

Team 5

Chrysler Advanced Breakout Board Final Proposal

Team Members:

Richard Hendrick – Leader

Andrew Haumersen – Presentation

Sana Siddique – Web Designer

Xuran An – Documentation

Meng Cao – Lab Coordinator

Professor Jian Ren- Facilitator



CHRYSLER

Executive Summary

The sponsor currently does not have an organized way of going about checking for connectivity and bus communication with prototype car modules. The method now consists of having all of the modules plugged into one heap and has to dig through this when required to “test connectivity”, i.e. unplug it and plug it back in. The advanced breakout box will simplify this procedure by giving each module its own port to plug into and its own connection to the bus communication that can all be toggled and controlled by an easy-to-use computer interface.

Table of Contents;

[Introduction](#)

[Background](#)

[Objectives or Design Specification](#)

[FAST Diagram](#)

[Conceptual Design Descriptions](#)

[Ranking of Conceptual Designs](#)

[Proposed Design Solution](#)

[Risk Analysis](#)

[Project Management Plan](#)

[Budget](#)

[References](#)

Introduction

Our project name is Advanced Communications Bus BreakOut Board.

Our sponsor is Chrysler.

Our facilitator is Jian Ren.

As technology continues to develop faster and faster, our world becomes smaller and smaller because of all kinds of transportation such as airplane, ship, car, train etc. The most common vehicle for people to travel around is cars. The process of development and manufacturing of cars has come a long way in the last 60 years. Nowadays, more and more people can afford a car, especially in United States. In this case, there is a huge competition in the car's market. Why do people need a car? The most important reason is that cars can make people feel convenient when they go from one place to another. It is not only about getting to our destination faster, but also including best features in the car. All of the car's companies try their best to make their customer feel comfortable and happy while traveling, because this is the essential part to win the attention of customers. Therefore, lots of new modules coming out one by one.

Chrysler company is an American automobile manufacturer which founded by Walter Chrysler in 1925 headquartered in Auburn Hills, Michigan. It is one of the "Big Three" American automobile manufacturer. Chrysler has developed several new modules which will used in new vehicles. However, they do not know whether they are working well or not. It is inadvisable to test them after put them together in a car. They need to test them and make sure everything is working fine before. Currently it takes Chrysler about 3-4 years of testing to get a car in the market. Most of this time is consumed by the electrical engineer for testing. This time frame is unacceptable and testing of cars needs to be optimized.

Our task of this project is basically deal with this problem which means our advanced breakout board is a device for testing and toggling modules on a pre-prototype vehicle build. Our device need to make it easier to test connectivity and communication on a pre-plywood buck assembly. The board would allow the engineers to use their laptops to control which modules are active and inactive on a bench top communication bus. This device also will decrease the amount of time during early development work, thus, allowing the engineers to identify issues with module connectivity prior to the installation on the prototype.

Engineering Skills Required:

1. Sensor Design

The system need to read voltage values and display this data real time.

2. Programming

The system needs to have an easy to use GUI.

The system needs to be "plug-and-play" for any standard Windows laptop.

3. PCB Design

The PCB needs to be able to accommodate approximately 15 modules.

4. Packaging Awareness

The device would need to be packaged so it could be used on a test bench.

By the end of this semester, our advanced breakout box will allow user to toggle on and off modules with their laptop, take voltage readings of the communication bus, and record this data in an easy to access format. The device needs to be packaged and durable enough for repeat bench top use.

Background

It is important and necessary to test connectivity and communication of modules on a pre-prototype vehicle. How to achieve this goal?



This is pretty like what they did for testing new modules. There are lots of wires and banana to banana connectors in a single device. If they want to test connectivity of module, they need to connect bunch of banana connectors one onto another. What about test different module? They need to disconnect previous connections and reconnect them in another way. As the number of modules on any given vehicle grows, it is easy to get wrong, cluttered and confusing while connecting wires and connectors.

We had visit Chrysler company several weeks ago. They have lots of new cars with new modules need to be put into market. They also plan to finish them two years earlier to get more profit. Therefore, it is very important for them to finish testing this new modules. However, their method is basically all hand working. It really slow and lack of accuracy.

Our advanced breakout board will be more accurate and can speed up testing process. Basically, we can connect all the testing modules on our breakout board and user can simply control them by laptop. Engineers can read the testing data through the laptop.

Objectives or Design Specification

After our visit to Chrysler's headquarters in Auburn Hills MI the team had a very good idea of what was needed to fulfill the customers needs. In order to help solve Chrysler's problem of not being able to easily change and take readings of new modules in a test bench setting we have proposed a new breakout box to help speed up the prototyping process. This breakout box will not only make readings more accurate and reliable but it will also allow engineers to perform more test prior to installing the new modules on a wooden mock up of the vehicle. Ultimately our breakout box will help to shorten the time it takes from prototyping to production on new vehicles by shortening the testing and debugging phase of new modules on prototype vehicles.

In order to meet all the criteria Chrysler has given us our breakout box must perform a number of basic functions. Our design must be able to support ten different modules, such as ABS, ECU, Headlights, HVAC, etc., being plugged in at the same time and connected to CAN busses via an OBDII port. These modules must be able to be toggled on and off individually not only with battery power but also with the ignition signal in order to test for function, startup processes, and connectivity. Because some modules such as headlights have very high current draw we have split up our board into having five high current connections and five low current connections instead of making all ten able to handle the high current. We have chosen this method because it will save us money in production of our PCB board, our power switching components, and it will make our design smaller due to not having as large of traces on all of the PCB connections. These two different current connections will be split into having five high current connections able to draw up to 15 amps and five low current connections being able to draw up to 250 milliamps. Another difficulty Chrysler faces is taking real time voltage and current readings of both power draw, and voltage on the CAN buses. To solve this problem our breakout box will be capable of displaying and saving real time current values of the power draw of all ten individual modules as well as nine different voltage readings, CAN high to ground, CAN low to ground, and the difference for all three CAN buses. These readings must all be accurate within plus or minus one percent. Another important test function that our breakout box will provide is the ability to change any module to communicate on any CAN bus simultaneously. This will provide the ability to see how certain modules behave on the three different can buses and also help to isolate any module that is not functioning properly or two modules that are interfering with each others data signals. One important part of this function that we must meet is that we do not induce any signals or corrupt any signals on the CAN buses, we have created our design to aid in this but will do testing after our first build to determine if we need to add any filtering to our CAN multiplexing. Since our breakout box will provide so many different functions the need to have an easy to use interface or way to display the information is a must. To accomplish this our breakout box will be able to plug into a computer via usb and have an easy to use GUI that will provide all the necessary functions including: toggle power and ignition signals, display and record real time voltage and current readings, and change which can bus any individual module is communicating on. Last the box must be somewhat portable, it will be used in a test bench

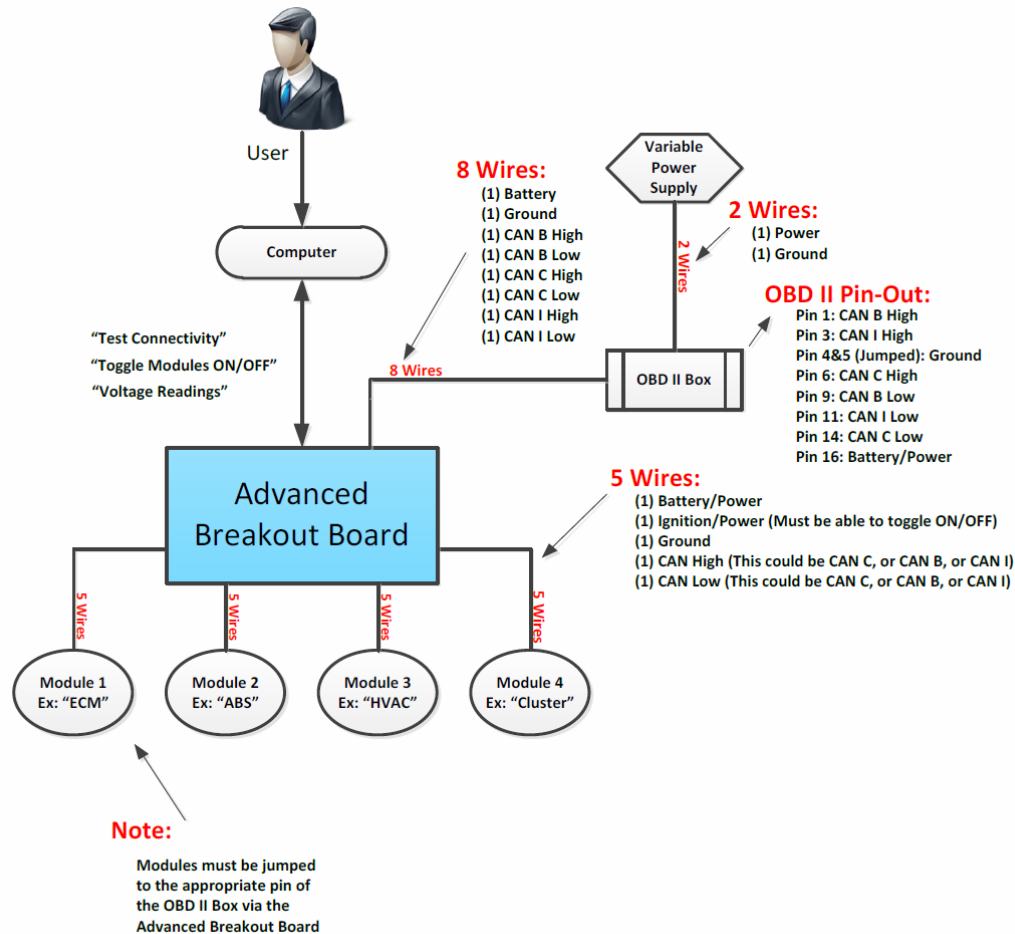
setting but must be able to be carried from bench to bench to perform different testing applications.

The table below is a breakdown of what we believe is the importance of each design parameter to the customer.

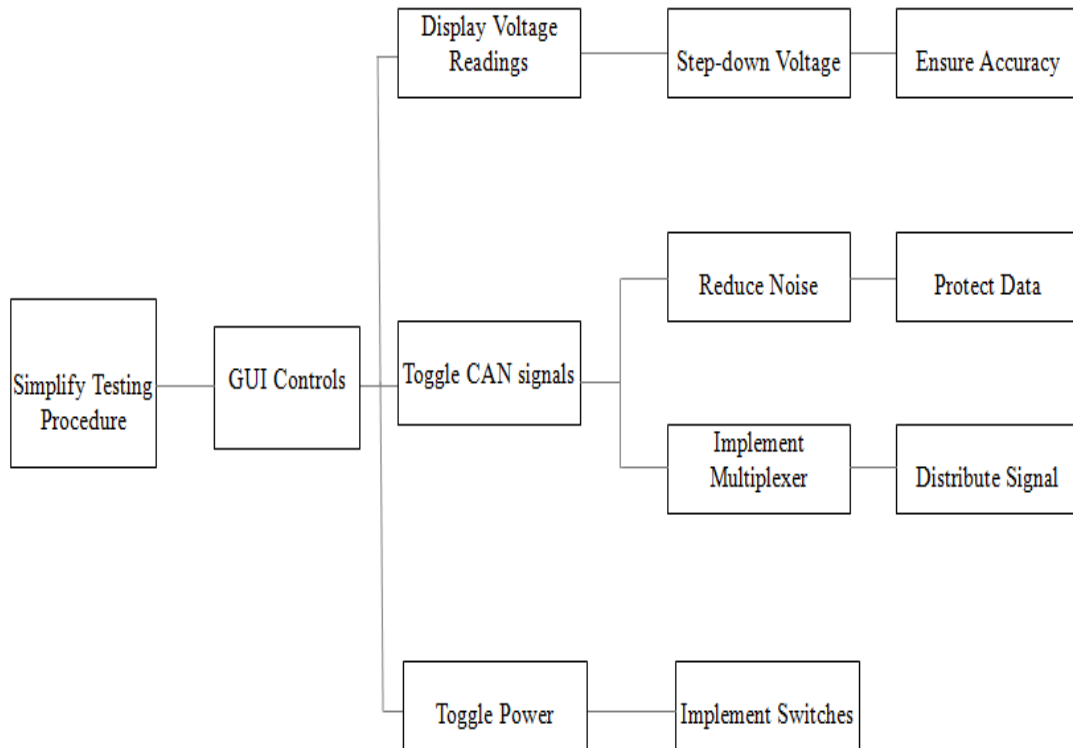
Design Parameter	Importance to Customer
Connection of 10 modules	4
Toggle power	5
Draw 15 amps	5
Voltage/Current readings	5
Accuracy of readings	5
Distribution of CAN signals	5
Integrity of CAN signals	5
Easy to use GUI	4
Mobility of breakout box	3
Low cost	1

We believe that each criteria listed below must be satisfied in order to make the design feasible and the customer happy, here is a breakdown of why we rated the parameters what we did. The connection of 10 modules is a 4/5 because Chrysler was wanted to have at least 8 modules and 10 if possible so we are meeting the higher objective. Toggle power is 5/5 because the modules must be tested in a start up scenario of powering on and powering off a vehicle and seeing how they react to complete voltage loss (toggle of battery power). A max of 15 amps must be met to power some high current modules so this is also 5/5. Displaying real time voltage and current readings and keeping them accurate is the only way for Chrysler to determine the functionality of the modules so again 5/5. Distributing of modules on different CAN busses greatly increases the ability to diagnose issues with modules but only if the integrity of the bus is maintained through the breakout board so this is a 5/5. Having an easy to use GUI makes the product much easier to use and keeps things organized but is not absolutely essential for functionality, therefore a 4/5. The mobility of the box again is not essential because it will spend most of its life sitting on a bench but still must be able to be moved occasionally so 3/5. The last design parameter is low cost, we rated this a 1/5 because Chrysler told us cost essentially does not matter, they are doing anything they can to speed up prototyping of vehicles and our breakout box should take two weeks out of the test process.

The ultimate objective of our design is to make Chrysler's test procedure for new modules easier and less time consuming in order to speed up the process and help to reduce the time it takes a new vehicle to go from prototyping to production from 4 years to 2 years. We believe with all of the functions our breakout box will perform it will help to cut 2 weeks out of the prototyping process and aid in the reduction from 4 to 2 years. Below is a diagram of where our breakout box fits into the test procedures.



FAST Diagram



Conceptual Design Descriptions

In order to achieve the requirement above, we have several options. The design can be divided into six different parts, microcontroller, A/D converter, multiplexer, switches, PCB design, and GUI.

Microcontroller

This project require both toggle modules using laptop, and send data back to the laptop, microcontroller is needed to accomplish this. Rather than stand-alone chips, we decided to go with microcontroller development board that already designed with protection circuit. It will be easier to program with, as well as communication with computer. Three different type of low-cost microcontroller board are compatible for this design, Arduino, Raspberry Pi, and Beaglebone Black.

Arduino/Raspberry Pi/Beaglebone Black

A/D converter

Neither of the microcontroller have the sufficient A/D converter. Therefore, additional A/D converters are required. For this design, also for prototype build, all the semiconductor chips need to be in DIP packet. Two chips are considered for this project, MCP3208 from MicroChip and ADS7822P.

MicroChip MCP3208 8-Channel 12-Bit Resolution A/D converter

Texas Instrument ADS7822P 4-Channel 12-Bit Resolution A/D converter

Multiplexer

Multiplexer also need to be in DIP packet. The multiplexer required to be at least 3 to 1. So 4 to 1 Mux is the multiplexer that fit the requirement best. Also, in order to make PCB looks cleaner, dual 4x1 Multiplexer is the best choice.

Texas Instrument CD74HC4052E Dual 4x1 Multiplexer

VISHAY DG409DJ-E3 Dual 4x1 Multiplexer

Switches

In this project, each module need to be toggle on and off. Since the breakout board power each individual module, switches are needed to pass and cut power to different modules. The switches are also need to be controlled by microcontroller throw I/O pins. Transistors and relays are considered to be used in this project as switches.

PCB design

In this project, extra PCB design are required for the multiplexer chips and A/D converter chips. The extra PCB needs to be able to communicate with the microcontroller board.

GUI

For the GUI we basically considered two options- GTK+ toolkit and QT toolkit. GTK+ and Qt are open-source cross-platform user interface toolkits and development frameworks. These are very popular frameworks for Linux because they are open-source and give developers a powerful toolkit to design GUI. Qt has C++ based libraries and it supports Java, Perl, Python, PHP and Ruby based development. GTK+ has C based libraries. It supports several languages, including C++, Java, Perl, PHP, Ruby and JavaScript.

Ranking of Conceptual Designs

Microcontroller

	Arduino Uno	Raspberry Pi A/B	Beaglebone Black
CPU clock	16MHz	700MHz	1 GHz
On board memory	32 KB	256MB/512MB RAM	512MB RAM/ 2GB Storage
GPIO	14	8	46
A/D Converter	6	none	7
USB port	none	1/2	1
Supply Voltage	6-20V	5V	5V
Other		HDMI,Ethernet,SD Slot	HDMI,Ethernet,SD Slot
Price	\$27	\$25/\$35	\$45

<http://arduino.cc/en/Main/ArduinoBoardUno>

<http://www.element14.com/community/docs/DOC-51668?!CID=raspi-group>

<http://beagleboard.org/Products/BeagleBone%20Black>

	CPU	Memory	GPIO	A/D	USB	Supply Voltage	Price	Total
weight	1	2	5	4	2	2	4	25*5
Arduino	2	1	2	2	0	5	5	52

Rasberry Pi	4	3	1	0	5	2	5	44
Beaglebone Black	5	5	5	2	4	2	4	76

After comparison, Beaglebone Black fit the project best. For this project, the GPIO, A/D converter weight the most, which Beaglebone Black when on both. Beaglebone also has the fastest CPU speed and largest RAM, as well as it has large on board memory that can be used to record experiment's data. The price is a little bit high but still competitive.

A/D converter

	MCP3208	ADS7822P
Manufacture	MicroChip	Texas Instrument
Resolution	12-bit	12-bit
Channel	8	4
Packet and Pins	DIP-16	DIP-14
Price	3.48	4.16

<http://ww1.microchip.com/downloads/en/DeviceDoc/21298e.pdf>

<http://www.ti.com/lit/ds/symlink/ads7822.pdf>

	Resolution	Channel	Price	total
weight	5	5	5	15*5
MCP3208	4	5	5	70
ADS7822P	4	3	4	55

The resolution of the two chips are the same. The difference is the number of channels that can measure for each chip. MCP3208 can measure 8 different channel compare to 4

different channel on ADS7822. This will save a lot of space on the PCB. Also, the price is lower for MCP3208, consider it can measure 8 channel on a single chip, this is much cheaper than ADS7822P.

Multiplexer

	CD74HC4052E	DG409DJ-E3
Manufacture	Texas Instrument	VISHAY
Channel	Dual 4x1	Dual 4x1
Packet and Pins	DIP-16	DIP-16
Price	\$0.46	\$3.60

<http://www.ti.com/lit/ds/symlink/cd74hc4051.pdf>

<http://www.vishay.com/docs/70062/dg408.pdf>

For multiplexer in the project, we need to toggle module to 3 different CAN buses. Each CAN bus has CAN high and CAN lower. For ten modules means 20 muxes. So we decided to use Dual 4x1 multiplexer, which can toggle CAN high and CAN low at the same time. Also reduce the chip from 20 to 10 piece. These two multiplexer chips are basically the same. CD74HC4052E from TI which has the unbeatable price, so it becomes the first choice.

Switches

For switches, we need to toggle both high power module and low power module. Transistor can set up as a switch and can be easily controlled by microcontroller. Well designed relay board can also be controlled by microcontroller. For safety purpose, we decided to use transistor(triode) for lower power module and relay for high power module.

PCB Design

The same problem with PCB. The device need to power both low power module and high power module. The high current on PCB will produce noise. If something wrong happened, high current may also blow up the chips. So we decided to use separate PCB for high current and low current.

GUI

As mentioned before the top 2 choices for developing GUI were using GTK+ toolkit or QT toolkit. Qt can run directly on the hardware, without the need of X11 or a window manager whereas GTK+ applications require X11 server and window manager to run which means that a simple hello world application on GTK+ will have 3 processes running which will slow down the overall

application. QT is also faster with some widget. Hence, QT seems to be the superior choice and we will be using python to program the GUI. QT has python bindings available as well. we will be using PyQt to build the GUI.

Other

For protection, we will also consider using fuses and protection circuit to protect chips and modules.

Proposed Design Solution

To achieve all the features for a functional Advanced breakout board our microcontroller- the Beaglebone Black will need to run a GUI application that will allow the use to toggle modules on and off and display the current values for the modules and the CAN bus voltages in real-time. It should also be able to transfer this data to a spreadsheet for each session of module testing. This will be accomplished by using the QT toolkit as mentioned earlier. Qt is a complete consistent framework. You can easily connect HTTP events to GUI elements, fill forms with results from a database query or build an interactive visualization of large datasets. Some of the notable QT 4 modules that will be used for this project are QtCore, QtGui, QtScript, QtSql and QtWebKit. The module voltages and CAN bus voltages will be displayed on the GUI using the A/D converters and the General Purpose Input Output ports on the BeagleBone. The BeagleBone will be using Ubuntu operating system to accomplish the above tasks.

To be able to connect any of the module to any CAN bus voltages while keeping intact the integrity of the CAN voltages we will have to do multiplexing and then send the data to the laptop. The multiplexing will be done so that its very simple for the user to select which module goes on what CAN bus.

5 module inputs out of 10 need to be able to handle high amounts of current ranging from 7A to 12A while the others will have a maximum current reading of 200mA. The fuses for the board will be designed accordingly to protect the modules and the board.

The PCB board is going to be multi layered as well because this will make the device more portable and very easy to transport.

To test this we will be using real modules and the OBD 2 box from Chrysler . Since Chrysler currently uses OBD 2 box to get the current and voltage readings, we will initially record module current and voltage readings for various combinations of modules connected to the CAN voltages using only the OBD 2 box. Then we will connect our device and take the same voltage and current reading and calculate the accuracy and deviation for both sets of data. Assuming that the OBD 2 box by itself returns pretty accurate values of current and voltages, our goal is to have our output values as close to OBD 2 box values as we possibly can.

Risk Analysis

The main challenges that lie ahead as far as Graphical User interface is concerned are the application needs to run fast enough to display the readings in real time and store the correct data in the spreadsheet. If the values take too long to change on the GUI when modules are toggled on and off then we risk entering the data on the spreadsheet prematurely, hence affecting the accuracy of our readings and decreasing value of the overall product. This is definitely a moderate risk but it directly affects the usability of the product.

At no cost would we want to fiddle with the integrity of the CAN bus voltages when they are connected to multiple modules. We will have to be very careful about this since we don't want any corrupt current and voltage values and this would be very difficult to fix. This definitely falls in the high risk category.

We need to be extremely careful with our multiplexing design because the smallest of error in that will be magnified in the output displayed on the GUI and also the calculations in the program will be completely based on the multiplexing and voltage division in the hardware. This is a low risk category and everything should work fine as long as we are testing at every step. We also need to optimize the multiplexing so that we are not using too many multiplexers to accomplish our task and reducing overall cost of the product.

Project Management Plan

Personnel

Richard Hendrick – Richard's non-technical role is the group leader, and is responsible for keeping everything on task and keeping things consistently moving forward. He manages the available resources along with keeping track of the team's budget. His technical role consists of managing the number of usable I/O ports available on the BeagleBone Black. He will also help with developing the GUI and programming the microcontroller.

Andrew Haumersen – Andrew's non-technical role consists of preparing the team's presentations and making sure that everyone is prepared to present on their own topics. For the technical role, Andrew is head of designing and implementing the multiplexing circuit required for the CAN buses to be connected to the 10 different modules.

Sana Siddique – Sana is responsible for the team's web page and keeping it updated for her non-technical role. For the technical aspect, she is leading the effort to design a user-friendly GUI that people will easily be easily adaptable for any and all Chrysler employees that may come through requiring our product. She also developed the risk analysis for the current design and helped point out any design flaws with the final design. Sana will also be working with Richard in programming the microcontroller to fit the team's needs.

Xuran An – Xuran's non-technical role is collecting and maintaining the team's documents i.e. papers, technical reports etc. His technical role consists of handling the A/D conversions that all need to happen in order for there to always be accurate information be fed out to the GUI.

Meng Cao – Meng's non-technical role has been making sure that any outside materials that are required for the final design are ordered and received in a timely manner. His technical role has mainly focused on designing the PCBs that are required while also working with Xuran in finding additional A/D converter chips to aid in the numerous readings and calculations that will be required.

Resources

In order to fully implement our breakout box, team 5's hardware requirements extend beyond what's available in the 480 lab. First off, the microcontroller needed to be purchased from a separate vendor, along with the additional A/D converters and all of the multiplexers. These were successfully ordered through the ECE department. The remaining hardware needed for testing is being provided by Chrysler, which is a number of different prototype modules that resemble the kinds that they currently test every day. They are also providing an OBDII scanner tool which will be used to check the CAN buses at any time to validate the measurements. For software, all the packages needed are open-source and are readily available for download from the respective websites. This includes both the software for programming the chip and writing a user-friendly GUI.

Proposed Schedule (Gantt)

See attached Gantt Chart.

For future non-technical deliverables, the Design Issues paper is due and will be completed by October 18th. On top of this, the two page progress report, photocopies of engineering notebooks, and business canvas assignments will also be due and completed around the week 9 deadline.

Deliverables for upcoming demonstrations:

Week 9: By week 9 Team 5 aims to have a fully working multiplexed test circuit on a breadboard that represents the CAN bus signals being multiplexed in the final design implemented through a PCB.

Week 12: By week 12 the goal is to have a working GUI and microcontroller that is taking readings and outputting the digital values to the interface.

Week 15: The final and fully implemented design will be finished and tested before this week and Design Day. Chrysler is expecting a fully working product by the third to fourth week of November, actual dates to be determined.

Budget

The materials list is as follows:

Item	Quantity	Ind. Price	Total Price
BeagleBone Black	2	\$45.00	\$90.00
A/D Converter	2	\$3.48	\$6.96
Dual 4x1 Multiplexer	12	\$0.46	\$5.52
	Materials Total		\$102.48

Justification

BeagleBone Black- The design requires the use of a microcontroller to handle the interaction between our hardware and Chrysler's laptops. Two boards were purchased to help speed up and aid in the development process while also allowing a backup board in case something were to go wrong as deadlines come up.

A/D Converter- Additional A/D converters were purchased due to the number of sequential calculations and measurements that will need to be done at any given second. The A/D converters that are located on the BeagleBone Black. No spare chips were ordered, so extra precautions are being taken to ensure that these stay in perfect condition throughout the design process.

Dual 4x1 Multiplexer- This design requires 20 multiplexers to be used to multiplex the CAN bus signals to the 10 different modules that will be required to support at any given time. 10 dual-mux chips satisfy this requirement. 12 were ordered in case there were any DOA or if any were to go bad during the design process. Two additional chips give a total of four extra multiplexers as backup in case of either of these situations.

Future Budget Allocation

With the current total just over \$100, this allows team 5 to allocate funds for potential design improvements if time permits. The design does require multiple PCBs which are free when made through the ECE department. However, the boards the Department makes can only go 2 layers deep. The CAN bus PCB potentially needs to be more than 2 layers thick (for noise insulation reasons) which may require an order outside the Department. The ideal final product will reside in a robust enclosure that would help prolong the life of the device. Since this charge will only need to reflect the cost of material, there is no concern of breaking budget in the final designs of our product. Team 5 has planned and allowed enough of the budget left over to handle both of these cost requirements if necessary.