

DAQ System for Smart and Connected Devices

by Sara Vonk

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DAQ SYSTEM

By Sara Vonk



Contents

Contents.....	1
Table of Figures	1
What is Data Acquisition (DAQ)?.....	2
Types of DAQ systems on the market	2
VBOX	2
ShockClock manufactured by Race Tech	3
Testing Theory	3
RPM	3
Engine Temperature.....	4
Suspension Travel.....	4
Pitch, Roll and Yaw	4
Speed Sensor	5
Temperature Sensors	6
Displacement & Laser Ride Height Sensors.....	7
Gyroscope.....	9
Microchip Specification	9
Overview of chip specifications	11
Micro controllers.....	11
Circuit Design.....	12

Table of Figures

Figure 1.....	2
Figure 2.....	2
Figure 3.....	3
Figure 4.....	5
Figure 5.....	13
Figure 6.....	13
Figure 7.....	14
Figure 8.....	14
Figure 9.....	14
Figure 10.....	15
Figure 11.....	15
Figure 12.....	15

What is Data Acquisition (DAQ)?

Data acquisition is the process of measuring and logging intangible things such as voltage, temperature, distances, sounds and speeds. A DAQ system consists of sensors, which read the data and a main core which processes the data acquired into a form that is easier for people to digest. [1]

Types of DAQ systems on the market

VBOX

VBOX is one of the most popular car DAQ companies. They produce multiple DAQ systems for measuring car capabilities. Their most popular VBOX is The Race Logic. This DAQ system specialises in measuring the speed of the car and the slip angle. This VBOX is a multi-purpose non-contact speed sensor. It uses a dual antenna GPS engine, it can calculate speed, direction of travel and accurate slip angle. The VBOX also has a built in display which allows the user to set up the device without a laptop. It can be used with any VBOX GPS data logger, as well as most third-party data loggers. This VBOX logs slip angle, yaw rate, pitch or roll angle, true heading, lateral velocity, satellites in view, UTC time, latitude, longitude, velocity, heading, altitude, vertical velocity, distance, longitudinal acceleration, lateral acceleration, distance from trigger, trigger time, trigger velocity. [2]

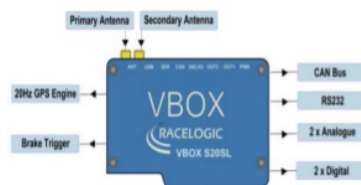


Figure 1



Figure 2

ShockClock manufactured by Race Tech

The ShockClock is a suspension data acquisition system that uses transducers to detect how long or short a carbon fibre tube is by recording the wavelengths of sound after passing through it. The carbon fibre tube is in two parts consisting of a smaller tube and a larger tube. The smaller tube sits inside the larger tube. If this was used on a bicycle one end would be attached to the centre of the wheel and the other end attached to the main frame. As the bicycle goes over bumps the ShockClock will measure the movement of the wheel relative to the bicycle frame. There for this device measures the suspension. [3][4][5]

Transducer

Ultrasonic Acoustic Wave-Guide Transducer (UAWG)[6]

Sampling rate of 240 samples per second. [6]

The standard transducer measures 380 mm (15") of travel. [7]



Figure 3

Testing Theory

RPM

RPM stands for revolutions per minute, it refers to how fast a machine is operating. In vehicles, rpm measures how many rotations the engine's crankshaft makes every minute. [8]

In DAQ systems non-contact tachometers are used in order to log a vehicle's RPM. Non-contact tachometers use light sources (usually laser or infra-red) to count the crankshaft's rotations. The rotations would be measured via a piece of reflective tape and the laser that is aimed at the crankshaft. Once every rotation the light will be reflected back to the light source and this will be compared to the time between each reflective interval. [9] The speed of a vehicle can be measured in the same way using the tires rotations instead of the crankshafts.

Engine Temperature

Vehicles are very prone to overheating. The DAQ system that is being designed in this assignment will incorporate an engine temperature sensor. There are multiple ways of measuring temperature such as IR laser, thermocouple, RTD's (resistance temperature detectors) and semiconductor integrated circuits. Using one or more of these components the engine temperature can be determined. In general, anything about 115 degrees is classified as overheating. [11]

Suspension Travel

Travel is simply the distance that the suspension of the vehicle can compress when absorbing force. The further the travel the more comfortably the suspension can absorb force. [12] This can be measured using either a device like the shock clock or a laser that measures the distance from above the tire to the road.

Pitch, Roll and Yaw

Pitch, Roll and Yaw are terms used to describe the movement of a vehicle. In terms of a car Pitch is when the headlights or rear lights move up or down. Yaw is when the headlights move left or right and Roll is when the headlights move in a clockwise or anticlockwise motion. [13] These three variables can be logged using suspension movement and a gyroscope or just a gyroscope on its own.

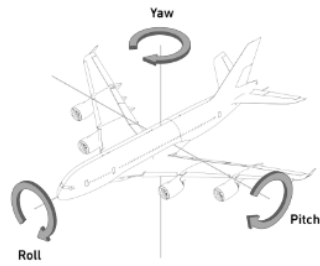


Figure 4

[14]

Speed Sensor

Below is a table comparing five different speed sensors that could possibly be used as the RPM and MPH sensors for the DAQ system. After careful analysis of the different instruments the first one was chosen. The slim body of the instrument and the flexibility will

make mounting the instrument to a vehicle simple. The technical aspects of the sensors were similar, the sensor chosen meets all the criteria. The chosen sensor has been highlighted.

	[15] 	[16] 	[17] 	[18] 	[19] 
Sensing range	0.08" to 0.11"	0.08" to 0.12"	0.08" to 0.11"	0.08" to 0.11"	Aluminum: 0.004" to 0.028" Titanium: 0.004" to 0.06"
Output	NPN or PNP	NPN. Internal Pullup Resistor Value 10K Ω	NPN. Internal Pullup Resistor Value 10K Ω	NPN. Internal Pullup Resistor Value 10K Ω	
Power supply	10-24Vdc (10mA)	5-24Vdc (10mA)	5-24Vdc (10mA)	5V-24Vdc (10mA)	9-30Vdc (Less Than 30mA)
Electronic connection	40" 24AWG 55spec Cable + DR25 Sleeve	22/24/26AWG 55spec Cable + DR25 Sleeve	22/ 24/26AWG 55spec Cable + DR25 Sleeve	20" 22AWG 55spec Cable + DR25 Sleeve	Sensor: Deutsch ASL606- 05SC-HE Supply/Signal: 20" 26AWG Cable + DR25 Sleeve
Operating temperature range	-40°F to 155°F (-40°C to +70°C)	-40°F to +300°F (-40°C to +150°C)	-40°F to +300°F (-40°C to +150°C)	-40°F to 300°F (-40°C to +150°C)	Sensor: -60°F to +575°F(- 50°C to +300°C) Sensor Cable: -20°F to 400°F(-30°C to +200°C) Controller: - 20°F to 180°F(-30°C to +70°C)

Temperature Sensors

Below are five different temperature sensors. They are all similar but all designed for different uses. The Temperature sensor in the DAQ system will be measuring the temperature of the water. This is an important fact as the sensor needs to be able to cope with being in contact

with liquids. The fourth one was chosen as it is designed to deal with all liquids. The chosen sensor is highlighted below.

	[20] 	[21] 	[22] 	[23] 	[24] 
Type	negative temperature coefficient	negative temperature coefficient	negative temperature coefficient	negative temperature coefficient	Thermocouple
Designed to measure	Air and gas	Air and gas	Fluid	Liquids	Surface temp, Gas, coolant, oil, thermal profiles
Range	-20°F to +300°F (-30°C to +150°C)	-20°F to +300°F (-30°C to +150°C)	-20°F to +300°F (-30°C to +150°C)	-20°F to +300°F (-30°C to +150°C)	-150°F to 2000°F (-100°C to +1100°C)
Output type	Analog	Analog	Analog	Analog	Analog

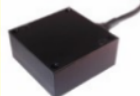
Displacement & Laser Ride Height Sensors

Below is a table that features five suspension sensors. Two of which are ride high suspension sensors that work of a similar principle that the shockclock did. The second sensor works by measuring the resistance of a wire. A wire is curled up like a yoyo inside the device and the end is attached to the volitie part of the suspension. As the suspension contracts the expands the resistance of the wire changes in a corresponding way. The other suspension devices work using lasers to measure the distance from the vehicle to the road. Below the chosen device is highlighted. A laser sensors was chosen as it is the least intrusive method of testing and therefore with have the least side effects on the results.

	[25] 	[26] 	[27] 	[28] 	[29] 
Application	Ride height, suspension set up, chassis Distortion	Pedal movement, suspension travel, steering angle, aero deflection	Suspension travel, ride height, spoiler deflection, steering column displacement	Suspension travel, ride height, spoiler deflection, steering column displacement	Throttle position, steering, pedal angle, pedal position, gear position, aero surfaces, actuators
Supply Voltage	11-30Vdc (50mA)	Maximum of 32Vdc at 1kΩ / 1W Max	40 Vdc	40 Vdc	5Vdc or 6-30Vdc (Max 32mA) Reverse Polarity Protected
Resolution	0.0008"	0.004" to 0.016"	N/A	N/A	12Bit
Connection	Half Flange Connector (N Keyway) ASX Cable: 26AWG, 55spec Wire + DR25 Sleeve	55spec, 26 AWG Cable + DR25 Sleeve C Solder Tab	719 male	719 male	20 inches, 55spec, 26 AWG Cable + FDR25 Sleeve

Gyroscope

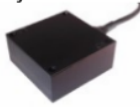
The gyroscope is necessary for measuring the Pitch, Roll and Yaw of a vehicle. Below are five different gyroscopes that were compared against each other in order to find the best one for the job. Most of these gyroscopes were overkill for the purpose of what they were going to be used for. The chosen gyroscope has been highlighted below. The gyroscope chosen has the lowest rate range and accuracy however this device was still suitable for the DAQ system that was going to be designed. The gyroscope is powered of under 5V. As the DAQ system is going to be isolated from the car it needs its own power supply. There for having unnecessarily power heavy instruments will only drain the battery faster.

	[31] 	[32] 	[33] 	[34] 	[35] 
Rate Range °/sec	±500 to ±24,000	±100 to ±18,000	±500 to ±24,000	±500 to ±50,000	±80 and ±200
Output (Vdc)	5 to 16 (common mode 2.5V)	5 to 16 (common mode 2.5V)	5 to 16 (common mode 2.5V)	5 to 16 (common mode 2.5V)	0.5V to 4.5V (Offset 2.5V)
Accuracy	±0.5% Non- Linearity (FSO)	±0.5% Non- Linearity (FSO)	±0.5% Non- Linearity (FSO)	±0.5% Non- Linearity (FSO)	±1.0% FS Linearity
Operational temperature range (°C)	-40 to +105	-40 to +105	-40 to +105	-40 to +105	-40 to +85
Connector	12x #30AWG Cond PFA Insulated, Braided Shield, PU Jacket	2x Cables; 12x #30AWG Cond PFA Insulated, Braided Shield, PU Jacket	2x Cables; 12x #30AWG Cond PFA Insulated, Braided Shield, PU Jacket	5x, #30 AWG Conductors, PFA Insulated, Braided Shield, PU Jacket	20 inches, 55spec, 26AWG Cable+DR25 Sleeve

[30]

Microchip Specification

Below is a table that lists all the components and peripherals that will make up the DAQ system. This table acknowledges what the pic needs to be able to support.

	Pins	Type A/D	Resolution	Clock speed
Speed 	1	Digital	8 bit counter	0.5 seconds
RPM 	1	Digital	8 bit counter	0.5 seconds
Temp 	1	Analog	10bit	10 seconds
Suspension 	4	Analog	10bit	0.0001 seconds
Gyro 	1	Analog	10bit	0.1 seconds
SD 	4	Digital	N/A	N/A
USB 	2	Digital	N/A	N/A
on/off 	1	Digital	N/A	Interrupt

Overview of chip specifications

Total pins 15 digital 9, analog 6 at 10 bit resolution, USB 2, voltage 5V, program memory 16K, RAM 0.5KB, clock speed 16MHz

Micro controllers

Below is a table of five microcontrollers that all met the specifications needed. The pic that is highlighted is the one that has been chosen to be the main pic in the circuit. This is the only pick with EEPROM. This is a positive feature to have on the chip as if there is ever a software update the clients can just update their current device instead of buying a new one.

	PIC18F2550 [36] 	PIC18F25J50 [37] 	PIC18F26J50 [38] 	PIC18F26J53 [39] 	PIC18F27J53 [40] 
Price \$	3.44	2	2.28	2.42	2.66
CPU Type	8-bit PIC MCU	8-bit PIC MCU	8-bit PIC MCU	8-bitPIC MCU	8-bit PIC MCU
Program Memory Size (KB)	32	32	64	64	128
Program Memory Size (Kwords)	16	16	32	32	64
SRAM	2048	3800	3800	3800	3800
Emulated EEPROM in FLash	256/HEF	0/HEF	0/HEF	0/HEF	0/HEF
Pin count	28	28	28	28	28
Internal Oscillator	8MHz, 32KHz	8MHz, 32KHz	8MHz, 32KHz	8MHz, 32KHz	8MHz, 32KHz
Max ADC Resolution (Bits)	10	10	10	12	12
Max ADC Sampling Rate (ksps)	100	100	100	100	100

UART	1	2	2	2	2
USB Modules	1	1	1	1	1
Temp Range	-40 to +85	-40 to +85	-40 to +85	-40 to +85	-40 to +85

[41]

Circuit Design

Below is a screen shot of the DAQ proteus schematic. Each section will be explained as to what it is and how it works.

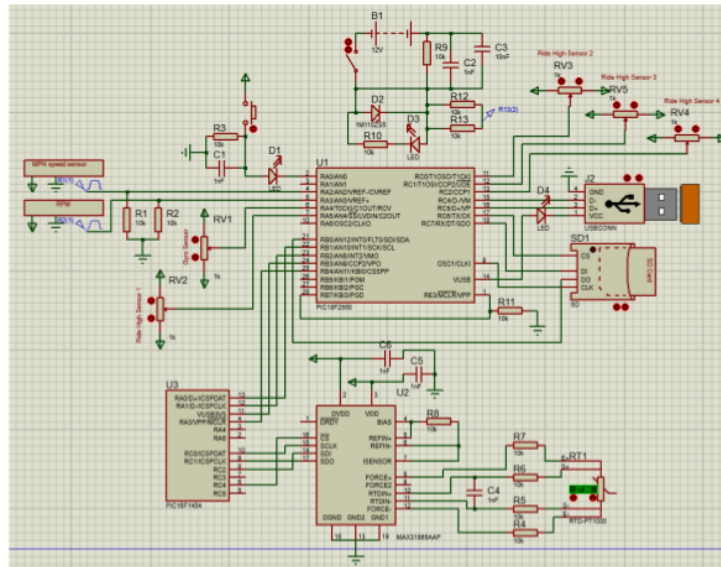


Figure 5

Below is a screen shot of the DAQ's power supply. It has a switch as the on/off button. There is an LED that will light up when the current is flowing. There is a Zener diode that clamps the voltage to 10V. There is a potential divider that halves the voltage from 10V to 5V for the PIC and the instruments that require a 5V supply. The devices that require more voltage can connect to the supply before the potential divider. There are two capacitors in the circuit. These are to absorb spikes when the switch is turned on/off. The small capacitor absorbs small spikes and the larger capacitor absorbs larger spikes.

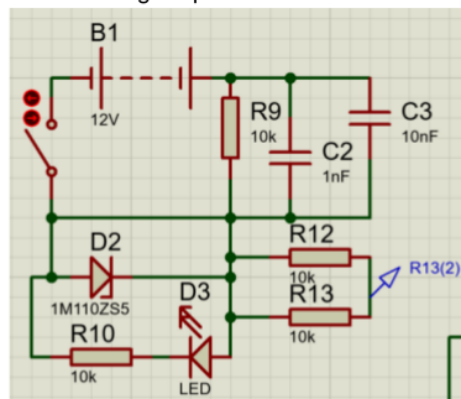


Figure 6

In the screenshot below is the circuit diagram of the temperature sensor. The temperature sensor used is a thermocouple type Platinum Resistance Thermometer. The Max31865AAP chip is designed for these types of thermocouples and converts the resistance of the wire

into a voltage that a pic can read. The Master pic (PIC18F2550) did not have enough ports to connect the MAX chip so a simple PIC16F1454 was implemented into the circuit to process the information from the MAX chip. This is then sent to the master chip through ports RA0,1,2 and 3. [42] [43] [44]

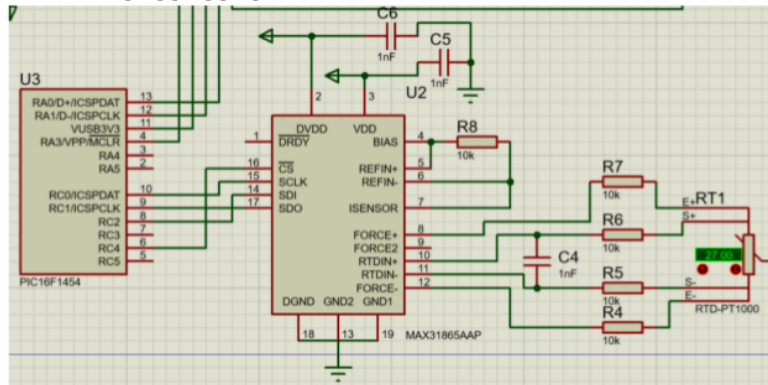


Figure 7

Below is the circuit diagram of the start button. Where as the switch in the power supply cut off the current this button just lets the circuit know when to start reading the data. This save the device from storing irrelevant data. The capacitor smooths out switch bounce and the LED lets the user know that there is current flowing through the button. The resistor pulls the voltage to 0V when the button isn't pressed.

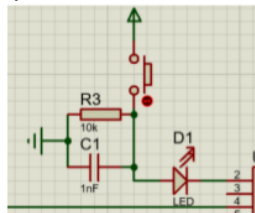


Figure 8

In the screenshot below it shows the RPM and the speed sensor. This is just a digital signal so it can go straight to the pic. There are pull down resistors on both to make sure there are no floating wires.

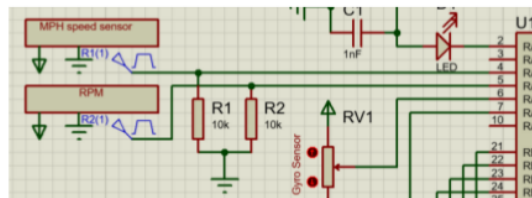


Figure 9

The configuration below is for the EEPROM, if the chip needed a software update pin RB7 would go high when a software update is ignolaged and would there for clear the chip vier the RE3 pin.

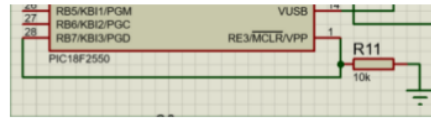


Figure 10

The variable resistors represent the suspension travel sensors. They give out a voltage relative to the distance measured. The pic's analog port can read these and calculate the distance.

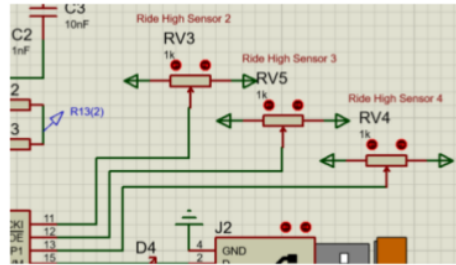


Figure 11

The data collected is stored onto the SD card. The data can also be acquired using the USB port. When the USB is transferring information the LED with light up/ flash.

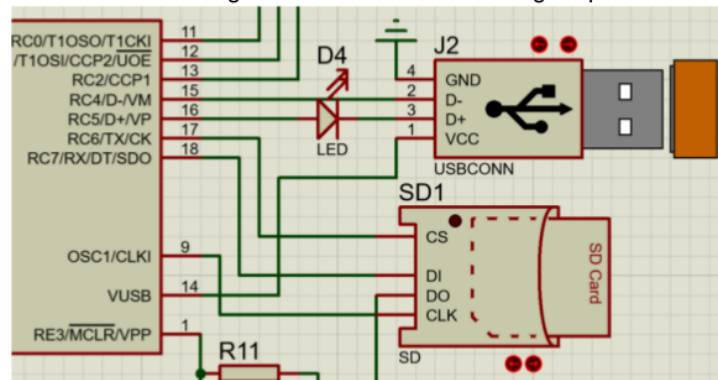


Figure 12

This Proteus schematic was developed on Easy-PC into a PCB board. Below there are multiple screen shot of the developed board. The board does not have a copper pour on to it as the Ground and the Voltage ports were scattered. These ports were connected by copper tracks instead of copper pour. The Easy-PC software did not have the necessary chips so place markers are there where the chips can be soldered to the board.

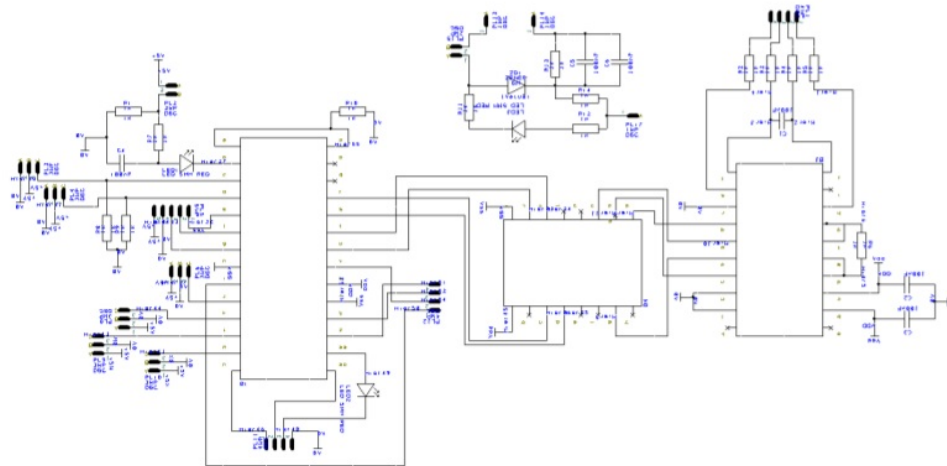


Figure 13 Easy-PC Schematic

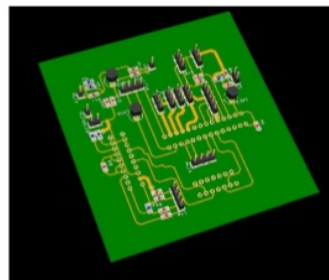


Figure 14 PCB Board

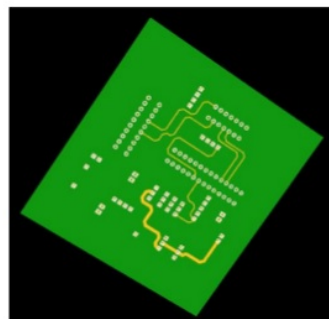
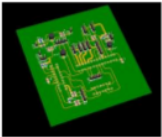


Figure 15 PCB Board Back

Determine

Below is a table of the physical aspect of the DAQ system. It shows the prices of everything and how the device would be sold.

Waterproof Electronic ABS Plastic [45]		£22.40	200 x 120 x 75mm
Battery [46]		£20.99	L: 16.1cm, W: 6.5cm, H: 9.4cm
Components (estimation)		Less than £10	
PCB bored		Difficult to estimate as costs per board very depending on the quantity that is being produced.	
Peripheral instruments		For the interments that the board is designed to be used with they would cost about £1000 to perches. The price would change depending on the quantity being ordered.	

Protective case		L 240mm, W185mm, D153mm	£69.72
Total			£1140

References

- [1] (What is Data Acquisition , n.d.)
- [2] (VBOX INDOOR POSITION SYSTEM , n.d.)
- [3] (Welcome to ShockClock , n.d.)
- [4] (Trek Data Acquisition and Suspension Testing, n.d.)
- [5] (ShockClock Installation Guide)
- [6] (Ultrasonic Transducer Principles , n.d.)
- [7] (Shockclock Overview, n.d.)
- [8] (What Does RPM Mean in Cars?, n.d.)
- [9] (About Tachometers/Stroboscopes , n.d.)
- [10] (Lets Learn about Car Engine Temperature and Things to Avoid, n.d.)
- [11] (Engine Overheating , n.d.)
- [12] (What Does TRAVEL Mean on a Mountain Bike:Is More Travel Better?, n.d.)
- [13] (Pitch, Yaw and Roll, n.d.)
- [14] (Pitch, Roll and Yaw (Picture), n.d.)
- [15](SP08 Wheel Speed Sensor)
- [16](SPI Sensor Speed Sensor)
- [17] (SPC Series Flanged Speed Sensor)
- [18] (SP Series Wheel Speed Sensor)
- [19] (KTSM and KS1T Series Turbo Speed Sensor)
- [20] (NTC Series NTC2 Air and Gas Temperature Sensor)
- [21] (NPT Series NPT2 Air and Gas Temperature Sensor)
- [22] (NTC Series NTC1 Fluid Temperature Sensor)
- [23] (NPT Series NPT1 Liquid Temperature Sensor)
- [24] (KTC Series Thermocouple)
- [25] (RHL4 Series Lightweight High Speed Laser Ride High Speed)
- [26] (KWP Series Wire Potentiometer)
- [27] (Aim Motorcycle Potentiometer Pop End Fitting, n.d.)
- [28] (Car/Bike Linear Potentiometer Diameter 13)
- [29] (KH Series KH41 and 42 Shaftless Rotary Position Sensor)
- [30] (Accelerometers/Gyro, n.d.)
- [31] (Model 603 Triaxial Rate Sensor, n.d.)
- [32] (Model 634 Six Degree of Freedom Sensor)
- [33] (MODEL 633 Six-Degree of Freedom Sensor)
- [34] (MODEL 610 ANGULAR RATE SENSOR)

- [35] (KG Series Angular Rate Sensor- Gyro)
- [36] (PIC18F2550, n.d.)
- [37] (PIC18F46J50 Data Sheet, n.d.)
- [38] (PIC18F47J53 FAMILY)
- [39] (PIC18F47J53 FAMILY)
- [40] (PIC18F2455/2550/4455/4550 Data sheet)
- [41] (New/Popular *-Bit Microcontroller Products, n.d.)
- [42] (PIC16(L)F1454/5/9)
- [43] (Process Automation: Another RTD Sensor Board, n.d.)
- [44] (MAX31865 RTD-to-Digital Converter)
- [45] (Therpin DIY Waterproof Electronic ABS Plastic Project Junction Box Enclosure x x, n.d.)
- [46] (uracell Original DR7-12 Valve Regulated Lead Battery - 12V | 7Ah - Replaces APC RBC17 | RNC2 | CSB GP1272F2 | Lucas LSLA7-12 | Panasonic LC-R127R2PG | Yuasa NP7-12 | V142401 | Y7-12, n.d.)

DAQ System for Smart and Connected Devices

GRADEMARK REPORT

FINAL GRADE

GENERAL COMMENTS

Instructor

45/100

PAGE 1

PAGE 2

PAGE 3

PAGE 4

PAGE 5

PAGE 6

PAGE 7

PAGE 8

PAGE 9

PAGE 10

PAGE 11

PAGE 12

PAGE 13

PAGE 14

PAGE 15

PAGE 16

PAGE 17



Comment 1

board

GRADING FORM: SMU GENERIC_GJ

**SARA
VONK**

44.80

RESEARCH-INFORMED LITERATURE



literature review is very limited and would be improved by adding more devices, a review of each device and followed up with a comparison table. 48%

4.8

KNOWLEDGE AND UNDERSTANDING



Good overall schematic design but a things to be kept in mind. When designing a complex board it is beneficial from a understanding point of view to limit the number of lines travelling around and instead use net names which you have done. Using a potential divider to provide the supply to a circuit is not wise. A simple 7805 would have done the job without any problems. The resistor in series with the led is 0K this will not allow the led to light as there is insufficient

12.5

current. All power connections on the circuit need to be given a supply voltage. Research of the available RS232 connections could have shown many USB to RS232 devices that would have negated the need for the MAX 31865. An led cannot be placed in the D+ line. Your PCB shows all connections in board and is incomplete without any ident. 50%

ANALYSIS



Good selection of microcontroller. Good selection of sensors with a very nicely laid out table showing the selection of sensors to be chosen from with an image or illustration of each. Good case selection. No selection of connectors. 60%

21

PRACTICAL APPLICATION AND DEP.



No costings or attempt at future enhancements. 0%

SKILLS FOR PROFESSIONAL PRAC.



The report is well presented with very well presented tabled data but could have been greatly enhanced with more devices. A good selection of references. 65%

6.5