



The Pressure Master rev A

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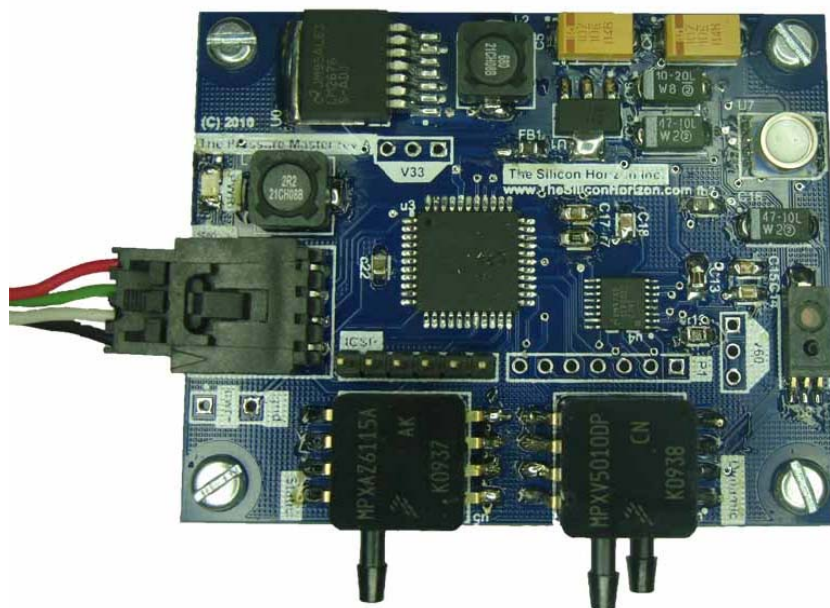


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Liability statement and terms of use

This product is not FAA certified!! (terms of use)

This product is not FAA certified. Therefore this device cannot be used in FAA certified aircraft etc. for flight instrumentation. This product cannot be used for IFR (Instrument Flight Rules) in non-certified aircraft either. This device is intended for UAVs, science experiments, data loggers, and other pressure applications where human life is not dependant on the device's operation. This device cannot be used in life support equipment etc. This device should not be used as a primary means of altitude determination in uncertified aircraft.

Additional terms of liability

By using this product you agree to all terms set forth above. You acknowledge that this device is not FAA certified for use in aircraft or other instances where human life would depend on the operation of the device.

By using this product you further agree to assume all liability and responsibility for any damages that may be incurred from operation or installation of the device in your application.

By using our source code, you assume all liability for the end application.

By using this product you agree to not hold The Silicon Horizon Inc. responsible for damages to personal property, persons, or other such items.

You, the end-user, assume all liability in operating this device.

This product has been developed by The Silicon Horizon Inc. exclusively for commercial / hobbyist applications. It has not been tested for, and The Silicon Horizon Inc. makes no representation or warranty as to conformance with, any military specifications or that the product is appropriate for any military application or end-use. Additionally, any use of this product for nuclear, chemical, biological weapons, or weapons research, or for any use in missiles, rockets, and/or UAV's of 300km or greater range, or any other activity prohibited by the Export Administration Regulations, is expressly prohibited without the written consent of The Silicon Horizon Inc. and without obtaining appropriate US export license(s) when required by US law. Diversion contrary to U.S. law is prohibited.

Overview

Applications – general

- UAVs
- Weather stations
- Uncertified Aircraft (no IFR) as a secondary data system
- Robotics
- Gas flow and analysis
- Near-Space / weather balloons
- Other pressure / temperature applications

Applications -- functional

- Airspeed with humidity compensation from approx 20-300 mph
- Pressure altitude up to 110K feet (Stratosphere)
- Density altitude with humidity compensation up to the Troposphere (approx 36,000 feet)
- Relative Humidity readings with condensation protection
- Temperature readings from -40 deg Celsius to +85 deg Celsius
- Saturation water vapor calculations
- Air density calculations
- Air speed calculations
- Other pressure applications

Application -- data ranges

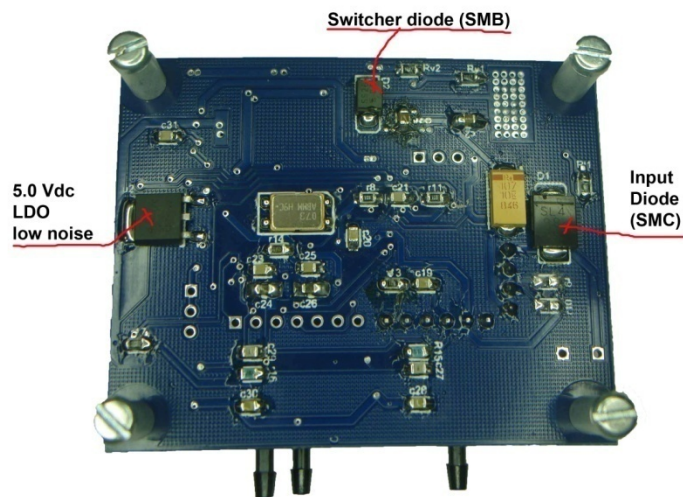
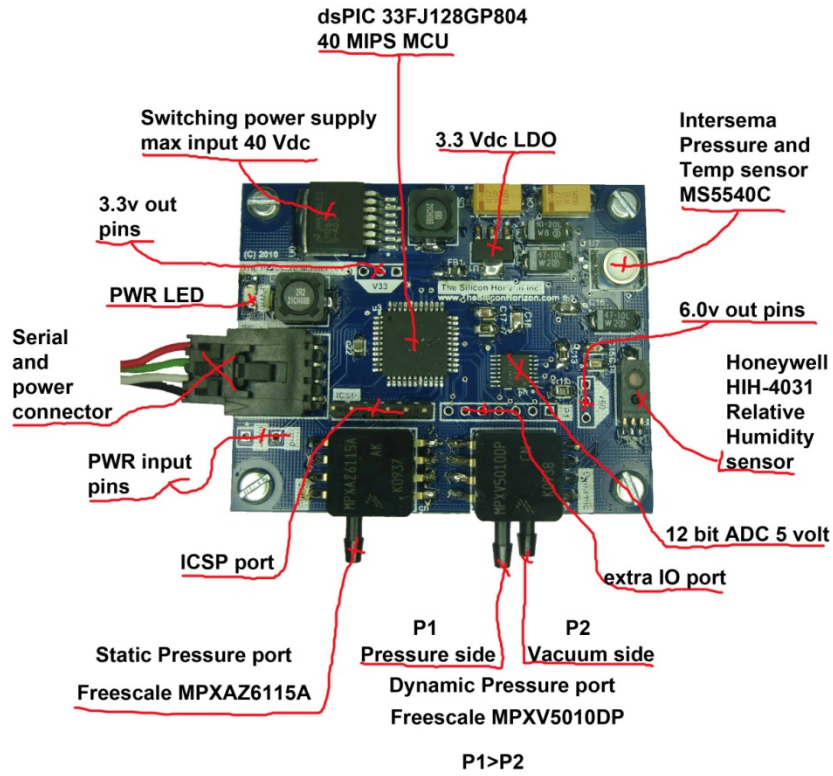
- Differential pressure from 0-10 KPa (Freescale MPXA5010DP)
- Static pressure from 15-115 KPa (Freescale MPXAZ6115Z)
- Static pressure from 1-110 KPa (Intersema MS5540C)
- Relative Humidity from 0 to 100%
- Temperature from -40 deg Celsius to +85 deg Celsius (Intersema MS5540C)

Hardware – overview

- 40 MIPS DSP MCU
- I2C or UART interface on lockable 4 pin molex connector
- 1 x Freescale MPXAZ6115A pressure sensors 15-115 KPa
- 1 x Freescale differential pressure sensor 0-10 KPa
- 1 x Intersema MS5540C pressure sensor 1-110KPa
- Honeywell humidity sensor with condensation protection HIH-4031
- tube ports for the freescale sensors allow pitot and static tubes
- switching power supply - upto 40 Vin DC
- low noise <1% VREG on ADC and sensors
- extra ADC lines and other functions available
- ICSP port for programming
- small 2" x 2.5" size
- Temp stability / compensation for power supply etc.
- 3.3 and 6v DC available for external use (see specifications for max amperage)

Diagrams

Overview - (Part identification)



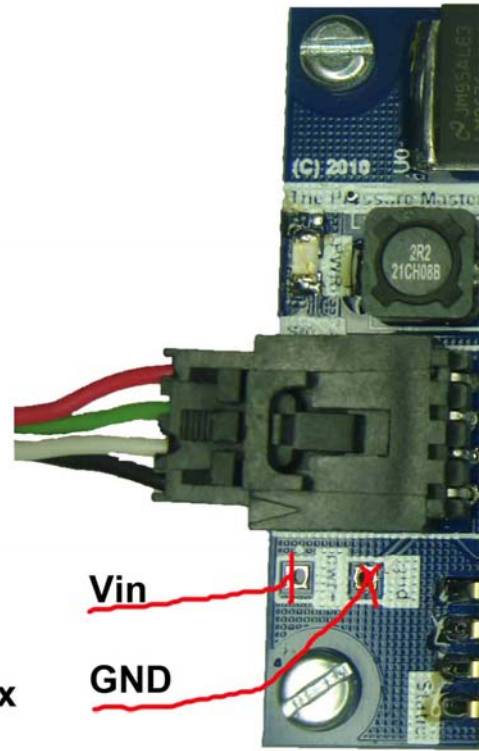
Serial Port diagram

Serial port and power pins

	I2C	//	UART
1. (RED)	Vin	//	Vin
2. (GREEN)	SCL	//	RX
3. (WHITE)	SDA	//	TX
4. (BLACK)	GND	//	GND

**** TX is output from this board**

**Can power board from connector
or from power pins--upto 40 Vdc max**



I2C Port (slave)

The I2C port operates at 100 KHz speed.

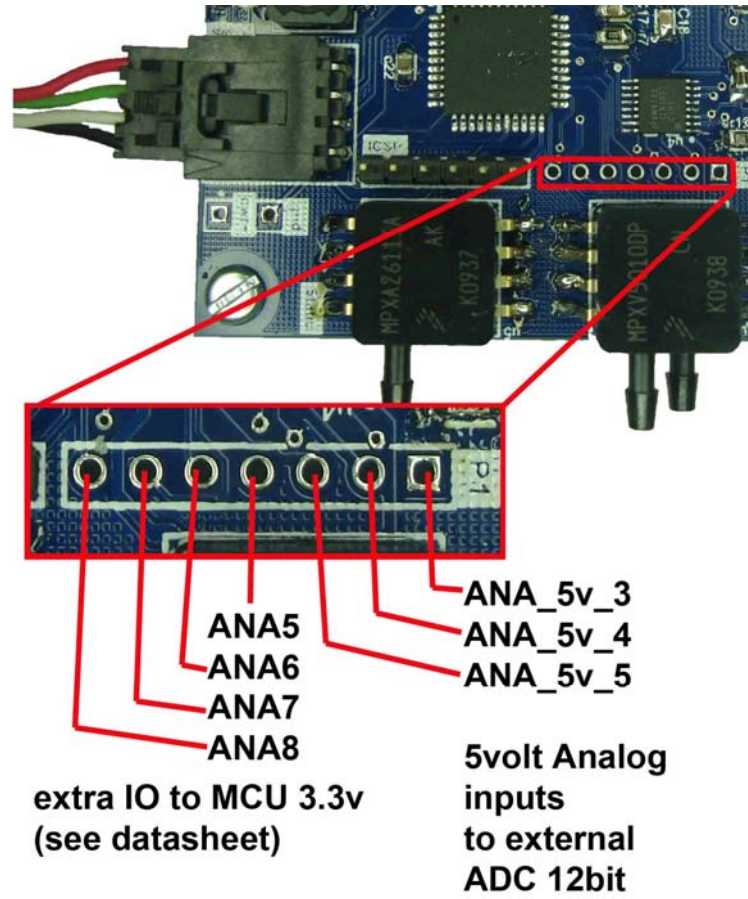
SDA, SCL are internally pulled high.

UART Port

The UART port operates at 57600, 8N1.

The Default output rate is 10 HZ and can be configured by recompiling the sourcecode with custom values. Also see the serial commands section of the manual for more information.

Extra IO pins diagram



dsPIC33FJ128GP804 MCU pin mappings for extra IO pins

AN8/CVREF/RP18/PMA2/CN10/RC2	27	AN8
AN7/DAC1LM/RP17/CN9/RC1	26	AN7
AN6/DAC1RM/RP16/CN8/RC0	25	AN6
AN5/C1IN+/RP3/CN7/RB3	24	AN5
AN4/C1IN-/RP2/CN6/RB2	23	

Operation

UART vs I2C serial

Depending on which version firmware you have selected, the serial port will either be UART or I2C slave mode.

UART mode serial

The UART mode serial port will output data at approx 10 HZ (10 times per second) on the TX line (see diagram for pinouts). The output rate and specific data can be adjusted by either recompiling the sourcecode or sending the proper command to change the data output. The data rate is 57600 BAUD at 8N1.

The Default data output for the UART firmware boards is as follows:

```
$PRMST,  
    staticpressure,  
    dynamicpressure,  
    temp_celsius,  
    pressure_altitude_meters,  
    density_altitude_Meters,  
    airspeed_mph,  
    humidity,  
    airdensity  
    !!!<CR>
```

Example:

```
$PRMST,101325.00,50.00,30.00,5.00,10.00,5.00,33,1.225!!!<CR>
```

(All pressures are in Pa)

UART commands and settings

The following UART commands can be sent to the device on the RX line (3.3v) at 57600 baud, 8N1.

Change data output mode

Command syntax:

@CHMODE,x!<cr>

Where x is the mode number **byte** as follows

- 1 Default data output in one sentence string.
Temp in Celsius, Airspeed in MPH, Altitude in Meters, Pressure in Pascals
- 2 Alternate data output in once sentence string
Temp in Fahrenheit, Airspeed in knots, Altitude in feet, Pressure in Pascals

\$PRMST,101325.00,50.00,30.00,5.00,10.00,5.00,33,1.225!!!<CR>

As above, but with different units.

- 3 Data sent out with descriptions, 1 data element per row with <CR>

101325.00 Pa static pressure<cr>
101322.00 Pa static pressure intersema<cr>
35.0 temp Celsius<cr>

..
Etc.

- 4 Send out calibration data from the Intersema module (for error checking)

W1=56567<cr>
W2=3567<cr>

..
Etc.

GPS altitude fix

A GPS altitude can be send to the module to allow the module to correct for current day conditions.

IE: The known GPS altitude (from a good fix with a low PDOP and high number of SATS) is sent to the module, then the module will take the current pressure with that altitude and calculate what the pressure is at sea level for the current conditions. This is great for local flying and will deviate all functions and data from the U.S. Standard Atmosphere model.

This function should be called on initial startup of the external control system one time only after a good GPS fix (low PDOP and high number of satellites) have been reached.

Command syntax:

@GPSFIX,xxxxxx.xxx!<cr>

Where the altitude is in meters, floating point. IE: @GPSFIX,1133.20!<cr>

I2C (slave mode)

The I2C equipped board differs by 2 pullup resistors on the SDA and SCL lines that the UART version does not have. The firmware is also different.

The I2C bus operates in slave mode, at 100Khz bus speed.

LCD options

It is possible to hook up an LCD to the UART or I2C port, however some custom firmware modifications would have to be done to support that function.

The easiest way to do this would be to have a LCD that operates through UART serial interface. Then the firmware can be modified with the appropriate UART characters to properly display on the LCD with minimal changes to the firmware.

The I2C LCD interface is possible, however the board must be configured as an I2C master, and control the LCD...and that is a much harder task to accomplish.

If the LCD has an internal voltage regulator (5 volt LCD's) then you can use the 6 volt header to power the LCD (upto 500 mA of current).

For 3.3v LCD's with no internal voltage regulator, the board will support upto 250 mA from the 3.3v header.

Powering external modules from the board

The board can power external modules from its switching power supply as long as current ratings aren't exceeded. This can be used to power a LCD or other display.

The maximum current ratings are as follows:

3.3 Vdc 250 mA

6.0 Vdc 500 mA

Pitot and static tubes

Depending on your application and altitude you may use professional or hobbyist pitot and static tubes. A “T” adapter may be used to provide static pressure to both the Freescale static pressure sensor and the static pressure port of the Freescale dynamic pressure sensor.

The temperature and pressure for the Intersema module should be provided either in a “wet” compartment (o-rings can be installed on the Intersema module) or with a tube fitting over the Intersema module with different attaching methods. The temperature is used in calculations and should be thought of in your application when positioning the board.

The relative humidity sensor can also be positioned in a “wet” compartment with exposure similar to the Intersema module or the proper hoses can be attached to allow the sensor to sample the relative humidity for humidity compensation.

The “wet” compartment method is ideal for NearSpace balloons and other high altitude experiments. The other components of the board can be protected in the compartment with simple materials (plastic etc) while allowing both the Intersema and Humidity sensors exposure to the environment. Note the operating temperatures of the devices with their respective datasheets.

For other UAV installations, a permanent tube is recommended for the Intersema and humidity sensors, or a boxed environment that allows proper measurement of the air data for temperature and humidity.

Software filtering of data

All data is filtered through a 10 place rolling average filter. This eliminates a lot of noise from the sensor sources, leaving simply the error of the sensors as specified in each sensor datasheet.

If faster updates are needed, the rolling average filters can be lowered to 5 or less, which will result in faster calculations of data, and allow much faster update rates (with more noise as a result).

The Freescale pressure sensors use FIR filters for better filtration since it is read at a higher rate. The Intersema sensor uses the rolling average filters since it is more data intensive to read from that sensor.

See data graphs for more detailed performance values.

Theory

Pressure Altitude

Pressure altitude is calculated from the Troposphere through the Stratosphere with the following equations:

Non-isothermal Layer

Troposphere
Stratosphere1
Stratosphere2

$$ALT \text{ (meters)} = \left[\frac{\left(\frac{P_{current}}{P_{bottom \text{ of layer}}} - \left[\frac{(Lapse \text{ Rate}) * (R_{air})}{(G_{accel \text{ gravity}})} \right] * T_{bottom} \right) - T_{bottom}}{(Lapse \text{ Rate})} \right] + ALT_{initial}$$

Isothermal Layer

Tropopause

$$ALT \text{ (meters)} = \left[\frac{\ln \frac{(P_{current})}{(P_{bottom \text{ of layer}})}}{\left[- \frac{(G_{accel \text{ gravity}})}{(R_{air}) * (T_{bottom \text{ of layer}})} \right]} \right] + ALT_{initial}$$

Where...

R = 287.05 ideal gas constant of air in J/kg * deg K

G = 9.80665 m/sec² Acceleration due to gravity

Lapse Rate = temperature gradient (ie: for Troposphere -0.065) in deg K/meter

Density Altitude

Density altitude is calculated in the **Troposphere only** and the calculation is not valid for any other atmospheric layer.

Troposphere

$$ALT = \left(\frac{T_{bottom\ of\ layer}}{Lapse\ Rate} \right) * \left[1 - \frac{1000 * R_{air} * T_{bottom\ of\ layer} * Density^{\left[\frac{(Lapse\ Rate)}{(G * M) - (Lapse\ Rate)} \right]}}{M * P_{pressure\ static\ initial}} \right]$$

Where:

L = Temperature lapse rate in deg K/km (varies for each atmospheric layer)

G = 9.80665 m/s² Acceleration due to gravity

R = 8.31432 gas constant of dry air in J/mol*deg K

M = 28.9644 Molecular weight of dry air, gm/mol

Pressure static initial = 101325 Pa (standard atmospheric sea level for Troposphere)

T_{bottom of layer} = 288.15 deg Kelvin at sea level (standard atmosphere)

Density = Density of air as calculated previously

Air Density

The air density is calculated from the Troposphere to the Stratosphere.

It is compensated for relative humidity by figuring the saturation vapor of water, and the pressure from water vapor.

Saturation vapor of water

$$E_s = 6.112 * e^{\left(\frac{17.67 T}{237.3+T}\right)} \quad \text{where T is in Celsius}$$

Pressure due to water vapor

$$P_{water\ vapor} (Pa) = \frac{\left(\frac{Relative\ Humidity}{100}\right) * (E_s)}{100}$$

Air density

$$\rho \left(\frac{kg}{m^3}\right) = \left(\frac{P_{dry\ air}}{R_d * T}\right) + \left(\frac{P_{water\ vapor}}{R_w * T}\right)$$

Where...

T = Temperature in Kelvin

R_d = 287.05 gas constant for dry air in J/kg * deg K

R_w = 461.495 gas constant for water vapor in J/kg * deg K

Relative Humidity = Rel humidity in whole percentage (ie: 80)

Air Speed

Humidity compensated air speed is calculated from the Troposphere to the Stratosphere.

$$P_{dry\ air} (Pa) = P_{static} - P_{water\ vapor}$$

And finally....

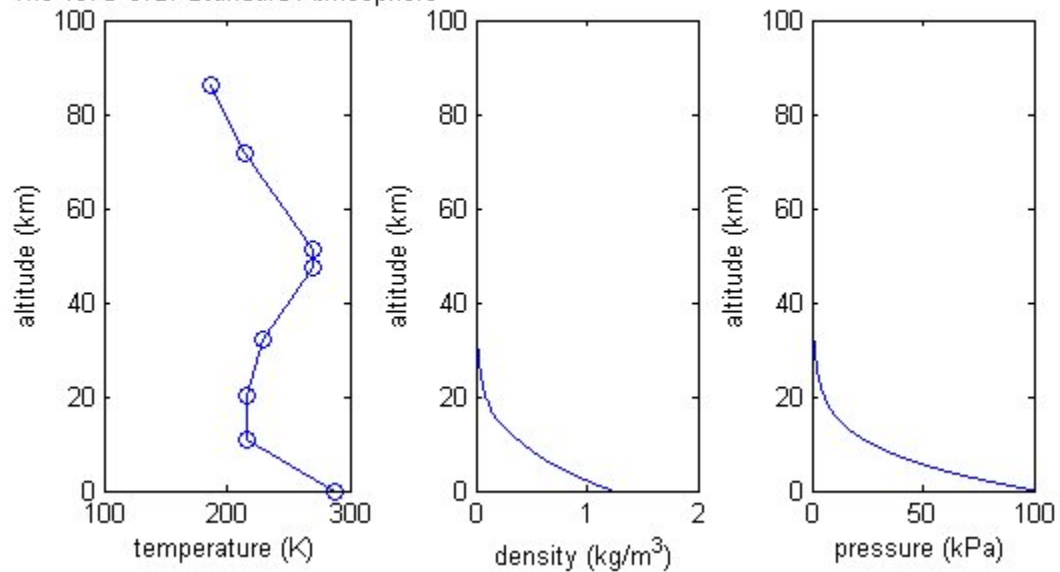
$$Air\ Speed\ \left(\frac{m}{sec}\right) = \sqrt{\frac{2 P_{dry\ air}}{\rho}}$$

Misc. Graphs

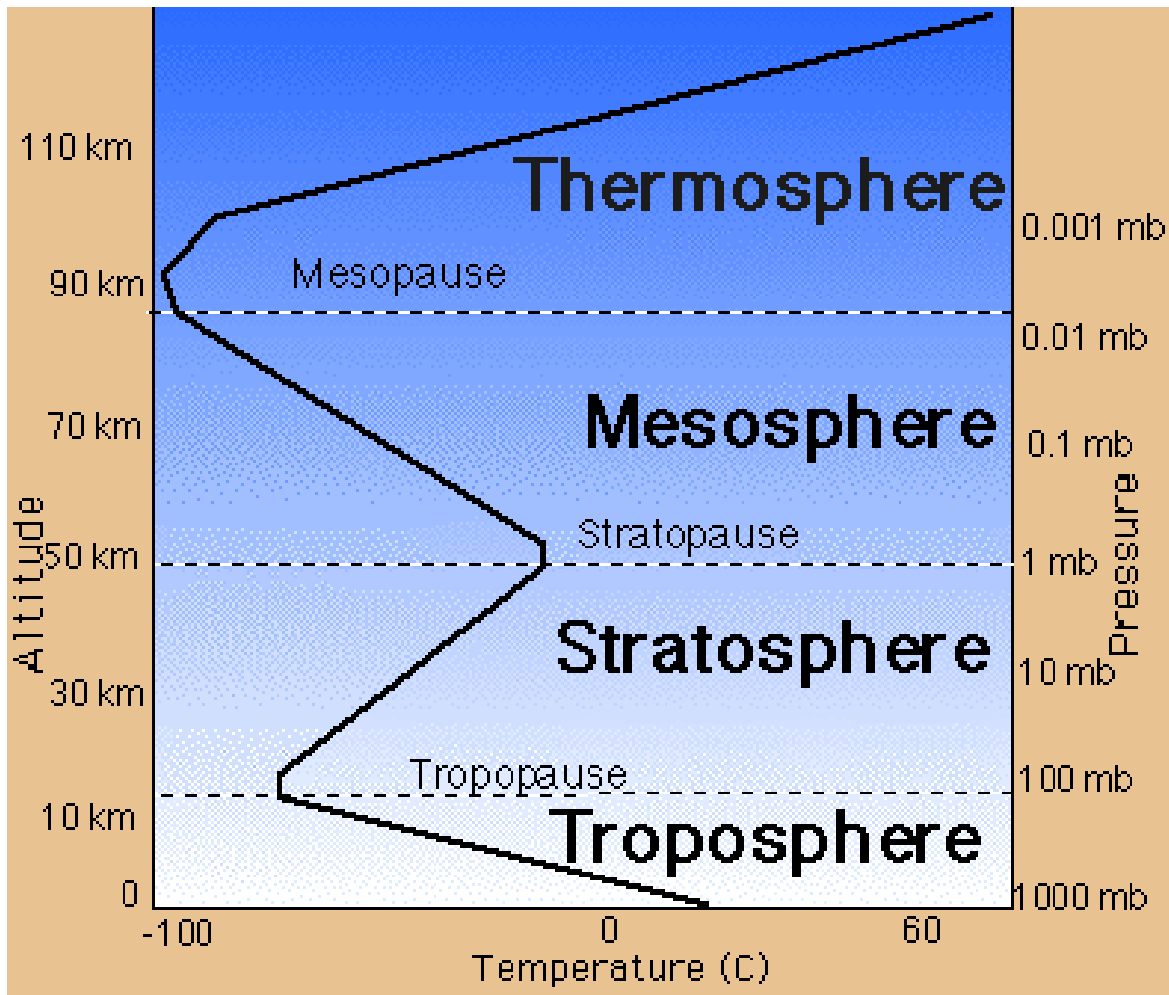
U.S Standard Atmosphere model 1976

Subscript <i>b</i>	Height Above Sea Level		Static Pressure		Standard Temperature (K)	Temperature Lapse Rate	
	(m)	(ft)	(pascals)	(inHg)		(K/m)	(K/ft)
0	0	0	101325	29.92126	288.15	-0.0065	-0.0019812
1	11,000	36,089	22632.1	6.683245	216.65	0.0	0.0
2	20,000	65,617	5474.89	1.616734	216.65	0.001	0.0003048
3	32,000	104,987	868.019	0.2563258	228.65	0.0028	0.00085344
4	47,000	154,199	110.906	0.0327506	270.65	0.0	0.0
5	51,000	167,323	66.9389	0.01976704	270.65	-0.0028	-0.00085344
6	71,000	232,940	3.95642	0.00116833	214.65	-0.002	-0.0006096

The 1976 U.S. Standard Atmosphere

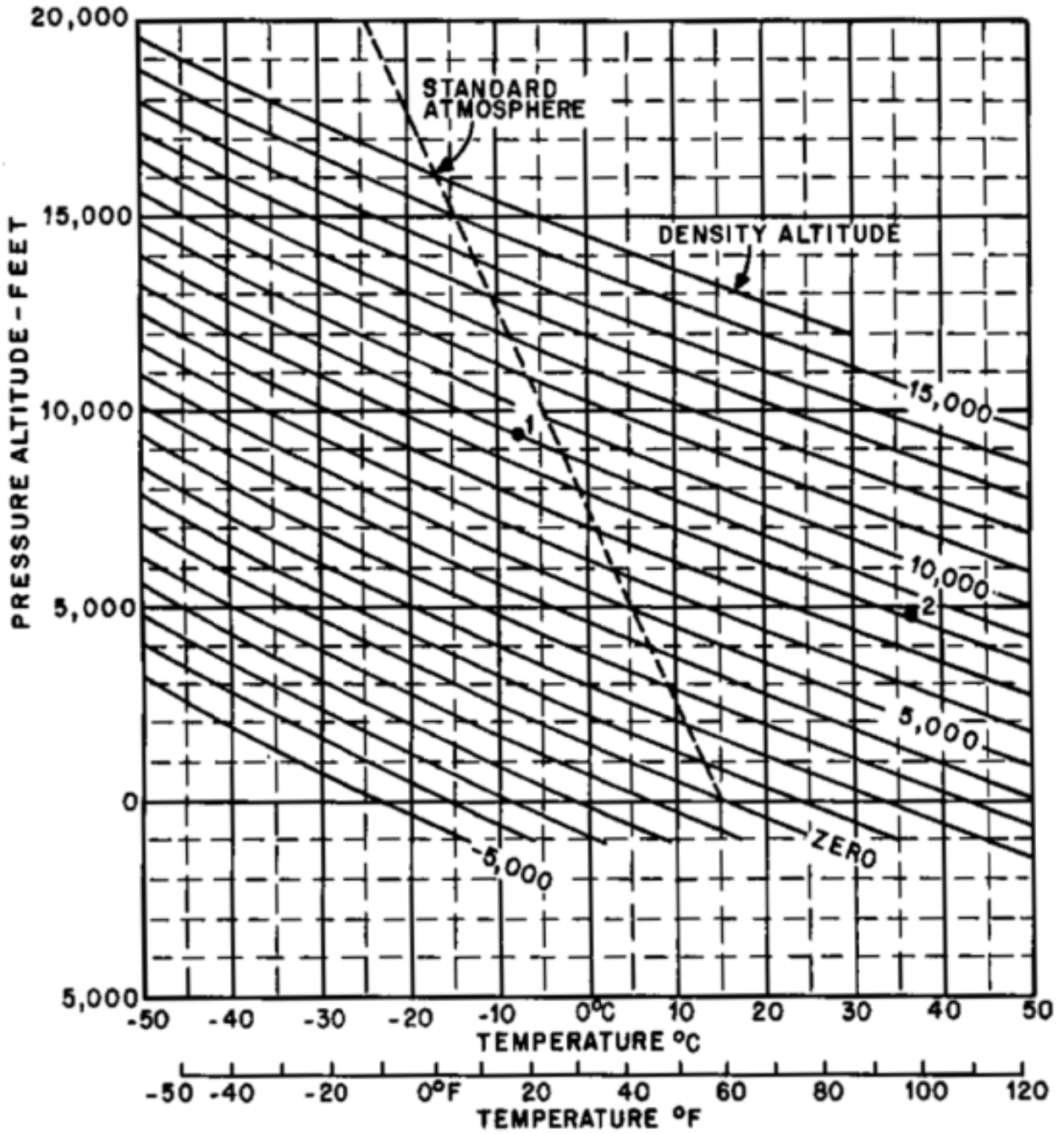


Graphical representation of atmospheric layers

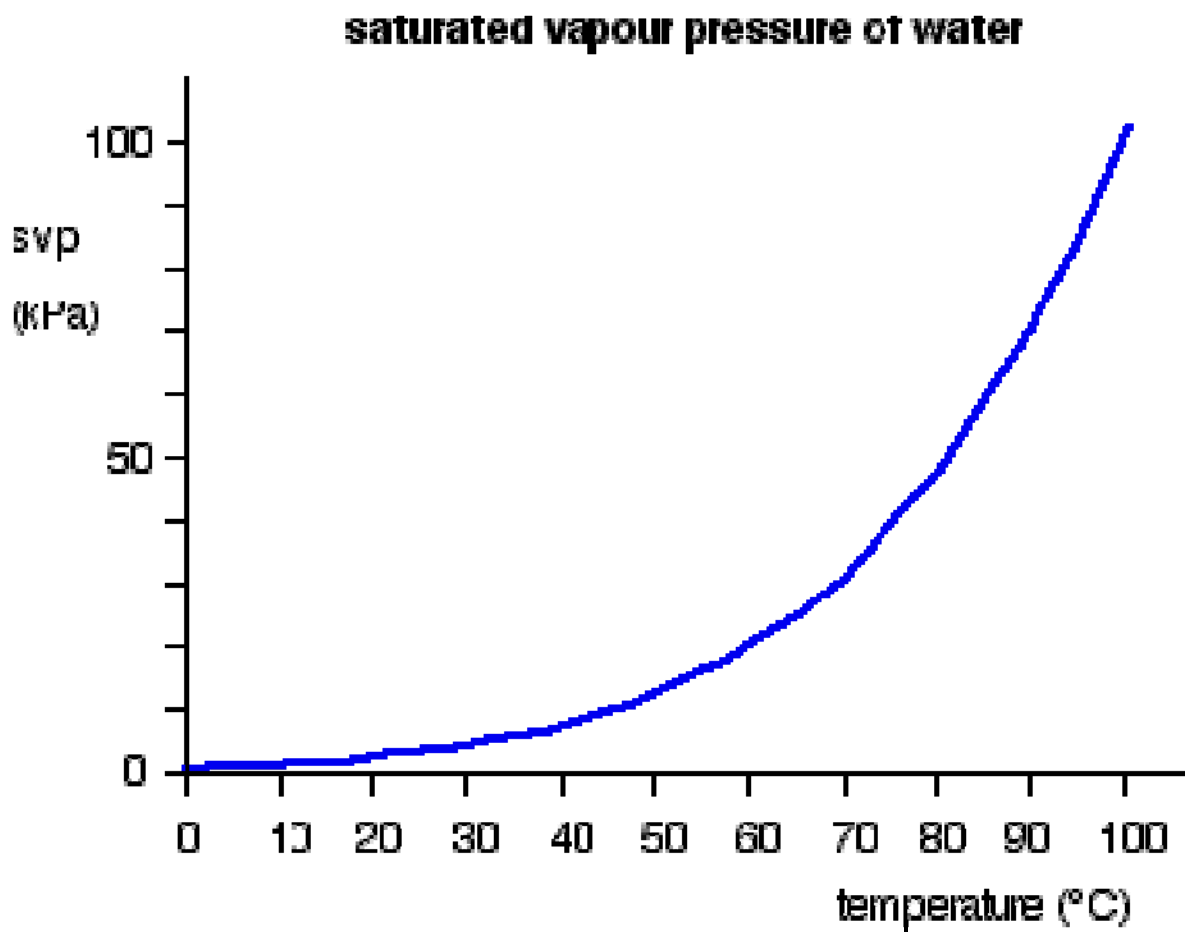


Density altitude chart (only in dry air, uncompensated for relative humidity)

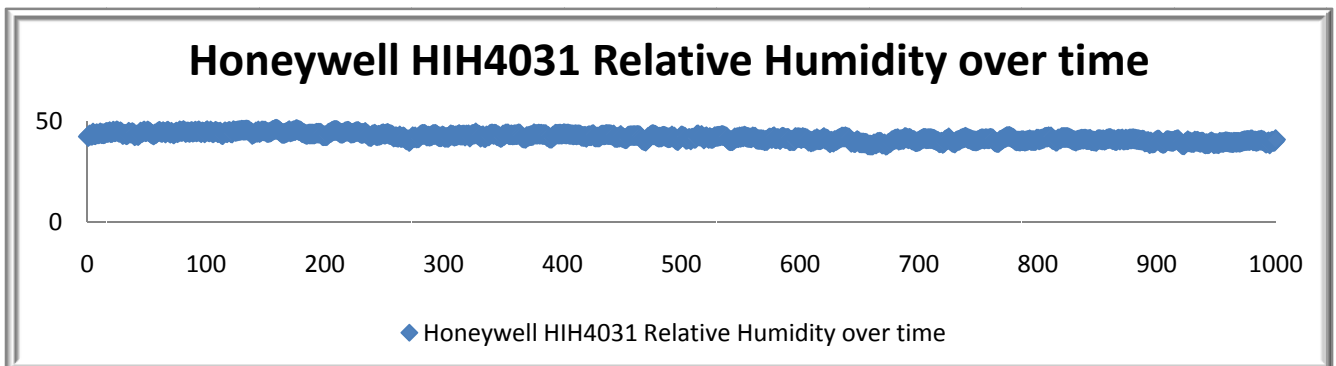
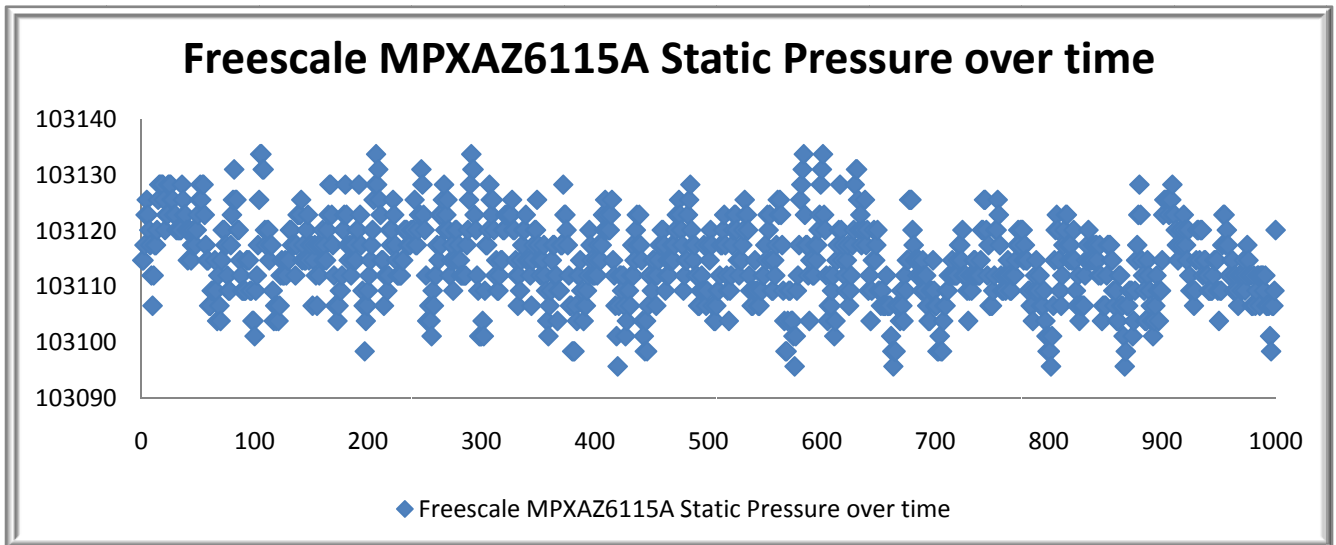
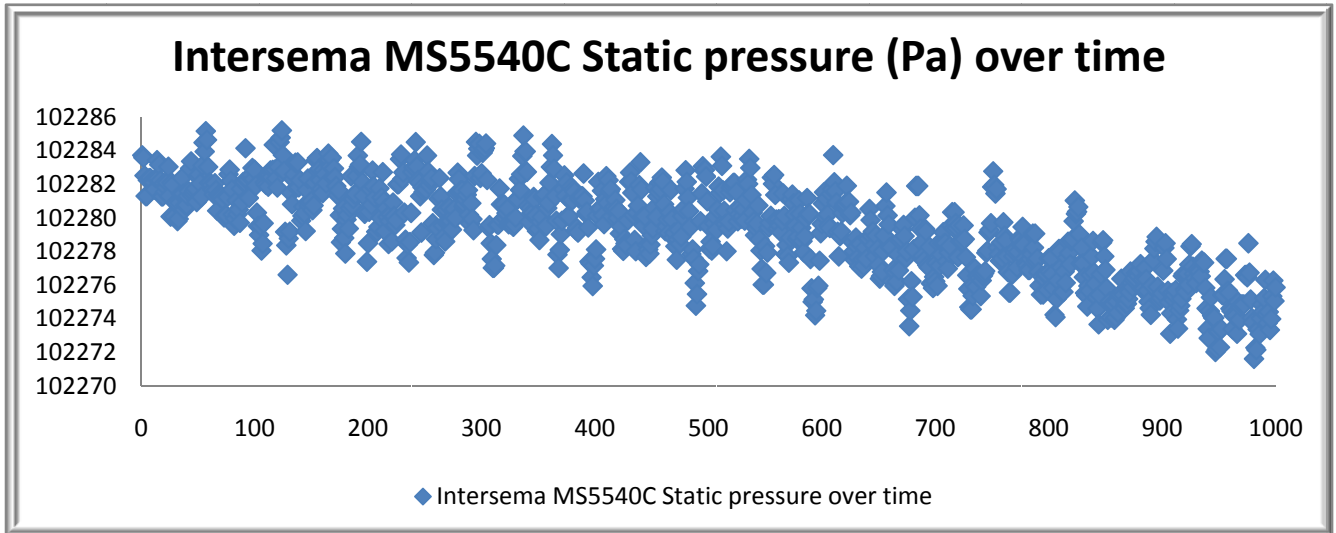
Troposphere only



Saturation water vapor VS Temperature

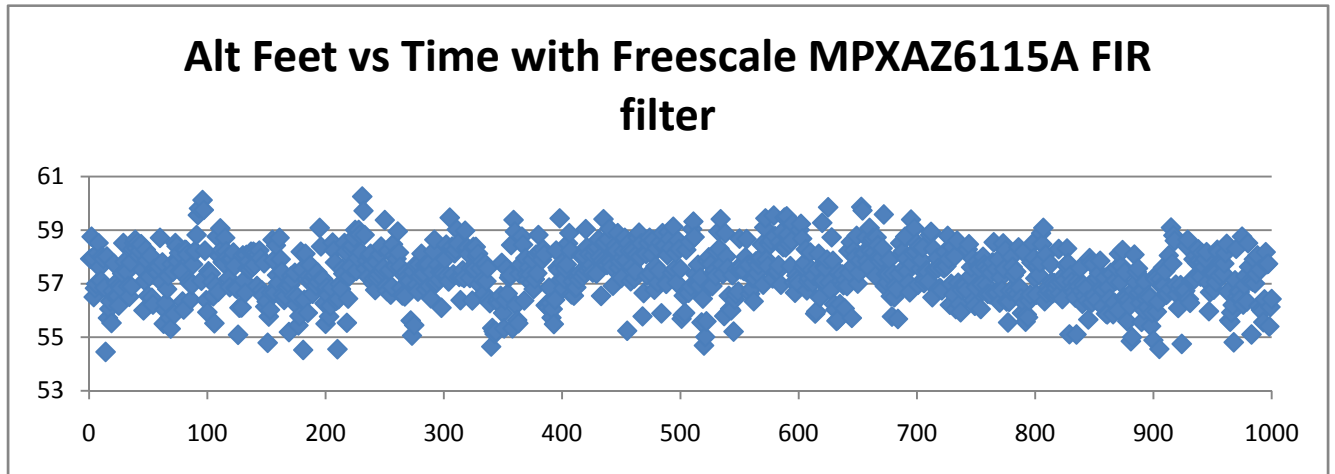


Software filtering output of assorted sensors over time (Rolling Average)

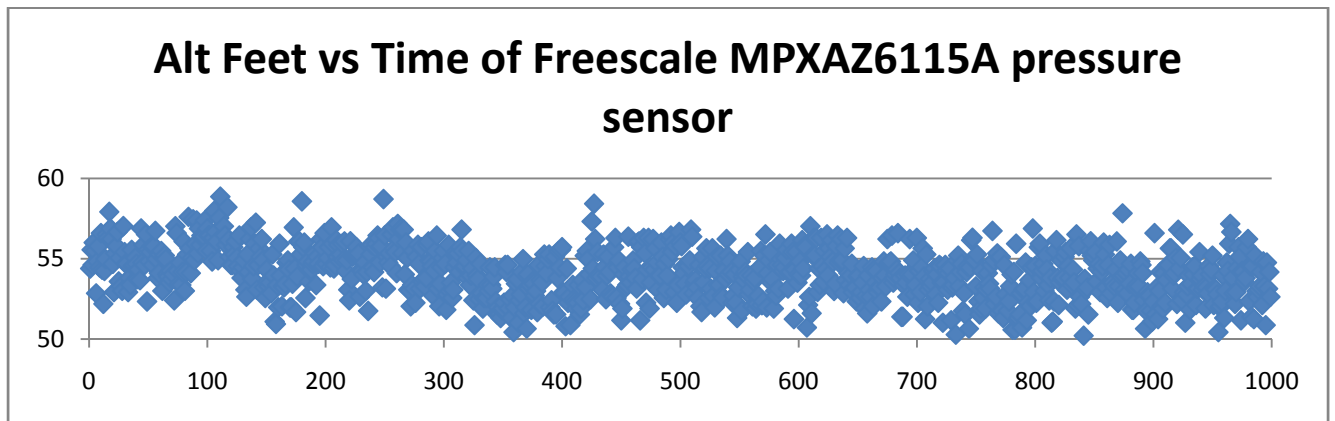


Altitude output using Freescale MPXAZ6115A

FIR filtering (default in firmware)

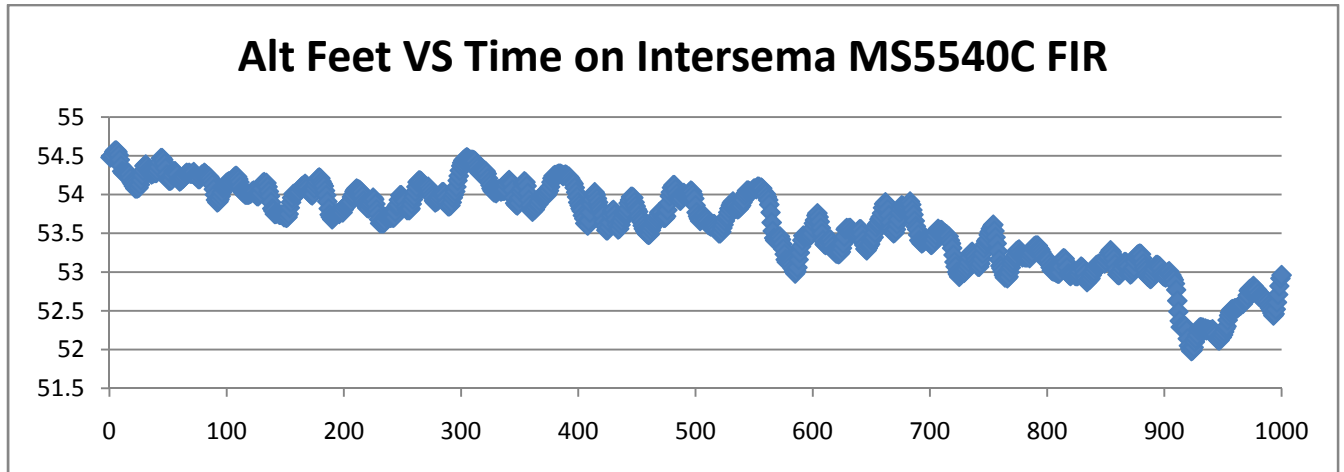


Rolling Average Filtering

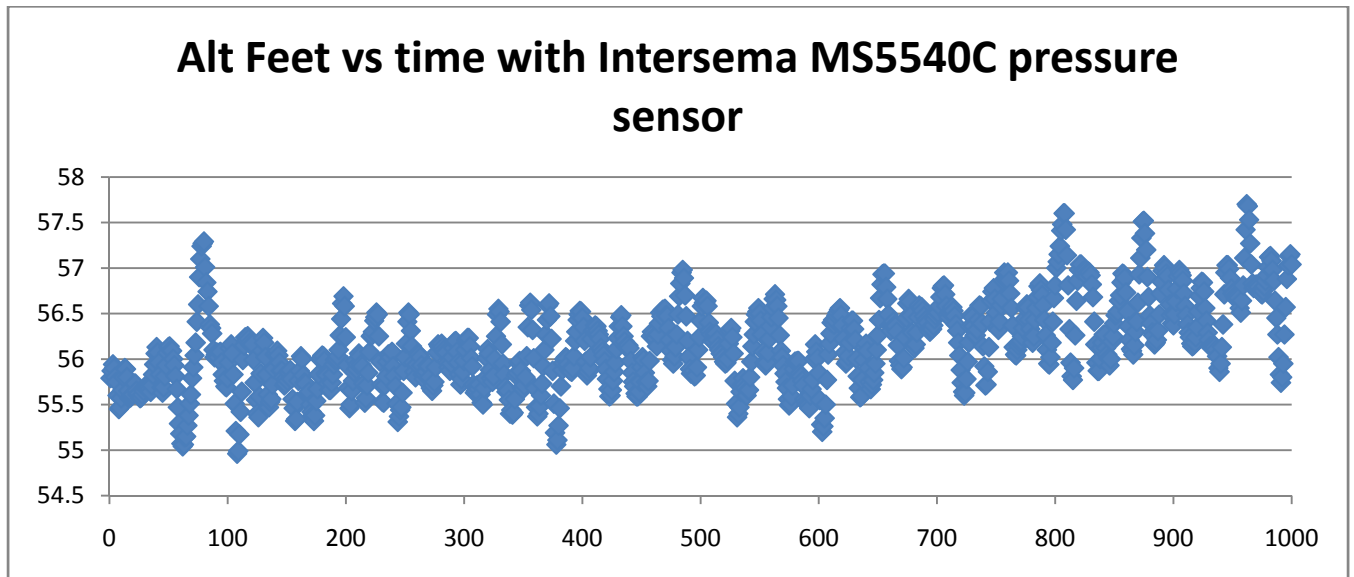


Altitude output using Intersema MS5540C sensor

FIR filter



Rolling Average filter (Default in firmware)



Device specifications

General

Item	Min	Max
Voltage input DC	9.0	40.0
6.0 Vdc line current		500 mA
3.3 Vdc line current		250 mA
Temperature	-40 deg Celsius	85 deg Celsius

Data lines

Item	Min	Max
SDA, SCL	0	3.3 Vdc
RX, TX	0	3.3 Vdc
I2C data rate		100 Khz
UART data rate		57600 BAUD, 8N1
ANA_5V*		5.0 Vdc analog input only
ANA*		3.3 Vdc IO as configured

Sensor operating ranges

Item	Min	Max
Freescale MPXAZ6115A	15 KPa	115 KPa
Freescale MPXA5010DP	0 KPa	10 KPa
Intersema MS5540C Temp	-40 deg Celsius	85 deg Celsius
Intersema MS5540C Pressure	1 KPa	110 KPa
Honeywell HIH-4031 Humidity	0 % RH	100 % RH

Sensor accuracy and precision

Please consult the individual sensor datasheets for accuracy and precision information.