UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

Data Acquisition System for formula SAE race car

ECE445 - Project Proposal

Mohan Sha

Shaik Mohammad Farooq

Raviraj Mahajan

TA: Ryan May

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1. Introduction

Title: Data Acquisition System for Formula SAE race car

1.1 Statement of Purpose:

The current UIUC Formula Electric racecar has no reliable data display at all. All they have is a row of LEDs connected to a potentiometer on the gas pedal. The potentiometer's readings is the number of lit LEDs, from this the driver gets an estimation of the amount current flow to the motor. From this current, the driver then guesses what the speed is. Our task is to build them a data acquisition system, collecting and displaying real time data either on the dashboard or on the steering wheel. The final design of could be useful and marketable for any university level formula team. It will however not satisfy the needs of a Formula F1 racing car as we are making a much relatively cheap design to satisfy the basic needs. Real time inputs such as temperature of the motor and coolant, pressure in the tires will inform the driver and the team of any ongoing discrepancies in the reading and hence help the driver in driving safely.

One really cool feature of the project is that after we install the DAQ system on the race car we will get to assist the Formula SAE team during the real race which is going to be held in July, 2013.

1.2 Objectives

1.2.1 Goals

- Provide the driver and his/her team with real time input about the condition of the car. It will help the team to look for faults and take action immediately.
- Faster and accurate display of the data compared to current techniques. (We need to check out the current techniques and figure we are capable of making a better DAQ.

1.2.2 Functions

- Acquire data from various sensors – temperature sensors, pressure sensors, speed sensors, voltage sensors and current sensors.
- Acquire and display the data for the temperatures of the coolant, the batteries and the motor. Similarly, acquire and display speed of the motor and wheels and pressure of all the tires.
- Ensure that response time of the sensors is optimum and the data acquired from the sensors is displayed instantaneously.

- Data should be wirelessly transmitted to a computer located at the pit where the rest of the team monitors the race.
- Ensure that the data is wirelessly properly transmitted over high speeds and over required distance from the pit.

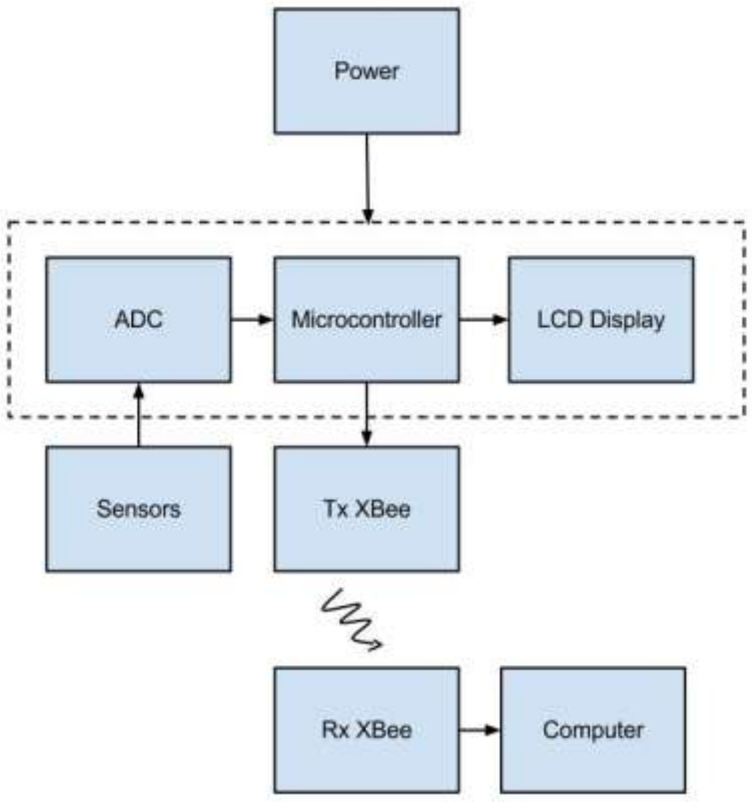
1.2.3 Benefits

- Service time efficiency due to on-site data analysis and fast feedback.
- Service cost efficiency due to time efficient method and higher calibration quality.
- Single display with all the required data enables faster testing of the car before the race rather than manually checking each component with the help of various hardware tools.
- Wireless data transmission allows formula SAE team to take immediate action upon finding a fault while the race is on.

1.2.4 Features

- Wireless data transmission for over a track of 0.5 mile.
- LCD or alpha-numerical display of multiple data.
- Simultaneous multiple data sensing.

Block Diagram



Block Descriptions

We are using a micro controller for analog to digital conversion of the signal and for wireless transmission. The sensor values will be sent to the LCD display from the microcontroller and also to the Xbee module. The Xbee module will transmit the data from the microcontroller to the computer.

1. Temperature sensor.

There are several temperature monitoring points on the car, the motor, coolant. The battery system temperature may require temperature sensors, or we can use the BMS.

2. BMS or voltmeter and ammeter.

This is readily available from the team. This can provide the temperature sensor reading from the sensors mounted in the battery pack. If we do so, we will need to buy fewer temperature sensors. The BMS can also tell us the voltage and current from the battery pack, as well as the capacity of the battery remaining. Otherwise, we will need to install a voltmeter and ammeter and then use their previous battery capacity meter.

3. Motor speed sensor.

The motor speed in an electric car is very important, coped with the motor temperature sensor, and the motor shutdown circuit. This data will be our only accurate knowledge of what the motor us doing, because electric motor only has one moving part and is silent when the car is not moving. And by listening to it, the driver can tell very little.

4. Vehicle speed sensor.

As mentioned before, the driver has to guess how fast the car is going. And in the world of motor racing, that's nowhere near good enough. We need the sensor to be very reliable, sturdy and accurate. And there is no way of calculating the car speed from the motor speed. That's why we definitely need another type of sensor.

5. Tire pressure sensor (TPMS).

Until now, the only way to measure the tire pressures to plug a met into the air inlet port. While the car is driving, the driver will know that there's something wrong with the tires only when the car drivers itself unevenly, or when the tire blows up. Too late! We need the driver to know immediately when there's even a single psi difference.

6. Display.

Since the car is open top, we can only use LCD displays that have a very strong backlight, the other option is to go with the old fashioned hexa-decimal display. Then there's the position of the display. There is limited space on the steering wheel, and it moves. So we have thought of putting the display on the dashboard as well as the steering wheel.

7. TX XBEE

This block is implemented using a XBEE wireless module. It is responsible for transmitting the serial data generated by the processor block from the TX Unit. The XBEE wireless module employs the Zigbee protocol to communicate to the receiver module.

8. RX – Unit

This block is implemented using XBEE wireless module. It is responsible for receiving the serial data from the TX block.

Design Requirements

Choke

As the first stage of our system, which is in direct interaction with DUT, the choke has to be used at the sensors' terminals to make perfect isolation between DUT and the calibration system. Chokes should not drain more than allowable current. The chokes have to have a flat response over frequency span of 10Hz to 500Hz with 1:1 transfer ratio, and minimum coupling loss. The chokes have to have small impedance over the operating frequency, and the fuses should be capable of handling 0.25A. Chokes are for the mere reason of preventing high voltage spikes entering the calibration system.

Gain Controlled Amplifier

To scale up or down the sensors' signal to an acceptable level seen by the microprocessor's ADC. This range is 0 to 5VDC. The amplifier should have a low noise level, low power consumptions and controllable gain of 0.5 to 5. The LP filter should have a flat response over frequency span of 10Hz-100Hz with 3dB at 200Hz and 20dB at 1 KHz. The inputs are directly connected to the choke, and the outputs are driving the microprocessor's ADC.

TX Microprocessor

Should be able to handle process and transmit the collected data into a serial connection, fast enough for a car at 150MPH. The microprocessor is clocked at 20MHz. So the calculation should be performed to take enough number of samples for a car going at minimum and maximum speed. The sampling at 8 KHz should be downed sampled according to these calculations and optimized for minimal data traffic on the serial data bus going to XBEE TX at 9600 rate.

XBEE TX Side

Make proper connection with the microprocessor through the serial channel.

XBEE RX Side

The receiver should be placed within the covering range of TX side, and make proper serial connection with the main data analyzing microprocessor.

TX Power Supply

It should provide a regulated 5VDC at minimum current drive of 100mA. This power supply is being used to drive all the blocks within the TX unit. The power supply regulator is fed from a 9V battery.

RX Power Supply

It should provide a regulated 5VDC at minimum current drive of 40mA.

Design Verification

Choke

The Chokes' input will be connected to a function generator sweeping from 10Hz to 500Hz and the output response will be traced analyzed on the scope. This process can be done on a network analyzer. The average input impedance will be calculated using a network analyzer. A passive network will be added to the input to scale the impedance to a proper level, so the drain current is less than 5mA.

Gain Controlled Amplifier

Sweep the input from 10Hz to 1KHz to ensure proper pass and stop band regions with proper attenuation at the stop band. Check the noise level. If the filter does not meet the specifications, use a higher order filter.

TX Microprocessor

Should be able to handle process and transmit the collected data into a serial connection, fast enough for a car at 150 MPH. The microprocessor is clocked at 20MHz. So the calculation should be performed to take enough number of samples for a car going at minimum and maximum speed. The sampling at 8 KHz should be downed sampled according to these calculations, and optimized for minimal data traffic on the serial data bus going to XBEE TX at 9600 rate.

XBEE TX Side

In case the XBEE does not make a proper connection with the microprocessors, test the functionality of XBEEs. Connect RS232 to XBEE units on two separate computers and use terminal to send and receive data. If passed, then program the microprocessor to only transmit specific data to XBEE. Proceed to the RX XBEE, and program the microprocessor to respond to the specific transmitted data by activating a LED. Repeat this for number of specific words.

XBEE RX Side

In case the XBEE does not make a proper connection with the microprocessors, test the functionality of XBEEs. Connect RS232 to XBEE units on two separate computers and use terminal to send and receive data. Put the XBEE units next to each other to avoid and test again to ensure proper link between the units. Repeat the steps described in the previous part.

TX Power Supply

Load both by proper resistive loads and monitor the voltage and current. Then load by the actual circuit and monitor the voltage and current. Observe the difference. In case of any reduction in voltage for the second case, change the power regulators to handle more power. If the problem yet exists, try to disconnect one block at the time to find the problem making block. Find all block with the same problem, and assign a new power regulator for those blocks. The working block will produces lots of noise on the power line, measure the noise level and use decoupling caps to attenuate the noise.

RX Power Supply

Load both 5V and 3.3V by proper resistive loads and monitor the voltage and current.
Then load both 5V and 3.3 V by the actual circuit and monitor the voltage and current. Then follow the steps from the previous part. If any, it is most likely that the 3.3V regulator will behave non-idealistically. Change the chip to handle more power.

Tolerance Analysis

Choke

We are implementing a capacitor for a choke. Signal variations are present because the frequency response is not perfectly flat at low frequencies. These signal variations will translate to the amplifier stage. For this reason, the maximum tolerance accepted is ±5% on a narrow band of operating frequency, to prevent partial saturation and loss of the signal.

Cost Analysis

Labor

Name	Hourly Rate ($ / hour)	Hours invested over entire period of project	Total Cost = Hourly Rate x 2.5 x Hours Invested
Mohan Sha	50	150	$18,750
Farooq Shaik	50	150	$18,750
Raviraj Mahajan	50	150	$18,750
Total		450	$56,250

Parts

Item	Serial Number	Quantity	Cost per unit ($)	Total Cost ($)
J Type Thermocouple	BT-000-J-2 1/4-60-1	2	28	56
Pressure Sensor	PX309-150GV	1	175	175
TI MSP 430	MSP-EXP430G2	1	4.30	4.30
A/D Converter	NXP PCF8591P	6	4	24
XBee Pro 60mW Wire Antenna - Series 1	WRL-08742	1	37.95	37.95

Total				297.25

Some parts may already have been bought by the SAE Racing Team

Grand Total

Section	**Total**
Labor	$56,250
Parts	$297.25
Total	**$56,547.25**

Schedule

Week	**Task**	**Responsibility**
2/4	Complete and submit proposal	Farooq, Mohan, Raviraj
	Design preliminary circuit to connect all components	
	Meet with SAE: Race Team member to discuss technical specifications and expectations	
2/11	Prepare draft for Mock Design Review	Farooq, Mohan, Raviraj
	Design final circuit	Farooq, Mohan, Raviraj
	Order Xbee transceivers, TI MSP 430 and LCD/Alphanumeric display	Raviraj
2/18	Write pseudo code for the MSP 430 program	Raviraj
	Design overall circuit connecting all the components	Farooq, Mohan
	Test and calibrate sensors	Farooq, Mohan
2/25	Program and test A/D converted and LCD	Mohan
	Program and debug MSP 430	Raviraj
	Program and test Xbee	Mohan, Farooq

¾	Assemble all components together for testing	Farooq, Mohan, Raviraj
	Design PCB layout for MSP 340 and sensor inputs	Raviraj, Farooq
	Submit PCB for fabrication	Raviraj
3/11	Solder components onto PCB and Submit Individual Progress Reports	Farooq, Mohan, Raviraj
	Test PCB and put together the rest of the system	Raviraj
3/18	Spring Break!	
3/25	Test functionality of entire system	
	Present Mock Demo	Mohan
4/1	Test system under stressful conditions similar to race track	Farooq, Mohan, Raviraj
	Present Mock Presentation	Raviraj
4/8	Verification of specifications	Farooq
4/15	Corrections to working of the project	Farooq, Mohan, Raviraj
	Help attach the system onto the race car	Farooq, Mohan, Raviraj
4/22	Demo	Mohan
	Presentation	Raviraj
4/29	Final Paper due	Farooq
	Check in supplies	Raviraj