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Penetrometer for Soil and Snowpack Characterization

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Soils form an essential element in the ecosystem. It is important to know how well the soil will perform as a filter of wastes, as a home to organisms, as a location for buildings etc. An important tool used to characterize soil, is penetrometer. Variants of penetrometer are also used for studying snowpack parameters like hardness, temperature, density etc. These parameters are used to determine the stability of the snowpack in relation to its avalanche potential. The paper discusses design of a low cost, versatile PIC (Programmable Intelligent Computer) based, battery operated, portable, and programmable penetrometer developed by the authors.

Key Words: Penetrometer, Programmable Intelligent Computer, Soil, Snowpack

INTRODUCTION

Penetrometer is defined as a device which penetrates smoothly after impacting the soil surface or a snowpack with an initial velocity, continuously measures one or more of the properties and transmits them to be recorded onboard[1]. Penetrometers are used to determine the resistance to penetration of a soil or a snowpack. Penetrometers can be applied for general soil research, checking an artificial compaction of soil, changes in snow conditions in changing climate, to understand stability of snow and determining what it would take for a particular area of snow to become unstable, resulting in an avalanche etc. Penetrometer is one of the most widely used tool for estimating resistance to root growth in soil, and may also be used for detecting layers of different soil strength[2].

Penetrometers are used to establish the thickness of different strata when investigating the suitability of site for construction works. Information concerning the physical properties of soils is also important for soil characterization, which is used to access the bearing capacity and to analyze stability problems[2]. Soil penetration resistance is an important mechanical property that can be used as an indicator of soil compaction and is important in determining the least limiting water range[3].

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Snow has an important role in hydrological and climatologically cycles, both globally and locally. It is important to study snowpack (snow cover duration, extent and also structure) and changes in snow conditions in changing climate. Snow properties can vary widely over small distances, both vertically within a snowpack and horizontally over space. The detection and classification of snow layers are extremely important when determining the stability of the snowpack in relation to avalanche potential. Layers, which commonly form between 0 and 0.15 m below the snow surface, consistently create significant snowpack weaknesses. Also snowpack stability is important tool for travellers. Thus a snowpack is characterized to understand, its stability and determining what it would take for a particular area of snow to become unstable, resulting in an avalanche. Therefore an evaluation of current avalanche conditions by investigating various parameters is called *avalanche forecasting*. It is predicted on the assumption that instability in snowpack can be recognized and interpreted.

The different variables that affect the snowpack are pressure, temperature both inside and outside the snowpack, and the breaking down of the individual snow crystals. When the crystals are piled-up, the pressure can be quite great, especially on something as fragile and unstable as a snow crystal. This pressure causes the crystals' fragile points, the branches, to break off and get compressed. In turn, the snowpack's thickness will decrease while the density increases.

High resolution snow Penetrometer, or Snow Micro Pen (SMP), provides a technique to quickly measure snow penetration resistance and gain information on snow stratigraphy without opening a snow pit. This instrument measures the penetration resistance of snow faster and at a higher resolution[4]. The SMP is a motor-driven, constant speed micro penetrometer which generates high resolution data, sampling approximately 250 measurements of hardness (penetration resistance) per mm. SMP is capable of discriminating between different crystal types and different layers[5].

Sophisticated Penetrometers especially for characterization of a snowpack are not commercially manufactured in India. Thus they have to be imported at a high cost.

A low cost, PIC (Programmable Intelligent Computer) based Penetrometer has been developed that can simultaneously record the hardness and temperature profile of the pack.

EXPERIMENTAL

The hardware concept of the system is shown in Fig. 1. The designed Penetrometer is a low cost, versatile, PIC (18F452) technology based, battery operated, portable, and programmable system, with 10-bit resolution. PIC 18F452 acts as a master controller and sends the signals in terms of variable speed to another microcontroller (PIC16F84A) to drive a stepper motor connected to penetrometer probe . connected to the tip of the probe is a force

sensor (Kistler FSH 9203) and a temperature sensor (AD590). Signals from these sensors are conditioned and presented to the inbuilt ADC of the master microcontroller. The PIC begins processing the signal from the sensor inputs and processed digital output is passed to the LCD for real time display. This data gets recorded on 256 MB MultiMediaCard (MMC) Secure Digital (SD) card. The stored data can be downloaded to a PC through Card reader that is connected through Universal Serial Bus (USB) port. The system is largely based on programmable chips, further expansion or modifications can be implemented in the system without the need for major hardware changes.

The control program is written in Reduced Instruction Set Computing (RISC) based assembly language for PIC 18F452 and 16F84A. The software is able to show the real time values from the analog channels for immediate analysis. The software implementation can be categorized in three parts. First part consists of selecting the name of data file and speed of the probe and sending these values to secondary microcontroller (16F84A) for driving the stepper motor.

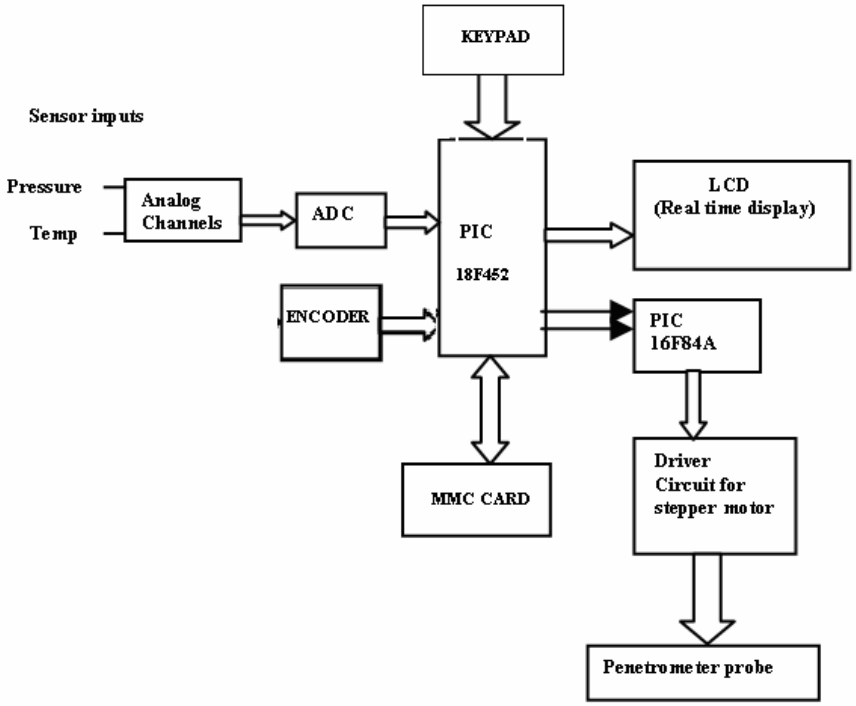

Fig. 1: Block diagram of hardware design

A separate routine is written for motor control mechanism. Second part is the programming for analog to digital conversion and for real time operation with the system and final part is storing the acquired data in MMC Card. This data can be transferred to Personal Computer (PC) through USB based MMC card reader for

further analysis. The data is acquired at the fixed rate irrespective of the speed, which is programmable. Thus a higher speed is used where lesser resolution is required, and a lower speed is employed for higher resolution. Each sample of data contains hardness and temperature value of snowpack.

General procedure

The snow pen is fixed on the snowpack with a bipod stand and command is given by piano switch to start the motor. The motor makes the pen to penetrate in the pack to pre-programmed length, or till it hits the ground or other hard material. The probe returns automatically to its original position. While the probe is in downward motion, hardness and temperature is measured at a fixed rate.

Detection Method

Detection is done by force sensor and temperature sensors attached to the tip of the snow micro pen designed to acquire this data in MMC card.

RESULTS AND DISCUSSION

Soil and Snowpack characterization yields valuable information that can be used by experts for variety of tasks. Penetrometer is an important tool that can be used for this type of characterization. The authors have developed a low cost, versatile, Penetrometer that may become an import substitute for Indian market. It has all the features of a snow micro pen for measurement of snow hardness. Trials on snowpack have shown no compromise on the accuracy of this pen vis-à-vis commercially available pen. This is in spite of its much lower cost, on account of indigenous technology used. In addition, it can measure temperature of snowpack as well. Profile of hardness and temperature of a snowpack as acquired by the developed penetrometer is shown in Fig. 2. The abrupt rise in hardness at the end of snowpack indicates beginning of soil-layer. The intermediate small change in hardness of the snowpack is indicative of beginning of a new snow layer. The fall in temperature as the Penetrometer probe traverses past the upper layer of snow, is also on the expected lines. The upper layer of snow has higher temperature on account of warmer ambience in day time. The uniformity of temperature along the inner layers indicates the insulating nature of snow. This type of profile indicates no slippage of the layers, suggesting a very low probability of snow avalanche. This has been cross verified by studying the snowing pattern on the snowpack. On account of PIC used for processing the signal, the power consumed is also lesser and thus it can be used for larger number of trials without recharging the battery. Alternatively, a smaller battery may be used.

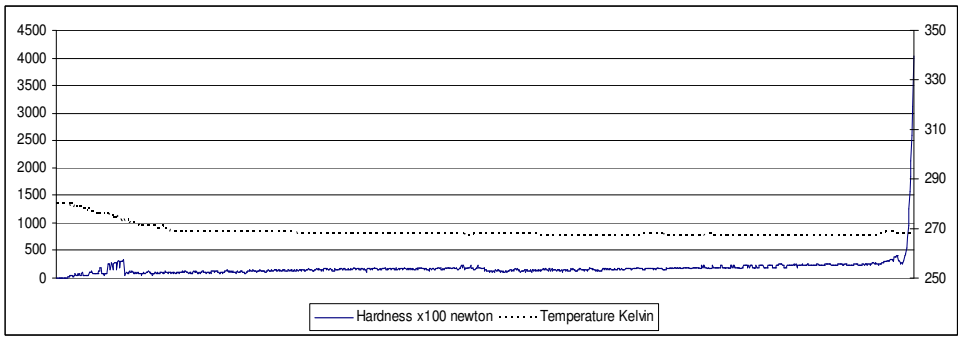

Fig. 2: Profile of hardness and temperature of a snowpack

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