PROJECT OBJECTIVES:

The main objective is to develop a model which detects the soil moisture using EC-10 soil moisture sensor and activate a pump based on the level of moisture content in the soil. Data acquisition MDA-300CA board is been used which reads the analog values from the sensor probe and activates the pump based on the threshold set. The moisture probe works on the principle of variable impedance that must be measured using the MDA and MICAz mote.

HARDWARE REQUIREMENTS:

MICAz Motes, MDA-300CA, MIB, ECHO-10 Sensor, Resistors - 2 each of 10K ohms, External 3.3 Volts DC supply, Probes, Darlington Transistor array IC ULN2803A, Breadboard, Connecting Wires.

COMPONENTS DESCRIPTION:

MDA300CA: It is an extremely versatile data acquisition board with multifunctional direct user interface, the MDA300CA offers a convenient and flexible solution as shown in Fig. 1. Resistors each of 10K need to be added (soldered) to the MDA300CA board to properly scale the voltage levels of external analog sensors so that the maximum voltage is 2.5 VDC. These resistors form a simple two-resistor voltage divider. It has upto 11 channels of 12-bit analog input, an on-board sensor excitation and high-speed counter. 64K EEPROM for sensor calibration data. Its primary applications are: a) wireless low-power instrumentation, b) precision agriculture and irrigation control, c) weather measurement systems, d) habitat monitoring, e) soil analysis, f) remote process control.

Analog sensors can be attached to different channels based on the expected precision and dynamic range. Mote samples analog, digital or counter channels and can actuate via digital outputs or relays. The combination of a MICAz and a MDA300CA can be used as a low-power wireless data acquisition device or process control machine.

We used the E2.5, A3 and GND pins for providing the Excitation Voltage, Analog Input and Ground respectively. The result of ADC can be converted to voltage using:

Voltage = 2.5 × ADC_READING / 4096

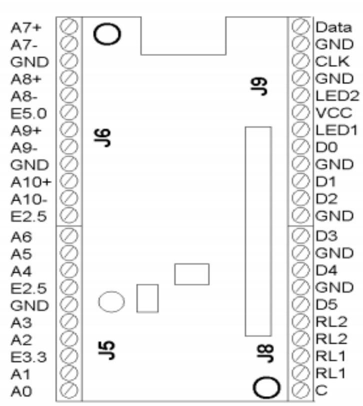


Fig. 1: Pin configuration of MDA300CA

ECHO-10 Sensor:

The EC-10 sensor measures the dielectric constant of the soil in order to find its volumetric water content. Since the dielectric constant of water is much higher than that of air or soil minerals, the dielectric constant of the soil is a sensitive measure of water content. The EC-10 have a very low power requirement and high resolution. This gives the ability to make as many measurements as required (even hourly) over a long period of time, with minimal battery usage. EC-10 sensors require an excitation voltage in the range of 2 to 5 volts. EC-10 are particularly good at measurement of soil moisture in wet conditions but, in dry conditions it needs careful calibration for specific soil type. Also, in the presence of contamination it needs extra calibration. EC-10 sensors are particularly good at measurement of soil moisture in wet conditions.

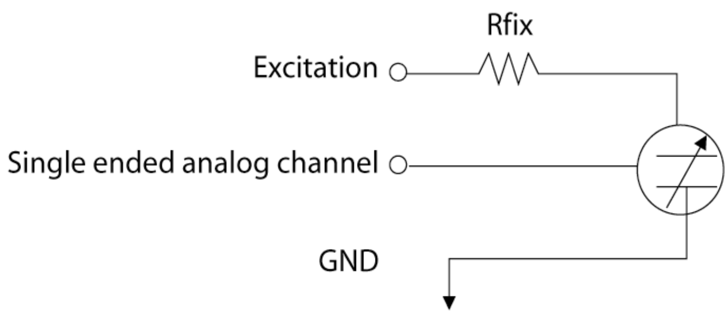


Fig. 2: Configuration

For the EC-10 sensor the current requirement at 2.5V is around 2mA, and at 5V it is 7-8mA.

ECHO-10 Conversion:

```
Conv = ((float)adc) *2.5 /4096;

result = (int)(100*(0.000936 * (conv * 1000) - 0.376) + 0.5);
```

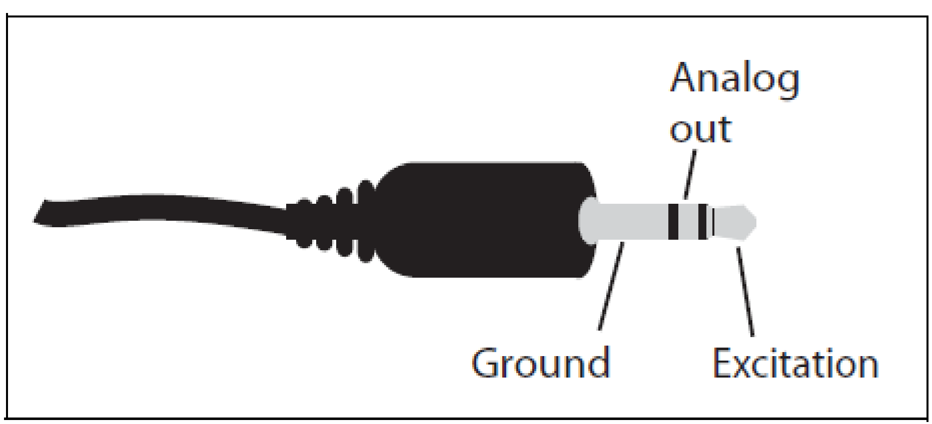


Fig. 3: Stereo Plug Configuration

There are three pins on the ECHO-10 sensor:

1) **Excitation Voltage (White):** The excitation voltage is provided by the MDA300CA board. The sensor needs an excitation of E5.0. By providing the excitation voltage the sensor reads and generates analog values for varying moisture content.
2) **Analog Out (Red):** This pin provides us with the voltage generated by the sensor when it is in dry soil and wet soil. The analog pin is connected to the A3 pin of MDA300CA board.
3) **Ground (Green):** The ground pin is also connected to the GND pin on the MDA300CA board.

Sensor Calibration Values:

Following is a list of the both the millivolt and RAW calibration values for the EC-10, where **θ** is the volumetric water content, mV is the millivolt output of the sensor, and where x is the RAW sensor output.

EC-10:

mV: $\boldsymbol{\theta}$ $(m^3/m^3) = 0.000936mV - 0.376$ RAW: $\boldsymbol{\theta}$ $(m^3/m^3) = 0.000571\,x - 0.376$

Fig. 4: ECHO-10 Sensor Placed in Soil

MICAz mote: The MICAz is a 2.4 GHz Mote module used for enabling low-power, wireless sensor networks. It has a data transmission rate of 250Kbps and its transmission module uses IEEE 802.15.4 standard. MICAz Mote can function as a base station when it is connected to a standard PC interface or gateway board. The MIB520 provides a serial/USB interface for both programming and data communications.

Driver Circuit for Pump: The driver circuit consists of a Darlington Transistor array IC ULN2803A, an external DC supply. Initially we used an NPN transistor to drive the pump but the transistor was getting heated up as the pump needed a current of about 800mA to drive but the NPN transistor circuit was able to provide about 500mA which was insufficient.

So, we decided to use ULN2803A Darlington Transistor Array IC which provides a output of 1.5A when three of the pins, i.e. three Darlington pairs are connected in series as each pair draws a current of 500mA.

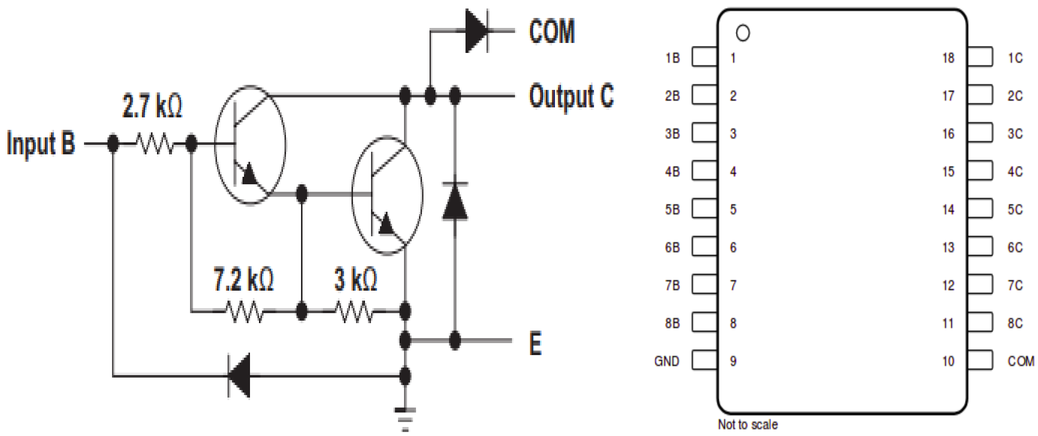


Fig. 5: Functional Block Diagram and Pin Configuration

IC ULN2803A is 18-pin IC with Collector-emitter voltage of 50V and consists of eight high voltage, high current NPN Darlington transistor pairs. In the IC we short the pins 1, 2 and 3 to form two pairs of Darlington and the input from the MDA300CA of 5V as a Excitation voltage is provided from pin E5.0. The pin number 10 is provided with a supply of 3.3V to drive the IC and pin 9 is ground. Then pin numbers 16, 17 and 18 are shorted and then the pump is connected across these shorted pins and 3.3V. The following figure shows circuit diagram for connections:

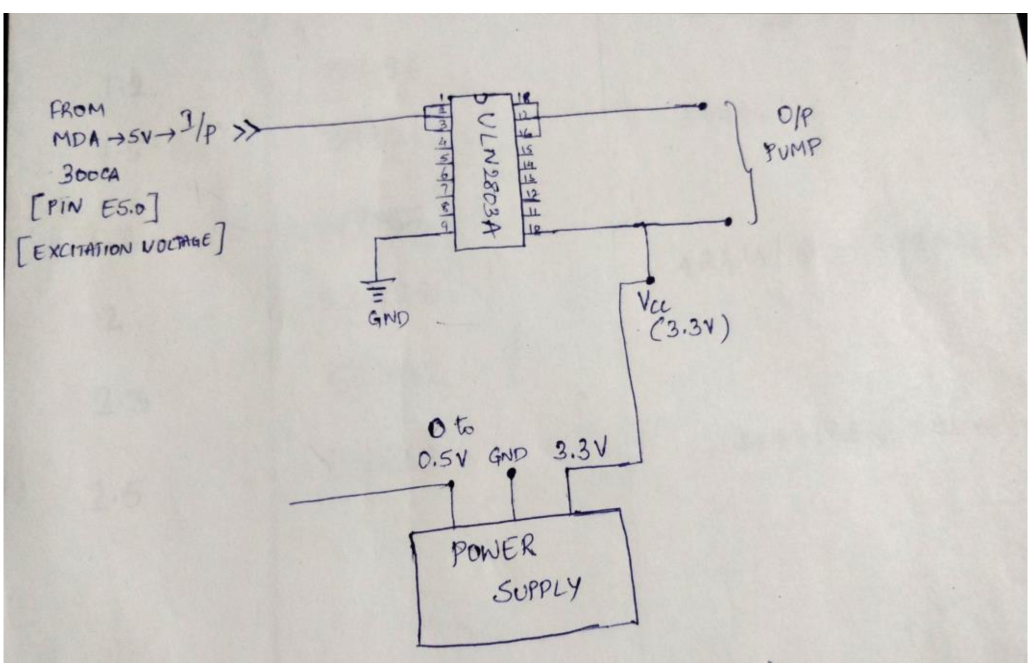


Fig. 6: Circuit Diagram

ISSUES FACED:

1). Getting the excitation value from MDA300CA data acquisition board and finding the necessary code for MDA to get analog input.

2). ECHO-10 Sensor calibration according to the water content and forming a properly analysed result according to the sensing.

3). Driver circuit that can be used for driving the pump was the other issue as we used NPN transistor which can provide current of 800mA but was insufficient for driving pump which needs 1A instead, we then tested UTN2903A IC which provided current up to 1.5A when 3 Darlington pairs are in series as each pair drives 500mA.

4). Integrating the Sensor and MDA board was another task and receiving the sensed values on Base Station and displaying them on terminal.

PRINCIPLE OF OPERATION AND WORKFLOW:

Our main aim is to sense the soil moisture level through volumetric water content which we have calculated in the formula as mentioned. The output of the soil moisture always gives 10-40% of what the input is given. Since we are providing 5V as excitation to the pin our output ranged from 0.4 to 1.8V from dry to wet soil respectively. We set threshold at 1.2 V making the pump to turn on below 1.2V since volumetric water content is directly proportional to voltage and lesser voltage indicating dry soil and turn off pump as voltage level exceeds 1.2 V indicating the required moisture level for the soil.

1. Initially we figured out providing excitation voltage from MDA board.
2. Then established communication between moisture sensing node and base station node.
3. Figured out the calibration and calculation of volumetric water content of soil and read values.
4. Established the relation between voltage read and volumetric water content and made a tabular column for various samples of soil.
5. Determined the threshold through the voltage levels.
6. Developed a driver circuit for turning on the pump.
7. Interfaced the pump to MDA board and provided necessary excitation to turn on and off the pump.

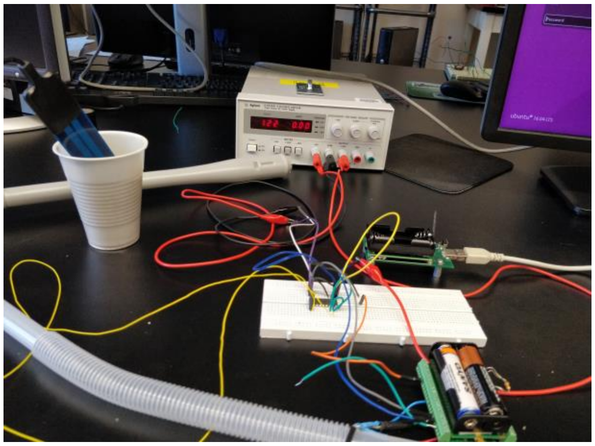


Fig. 7: Implementation

CODE SNIPPETS:

Soil moisture sensing node

We used 2 timers and MDA analog pins with 2.5V and 5V excitation as shown below.

```
module MoistSensorC {
uses interface Boot;
uses interface Leds
// TIMERS
uses interface Timer<TMilli> as Timer0;
uses interface Timer<TMilli> as Timer1;
uses interface Packet;
uses interface AMPacket;
uses interface AMSend;
uses interface Receive;
uses interface SplitControl as AMControl;
// MDA PINS
uses interface GeneralIO as TWO_HALF_VOLT;
uses interface GeneralIO as FIVE_VOLT;
uses interface Read<uint16_t> as MoistSensor;
}
```

Timer 0 and Timer 1 are periodically fired every 1 second after successful boot of the micaz mote and 2.5 volt and 5 volt are set as excitation voltages

```
 event void Boot.booted()
 {
   call TWO_HALF_VOLT.set();              //excitation voltage for moisture sensor.
   call FIVE_VOLT.set();                  //excitation voltage for activating pump.
   call Timer0.startPeriodic(1000);    // Fire Timer0 periodically every 1sec
   call Timer1.startPeriodic(1000);    // Fire Timer1 periodically every 1sec
    call AMControl.start();
 }
```

After timer 0 is fired it triggers the moisture sensor read event which reads the input by sensing the moisture sensor on MDA's channel A3

```
event void Timer0.fired()
{
    call MoistSensor.read();
}
```

After timer 1 is fired it triggers to activate pump through 5 volt pin

```
event void Timer1.fired()
 {
   call FIVE_VOLT.set();
 }
```

After the sensor reading is done the code puts the reading in the variable val and volumetric water content is calculated according to formula in the manual

```
event void MoistSensor.readDone(error_t result, uint16_t val)
 {
   result = (val*2.5)/65535;       //divided by 65535 since val is 16 bit value to make it user readable voltage
  output_volt = (val*2.5)/4096;  //calculate output_volt as per formula in the manual. Used 4096 for division as MDA has 12-bit ADC
   vwc = (int) (100*(0.000936 * (output_volt * 1000) - 0.376) + 0.5); //calculate volumetric water content as per formula in manual
```

val is attached to message payload through value variable and sent to base station and if the result is successful toggles LED1

```
MoistSensorMsg* btrpkt = (MoistSensorMsg*)(call Packet.getPayload(&pkt, sizeof (MoistSensorMsg)));
  btrpkt->value = val;  //val from ADC is read into value and sent to base-station
  if (call AMSend.send(AM_BROADCAST_ADDR, &pkt, sizeof(MoistSensorMsg)) == SUCCESS)
        if (result == SUCCESS)
           call Leds.led1Toggle();   //if the value is read successfully then toggle green LED
```

Excitation of 5V from MDA-300CA is given to turn ON and OFF the motor after some threshold. The threshold is found as follows. Since 5V is given as input, output would be 10-

40% of the input which is around 0.4-2V. So we have set the threshold at 1.2V and accordingly turned ON motor when voltage is below 1.2V sensing it as dry.

```
        if ((val)<40000)        //dry soil
        {
        call FIVE_VOLT.set();   //set 5V
        call Timer1.startPeriodic(1000);
        }
        if ((val)>40000)        //wet soil
        {
        call FIVE_VOLT.clr();   //turn off motor
        call Timer1.startPeriodic(1000);
        }
    }
```

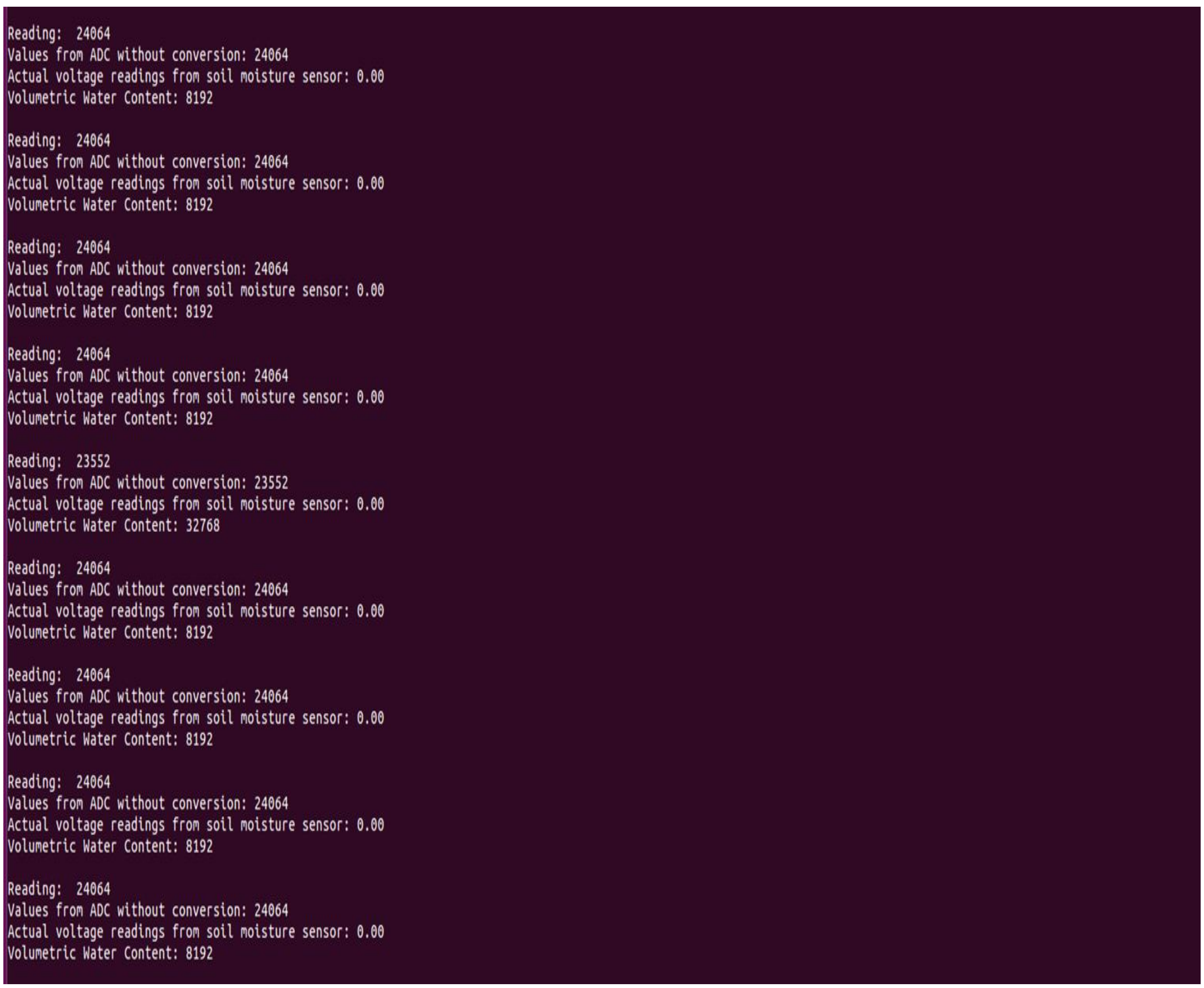
<u>Receiver Node:</u>

Base Station receives the packet sent from the sensing node and displays the volumetric water content on the terminal

```
if (len == sizeof(BaseStationMsg))
  {
        BaseStationMsg* btrpkt = (BaseStationMsg*)payload;
        printf("Reading:  %u\n", btrpkt->value);
        val=btrpkt->value;
        result = (val*2.5)/65535;
         // divided by 65535 since val is 16 bit value to make it user readable voltage
        Voltage = (val*2.5)/4096;
        // calculate output_volt as per formula in the manual. Division by 4096 as MDA has 12-bit ADC
        vwc = (int)(100*(0.000936 * (Voltage * 1000) - 0.376) + 0.5);
       //calculate volumetric water content as per formula in manual and print values on terminal using printfFloat function
```

```
printf("Values from ADC without conversion: %u \n",val);
printf("Actual voltage readings from soil moisture sensor:");
printfFloat(result);
printf("\n");
printf("Volumetric Water Content: %u \n", vwc);
printf("\n");
}
```

RESULTS:



```
Reading:  24064
Values from ADC without conversion: 24064
Actual voltage readings from soil moisture sensor: 0.00
Volumetric Water Content: 8192

Reading:  24064
Values from ADC without conversion: 24064
Actual voltage readings from soil moisture sensor: 0.00
Volumetric Water Content: 8192

Reading:  24064
Values from ADC without conversion: 24064
Actual voltage readings from soil moisture sensor: 0.00
Volumetric Water Content: 8192

Reading:  24064
Values from ADC without conversion: 24064
Actual voltage readings from soil moisture sensor: 0.00
Volumetric Water Content: 8192

Reading:  23552
Values from ADC without conversion: 23552
Actual voltage readings from soil moisture sensor: 0.00
Volumetric Water Content: 32768

Reading:  24064
Values from ADC without conversion: 24064
Actual voltage readings from soil moisture sensor: 0.00
Volumetric Water Content: 8192

Reading:  24064
Values from ADC without conversion: 24064
Actual voltage readings from soil moisture sensor: 0.00
Volumetric Water Content: 8192

Reading:  24064
Values from ADC without conversion: 24064
Actual voltage readings from soil moisture sensor: 0.00
Volumetric Water Content: 8192

Reading:  24064
Values from ADC without conversion: 24064
Actual voltage readings from soil moisture sensor: 0.00
Volumetric Water Content: 8192
```

Fig. 8: Output Screenshot– Base Station: Consistent Readings for 0 volt

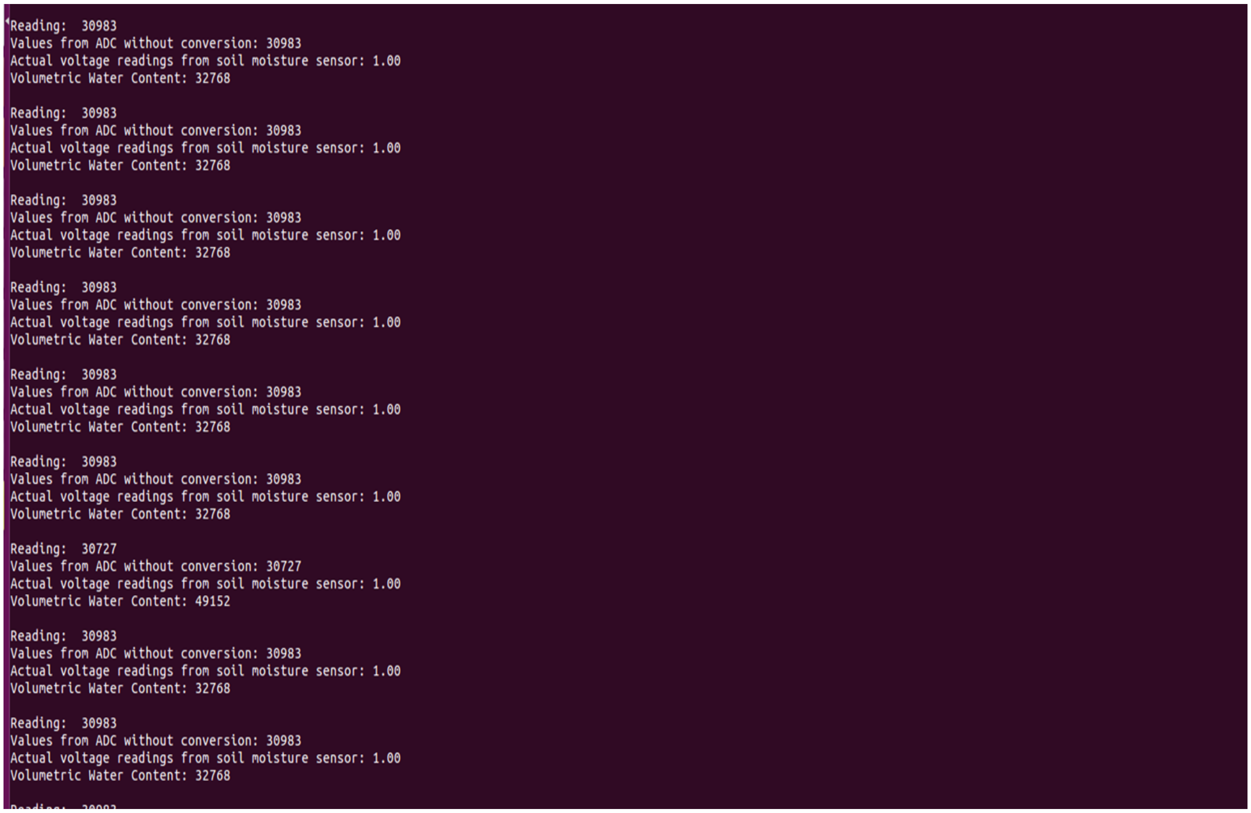


Fig. 9: Output Screenshot- Base Station: Consistent Readings for 1 volt

As observed in Fig. 8 and Fig. 9 the sensor calibrations corresponding to 0 and 1 volts have been displayed. As per our condition if our ‘val’ is less than 30,000 then we are setting ON the pump. Here for 1V we are obtaining around 32768 vwc and 38983 val which is greater than 30,000 hence pump is turned OFF. The general tabular column for various voltage ranges are as calibrated below.

Table 1: Calibrated values

Voltage Range	Raw Values from ADC (16 bit)	Volumetric Water Content
0	0	0
0.2	5242	12492
0.5	13107	16142
0.8	20971	29145
1.0	26214	32768
1.5	39321	37496
2.0	52428	42414
2.5	65535	52428

CONCLUSION:

We successfully developed the model for detecting soil moisture by making use of ECHO-10 sensor which worked on the principle of variable impedance and MDA-300CA board. The analog values were read by MDA-300CA board and then accordingly activated the pump dependent on the need and the threshold which was set. The EC-10 sensor senses the moisture and the output at the ADC channel A3 which is from 0.4 to 1 V for dry soil and above 1.2V for wet soil and so the threshold is set accordingly. The pump is turned on each time the probe is inserted in soil which reads voltage less than 1.2V and stays off when it is above that.

FUTURE SCOPE:

Mobile application can be developed for monitoring the soil and starting the pump accordingly. Moreover, there can be tremendous improvements made in taking the proper readings displaying them and can be used for the soil moisture detection in the field of agriculture, golf turfs.

REFERENCES:

1).https://www.eol.ucar.edu/isf/facilities/isa/internal/CrossBow/Doc/MTS-MDA_Series_Users_Manual.pdf

2).http://manuals.decagon.com/Retired%20and%20Discontinued/Manuals/EC-20-EC-10-EC-5-Soil-Moisture-Sensor-Operators-Manual-(discontinued).pdf

3). https://github.com/tyll/tinyos-2.x-contrib/tree/master/uoit/mda300ca

4). http://balajipcse.blogspot.com/2011/11/tinyos-and-float-numbers.html