SAE Formula Car Display & Data Acquisition System

Authors: Joseph Groe, Miles Homler, Michelle Ohlson

Advisor: Professor Steven D. Gutschlag

BRADLEY UNIVERSITY

Department of Electrical and Computer Engineering

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Abstract

A data acquisition system will be built to assist the Bradley University mechanical engineering team in the annual SAE formula car race. Previously, vehicle failures with the formula car have prevented the team from competing, so the system will allow the team to monitor the car and check for any warning signs or problems. Any issues can be spotted as they occur, through real-time updated information sent to the driver and crew and a warning system that notifies the team when any values leave an acceptable range. The system will involve a microcontroller reading data from sensors on the car, converting that data into the proper formats to send it to the driver's display and a wireless transceiver, transmitting the data to an offsite laptop. This system will not only ensure the safety of the Bradley University team and other drivers in the competition, but will give the team a continually updated overview of the car, allowing issues to be found and repaired with less guesswork.

2. Introduction

The Society of Automotive Engineers (SAE) holds an annual competition for teams of engineering students to design and build a single seat race car according to rules provided by the SAE. The teams' cars will then be inspected and subjected to various performance tests at the competition to judge its design, construction, and performance.

In past years, the cars built by the Bradley mechanical engineering team have been unable to race due to performance issues. To ensure the car is running properly during testing and to assist the driver during the race, the ECE SAE Formula Car Display and Data Acquisition System design team will design a touch-screen display and data acquisition system to interface with sensors on the car. The sensors will read information about the car, such as engine speed, oil pressure, and ground speed in MPH. A GUI for the driver will display sensor information as real time data from the car, or data generated by an onboard microcontroller to test the display and provide a demonstration mode for judging during the SAE competition. In addition, a wireless system will be set up on the car to send vehicle data to be displayed and stored on an offsite laptop to permit monitoring vehicle operation in real time for added safety. The stored information will also permit data analysis at a later time to improve vehicle performance.

The display on the car will show the driver the most important information. This system will be used primarily to provide engine speed and warn the driver when a vehicle system has failed or is about to fail. As indicated above, the pit crew will also be able to monitor the car and warn the driver in case of failure. This is a very useful feature because the driver will frequently be busy driving instead of watching the display, and at least one engine has already been destroyed because the driver failed to see a critical temperature warning. The pit crew can also monitor far more information via the offsite laptop than could possibly made available to the driver.

3. Review of Literature and Prior Work

Numerous times over the past 15 years the electrical engineering department at Bradley University has tried to collaborate with the mechanical engineering department for the SAE Formula car competition. Since part of the SAE competition includes judging the aesthetics of the car, the touch-screen display system alone would significantly improve the car's rating during the judging portion of the competition. The SAE competition requires that all work is completed by non-professional students with a large emphasis on reliability, cost, and ease of maintainability.

Previous Bradley Electrical engineering teams have successfully completed this project before using an Amulet Touchscreen display and an ATmega128 microcontroller. This is a basic touchscreen display, and the team members have used the microcontroller in lab before. However, since the team will be using J1939 CAN bus for communication between subsystems, we need to upgrade to the Parker IQAN MD4-7 touch-screen display and AT90CAN microcontroller.

Included into the updated system will be a new wireless transceiver. With this transceiver, the manufacturer must pass strict guidelines with the FCC in terms of the transmitted frequency. The FCC also allows for unlicensed operations, but with our requirements we must use the licensed band. Fortunately, almost any board that we choose will already be licensed and registered with the FCC.

4. Standards and Patents Applicable to the Project

Since we are limited by inputs to the display, we must use a communication scheme. One such communication scheme already supported on the IQAN MD4-7 display is CAN (Controller Area Network). CAN is used widely in off-highway and other automotive applications. CAN is a 2 wired interface that communicates by sending data "frames". Frames can be a number of different sizes based on protocol, but every frame will have start-stop bits, arbitration bits, control bits, data bits, CRC bits, and ACK bits. Below is an example of a CAN message frame.

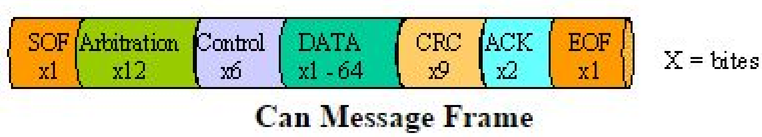

Figure 1: CAN Data Frame

Table 1 on the next page shows patents that are relevant to the wireless data acquisition system for this project. None of these patents appear similar enough to our system for patent infringement.

The ‘Data acquisition and display system for motor vehicle’ patent title sounds similar to our project, however, it is not the same. It is an on-board display system that connects to the car’s on-board computer via a data link connector. It communicates with peripheral devices (digital camera, GPS, and accelerometer) using bluetooth.

Table 1: Applicable Patents

Patent #	Application #	Title	CPC Class
7,991,535	20090204310	Portable, Palm-Sized Data Acquisition System for Use in Internal Combustion Engines and Industry	G07C 5/008 20130101; G07C 2205/02 20130101
	20090040034	Data acquisition and display system for motor vehicle	B60K 35/00 20130101; B60K 37/06 20130101; B60K 2350/901 20130101; B60K 2350/1028 20130101; B60K 2350/1024 20130101
	20080270074	User defined wireless data acquisition	G07C 5/008 20130101; E02F 9/267 20130101; E02F 9/264 20130101; G07C 5/085 20130101
7,593,808		Apparatus and method for engine performance evaluation	F02B 33/40 (20130101); F02B 37/013 (20130101); F02B 37/004 (20130101); F02B 37/18 (20130101); F02D 41/0007 (20130101); Y02T 10/144 (20130101)
7,505,847		Configurable electronic control system and diagnostic method	G05B 19/0425 (20130101); G05B 2219/24036 (20130101)

5. Subsystem Level Function Requirements with Specifications

The Display and Data Acquisition System will be composed of three main sections: the MD4-7 Display, the AT90CAN128 microcontroller, and two wireless transceivers, one connected to the microcontroller on the car and another on the offsite laptop. The MD4-7 will accept touchscreen input from the driver, who will choose between the Demonstration, Test, and Race modes. The MD4-7 will also display sensor information received from the microcontroller and sent to the display via CAN bus. The microcontroller will accept inputs from the various sensors mounted on the car. Depending on which mode the driver selects, the microcontroller will either use the sensor data collected in real-time from the car or test data generated on the microcontroller. In either case, the data will be converted to CAN bus format and sent to the display. The data will also be converted to serial data to be sent to the onboard transceiver, and from there to the offsite laptop.

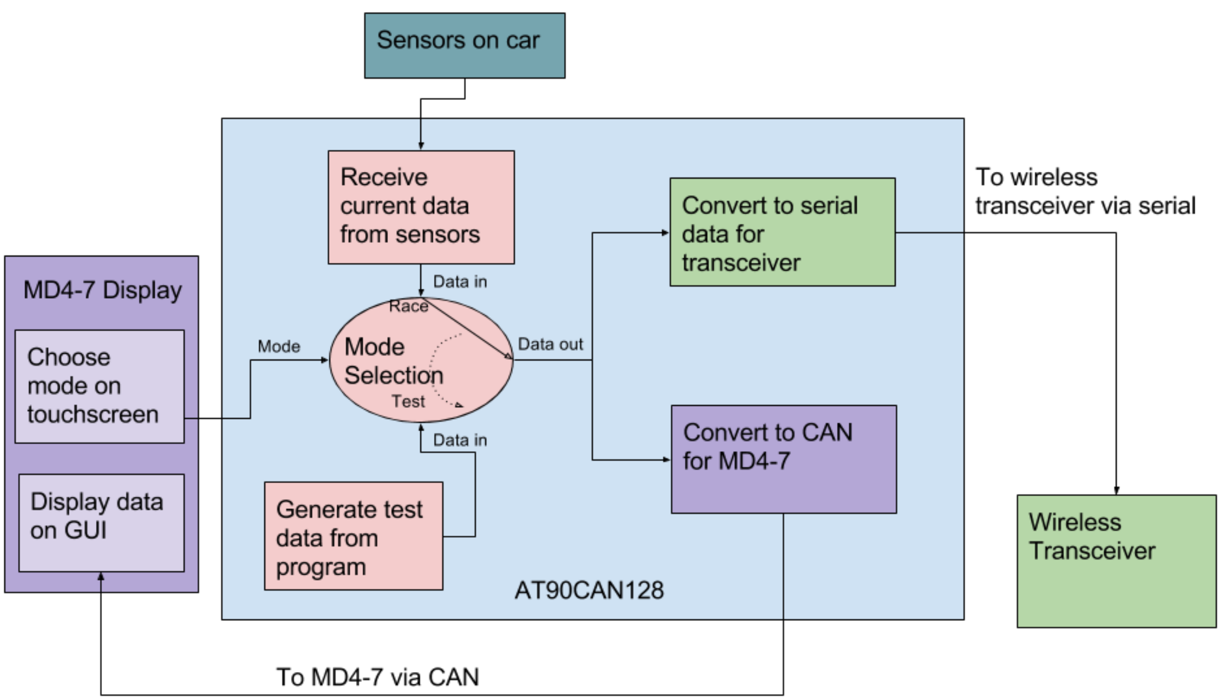

Figure 2: Vehicle Sub-system Diagram

On the laptop, the user will have the option to look at live data being sent from the sub-system on the car, or to review previously recorded data. When live data is being viewed, the system on the laptop will check to make sure the data is properly being received from the transceiver, and display a warning if an error occurs. If data is received properly, there will also be a warning system to alert the users when any received data is outside of an acceptable range or indicates an issue with the car.

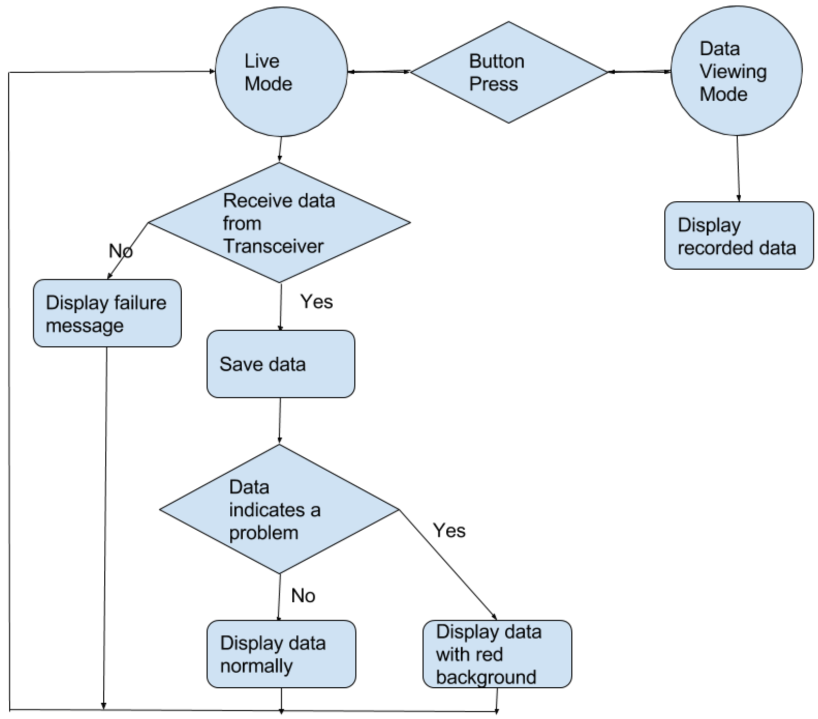

Figure 3: High-level Laptop Display Software Flowchart

Modes

The MD4-7 display and the laptop will both have two modes of operation for the user to choose between.

Display

Race Mode

The microcontroller collects data from the sensors and sends it to the display screen via the controller area network, which displays the important information to the driver. The data will also be sent to the laptop via EIA232. The laptop will display critical information in real-time, and also save it for later viewing. The display and laptop will warn the driver and crew if the sensor inputs indicate a vehicle failure or warrant a vehicle warning.

Test Mode

Once the microcontroller has received the Test mode command via the controller area network from the display, the microcontroller will then transmit “fake” values to both the display and the wireless transceiver. These values will range from the minimums and maximums of all the parameters of which we are displaying, checking that problems will be sensed and displaying warnings as would appear for normal operation.

Laptop

Live Mode

During practice, the data will be transmitted live from the vehicle sub-system to the laptop. The laptop will display the data and also save it for later viewing or analysis. The sensors, microcontroller, display, and wireless devices are are all required for this operating mode.

Data Viewing Mode

After practice, the recorded data will be available to view on the laptop. The sensors, microcontroller, and display are not used in this mode. The laptop also does not need data from the wireless transceiver.

6. Engineering Efforts Completed to Date

The team was able to secure a donation from the Parker Hannafin Corporation. They donated the MD4-7 which is a touch screen, 7” display. They also donated an expansion module that can be used to get sensor data. However, we decided to use the AT90CAN chip for the sensor data acquisition. Lastly, they donated the wire harnesses that connect to the display and the expansion model.

We have determined a liaison in the mechanical engineering department to communicate with in terms of sensor specifications. If this does not happen, Parker also offers sensors for multiple platforms that we can select and integrate into our system.

We had to find a replacement for the AC4790-200A transceivers used in previous iterations of this project. The ECE department had only one functional transceiver module left, and the AC4790-200A is now an obsolete part. However, the AC4790-1000M is currently available and is pin compatible, so it can be used with the same Aerocomm development kit and software that came with the AC4790-200A.

The AC4790 is a member of AeroComm’s ConnexRF OEM transceiver family. The AC4790 is a cost effective, high performance, frequency-hopping spread spectrum transceiver designed for integration into OEM systems operating under FCC part 15.247 regulations for the 900 MHz ISM band. [2]
Frequency band: 902-928 MHz
RF Data Rate: 76.8 kbps fixed
Serial Interface Baud Rate: 1.2 kbps to 115.2 kbps (fixed 9.6 kbps if pin 12 pulled low at reset)
RF Technology: Frequency hopping spread spectrum
Range, Line of Site, with a 3dBi gain antenna: 20 miles
Dimensions: 1.65” x 1.9” x 0.20”
Weight: < 0.75 oz
Certifications: FCC Part 15.247: KQLAC4490

Power:
Pin 10: 3.3-5.5V, +-50mV ripple
Pin 11: 3.3V +- 3%, +-100mV ripple

The RM024 is also an option for the wireless transceivers. It is also capable of using RS232 to communicate with the microcontroller and has a large enough range for the formula car.

Specifications from [3].
Frequency band: 2400-2483.5 MHz
RF Data Rate: 280 kbps or 500 kbps selectable
Serial Interface Baud Rate: 1.2 kbps to 460.8 kbps
RF Technology: Frequency hopping spread spectrum
Range, Line of Site, with a 2dBi gain antenna: 2.5 miles
Power: 2.3 - 3.6V, +-50mV ripple

When work began on the project, the team had initially planned to use the Amulet Touchscreen display used in the previous iteration of this project. However, team member Joe Groe's position at Caterpillar exposed him to Parker's touch-screen display systems. He was therefore able to secure a contact at the Parker-Hannafin dealer in Morton, Illinois. The dealer graciously donated an IQAN MD4-7 touch-screen display, an XA2 expansion module , and a wire harnesses for each component. The availability of the Parker-Hannafin enabled the team to replace the ATmega128 microcontroller with the AT90CAN microcontroller because CAN communication between the microcontroller and the display was not possible without the upgrade to the AT90CAN.

In terms of development for the display software, the IQAN design suite is a visual based software editor that allows the user to generate mock display screens. There is also a high level coding language called QCode which is similar to C programming, but thus far we have only designed a mock display screen with the Bradley logo as shown below.

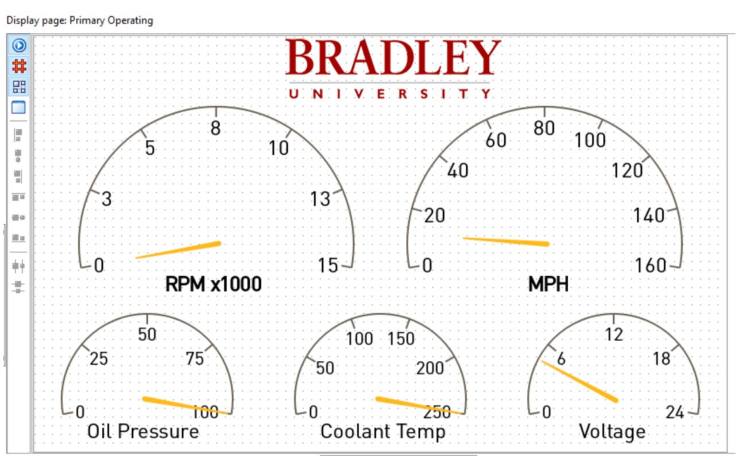

Figure 4: Mock Display Screen

Once the display was selected and development had begun, the team had to choose which microcontroller was to be used. Since the input ports on the display were limited to 2 voltage inputs, 1 frequency input, and 7 boolean inputs, the use of CAN interface necessary. Since the CAN communication protocol is very difficult to implement if the controller does not have an integrated CAN chip on the board, the AT90CAN controller was selected since it is still an Atmel controller and uses the same software design suite that was used for the ATmega128 that the team is familiar with from the ECE laboratory courses.

7. Parts list

Table 2: Parts List

Part	Price
Display Harnesses	$100 (Donated by Parker-Hannafin)
IQAN MD4-7 display unit	$1,200 (Donated by Parker-Hannafin)
AC4790-1000M Transceivers & antennas	$187
Sensors	$600
AT90CAN128	$130

8. Deliverables for ECE 499, Division of Labor, and Schedule for Completion

Deliverables

Parts list
Schedule
Division of labor
Vehicle Display
Microcontroller
Wireless communication
Laptop display and data storage/retrieval

Division of Labor

Joseph Groe - Display software, sensor inputs
Miles Homler - Sensor inputs, wireless transceiver outputs
Michelle Ohlson - Wireless transceiver software, computer GUI, data storage and retrieval

Schedule for Completion

Table 3: Schedule

Wireless Transceivers	January 18	February 18
Computer GUI	February 18	March 11
Display Software	January 18	February 18
Sensor Input Software	February 18	March 11
Microcontroller	January 18	February 18
Integration of Microcontroller	February 18	March 11
System Testing	March 11	March 25
Final Lab Testing	March 15	April 1
Install system to car (optional)	March 25	April 20

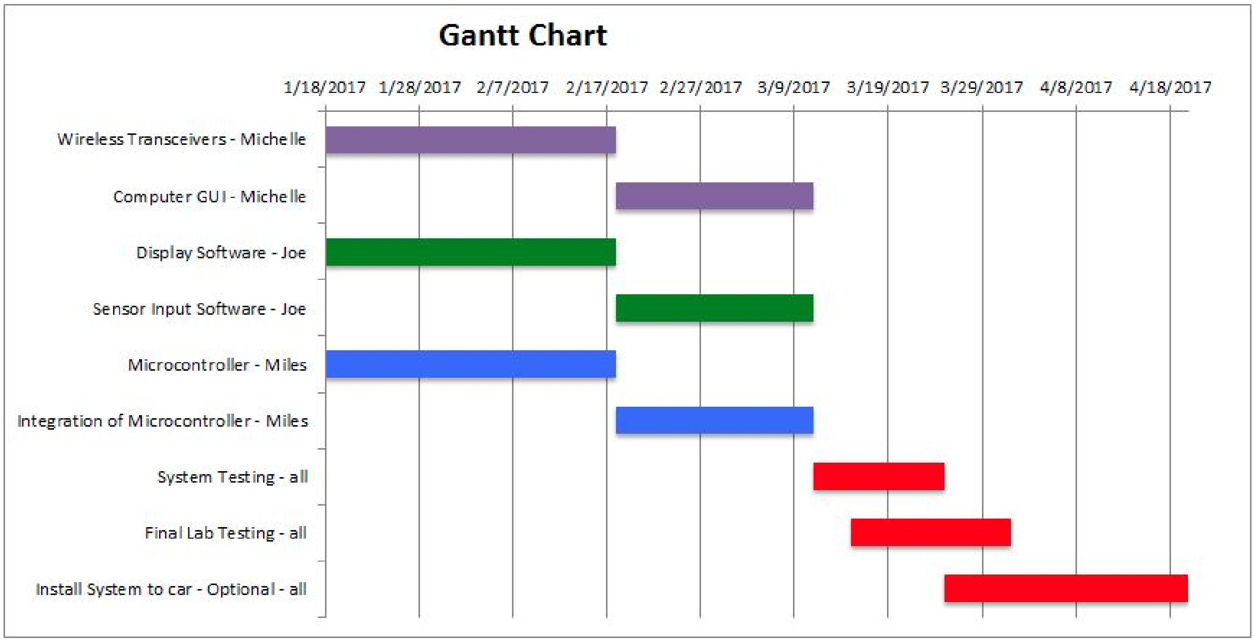

Figure 5: Gantt Chart

9. Discussion and Future Directions

Ideally, at the end of the project's completion, the team would like to implement this system on the mechanical engineering department's SAE formula car. This would require both teams to complete their respective projects. However, historically, this has not happened.

In terms of overall systems, the number of sensors could be increased significantly to include g-force sensors, seat-belt sensors, etc. The ideas are almost endless based on available sensors implemented on other automotive applications.

For the future, it is possible to envision adding a communication link with the engine and even adjusting engine parameters from the display as is common practice in many vehicles. For example, if the driver wished to change the idling RPM of the engine from the driver's seat, the driver could navigate through the touch screen display to an appropriate screen where a value could be entered and the engine would respond accordingly. This would require the engine to also communicate over CAN which is entirely possible. However, this would require a great deal of coordination between the mechanical engineering department and the electrical engineering department. Also, if that communication between systems was set up, the diagnostics for the engine could also be sent to the display. As an example, if a cylinder was not firing properly a message could be displayed informing the driver and crew.

10. References

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