior

❏ **chris de guzman**
To support@ross-tech.com

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To Whom It May Concern,

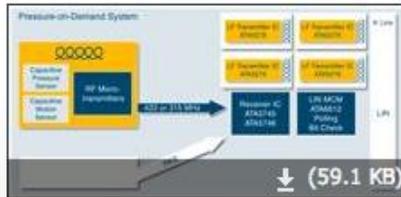
My name is Chris de Guzman. I am an Electrical Engineering student at the University of Central Florida. We are doing a Senior Design Project and we would like to ask for permission regarding the use of your image in our documentation. Attached is the image that we are asking permission of use for. Thank you very much for your consideration.

Chris de Guzman
UCF EE Senior

Permission to use image

chris de guzman
 To webmaster@atmel.com

 2 attachments (total 176.3 KB)



Part Number	Frequency Range (MHz)	Key Features	Package
AT91C46	315-430	ADU/PMU, Fully Programmable by the Microcontroller, Single-board Design for Both Frequency with Single 5V-MHz Crystal Type, Part 1, 2, 3	1000P10
ADU2162	216	ADU/PMU (2nd Phase) Expansion Kit, with Low Standby Time and Active Current Consumption	1000P10
ADU2161	432		
AT91C78	316	2nd Phase Control Receiver, 300 kHz Standby/1000 PPM Compensation to ADU/PMU, ADU2162	4000C1
ADU2164	432	2nd Phase Control Receiver, 300 kHz Standby/1000 PPM for Compensation to ADU2162, ADU2161	4000C1
ADU2163	432	2nd Phase Control Receiver, 300 kHz Standby/1000 PPM for Compensation to ADU2162, ADU2161	4000C1
ADU2165	432	Replacement 2nd Receiver IC with Fast PMU Switching Rate, Standby 0.1 to 0.2 MHz Standby/1000 PPM, 2nd Phase Programmable, 300 kHz Standby, High PMU Accuracy (± 100 ppm in U.S. Market), High Bleeding Capability	4000C1
ADU2166	432	Fast Switching Rate receiver (PMU) and PMU Receiver Module	4000C1
ADU2167	432		
ADU2168	432		
ADU2169	432		
ADU2170	432		
ADU2171	432		
ADU2172	432		
ADU2173	432		
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ADU2199	432		
ADU2200	432		

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Chris de Guzman
UCF EE Senior

Kevin R. Sullivan [Add to contacts](#)
 To chris de guzman

8/01/2011
[Action](#)

Hello Chris,

Yes, you can have permission to use this for educational purposes only. So yes, include it in your senior project. Any noted credit should go to Toyota Motor Sales, USA, Inc.

Good Luck

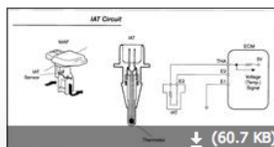
Kevin Sullivan
Professor of Automotive Technology
Skyline College, San Bruno, CA
sullivank@smccd.edu

chris de guzman
 To kevin@autoshop101.com

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Thank you very much for your consideration.

Chris de Guzman
UCF EE Senior

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chris de guzman
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I understand that this is not your product nor sell the item. If you steer me in the right email address, I would really appreciate it. Hamlin's site doesn't have a webmaster for this sort of thing.

Thank you very much for your consideration.

Chris de Guzman
UCF EE Senior

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