AWQuSam Engineering

Autonomous Water Quality Sampler (AWQuSam)

Detailed Design Review and Test Plan

Florida State University Department of Oceanography

February 9, 2012

Agenda

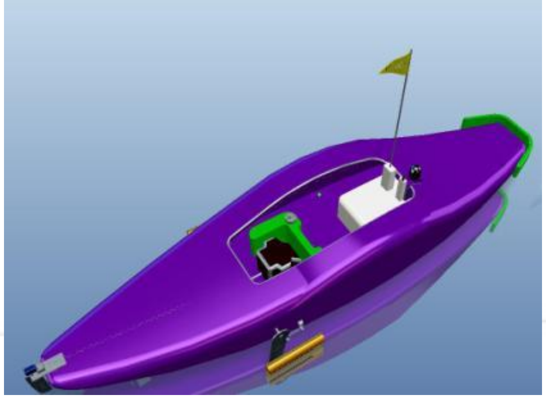
Thursday, Februrary 9, 2012

- Project Overview
- Data Acquisition
- Data Logging
- Data Handling
- Data Transmission
- Navigation
- Propulsion
- Steering
- Mechanical Housings
- Financial Update
- Project Schedule
- Testing Update

Project Overview

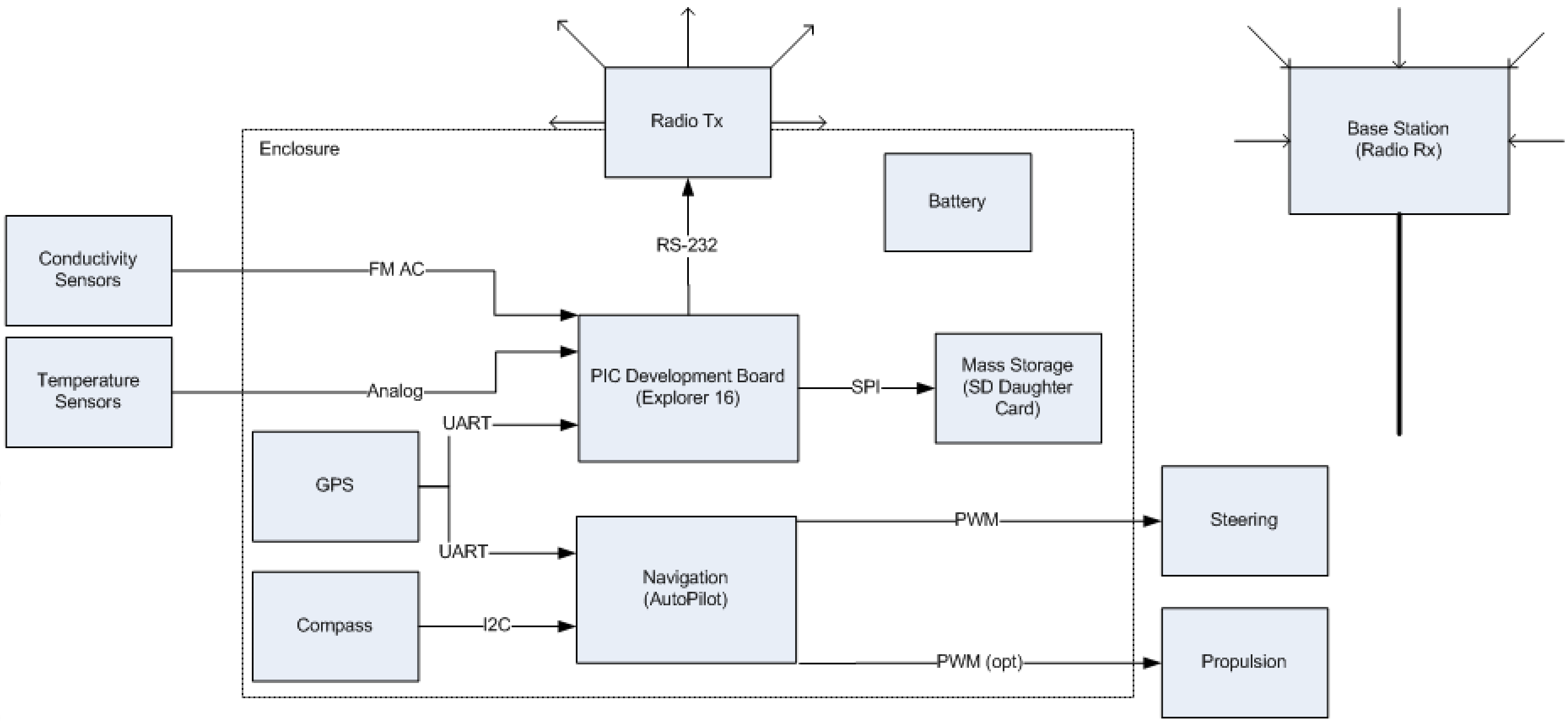
Brad Wells

Problem Description



- Gather Water Quality / Hydrographic Data
- Florida Shelf
  - Shallow Environment

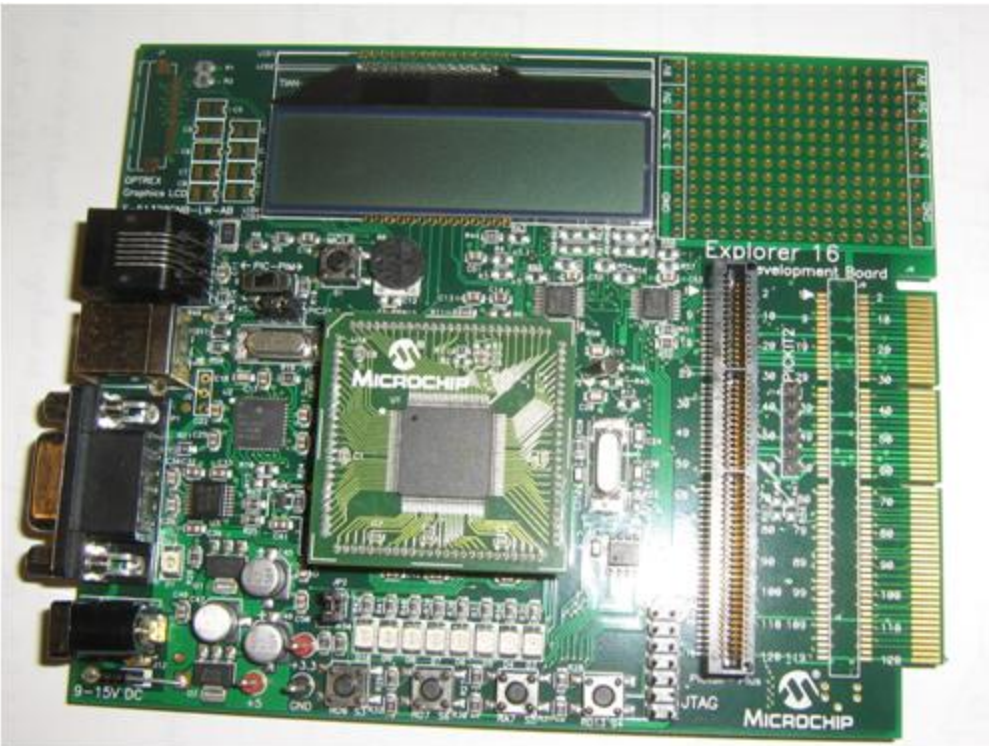
Design Solution



Data Acquisition

Brad Wells

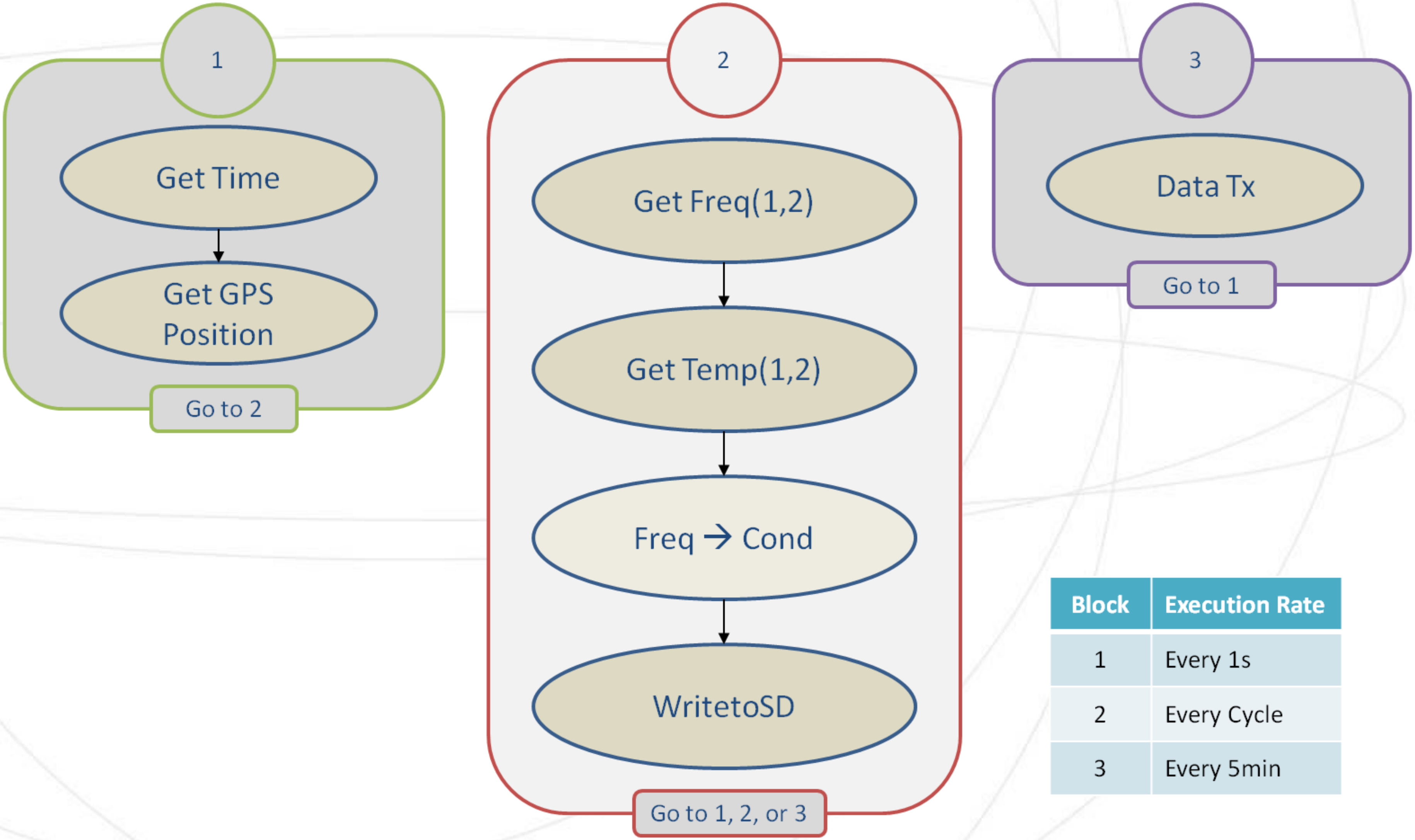
Explorer16 Development Board



dsPIC33FJ256GP710

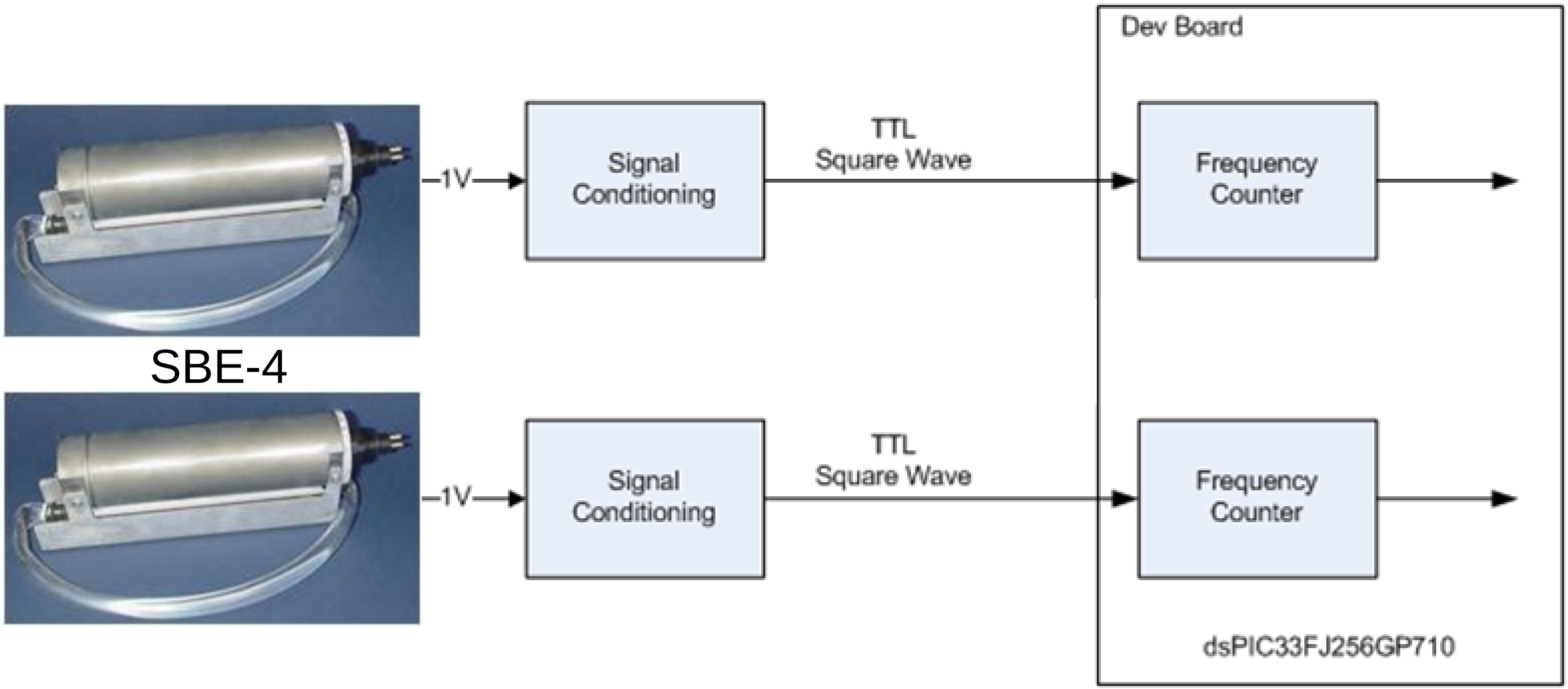
- 12 bit A/D Converter
- 2 UART
- 2 SPI
- 2 I2C
- Input Capture

Explorer16 Development Board



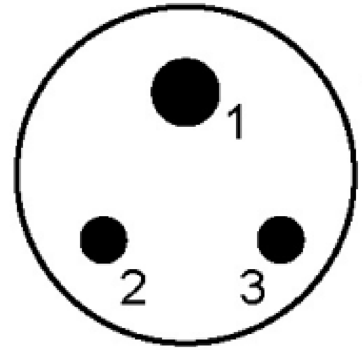
Block	Execution Rate
1	Every 1s
2	Every Cycle
3	Every 5min

Conductivity Sensors



Conductivity Sensors

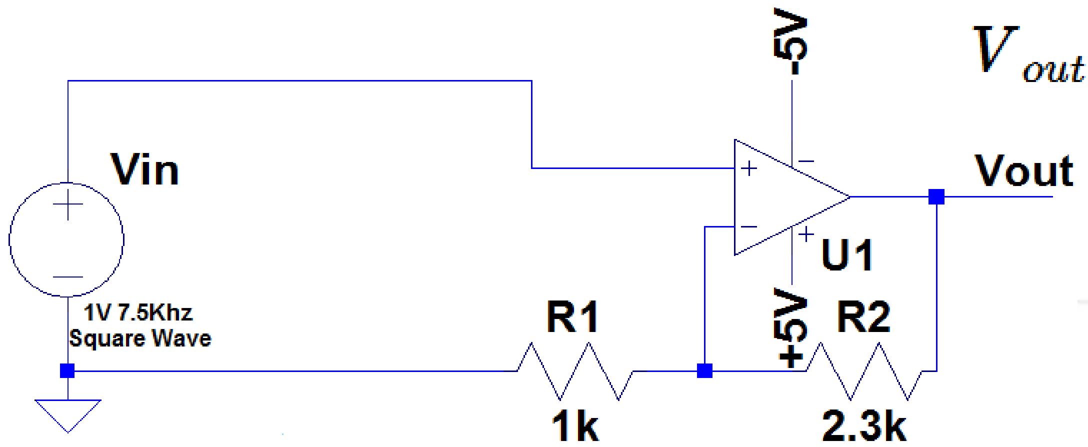
Connector:
XSG-3-BCL-HP



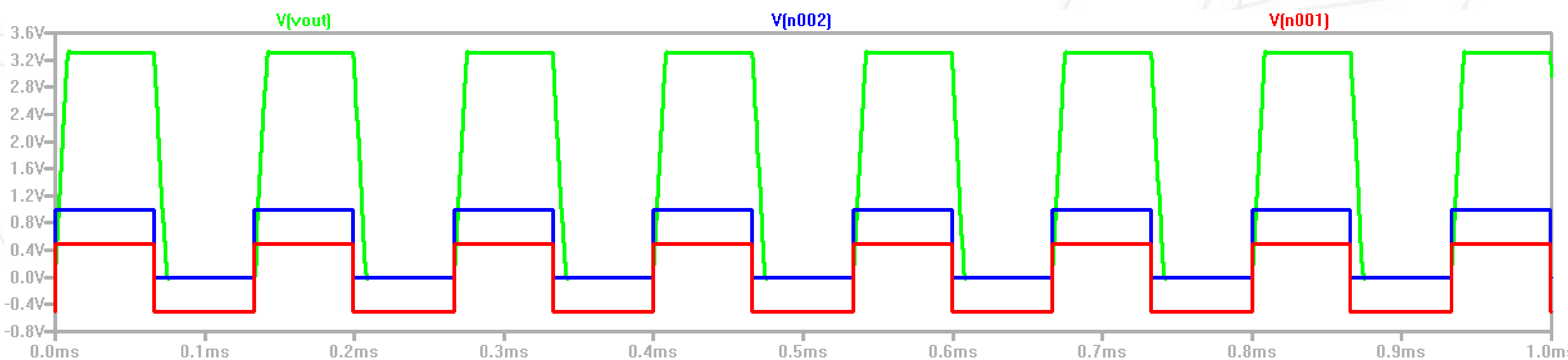
PIN	SIGNAL
1	Common
2	Signal
3	+ Input Voltage

$$\text{Conductivity} = \frac{(g + hf^2 + if^3 + jf^4)}{10(1 + \delta t + \varepsilon p)} \quad \text{Siemens/meter}$$

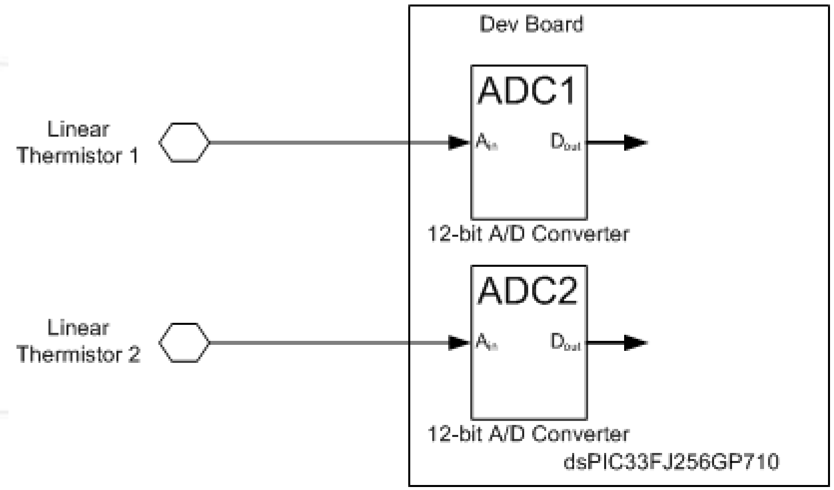
Conductivity Sensors

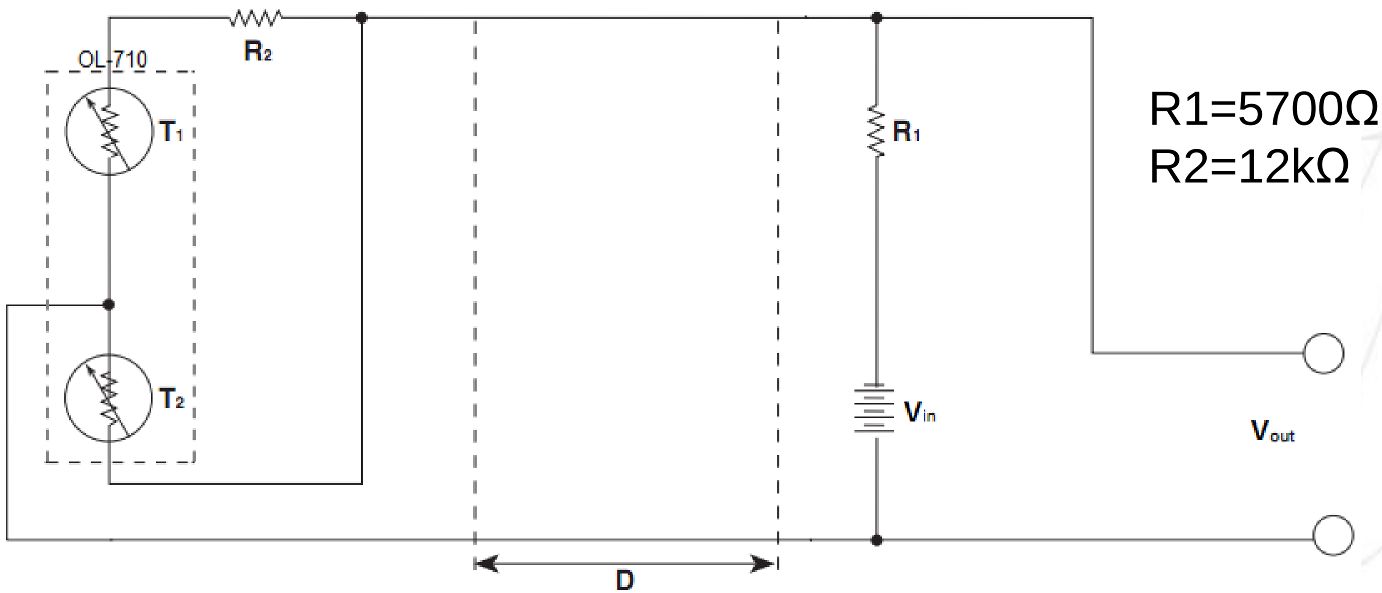


$$V_{out} = V_{in}(1 + \frac{R_2}{R_1})$$

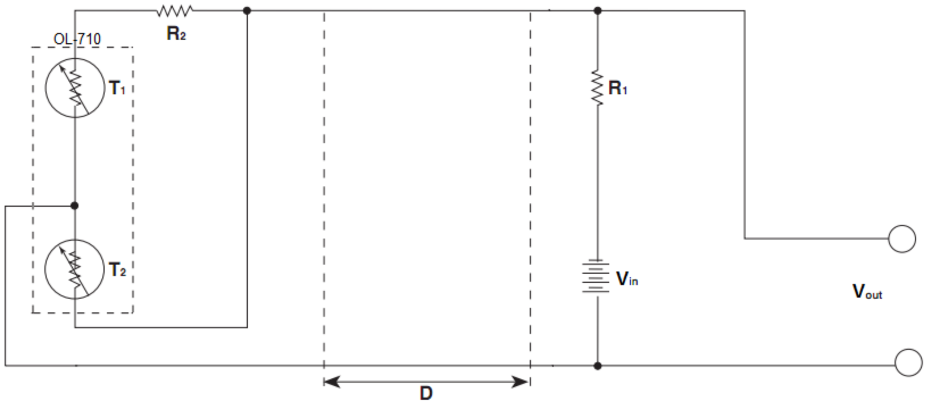


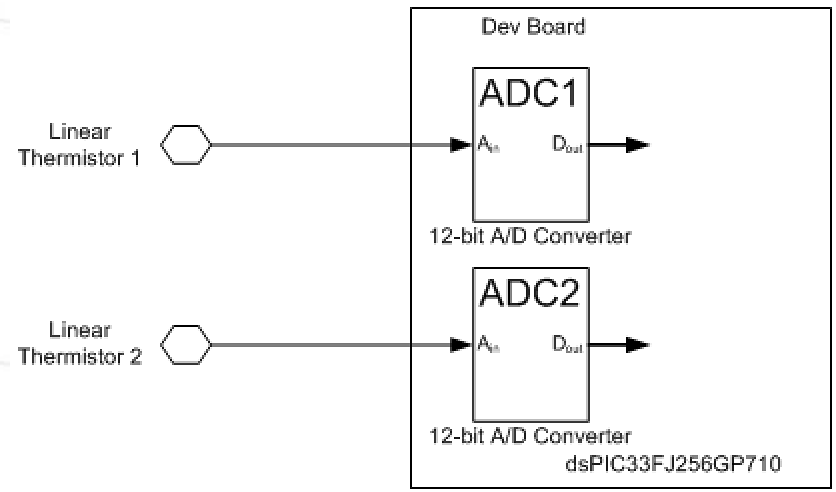
Temperature Sensors

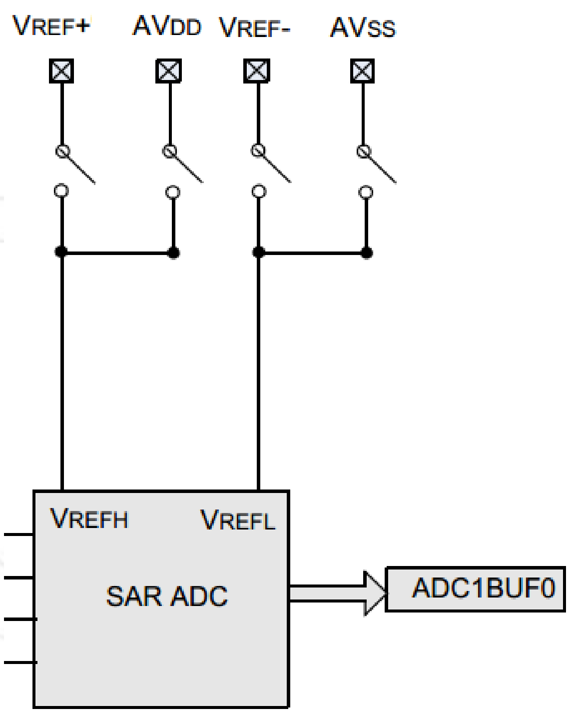




Temperature Sensors





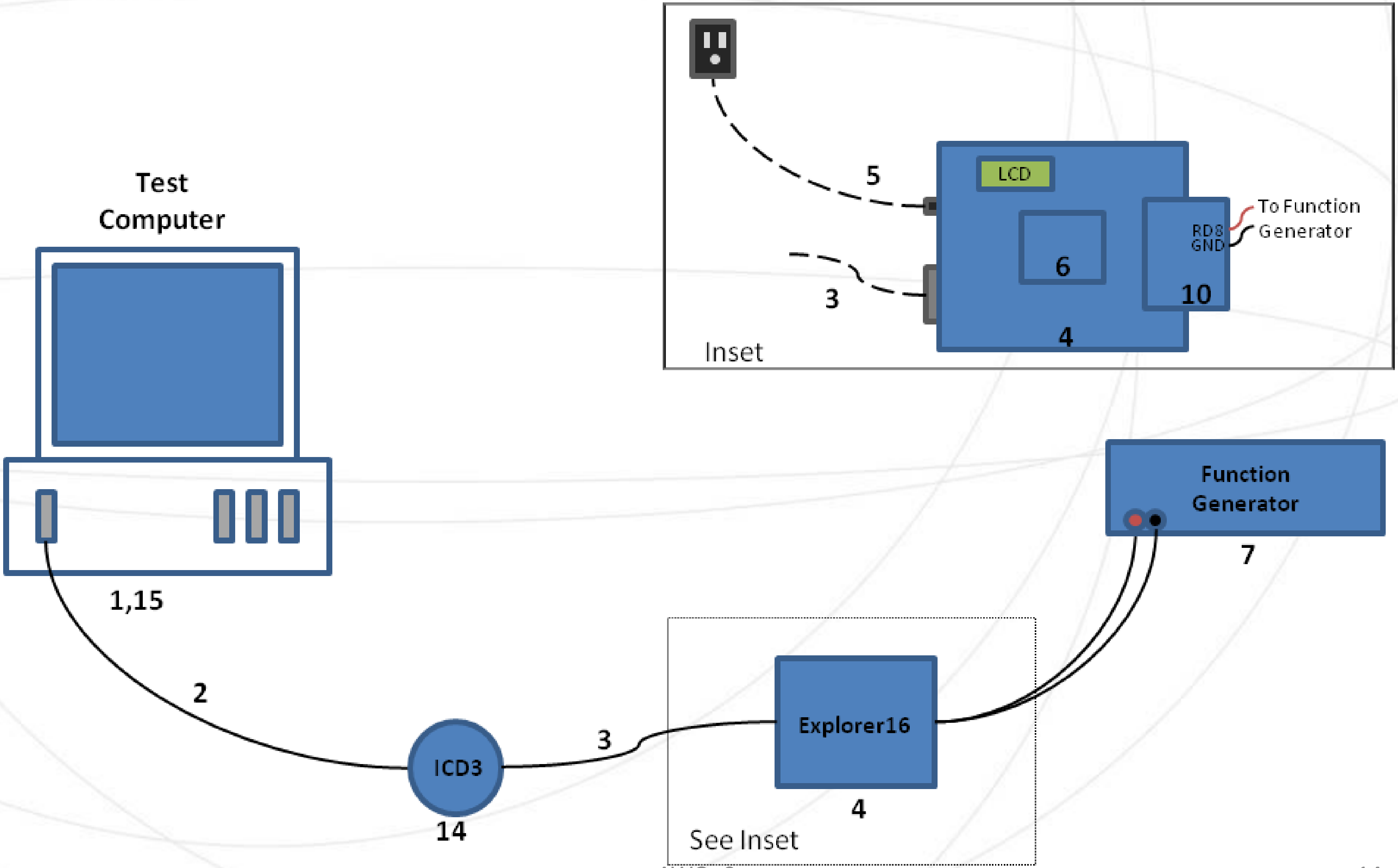


$$V_{out} = (-\,0.0056846 \cdot V_{in})\,T \;+\; 0.805858 \cdot V_{in}$$

0°C	40°C
2.6593314V	1.9089642V

Data Acquisition Testing

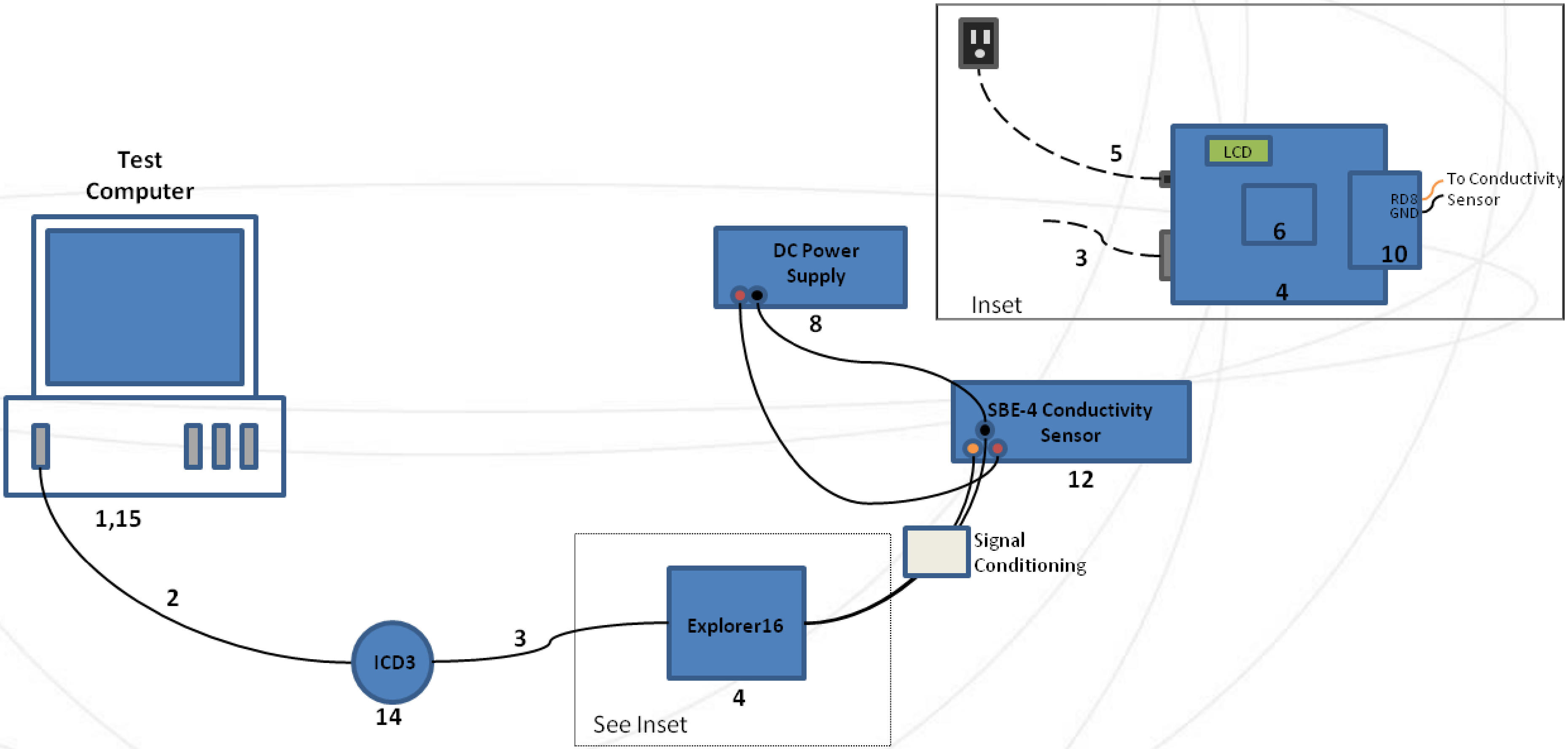
Frequency Counter



Data Acquisition Testing

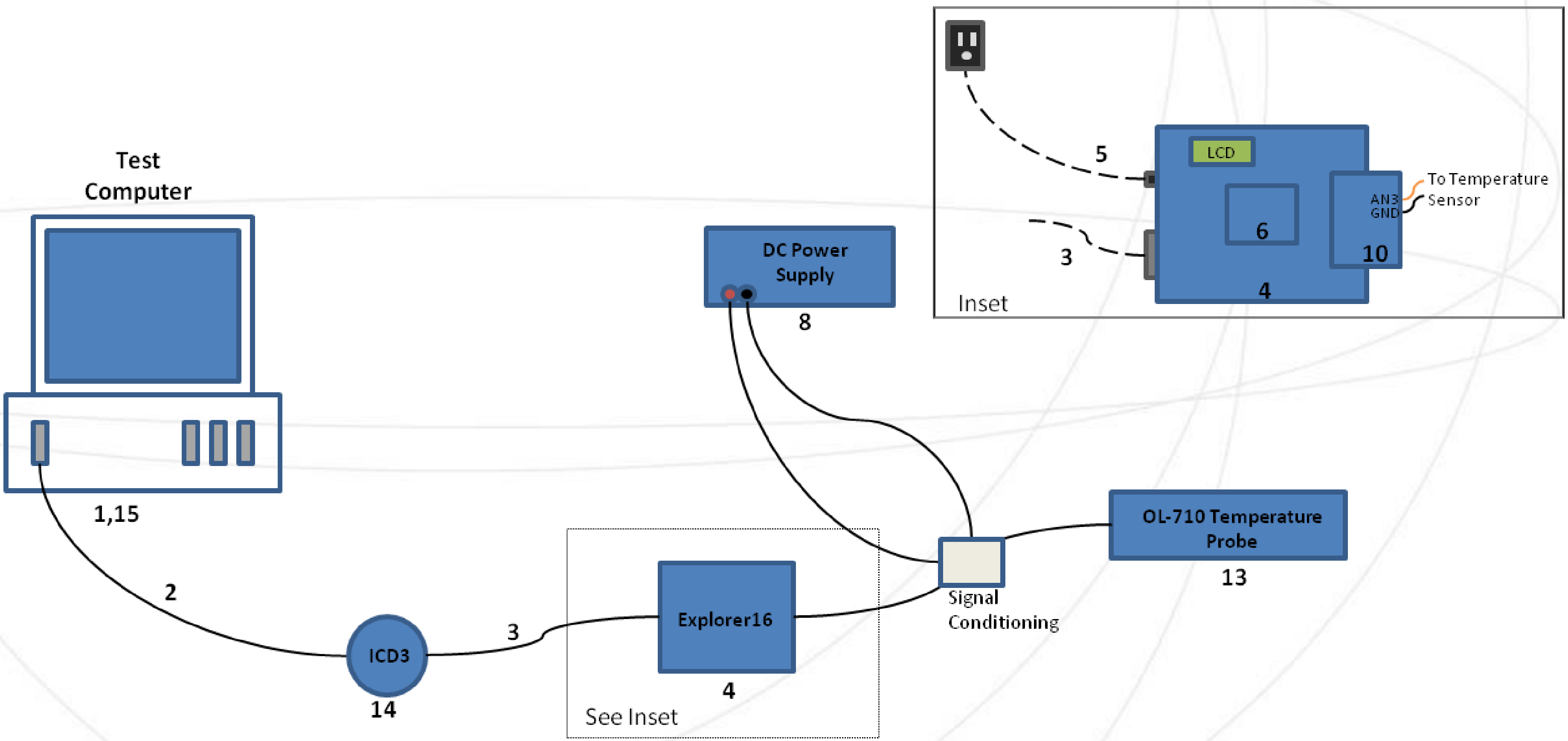
Frequency Counter

Data Acquisition Testing
Conductivity Sensor



Data Acquisition Testing

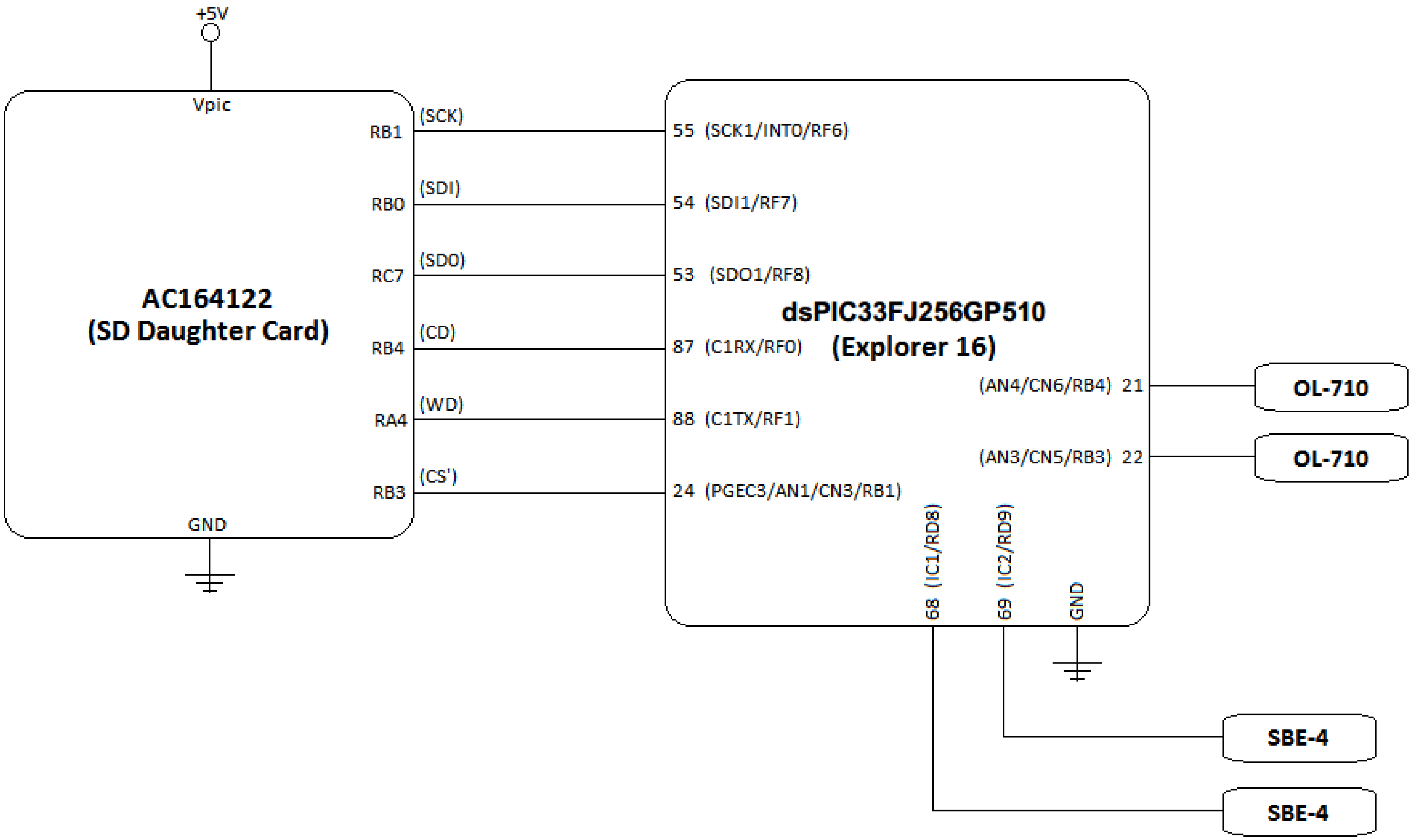
Temperature Sensor



Data Logging and Handling

Francisco Schroeder

Data Logging



Data Logging

- **Format**
  - Text File
  - Comma Separated Values

t=0s	Time, Latitude, Longitude, Conductivity1, Conductivity2, Temperature1, Temperature2
	, , , Conductivity1, Conductivity2, Temperature1, Temperature2
	, , , Conductivity1, Conductivity2, Temperature1, Temperature2
	, , , Conductivity1, Conductivity2, Temperature1, Temperature2
	, , , Conductivity1, Conductivity2, Temperature1, Temperature2
	, , , Conductivity1, Conductivity2, Temperature1, Temperature2
	, , , Conductivity1, Conductivity2, Temperature1, Temperature2
	, , , Conductivity1, Conductivity2, Temperature1, Temperature2
t=1s	Time, Latitude, Longitude, Conductivity1, Conductivity2, Temperature1, Temperature2
	, , , Conductivity1, Conductivity2, Temperature1, Temperature2

.
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- **Memory**
  - Memory needed = 10.36 GB
  - SD daughter card = 16 GB

- **Procedure**
  - Initialize card
  - Open/create File
  - Write to card
    - Function with data as parameters

Data Handling

- **Purpose:** Convert Data from array into a bit stream.
- **Length:** 109 Bits
  - Conductivity (10 bits * 2 sensors)
    - Left side of radix (0 - 7): 3 bits
    - Rigth side of radix (0 - 99): 7 bits
  - Temperature (13 bits * 2 sensors)
    - Left side of radix (0 - 45): 6 bits
    - Rigth side of radix (0 -99): 7 bits
  - GPS Coordinates (23 bits * 2 coordinates)
    - Sign (0-1): 1 bit
    - Left side of radix (0 -180): 8 bits
    - Rigth side of radix (0 - 9999): 14 bits
  - Time (17 bits)
    - Hours (0 - 23): 5 bits
    - Minutes (0 - 59): 6 bits
    - Seconds (0 - 59): 6 bits

Data Handling(Code)

```
//float encoding for bitstream
Bit* floating (float f, char c){
Bit *a, *fir, *sec;//fist and second
int first, second, r; //before and after radix
float temp;

//dividing into LHS and RHS of radix
first = (int)f;
temp = f - first;

//conductivity sensors
if (c == 'c') //10bits{
second = temp * 100;
        //generating RHS of radix as integer

//convertion
fir = integer(first, 3);
sec = integer(second, 7);

//concatination into a
a = fir;
for (r = 0; r < 7; r++)
        a[3 + r].x = sec[r].x;
}
//temperature sensors
else if (c == 't') // 13bits
{
        second = temp * 100;
                //generating RHS of radix as integer

        //convertion
        fir = integer(first, 6);
        sec = integer(second, 7);

        //concatination into a
        a = fir;
        for (r = 0; r < 7; r++)
                a[6 + r].x = sec[r].x;
}
```

Data Handling(Code)

```
//GPS coordinates
else //23 bits
{
	//sign bit generation
	if (first > 0)
	{
		a[1].x = 0;
		first = first * -1;
	}
	else
		a[1].x = 1;

	second = temp * 10000;
//generating RHS of radix as integer

	//convertion
	fir = integer(first, 8);
	sec = integer(second, 14);

	//concatination into a
	for (r = 0; r < 8; r++)
		a[1 + r].x = fir[r].x;

	for (r = 0; r < 14; r++)
		a[9 + r].x = sec[r].x;
}
return a;
}
```

```
Bit* integer (int i, int l)    // i = int to be converted
                               // l = bits needed
{
Bit* a;

int k;
for (k = 0; k < l; k++)
{
		int l = pow(2,k);

		if (i > l)
		{
			i = i - l;
			a[l - k].x = 1;
		}
		else
			a[l-k].x = 0;
}
return a;
}
```

Test Procedure

3.6 Data Logging

1. Tested
   - Writing to SD daughter card
2. Not-Tested
   - Writing Data

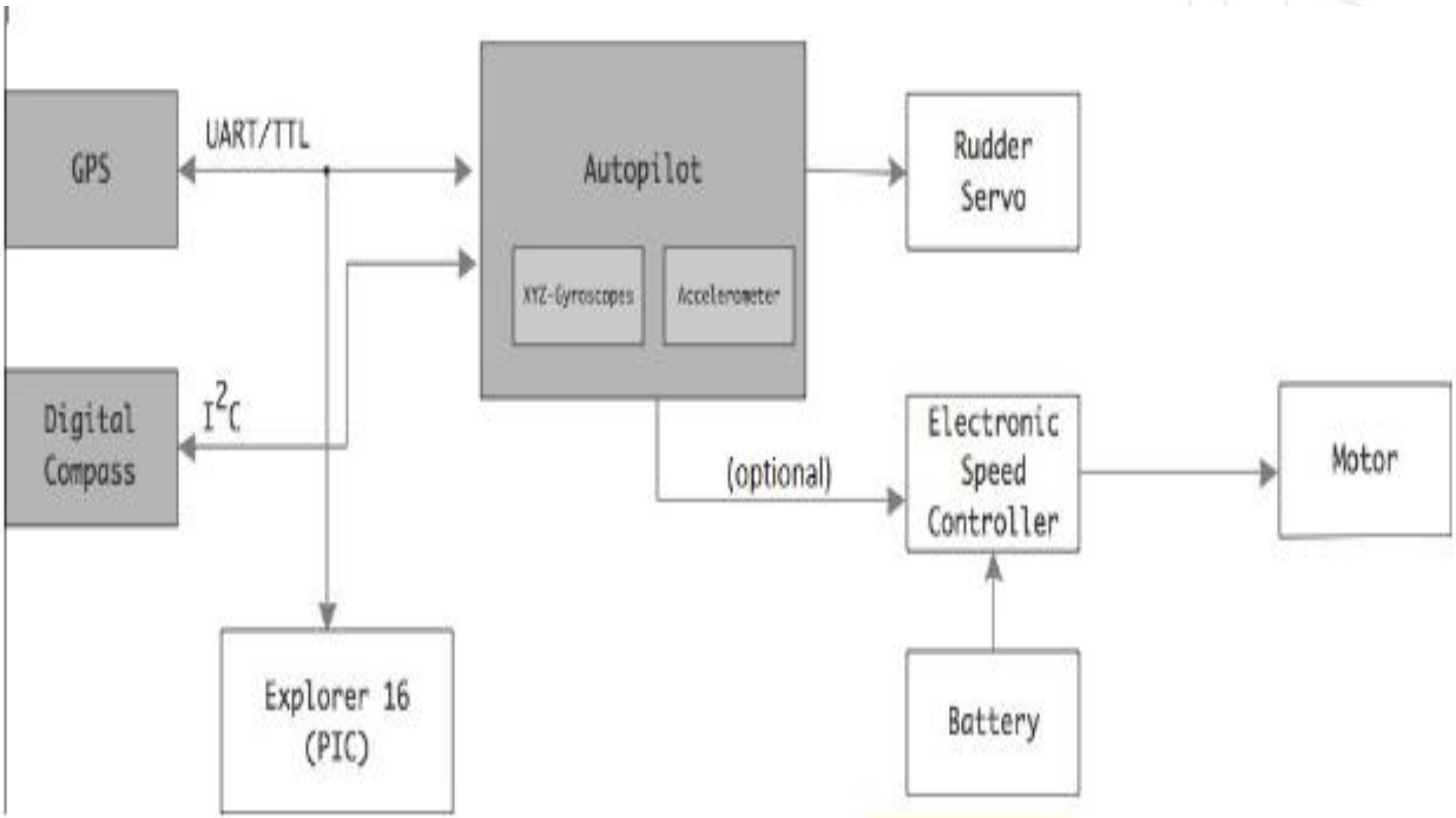
3.7 Data Handling

1. Tested
   - Output bitstream only with software interface
2. Not-Tested
   - Hardware Implementation

Navigation

Triesha Fagan

Top-level Architecture of Navigation System



Initializing the UDB4

Fast RC Oscillator → Master Clock

UART → GPS

I2C → Digital Compass

PWM → Steering servo motor control

Interrupts

Fast RC Oscillator → Master Clock

→ 8 MHz Internal Oscillator with Phase Locked Loop (4x) = Fosc =32 MHz

→ Device Operating Frequency = Fosc/2 = Fcy= 16 Mhz

→ Determines Baud Rate for UART

→ Determines duty cycle for PWM

UART → GPS

→ Set Baud Rate

- Default = 9600 bps
- dsPIC33FJ Baud Rate Generator:

Baud Rate = Fcy / (16*(BRG+1))

BRG = [Fcy/(16*Baud Rate)] – 1

Desired Baud Rate	UxBRG Value(base 10)	Calculated Baud Rate	Error
4800	207	4807	0.15
9600	103	9615	0.16
19200	51	19230	0.16

→ Test RTC of DD2523T Smart Antenna Board chip : GBX-5010 chip

- Real Time Clock = 32.768 kHz
- Pin 20 : Timepulse = 1 pulse per second with 30 ns timepulse accuracy
- Determine possible time synchronization method between Explorer 16 and D2523T GPS usinf rising/falling edge of GBX-5010 pulse

UART → GPS

→ GPS parsing code:

1. Check GPS NMEA Header for '$' or terminating sequence
2. Check set of 3-letters that follow '$' to determine NMEA sentence
3. Verify Checksum
4. Parse through comma separated data of GPRMC and GPGGA strings
5. GPRMC: Universal Time, Latitude, N/S Indicator, Longitude, E/W Indicator, Course
6. GPGGA: Position fix
7. Perform calculations on longitude and latitude coordinates from degrees decimal minutes to decimal degrees
8. Determine East or West, North or South direction Set NMEA output: GPRMC and GPGGA

PWM → Steering servo motor control

→ Calculate PWM Period

- PTPER = PWM Time Based Register
- PTMR = PWM Time Based Register

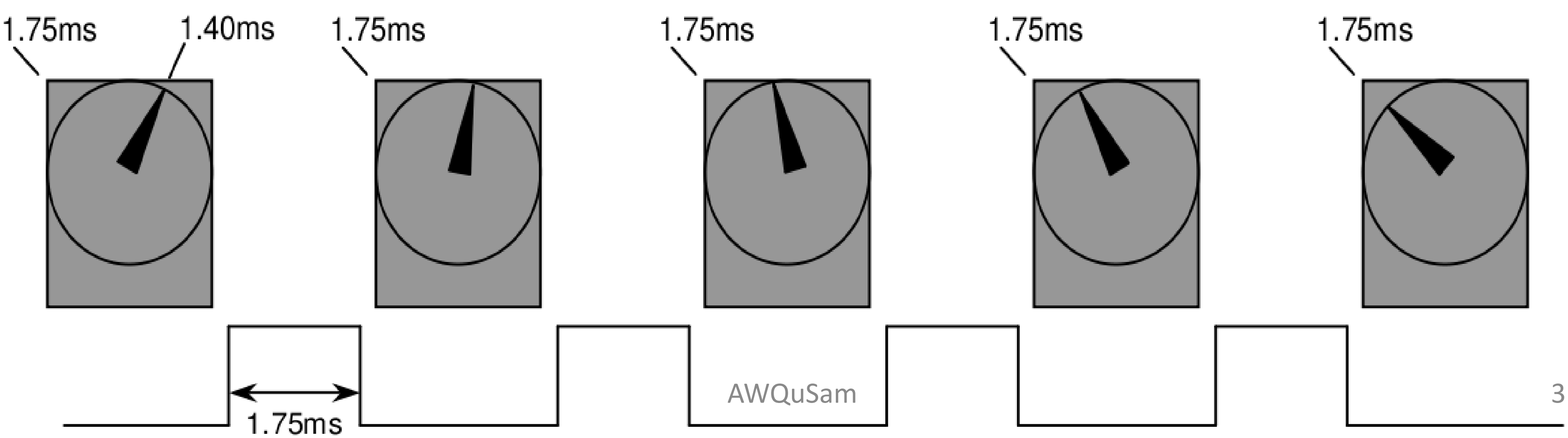
$$T_{PWM} = \frac{T_{CY} \cdot (PTPER + 1)}{(PTMR\ Prescale\ Value)}$$

→ Steering Servo - Traxxas High Torque Water Proof Servo

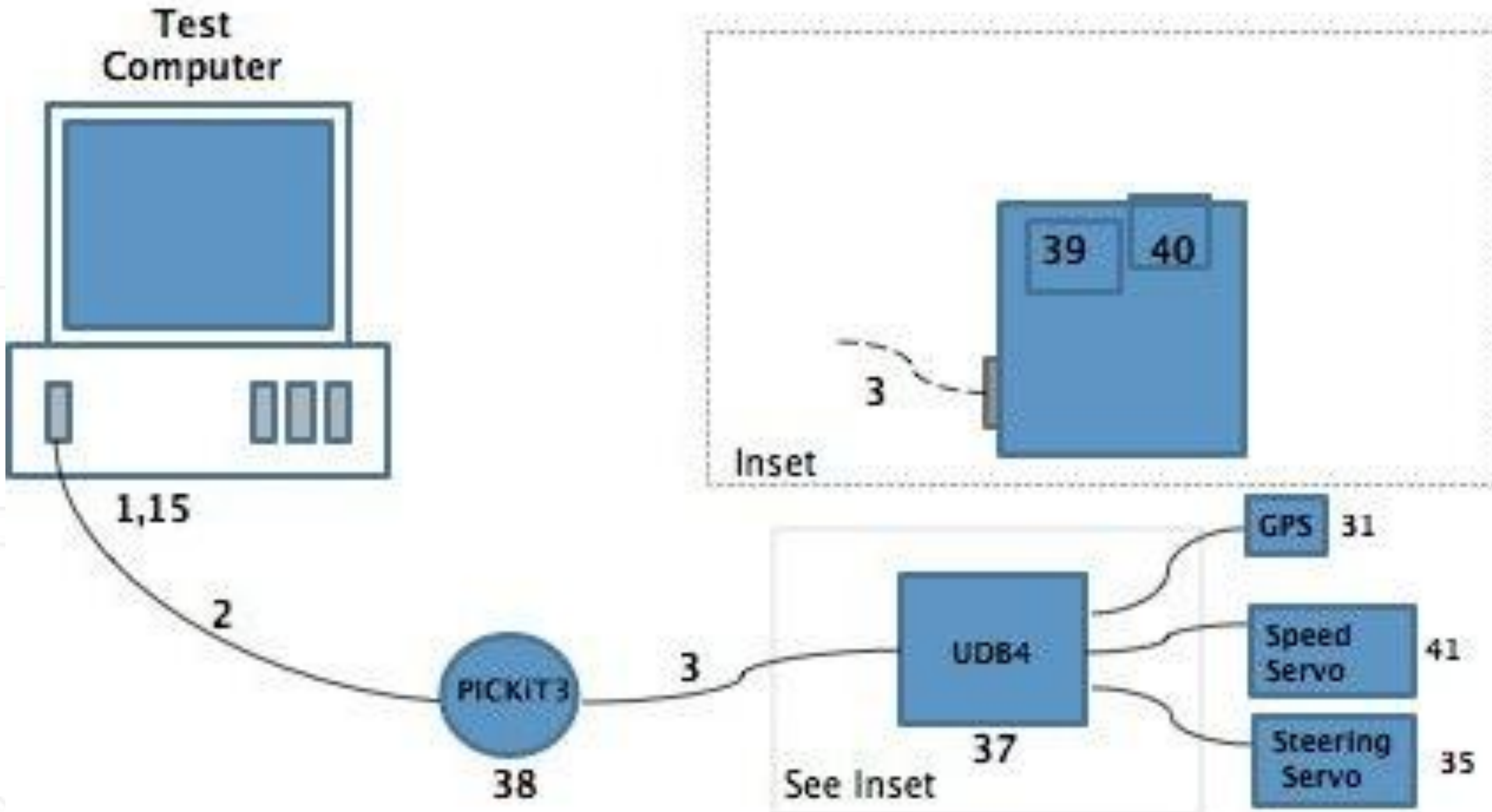
- 60 deg travel

→ Steering towards waypoints will be updated every 2 second

Note : AWQuSam's Speed = 5 knots = 8 ft/s



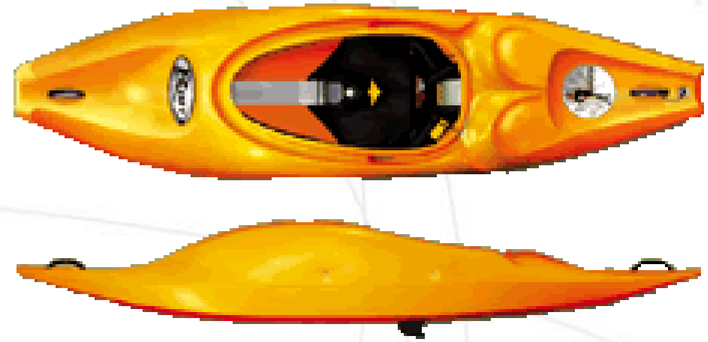
Test Configuration



Mechanical Housing Safety Features Cooling System

Juan Garcia de Paredes

Hull



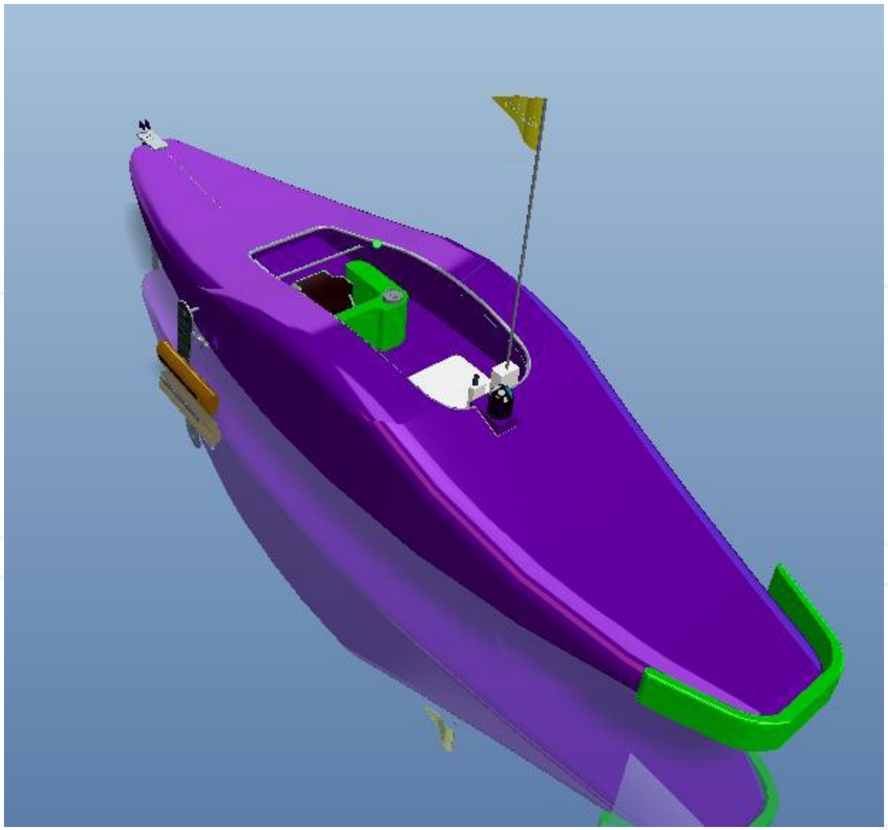


Figure 3.1.1.3: Hull Front View

- The prototype design for the AWQuSam shall use a Riot Trickster Kayak.

- Very durable, light weight (33lbs), easily transported, cheap, and fairly streamlined.

- Needed to be refitted
  - (1) internal support for propulsion and electronic components;
  - (2) structural support for sensors,
  - and (3) a stabilizing structure below the hull.

Hull

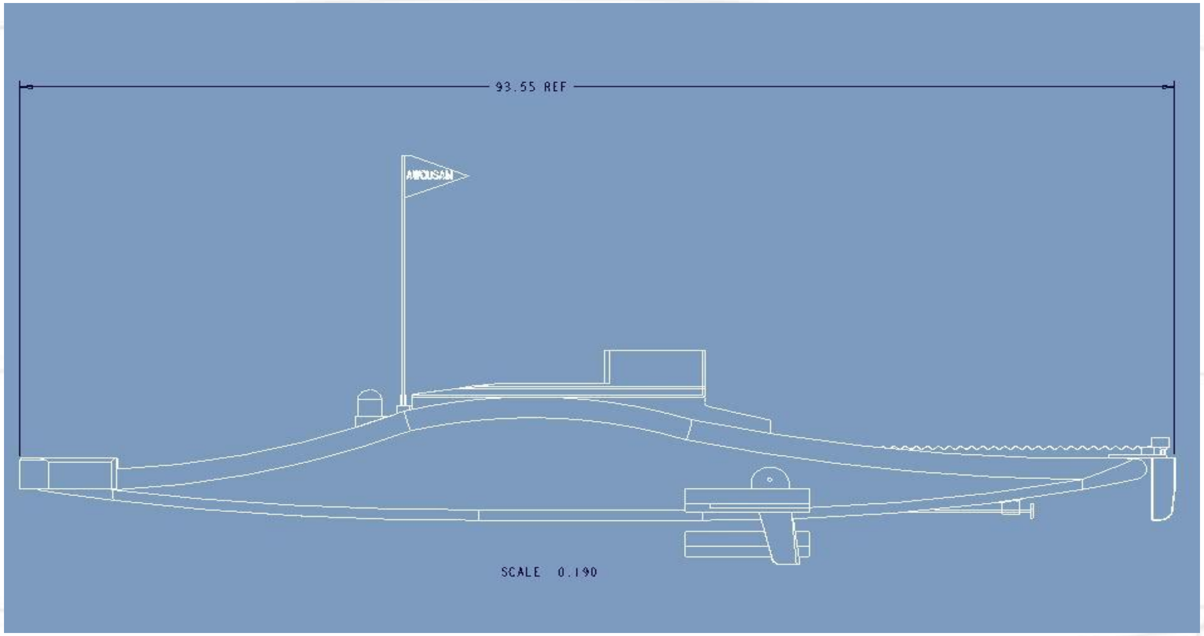


Figure 3.1.1.2: Wire Frame Side View with Dimension (7.8 feet)

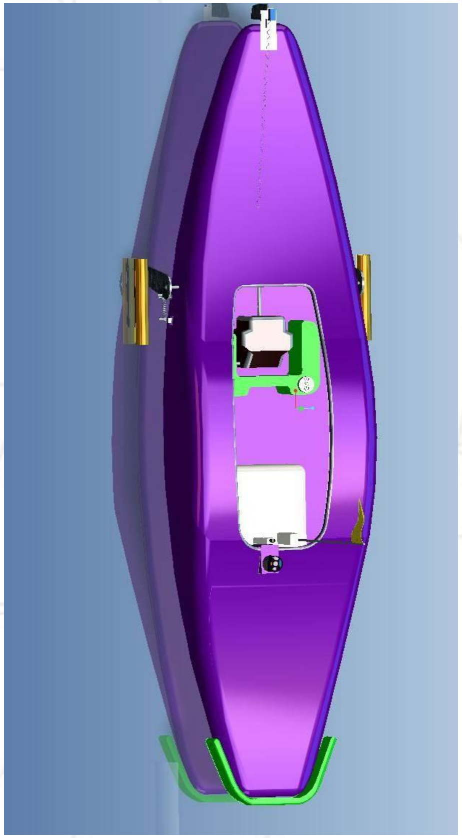


Figure 3.1.1.5: Hull Top View

The kayak hull will enclose all the electronic and mechanical components but shall allow for easy access.

Therefore two stabilizing keels are to be implemented and used both as a structural elements as well as a hydrodynamic elements

Hull

The keels will also house the sensors of the AWQuSam. These keels will ensure the AWQuSam moves in a straight line while also protecting the sensors from impact with any external object.

The keels will be held in place by a rotating about-an-axis-joint so that if it impacts on shallow ground it has some freedom to rotate and come back into position after impact.

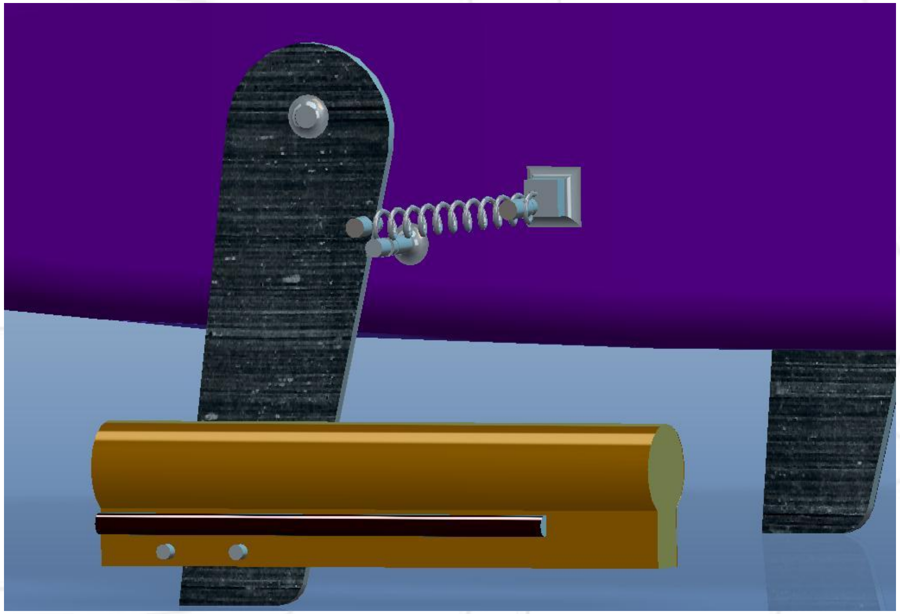


Figure 3.1.1.4: Side Keels and Sensors

Hull

Finally the top covering will be provided by a fire-retardant cloth that fits snugly on the Riot Kayak Trickster. It has an opening on top that allows the engine to exhaust and extract air. A depiction of the cloth can be seen on the image below.

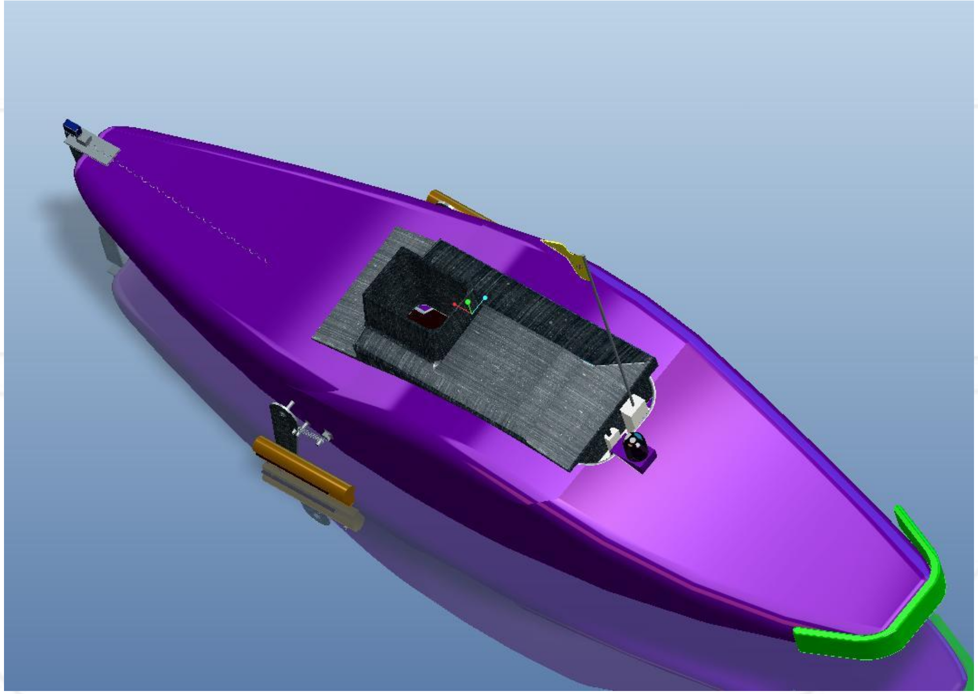


Figure 3.1.1.6: Hull with Top Covering

The internal structure will hold the engine and the shaft in place.

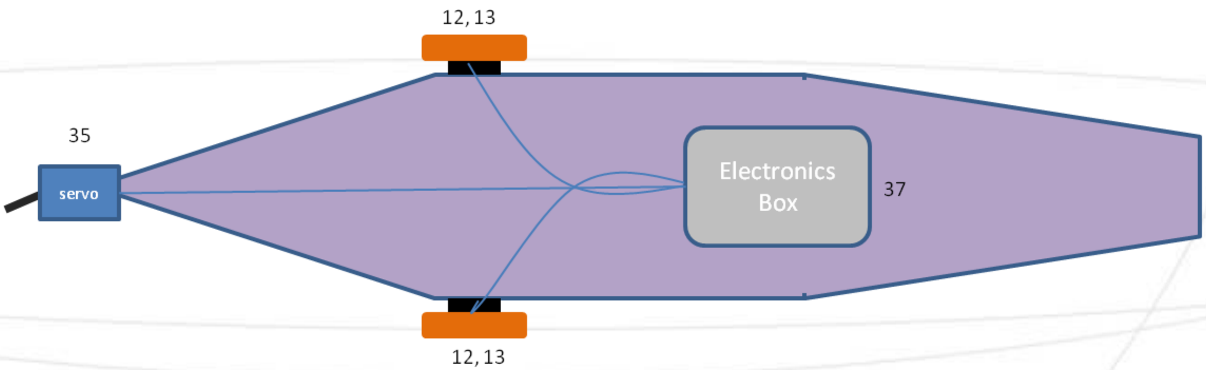
The engine and the shaft shall be placed in an angle coming out of the bottom of the back of the kayak as

The electronics box will be fixed into the bottom of the hull by 3M Velcro.

Electronic Housing

The electronics housing will be placed safely inside the hull and will enclose all electronic components.

The main challenge is to seal tight all electronic components during operation but prevent components from overheating.



Figures 3.1.2.2, and 3.1.2.3: Show Wire Assembly and Wire Covers

Electronic Housing

A big box will be fixed to the AWQuSam using 3M Velcro to reduce the amount of protrusions done on the hull. The box will be closed by a rubber water tight seal on the edges with all the electronic components fixed safely inside. Two small towers will come out of the box housing the GPS and transmission antennas. This is necessary for optimum signal transmission. These towers, essentially boxes, will also be water tight and permanently fixed to the main box.

Figure 3.1.2.3: View of Electronics Box, Antennas, and Siren

Safety System

The AWQuSam needs to be safe for the public and the environment.

Needs to be easily detectable by all spectators.

Vissually the AWQuSam will include a **LED night time lighting system** will serve as indication lights when operating at night. The LED lighting system will be integrated with the power system. A **photoresistor** may be used to ensure the lights are only turned on when it is dark outside. The kayak shall also be **painted** neon orange.

It will include **a loud siren** from a car alarm system with the ability of being turned off and on.

A **foam bumper** is placed in the front of the vehicle to cushion any collisions and prevent the AWQuSam from damaging any of the boats around in case of a collision and protect all unknown spectators from a dangerous collision with the vehicle.

Cooling System

Two major components of the AWQuSam produce heat and need to be cooled. These are the engine and the electronics box.

To enhance the cooling system freeze packets will be placed around the electronic box (not inside) providing low temperatures for the duration of the mission. The mass of freeze packets required will be determined experimentally.

Test Procedure

Hull and Thrust Test

1. Measure the weight of the kayak.

2. Place kayak in body of water to estimate buoyancy and ensure there are no leaks

3. Attach kayak to rope and rope to an analog force sensor. Measure the speed of the kayak (with a GPS) as a function of the thrust experienced by the kayak. Thrust is applied a boat powered by a gas engine.

4. Repeat Step 3 but adding 45 lbs extra in water weight to act as placebo masses for other components of the boat

Results: At 78lbs of weight, 18lbs of thrust -> Vehicle moves at 6.4 mph

Test Procedure

Mechanical Housing Stability, Bouyancy, and Safety features

1. Assemble hull structure and housing
2. Test the water tightness of the cover.
3. Test attachment and that all components in the hull are fixed in position. This will be done simply by group members. Wave simulation will be involved.
4. Place vehicle in water to determine the stability and bouyancy of the system.
5. Run the vehicle remotely control and maximum speed.
6. Test spring-keel mechanism.
7. Run the vehicle on shallow waters.
8. Test effectiveness of LED navigation lights.
9. Test effectiveness of siren.
10. Test effectiveness of bumber. The test will involve various runs of the AWQuSam in collision with fixed surfaces and the impact will be analyzed by the group members.

Test Procedure

Cooling System

1. Measure the temperature dissipated by the electronics inside the electronics box.
2. Test the amount of time the packets will stay above the measured temperature (from Step 1) outside but covered from the sun rays.
3. Test the effectiveness of the packets in maintaining the temperature of the electronics below thresh hold. Note that in this test operating conditions must be met (i.e. air draft and motion)

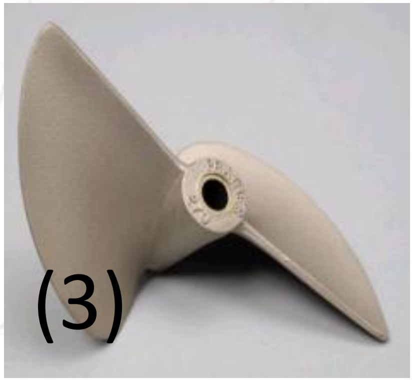
Propulsion System
Steering System

Carlos Sanchez

Propulsion System.

Will Consist on three major parts:

- (1) the engine;
- (2) the connecting shaft assembly;
- (3) the propeller



The Engine

•A small 4 stroke gasoline engine.

•A pull-cord for cranking.

•It is lightweight- only 3.33 kg.

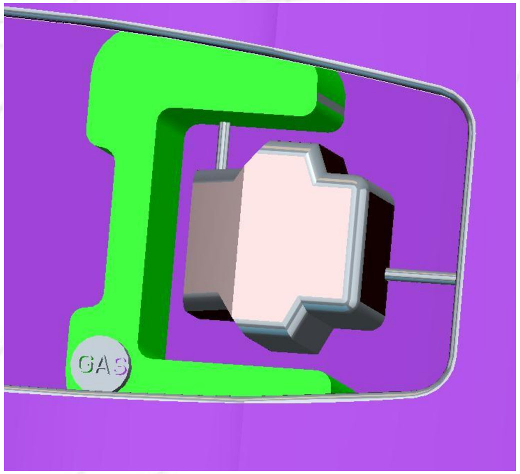
•Will consume about 2- 2.5 gallons of fuel on a 12 hour mission.

Figure 3.2.2: Honda GX35 Engine

It needs:

• An external fuel tank of that size will have to be fitted to the smaller internal tank.

•A hole in the engine tank will be drilled to make this connection.



The Shaft Assembly

Will allow the motor to transmit its torque through the shaft to the outside of the boat underwater and then to the propeller.

Consists on:

1. The aluminum strut which supports the shaft and attaches to the bottom of the boat.
2. A flexible dark metal shaft which transmits torque along its axis
3. A thin hollow Teflon tube to reduce friction
4. Which slides inside the hollow copper tube below.

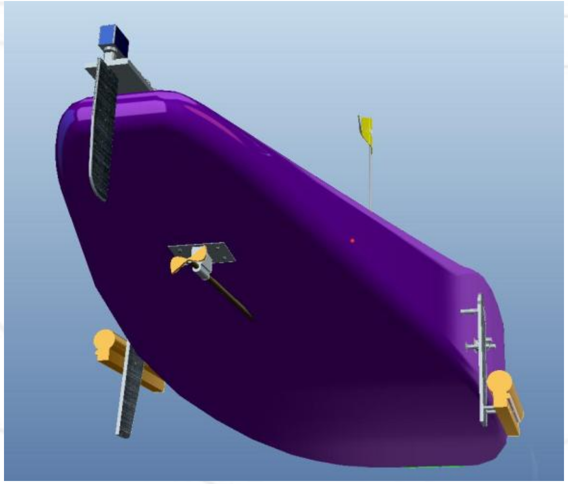


Figure 3.2.2: Shaft Assembly

Figure 3.2.3: Connecting Shaft Assembly

The Propeller

The chosen prop is a Prather Racing Counterclockwise 3.10 inch diameter, 4.5 inch pitch and about 30-40 % mean area.

After much research and analysis of a "*prop algorithm*" developed in the United Kingdom, the team found the appropriate prop size corresponding to the selected engine.

Numerous variables have to be taken into account :

rpm range, engine horsepower, outputted torque, hull displacement, gearbox

reduction if applicable, percentage of power loss due to bearings, speed length ratio,

drag "C" value and more.

Figure 3.2.4: Prather Racing Counterclockwise

Steering System

The steering will be achieved by having a waterproof high torque digital servo linked to a rudder.

Will be connected to the microcontroller board and will correct itself as a function of how far it deviates from the path. Pulse width modulated signals will control the servo.

Figure 3.3.2: TRX2075-Digital Waterproof Steering Servo

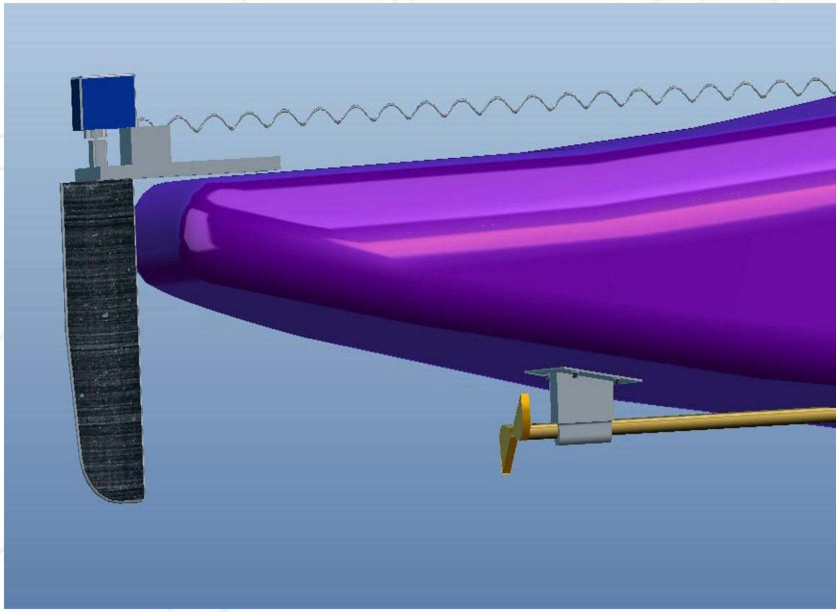


Figure 3.3.1: Steering Assembly

Test Procedure:

Propulsion System

1. Assemble propulsion system.
2. Test the normal operations of the Honda GX35 engine with 2.5 gallons of fuel.
3. Test engine in water AWQuSam. Measure variable speeds using placebo masses for other components.
4. Measure the temperature of the engine after an hour run.

Test Procedure:

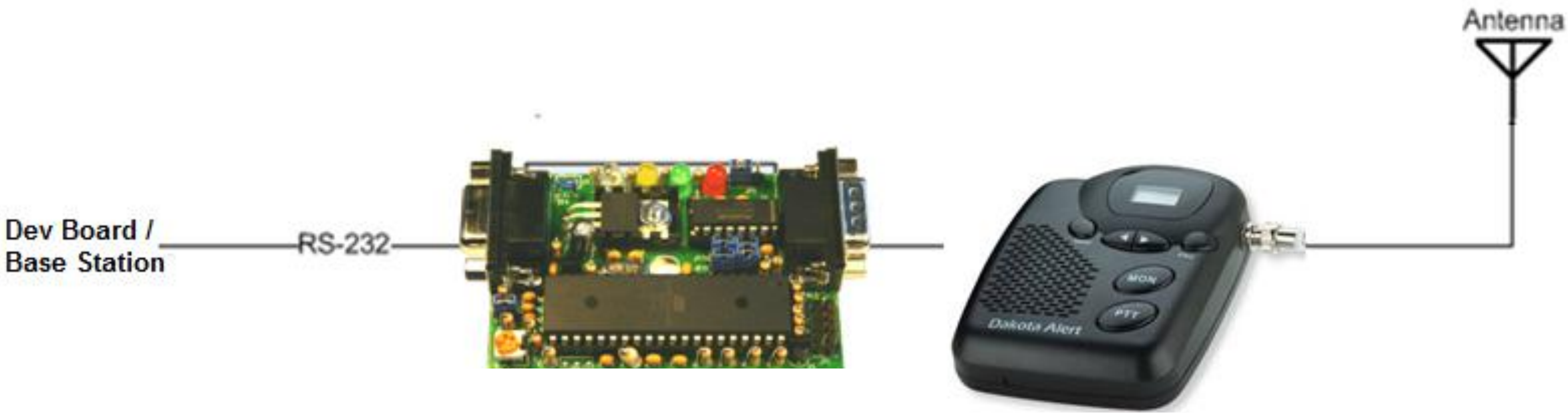
Steering System

1. Assemble steering system.
2. Test response of the servo motor on command in calm waters.
3. Test effectiveness of system to steer the craft appropriately.
4. Calibrate angle of the servo with steering intensity.
5. Test vehicle performance to run on a 360 degree turn.
6. Run the AWQuSam by remote control in rougher waters.

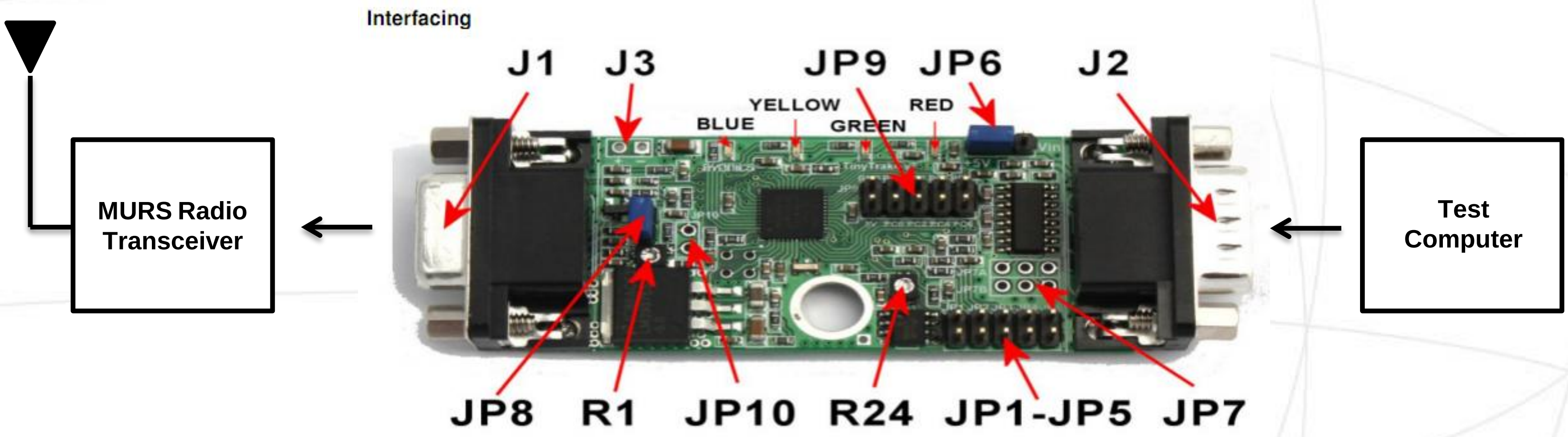
Data Transmission

Steven Golemme

Data Transmission



Data Transmission



TinyTrak4 Terminal Node Controller

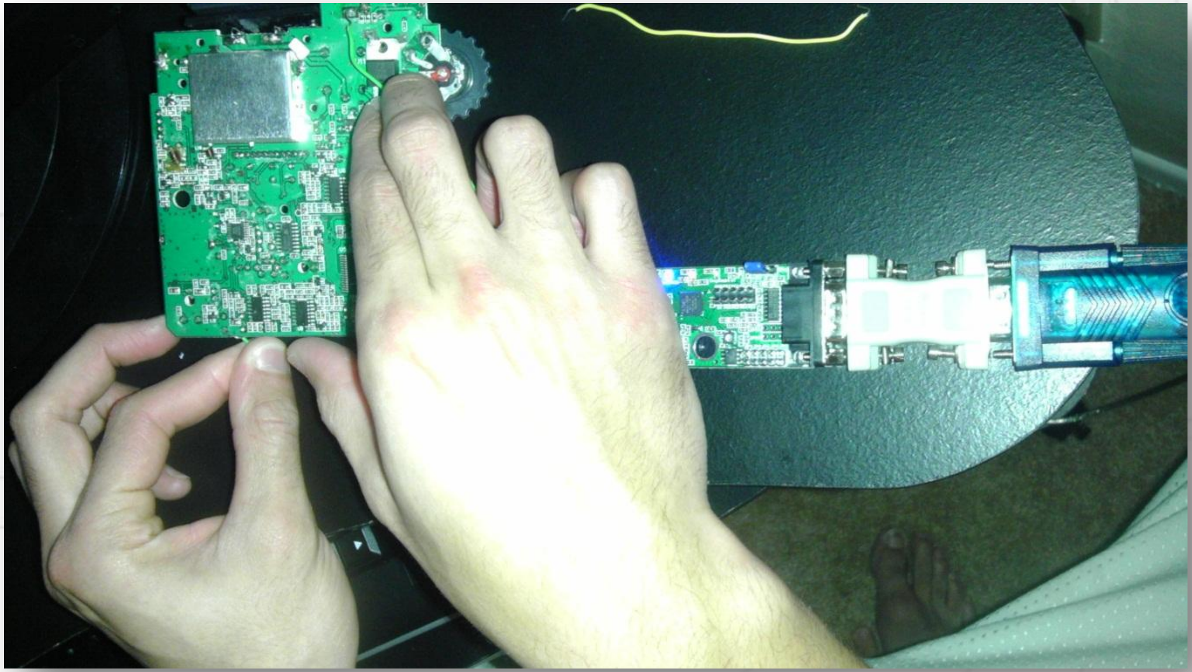
J1 - Radio

Pin	Function	Description
1	Audio out	Generated packet or other audio tones to be transmitted via the radio microphone jack.
2	Carrier Detect	Digital carrier detect state from radio. Can either be active high or active low.
3	PTT Out	This line is grounded when the radio should transmit. Connect to radio PTT input.
4	JP1	Optional J1 interface to the JP1 line. Can be an analog or digital input, or output, depending on firmware.
5	Audio in	Audio received from the radio via the earphone or speaker jack.
6	Ground	Ground return for power, audio, PTT and all other signals.
7	Power In	Power input to the TinyTrak4. Can be 6V to 18V.
8	PTT In	State of optional external microphone PTT switch. Grounded during transmit.
9	No connection	May be end-user wired for custom features.

J2 - Serial

PIN	Function
1	No Connection
2	Primary Serial data in from a GPS or computer
3	Primary Serial data out to a GPS or computer
4	Power out for GPS (Vin or 5V), or alternate power input
5	Ground
6	No Connection
7	Secondary Serial data out to a GPS or computer
8	Secondary Serial data in from a GPS or computer
9	No Connection

Testing Data Transmission



TinyTrak4 Power Up (Actual photo)

Testing Data Transmission

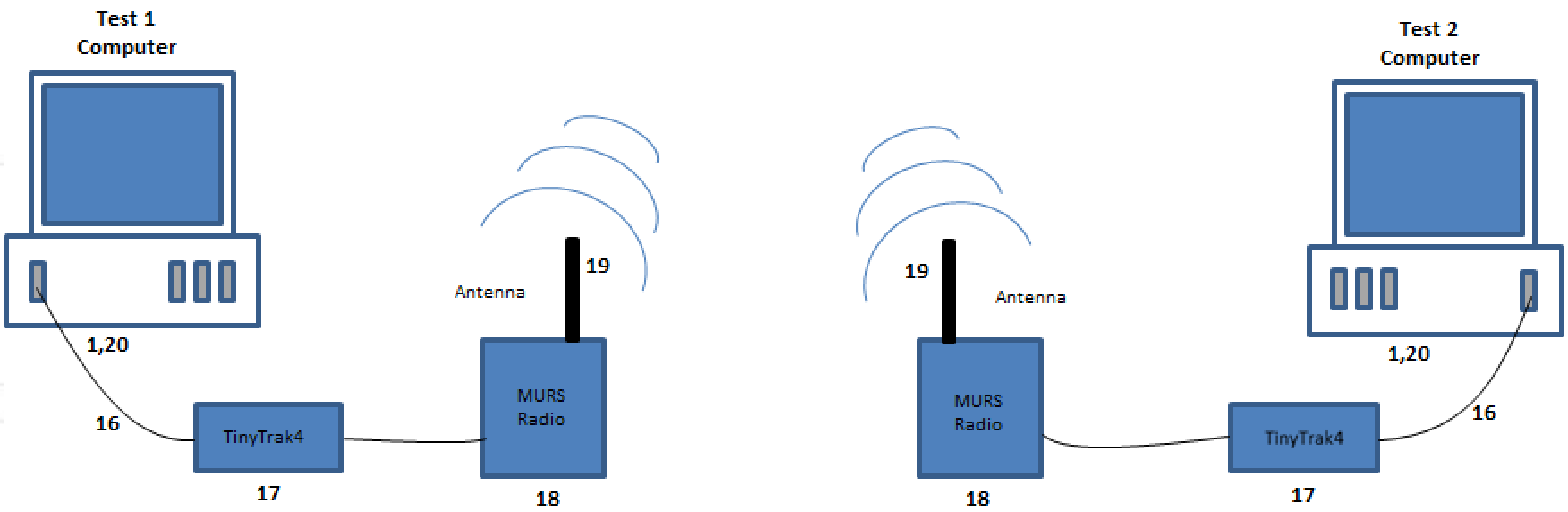


Figure 4.2.5: Test Configuration for Data Transmission

Test Procedure

4.3.4 Data Transmission

Step #	Step Description	Expected Results	P/F N/A	Comments
1	Place the system in the configuration shown in Figure 4.2.5		N/A	
2	Create character string in terminal on Test Computer one		N/A	
3	Send string from terminal to TNC to begin data transmission across MURS radio		N/A	
4	Receive string from TNC on terminal of Test Computer two.		N/A	
5	Verify that data received on Test Computer two is identical to data sent from Test Computer one.	The data received should be identical to the data sent without any errors.		
6	Increase data size to match typical output sent from AWQuSam and verify that the data received is identical.	The data received should be identical to the data sent without any errors.		
7	Increase the distance between the MURS Radios to be 5km.		N/A	
8	Verify data is received at the base station receiver.	The data received should be identical to the data sent without any errors.		

Budget Update

6 Budget Estimate

Item	P/N	Manufacturer	Distributor	Qty	Projected Cost	Actual Cost
PIC Development Board w/ Programmer	DV164037	Microchip	Microchip	1	$225	$225.00
SD Daughter Card	AC164122	Microchip	Microchip	1	$28.50	$28.50
Conductivity Sensor	SBE-4	Seabird	In House (FSU Oceanography)	2	-	-
Temperature Sensor	OL-710	Omega	Omega	2	$200	$173.00
Compass Module	SEN-07915	Honeywell	Sparkfun	1	$34.95	$34.95
GPS	GPS-09566	ADH	Sparkfun	1	$79.95	$79.95

Budget Cont

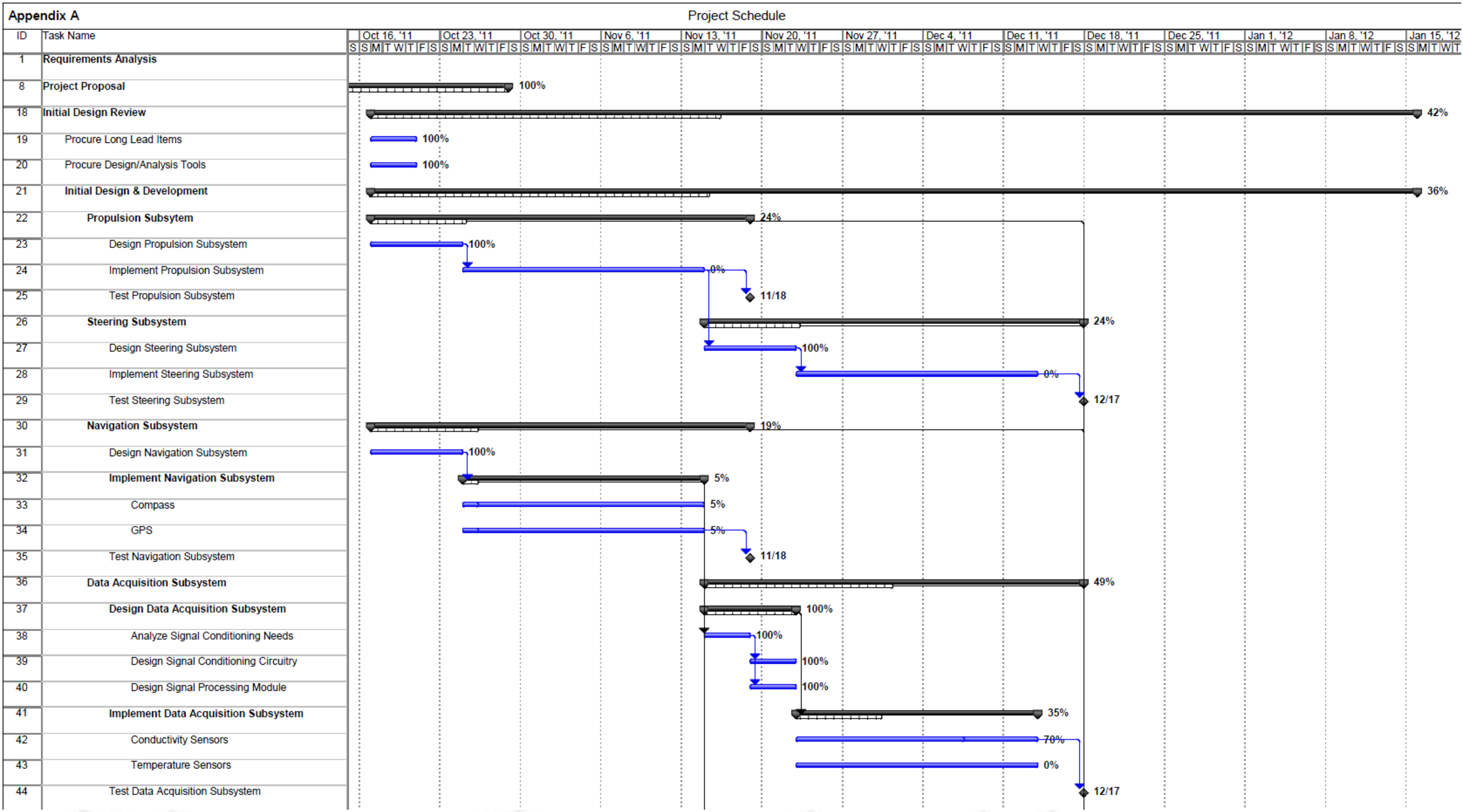
microSD 16GB Memory Card	COM-08163	A-Data	Sparkfun	1	$9.95	$9.95
USB to Serial Converter	USB-232-1	CommFront	CommFront	1	$30	$26.40
MURS Radio Modem	RV-M3-M	Raveon	Raveon	2	$260	$113.00
TNC	TinyTrak4	Byonics	Byonics	2	-	$202.00
Base Station Antenna	MURS-BASE	Firestik	TBD	1	$39.99	
4x4 Keypad	TBD	Grayhill	TBD	1	$20	-
Wiring and Accessories					$200	
Battery	SRM-24	Interstate Batteries	Amazon	2	113.95	
Servo Motor	High Torque Water Proof Servo	Traxxas	TBD	1	83.76	
Honda GX35 35cc Engine	#HEGX35NTT3	Honda	Bailey's	1	399.99	$299.38
GX35 - Clutch	Clutch	Honda	Small Engine Warehouse	1	38.97	$80.95
Prather 280 BC Metal Prop	PRAB280	-	FunRcBoats	1	-	$21.99
Kayak	-	-	CraigsList	1	98.00	$140.00
Shaft	SF2	Surface Drive Hardware	PMB Model Boats	1	$52.15	$52.15

Budget Cont.

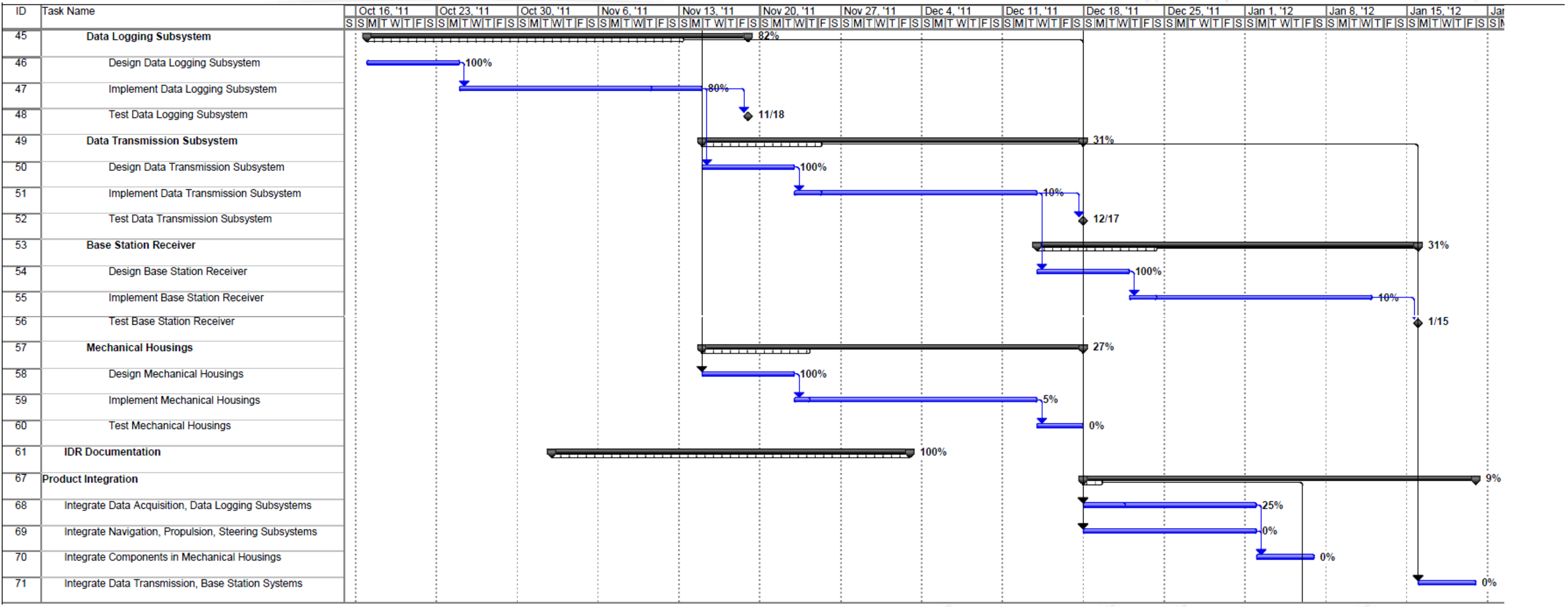
Engine Coupling	HF192A	Surface Drive Hardware	PMB Model Boats	1	$22.11	$22.11
Hoses	Discharge and Suction Hoses with couplings	TBD	TBD	1	40.00	
Mounting Hardware	Sealants and Bolts	TBD	TBD	N/A	40.00	
SubTotal:					$2017.27	
Total Proposed Expenditures:					$2000.83	$1509.33

Table5.1: Product Prototyping Budget

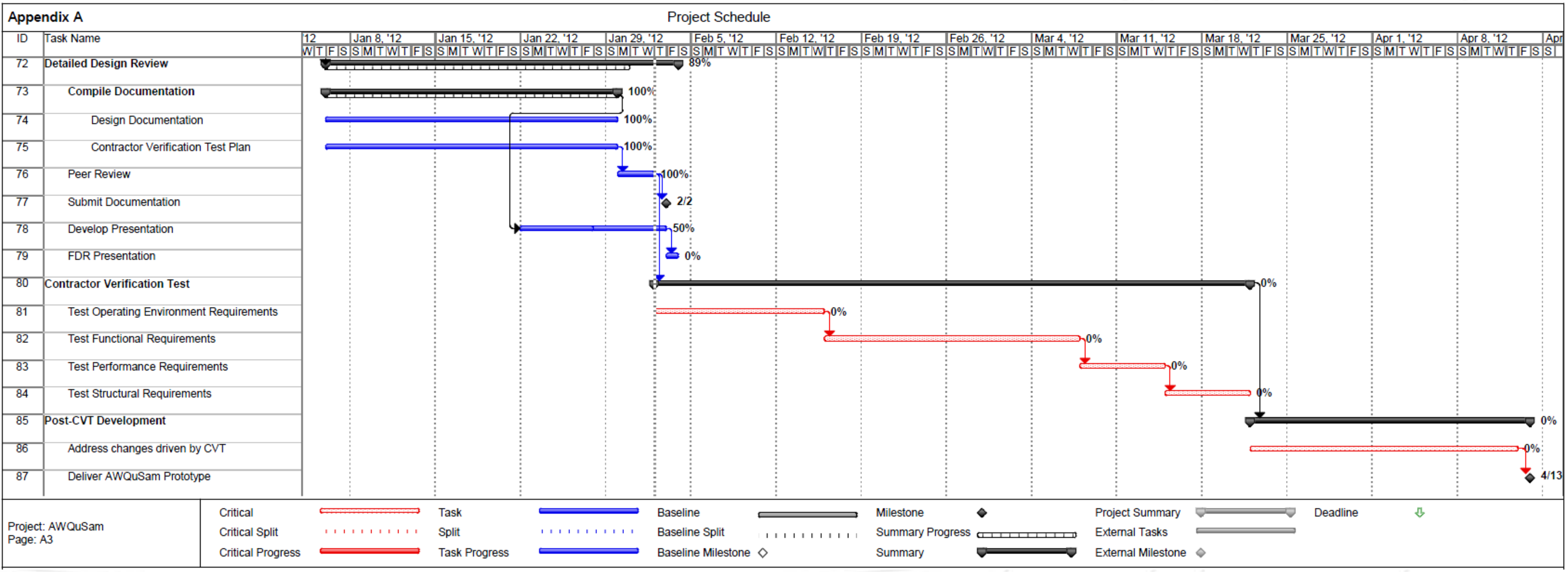
Project Schedule



Project Schedule



Project Schedule



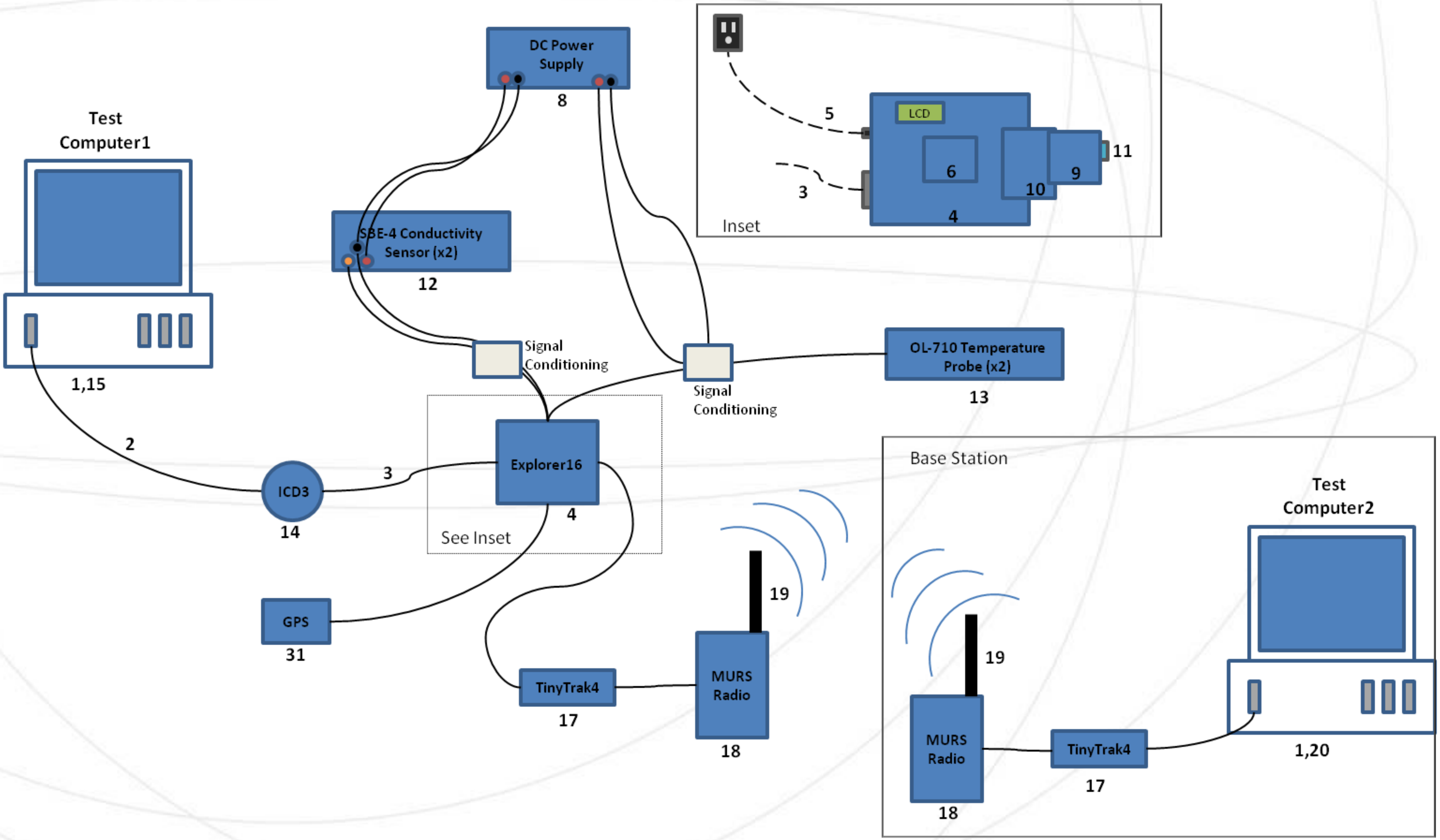
Module Testing Update

Module Under Test	Status
Data Acquisition – Conductivity Sensor	In Progress
Data Acquisition – Temperature Sensor	x
SD Data Logging	Complete
Data Transmission	In Progress
Hull and Thrust Test	Complete
Propulsion System	x
Steering System	x
Mechanical Housing (Stability, Buoyancy, Safety)	x
Cooling System	x
Navigation System	In Progress

System Integration Update

Integration Test	Status
Data Acquisition, Data Logging	In Progress
Data Acquisition, Data Transmission	x
Power System Integration	x
Electronic Housing Integration	x

Testing Update



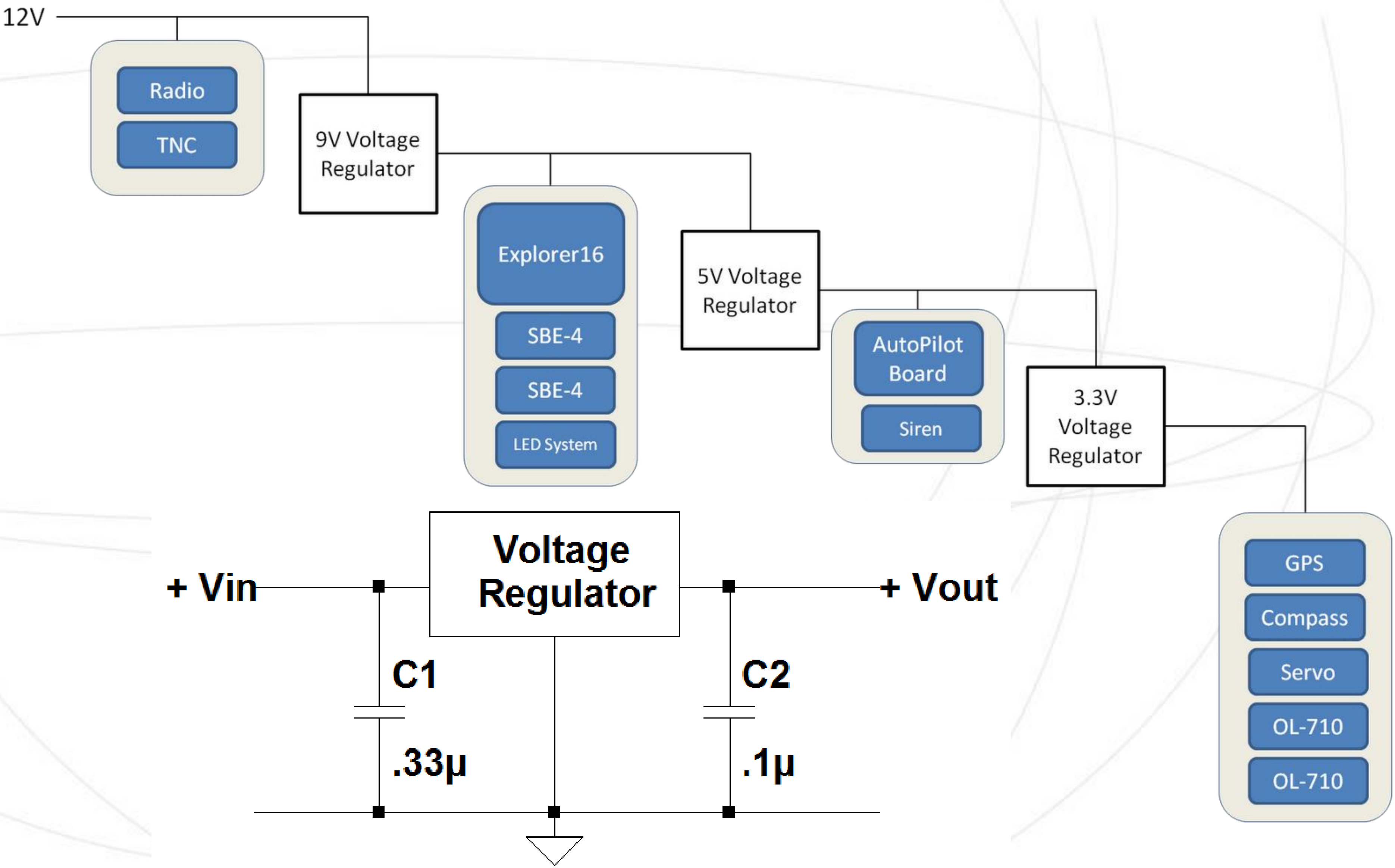
Questions?

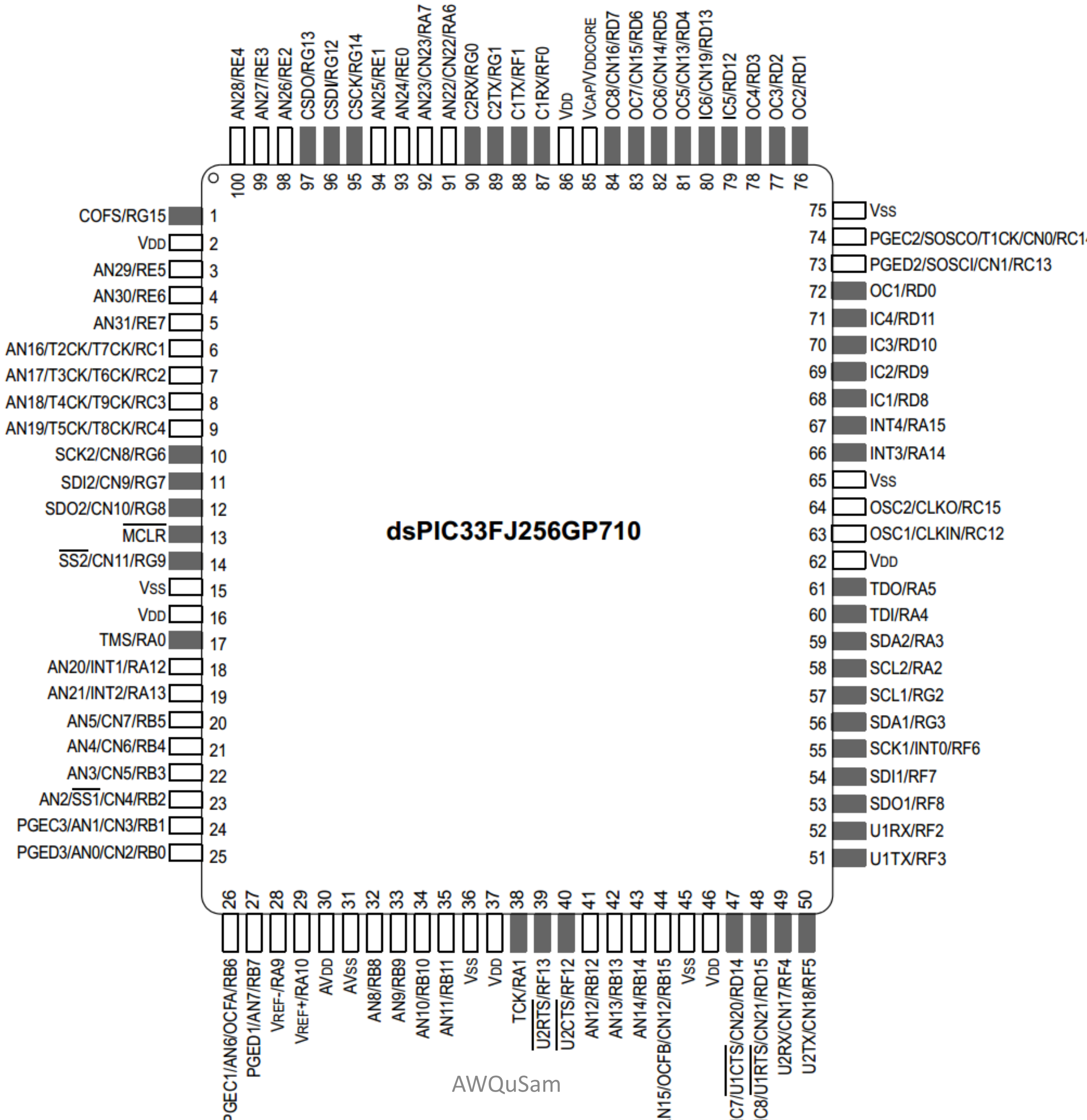
AWQuSam Engineering

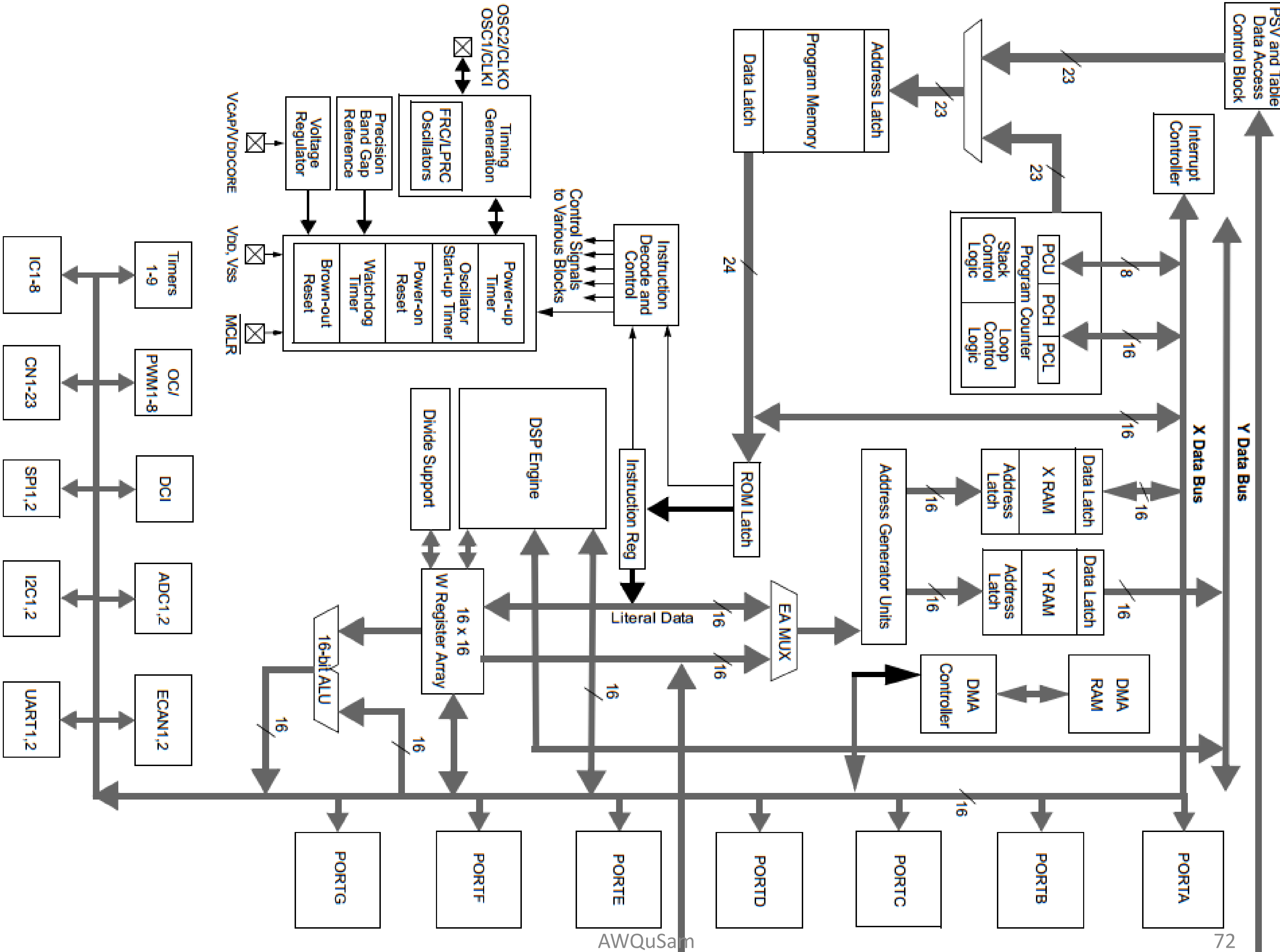
Thanks Each of You

Additional Slides

Power System




dsPIC33FJ256GP710
COFS/RG15
VDD
AN29/RE5
AN30/RE6
AN31/RE7
AN16/T2CK/T7CK/RC1
AN17/T3CK/T6CK/RC2
AN18/T4CK/T9CK/RC3
AN19/T5CK/T8CK/RC4
SCK2/CN8/RG6
SDI2/CN9/RG7
SDO2/CN10/RG8
MCLR
SS2/CN11/RG9
VSS
VDD
TMS/RA0
AN20/INT1/RA12
AN21/INT2/RA13
AN5/CN7/RB5
AN4/CN6/RB4
AN3/CN5/RB3
AN2/SS1/CN4/RB2
PGEC3/AN1/CN3/RB1
PGED3/AN0/CN2/RB0
PGEC1/AN6/OCFA/RB6
PGED1/AN7/RB7
VREF-/RA9
VREF+/RA10
AVDD
AVSS
AN8/RB8
AN9/RB9
AN10/RB10
AN11/RB11
VSS
VDD
TCK/RA1
U2RTS/RF13
U2CTS/RF12
AN12/RB12
AN13/RB13
AN14/RB14
AN15/OCFB/CN12/RB15
VSS
VDD
IC7/U1CTS/CN20/RD14
IC8/U1RTS/CN21/RD15
U2RX/CN17/RF4
U2TX/CN18/RF5
U1TX/RF3
U1RX/RF2
SDO1/RF8
SDI1/RF7
SCK1/INT0/RF6
SDA1/RG3
SCL1/RG2
SCL2/RA2
SDA2/RA3
TDI/RA4
TDO/RA5
VDD
OSC1/CLKIN/RC12
OSC2/CLKO/RC15
VSS
INT3/RA14
INT4/RA15
IC1/RD8
IC2/RD9
IC3/RD10
IC4/RD11
OC1/RD0
PGED2/SOSCI/CN1/RC13
PGEC2/SOSCO/T1CK/CN0/RC14
VSS
OC2/RD1
OC3/RD2
OC4/RD3
IC5/RD12
IC6/CN19/RD13
OC5/CN13/RD4
OC6/CN14/RD5
OC7/CN15/RD6
OC8/CN16/RD7
VCAP/VDDCORE
VDD
C1RX/RF0
C1TX/RF1
C2TX/RG1
C2RX/RG0
AN22/CN22/RA6
AN23/CN23/RA7
AN24/RE0
AN25/RE1
CSCK/RG14
CSDI/RG12
CSDO/RG13
AN26/RE2
AN27/RE3
AN28/RE4


PSV and Table Data Access Control Block
Y Data Bus
X Data Bus
Interrupt Controller
23
23
23
8
16
16
16
16
PCU
PCH
PCL
Program Counter
Stack Control Logic
Loop Control Logic
Data Latch
X RAM
Address Latch
Data Latch
Y RAM
Address Latch
DMA RAM
DMA Controller
16
16
16
Address Generator Units
Address Latch
Program Memory
Data Latch
24
ROM Latch
EA MUX
16
16
Literal Data
Instruction Decode and Control
Instruction Reg
Control Signals to Various Blocks
16
DSP Engine
Divide Support
16 x 16 W Register Array
16
16-bit ALU
16
OSC2/CLKO
OSC1/CLKI
Timing Generation
FRC/LPRC Oscillators
Precision Band Gap Reference
Voltage Regulator
Power-up Timer
Oscillator Start-up Timer
Power-on Reset
Watchdog Timer
Brown-out Reset
VCAP/VDDCORE
VDD, VSS
MCLR
PORTA
PORTB
PORTC
PORTD
PORTE
PORTF
PORTG
Timers 1-9
OC/ PWM1-8
DCI
ADC1,2
ECAN1,2
IC1-8
CN1-23
SPI1,2
I2C1,2
UART1,2