EE 318 Electronic Design Labratory-I, Elec Engg Dept., IIT Bombay, APRIL2007

Variometer

Group D15:
Suyog Gupta (04d07016), Nipun Dave (04d07023),
Shreyas Sagri(04d07024)

Supervisor: Prof. Dipankar

Abstract:

We intend to design a variometer which can be used by paragliders for identifying thermals and other such potential lift sources. This rising air keeps the paraglider aloft as it does not have any other power source.

Introduction:

Although human beings could readily detect abrupt changes in vertical speed, their senses do not allow them to distinguish lift from sink, or strong lift from weak lift. The actual climb/sink rate could not even be gauged, unless there was some clear fixed visual reference nearby. The invention of the variometer (by Max Kronfeld) moved the sport of gliding into a whole new realm. Variometer measures the rate of change of altitude by detecting the change in static pressure as altitude changes. The most useful forms of lift (thermal and wave lift) are found at higher altitudes and it is very hard for a pilot to detect or exploit them without the use of a variometer.

The variometer generates an audio tone whose frequency depends on the rate of lift or sink. This audio signal allows the pilot to concentrate on the external view instead of having to watch the instruments, thus improving safety and also giving the pilot more opportunity to search for promising looking clouds and other signs of lift.

The variometer also provides the paraglider with other data such as the actual height, temperature, time of flight, date and time. It can also transmit data regarding the present position of a paraglider to the base station so that the station can co-ordinate the paragliders to avoid a lethal mid-air collision. It can also store the flight data for later review by paragliders.

Requirements:

The minimum requirements of a variometer are:

1. Sensitivity of minimum 1m/s so that the paragliders can discern the strong lift region from the weak lift region in a thermal as the pilot wants to spend the maximum amount of time in the strongest part of the thermal.
2. Audio output indicating the rate of lift or sink
3. It should have small form factor so that it can be strapped onto the arm of the paraglider.
4. It should have low power consumption so that it lasts on a set of rechargeable batteries for atleast 10 hours.
5. It should have sufficient memory to store flight data such as the time, height, rate of change of height and other such flight details.

Design Approach:

Block Diagrams:

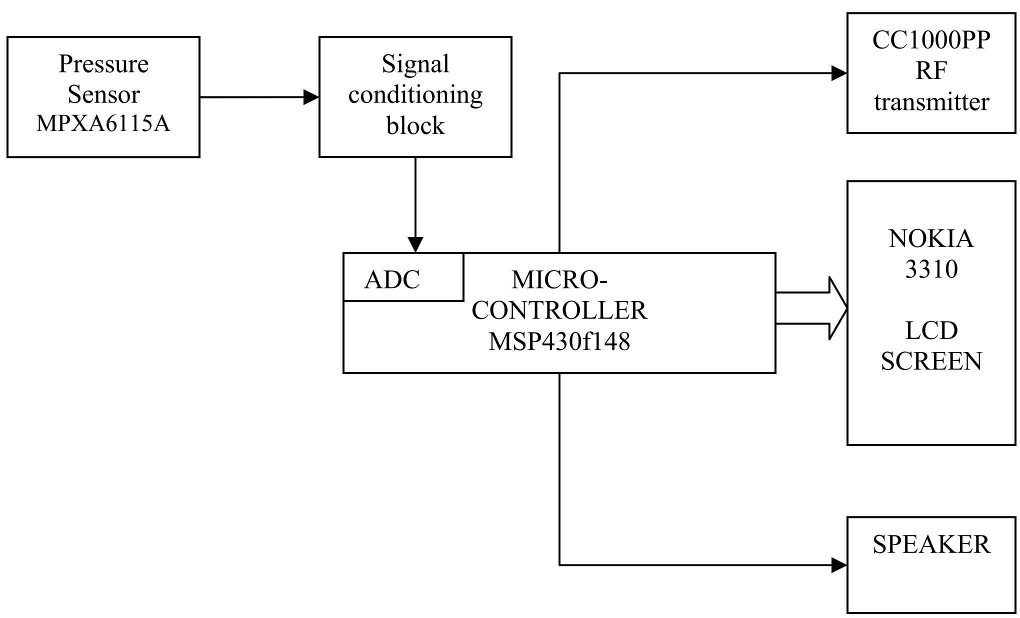

Fig.1 Circuit Block Diagram

Signal Conditioning Block:

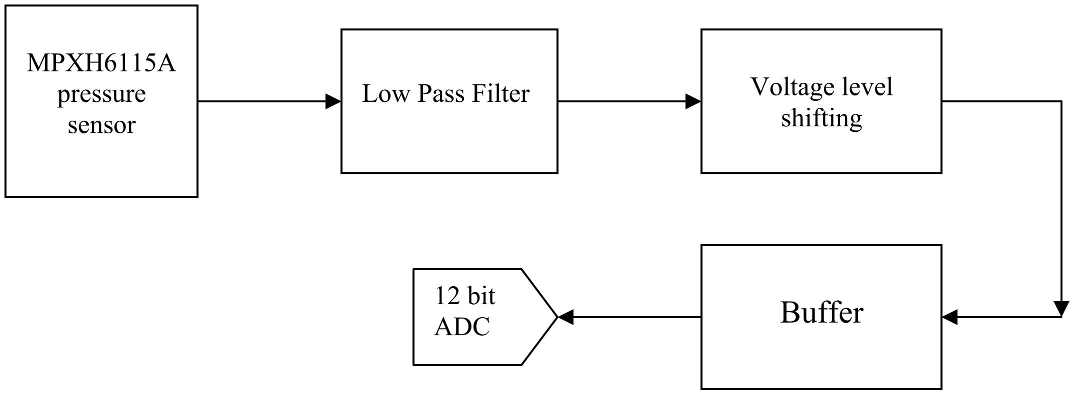

Fig.2

Components:

Pressure Sensor:

The pressure sensor MPXA6115A has been chosen because of the following features:

1. *Sensitivity:* 45.9mV/kPa which enables us to detect changes in pressure by 4.4 Pa which corresponds to a change in height of 30cm.
2. *Pressure Range:* 15kPa – 115kPa which corresponds to a height range of 0 – 13.6km which is much more than the heights usually reached by paragliders.
3. *Supply Current:* Typical current consumption of only 6mA.
4. *Linear Response*

Microcontroller:

The microcontroller MSP430f148 has been chosen because of the following features:

1. *Ultra-low power consumption*: At 3V and 1 MHz, 2mA in active mode and 360µA in low power mode. Wake-up from low power mode in less than 6µs.
2. *12 bit A/D Converter:* Internal reference, sample-and-hold, and conversion channel for internal temperature sensor. When the ADC is not actively converting, the core is automatically disabled and reenabled when needed, thus reducing the power consumption.
3. *48kbit Flash Memory*
4. *Inbuilt Temperature Sensor:* It can measure temperatures in the range -50ºC to 100ºC.
5. *Small LQFP package*

RF Module/Serial Communication :

The CC1000PP module has been chosen because of the following features:

1. *Plug and play module* for the ChipCon CC1000 RF transceiver IC.
2. *Power supply Range:* 2.1 – 3.6V which is coincident with the microcontroller's power supply.
3. *Low Power Consumption:* The 433MHz module has maximum current consumption of 24mA in the transmitting mode and 9.7mA in the receiving mode. It also has a special power down mode with only 100nA current consumption.
4. *Programmable output power:* Output power of Transmitter is programmable in the range -20 to 10dBm. (set to 8dBm in the module)
5. *Small size:* The module measures 28x20mm only.
6. *Interfacing:* Only 3 pins are required for the interface between the module and the microcontroller.

Note: - Due to lack of time and need to develop another microcontroller board (for the receiver chip), we have not implemented the RF module though we have the code ready. Instead we have developed a serial link between the microcontroller and a PC. We use MAX 232 IC for the same and transmit data through the UART mode. The circuit diagram is as follows.

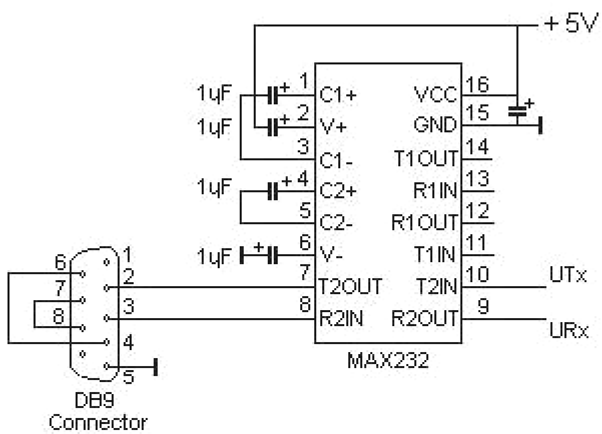

Fig.3 Link between MSP430f148 and Computer

LCD Screen:

The Nokia 3310 LCD screen has been chosen because of the following features:

1. *Low Power Consumption:*
2. *Supply Range:* 2.7–3.3V and hence compatible with the microcontroller power supply.
3. *Small Display size:* The screen measures 38x35mm only.
4. *Only 1 External Component needed:* 10µF. capacitor.

Li Ion Battery:

Li Ion batteries have been chosen because of the following features:

1. *Power:* 2200mAh which results in a running time of approximately 44 hours assuming worst case current consumption of 50mA.
2. *Easily Rechargeable*
3. *Small in size*

Hardware Implementation:

Schematic Diagrams:

Microcontroller Schematic:

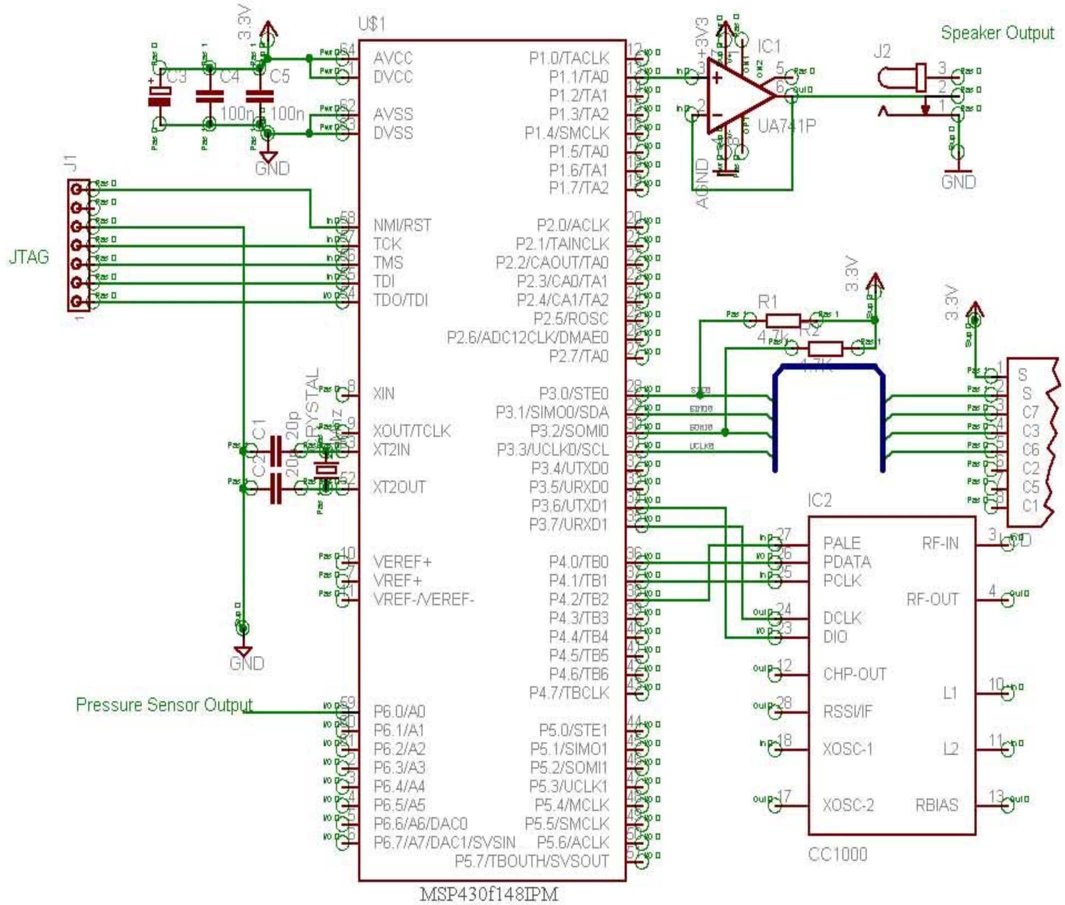

Fig.4 Microcontroller Schematic

Signal Conditioning Schematic:

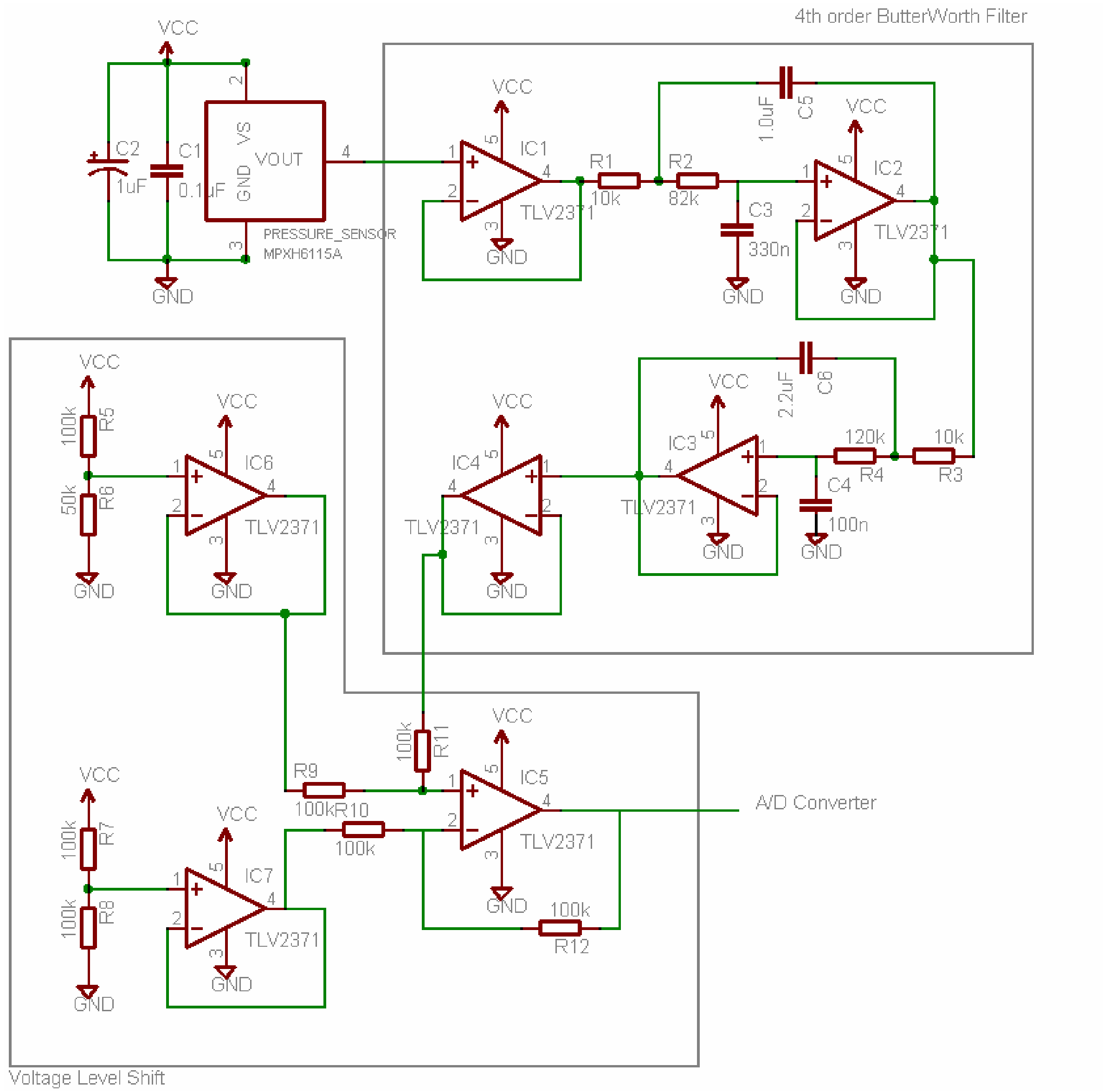

Fig. 5 Signal Conditioning Schematic

Low Pass Filter:

For the Variometer-altimeter, only relatively slow variations in height (~3m/s) are of significance. Consequently, there is a need to filter out the rapidly varying signals from the sensor output before feeding it to the Analog to Digital Converter. The low pass filter also serves to remove the high frequency noise signals riding on the input sensor signal.

The low pass filter is implemented using a 4^{th} order Butterworth filter in a Sallen-Key configuration giving a passband gain of 0dB. The 3 dB frequency of the Butterworth filter is chosen as 10Hz since the signals of interest do not vary very rapidly with time.

The simulated response of the filter is shown in figure 5.

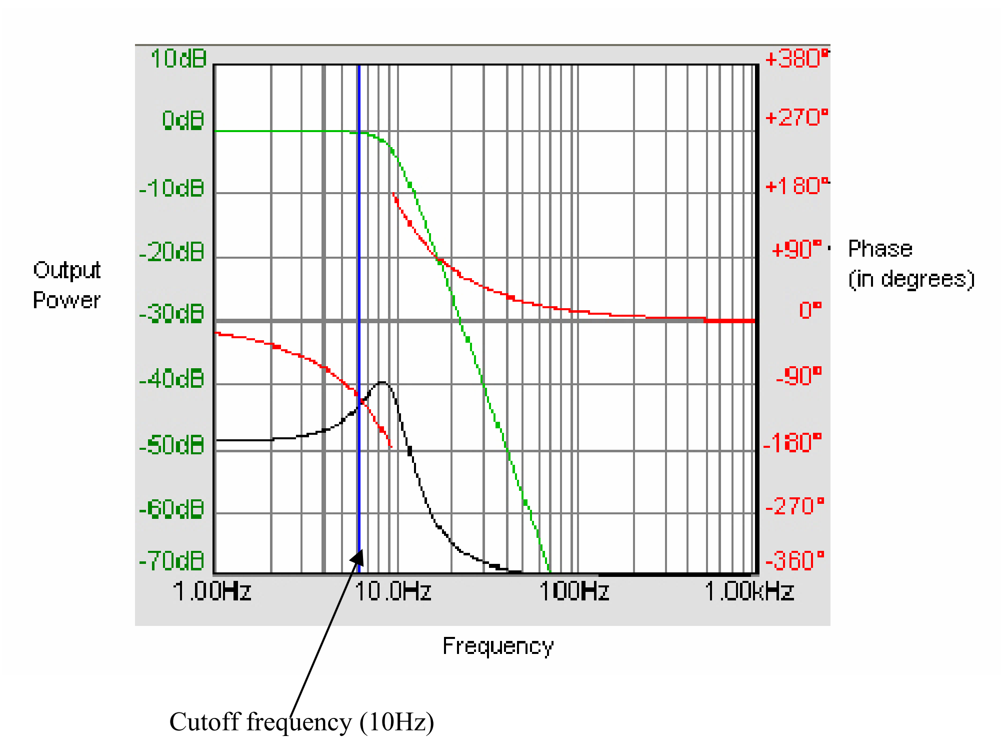

Fig. 6. Amplitude and Phase Response of the Low Pass Filter.

Voltage Level Shifting:

The applied voltage to the sensor is 5Vdc. For this supply voltage, the transfer function of the MPXH6115A pressure sensor is as given in figure 6 below. For our application, it can be safely assumed that the maximum pressure measured will be the pressure at sea level ~100kPa, since the pressure decreases with altitude.

Also, the maximum height (minimum pressure) that a paraglider may reach can be taken to be around 16000ft with the barometric pressure at this height being approximately 55kPa. Since the V_{out} varies linearly with the absolute pressure, the output voltage will always lie in range of ~ 2V to 4.2 V.

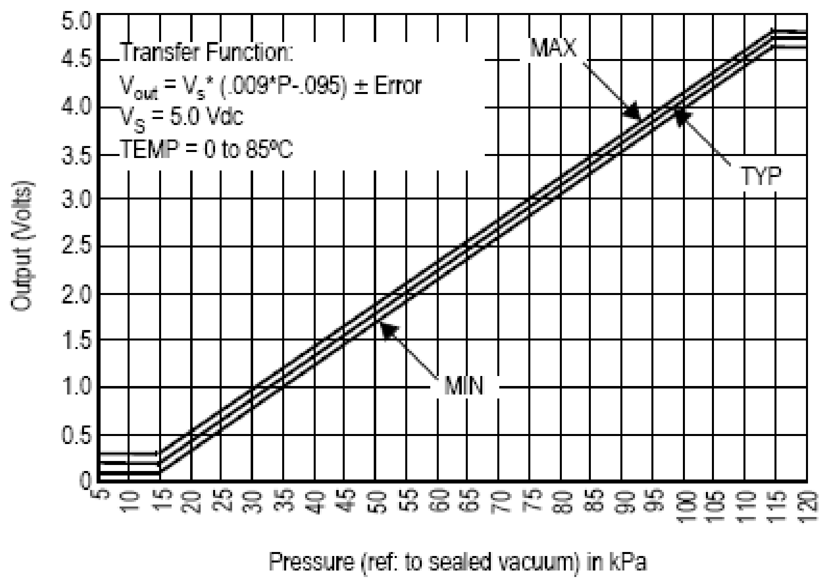

Fig.7 Pressure Sensor Transfer Function

However, V_{ref}, the reference voltage to the Analog to Digital Converter (ADC) of the µC (MSP430f148) cannot exceed the µC supply voltage of 3.3 V. Hence the output of the low pass filter (LPF) must be DC shifted in order to bring the it in the range of 0V-3.3V. In our implementation, we have DC shifted the output of the LPF by -1V so that the input to the ADC lies in the range ~ 1 – 3.2V.

Software Implementation:

- The ADC is programmed to take 16 samples of the filtered pressure sensor output every 50ms. These samples are then averaged out and only the average is considered. This results in an increase in the effective number of bits by 2. Thus we have 14bits of resolution resulting in sensitivity of 0.2mV.
- In the time period between the sampling, the microcontroller is run in Low Power Mode 0.
- The calculation of height, rate of change of height and temperature and update of LCD display is done in interrupt subroutines.
- The output of Timer B is varied to provide the variable frequency audio output.
- The flight data is transmitted only when the change in the location is beyond a threshold which can be set by the user.
- The Timer A is used to calculate the flight time.

Formula for obtaining the height from the pressure:

$$H = 44388.3\ (1 - P / 1012.9)^{.19026}\ \text{m}$$

Where H is expressed in metres
P is expressed in kPa.

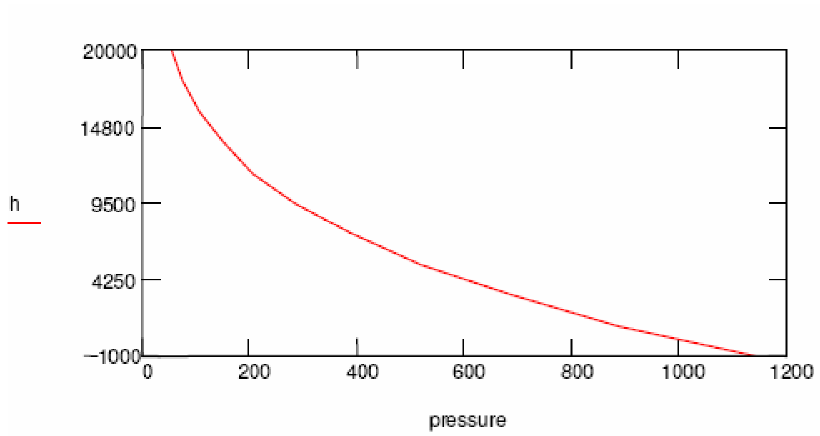

Fig. 8 Variation of Height with Pressure

Control Hardware:

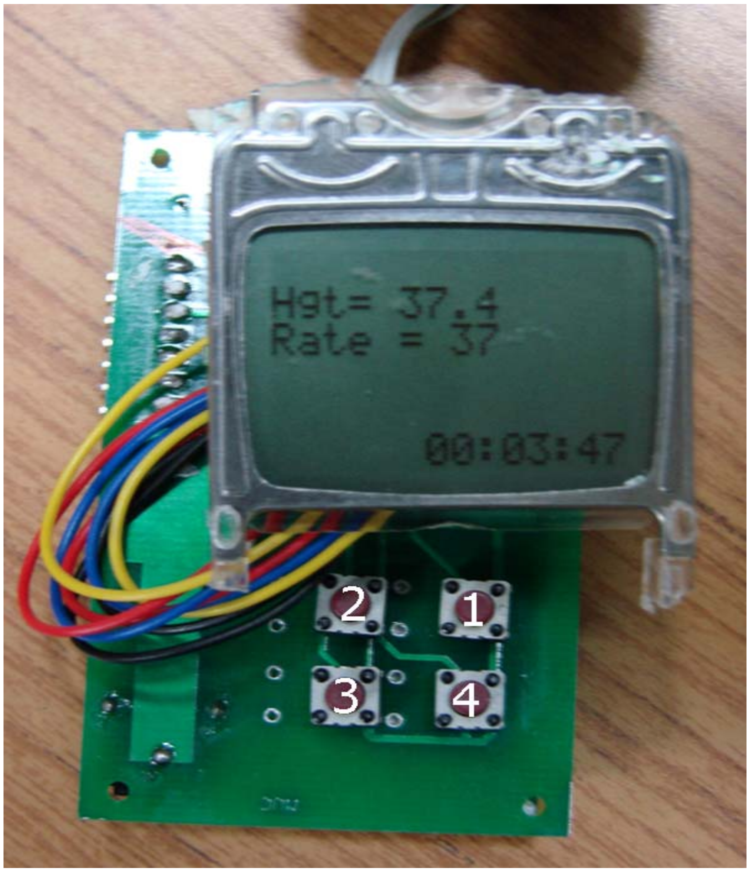

Fig.9 Variometer

1. A master On/Off switch is provided which can be used to shut off the system when not required.
2. An audio On/Off switch enables the user to switch off the audio function when not desired.
3. This switch can be used to start and stop the timer to measure the time of flight.
4. This switch is not implemented as of now.

Suggestions for further Improvement:

1. GPS could be added onto the board so that all the 3 co-ordinates of a paraglider are known and not just the height.
2. Wind speed, ground speed, direction/ heading and wind direction could also be determined and shown on the device.
3. A memory card could be added so that one can store a lot of flight data of many flights.
4. It could be made to run on solar power.
5. The RF data sent from other pilots can be used to warn a paraglider about another's proximity.

References:

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[2] http://www.amontec.com/lcd_nokia_3310.shtml
[3] http://www.ti.com
[4] http://www.iar.com/
[5] http://www.freescale.com