Design and Implementation of Low Power and Sleep Mode Data Logger for Automatic Weather Stations

Ashima, Sangeeta Kamboj

Abstract**: *In Automatic Weather Stations (AWS), data loggers are used for recording and displaying the output obtained from various sensors. In the paper, a data logger is designed and developed using MSP430F5529 launchpad, Node MCU section in wake up/sleep mode, a Resistance Temperature Detector(RTD) circuit and a power supply. Energia and Arduino software is also used for developing and uploading the code on the MSP430F5529 microcontroller and on Node MCU respectively. During designing of data logger the inbuilt Real Time Clock(RTC) is activated using RTC library which keeps track of time and date. The paper also presented cloud computation using Global System for Mobile communications(GSM) and WI-FI module for continuous monitoring of output taken from a RTD sensor integrated with designed data logger in real time. In the paper mathematical calculations are described for calibration of Analog-to-Digital Converter(ADC) MSP430F5529 which is used in development of data logger. The paper also presented hardware implementation results of developed data logger and with the use of microcontroller in sleep mode, the current consumption decreases from 10mA to 6mA and hence power consumption of the data logger from the battery is minimized . Therefore data logger can be made to work for a longer duration of time with higher efficiency.***

Index Terms**: *Data Logger, GSM, Microcontroller, Temperature Sensor, Cloud Storage.***

I. INTRODUCTION

A data logger is an electronic device which records data over time or in relation to location either with a built in instrument or via external instruments and sensors. In automatic weather stations, data loggers are used for recording and displaying the readings obtained from various sensors such as temperature, pressure and wind speed. These can send recorded data to cloud for storage by interfacing with any I2C protocol devices such as GSM or WI-FI module [1].

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Ashima, Student, Department of Electrical and Instrumentation Engineering,
Thapar Institute of Engineering and Technology, Patiala, Punjab, India
Dr. Sangeeta Kamboj, Assistant Professor, Department of Electrical and Instrumentation Engineering, Thapar Institute of Engineering and Technology, Patiala, Punjab, India

The microcontroller can be used in the designing of the data logger other than Arduino Uno because it is cheaper and can fire directly data to PC over USB (with some buffering at the beginning of USB transfer - speeding up) with 1000 KB/s. It also offers high frequency of 25MHz which is greater than 16MHz frequency of Arduino Uno. And Arduino consumes 20mA current which is more than maximum power even it is fully busy. The microcontroller offers several low power modes that consume less power during sleep mode and increases the efficiency of the battery. In the references [2-4], designing of various data loggers and their use are described in detail. An embedded product uses a microcontroller to do one task and one task only. Microcontroller can be interfaced with the real world devices such as LCDs, ADCs, sensors and keyboard [5]. In the paper, a microcontroller MSP430F5529 is used in the designing of single channel low power / sleep mode data logger for performing desired functions. During designing of data logger the inbuilt RTC is activated using RTC library which keeps track of time and date[6]. When the RTC of the microcontroller is initiated it takes the readings from the sensor and immediately goes into sleep mode. During sleep mode, the power to everything is cut but not the real time clock. Thus the microcontroller remains unpowered between every log entry and only the RTC remained active. Then at a particular time of the day an interrupt is called which wakes the microcontroller from sleep mode and after taking the readings again goes back to sleep mode. Therefore the battery can run for weeks and even months saving lot of power. In the paper cloud computation using GSM and WI-FI module is done for continuous monitoring of output taken by temperature sensor which is interfaced with the designed data logger [7].

II. METHODOLOGY

In the designing of single channel low power / sleep mode data logger for weather stations, MSP430F5529 launchpad, Node MCU section, a RTD (Resistance Temperature Detectors) circuit and a power supply is used. Energia and Arduino software is used for developing and uploading the code on the MSP430F5529 microcontroller and on Node MCU respectively. The RTD circuit consists of a RTD sensor and a series of resistors, capacitors and operational amplifier for filtering and amplifying the output obtained by the sensor. A 7.8 V battery is used for providing the power to the circuit whose output voltage is first converted to 5V by the use of a LM7805 IC. As soon as the MSP430F5529 launchpad is powered up, the in-buit RTC of the microcontroller is activated and displays the date and time on the serial terminal of the Energia software. The figure1 shows the steps used in designing of data logger. During sleep mode while designing data logger, the current consumption of the battery used by the microcontroller is reduced from 10mA to 6mA .The RTC is set to call analog interrupt after every one hour. This time of calling the interrupt can be increased or decreased according to the requirement. After 1 hour, interrupt is called and the microcontroller wakes up from the sleep mode. It again takes the ADC reading from the sensor and sends it to cloud storage. This process continues until the battery has completely discharged off and stops giving any power to the MSP430F5529 launch pad[8]. Due to the use of the microcontroller in the sleep mode, the battery can be used for longer duration of time and with greater efficiency.

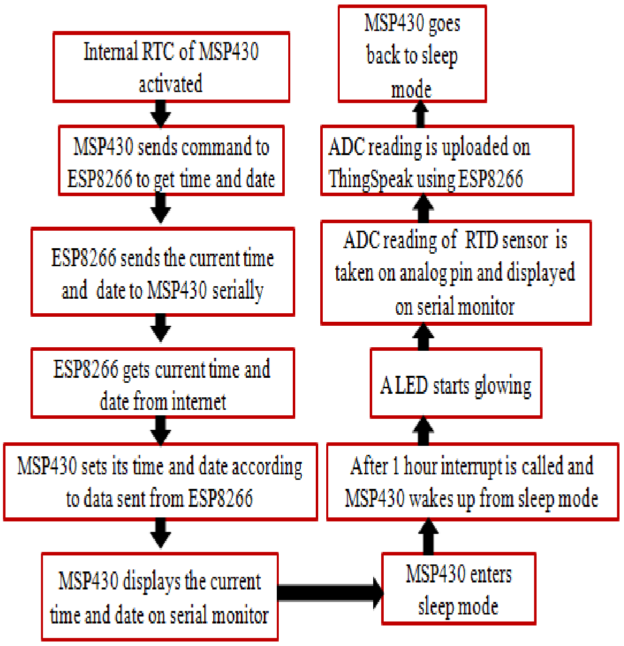

Figure 1. Block diagram of data logger's designing

The detailed description of various steps used in designing of data logger which sends data for cloud computation using modules are given in following sections:

A. Starting with MSP430F5529

The microcontroller used in the data logger is MSP430F5529 as shown in figure 2. A single ADC channel is initiated and a variable potentiometer is connected on its Analog pin and its output voltage has been taken and displayed on the serial terminal. Then calibration of the output voltage is performed and its value is noted down.

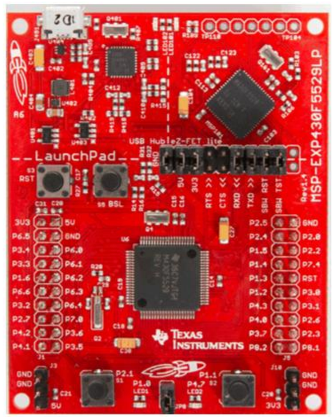

Figure 2. MSP430F5529 Launchpad Development Kit

B. Working on the Energia Software

Various free software development tools are available for MSP430 like TI's Eclipse-based Code Composer Studio™ IDE (CCS), IAR Embedded Workbench™ IDE (IAR), and the community-driven Energia open-source code editor. Out of all these softwares, Energia is the easiest to use having the software environment similar to Arduino Uno software. Programming on the Energia software as shown in figure 3 has been done using the microcontroller MSP430.

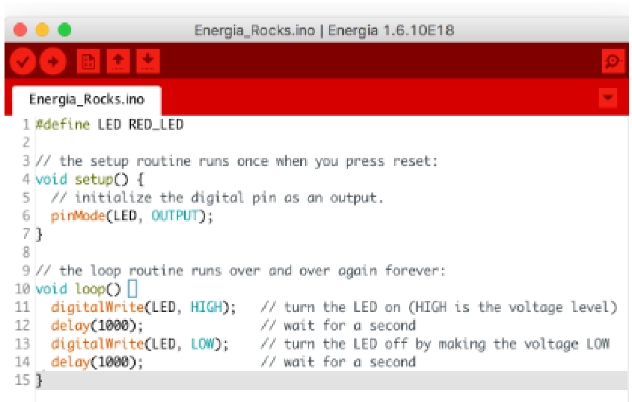

Figure 3. Programming in Energia software

C. RTC Activation

MSP430F5529 has an in-built real time clock (RTC) which keeps track of time and date and displays them on LCD screen or serial terminal as shown in figure 4. The RTC library includes all files necessary to setup a periodic interrupt, and keep real-time. It includes functions to handle the periodic-time interrupt and increment all time-keeping variables. Time-keeping variables include seconds, minutes, hours, days of the week, months, years, and even leap-years.

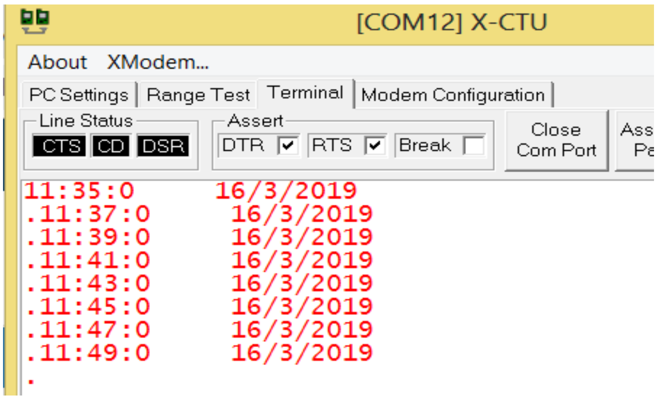

Figure 4. RTC activation

D. Wake up/sleep mode

The microcontroller MSP430 offers several low power modes. Firstly the RTC is initiated at a particular time of the day and after displaying the current time and taking readings from the sensors of automatic weather station and displaying them the microcontroller enters sleep mode. The current consumption during sleep mode decreases from 20mA to 6mA. Now at a specific time of the day it wakes up from sleep mode take the readings again and again goes back to sleep mode. This process repeats itself again and again.

E. Data uploading on cloud with sleep / wake up mode using GSM module or WIFI module.

The data from the sensors is uploaded on cloud for storage as shown in figure 5 using GSM module SIM7600 and wifi module ESP8266 using IOT algorithms named Thingspeak.

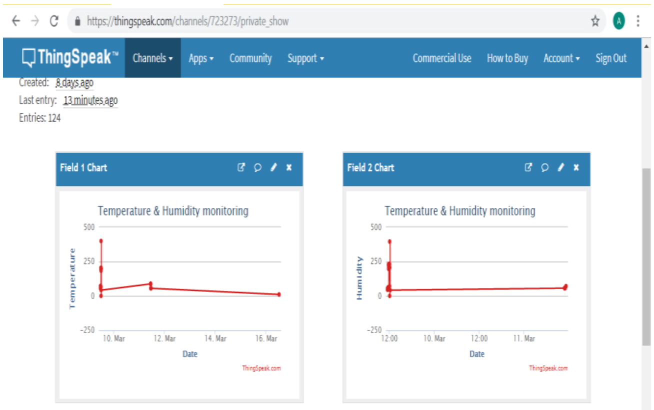

Figure 5. Data uploading on cloud

Thing Speak is an IoT analytics platform service from MathWorks. ThingSpeak allows to aggregate, visualize, and analyze live data streams in the cloud. ThingSpeak provides instant visualizations of data posted by devices. With ThingSpeak, the data is stored in channels. Each channel stores up to 8 fields of data . The connection between devices is shown in figure 6.

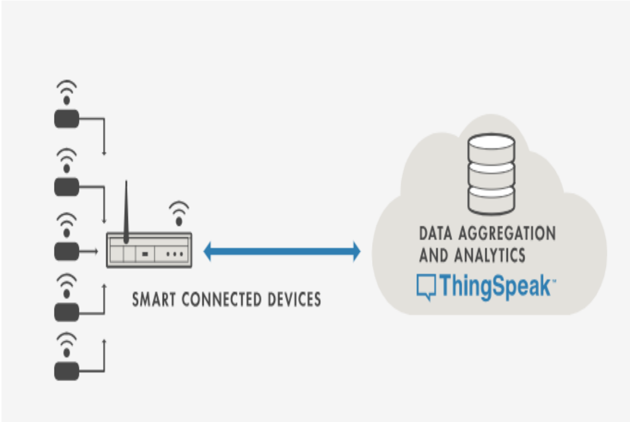

Figure 6 Connection between devices

F. Interfacing RTD sensor to the microcontroller

A RTD sensor is interfaced with the microcontroller as shown in figure 7 and its readings were taken and displayed on the serial terminal. The output voltage of the RTD sensor are caliberated with the help of a multimeter and it has been observed that the output voltage at room temperature i.e. 26 $^{\circ}$C is 1886.92 mV and at 88 $^{\circ}$C is 1950mV.

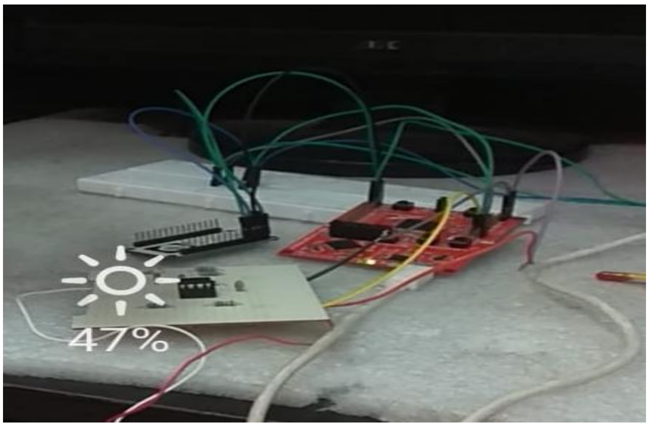

Figure 7. RTD sensor interfacing

G. Setting time of internal RTC by getting time by NTP & UDP protocol using ESP8266

The internal RTC of the microcontroller lacks VBAT pin to which a 3.3 V cell can be connected to supply power to the RTC even during power failure. Since there is no VBAT pin therefore during power failure RTC resets itself and there is error in the time during which microcontroller goes into sleep mode and upload readings to the cloud. To overcome this issue , current date and time is fetched by ESP8266 using NTP protocol and that data is sent to MSP430 serially and it sets its time according to it.

H. On battery testing

After the circuit of the data logger has been completed , it is tested along with a battery to check how long the battery can work in sleep mode. Then the efficiency of the circuit will be calculated and optimized method of power consumption will be calculated. The voltage of battery is checked using multimeter as shown in figure as shown in figure 8.

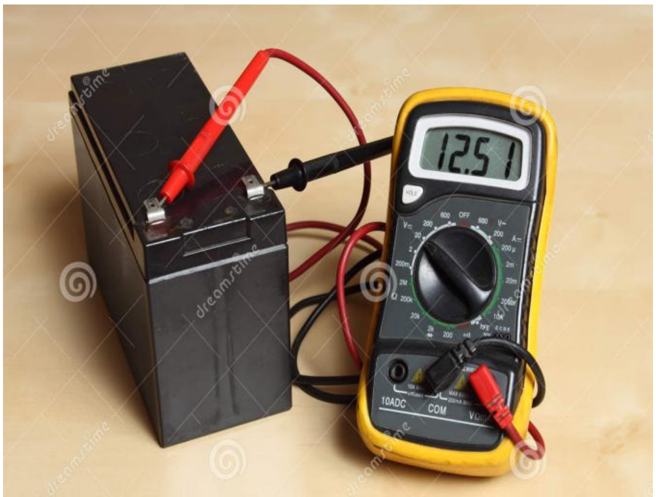

Figure 8. Battery testing using multimete

III. DEVELOPMENT OF DATA LOGGER

The figure 9 shows the developed Data Logger[9] in which all the components are integrated together and it incorporates various steps as described in section II.

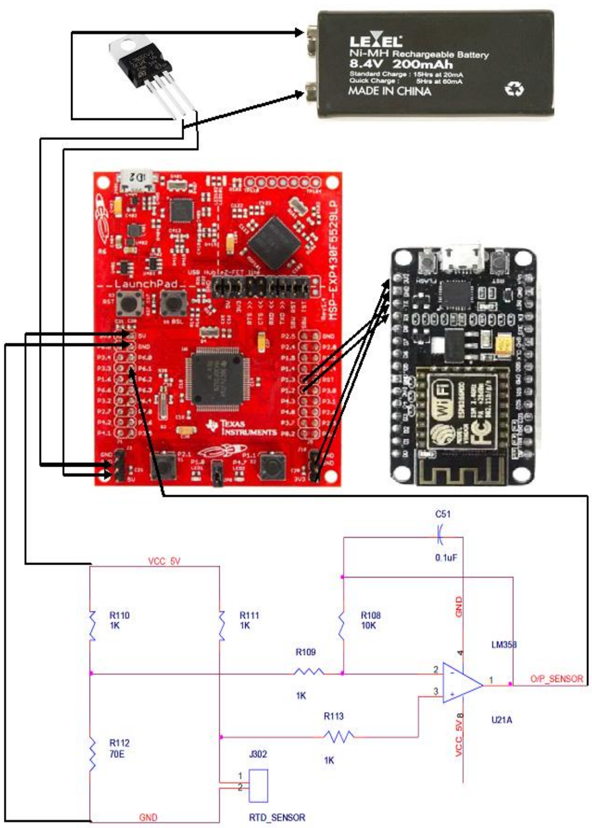

Figure 9. Circuit Diagram of Data Logger

A. Calibration of ADC of MSP430F5529

The minimum value of voltage taken by the microcontroller = 0 V

The maximum value of voltage taken by the microcontroller = 5 V

The ADC of the microcontroller is 12 bit i.e. it can take 2^12 values which is 4096.

Step size = (Vreference (mV)) / (ADC resolution) (1)

=5000/2^12

=5000/4096

= 1.22

Voltage in mV = Voltage obtained * Step size

= V*1.22 (2)

Now this voltage can be converted into sensor output like Temperature sensor, Humidity sensor etc.

Consider a temperature sensor whose output range is (0 – 100) °C

Then for converting the voltage obtained by temperature value, multiply voltage in mV by X where

X = (Max. temperature – Min. temperature) / (Max. voltage – Min. voltage) (3)

=(100–0)/(5000–0)

= 0.02

Output of Temperature sensor = Voltage in mV * X

=V*1.22*X (4)

B. Changing the Software Serial library of MSP430 according to MSP430F5529 microcontroller

The default operating frequency in Software Serial library of MSP430 = 16000,000 Hz

The operating frequency in Software Serial library of MSP430F5529 = 25000,000 Hz

F_CPU == 25000000L

Rxintra=rxstop=tx= 16000000 / X (5)

For 16000000L rxintra given at 9600 baud rate is 540

Now rxintra for 25000000 can be calculated as :

Rxintra=16000000/X

540 = 16000000 / X

X= 29629.62

Rxintra for 25000000 = 25000000 / X = 843

This is the value of rxintra=rxstop=tx at 9600 baud rate

Rxcenter = 1/2 rxintra = ½ 843 = 421 (6)

This is the value of rxcenter at 9600 baud rate

IV. HARDWARE IMPLEMENTATION RESULTS

The components such as MSP430F5529 Launchpad, NodeMCU, RTD sensor, voltage regulator 7805 and a 7.8 V battery are integrated together to obtain output on the serial terminals of Energia and Arduino softwares as shown in figure 10.

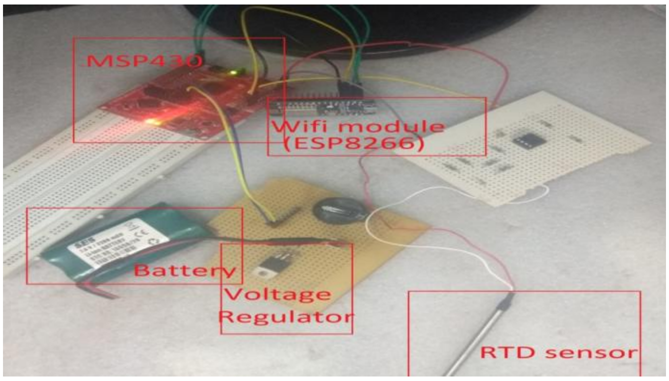

Figure 10. Integration of Components for Implementation of data logger

In figure 11, it has been shown that the RTC of the microcontroller MSP430F5529 is activated and displays the time and date and then it sets its RTC according to the current date and time sent by the ESP8266.

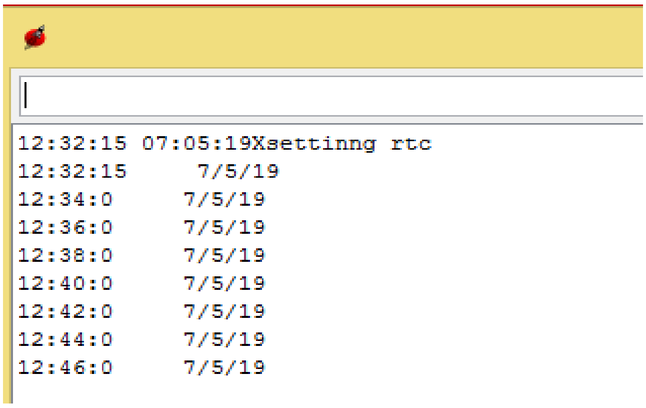

Figure 11. RTC setting

The interfacing between MSP430F5529 and ESP8266 has been shown in figure 12 and it has been found that the ESP8266 takes time from internet using NTP & UDP protocol and then it sends that data to MSP430 serially which sets its RTC according to that data.

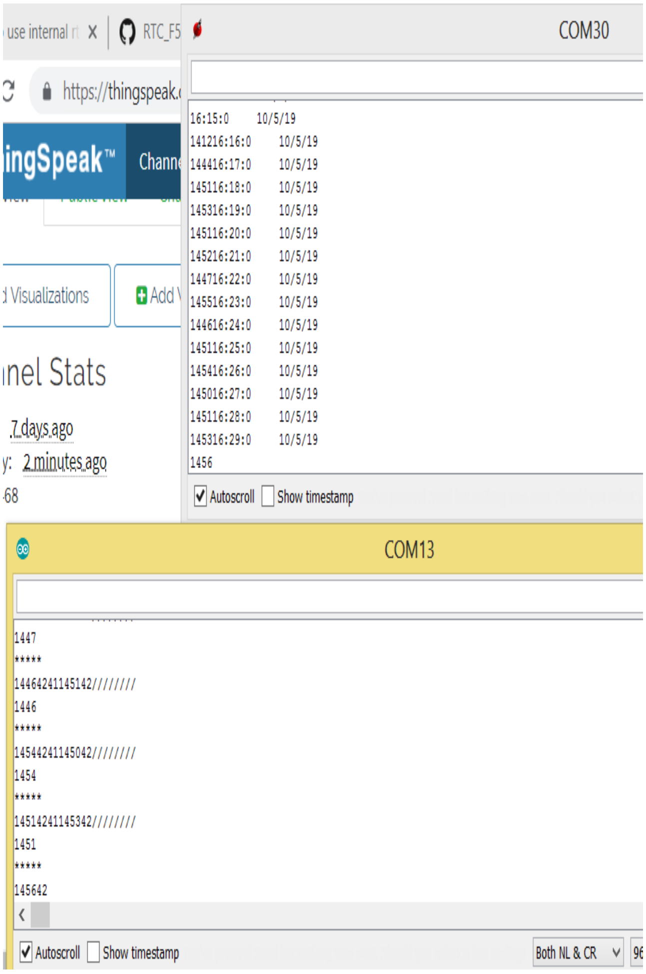

Figure 12. Interfacing of MSP430 and ESP8266

The ADC value of the sensor used in implementation of data logger has been uploaded on cloud named THINGSPEAK as can be seen in figure 13.

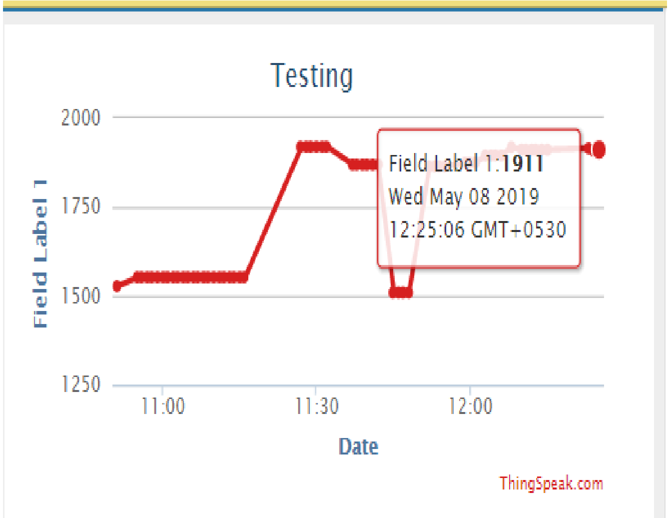

Figure 13. Cloud computation

V. CONCLUSION

The designing and development of data logger for weather stations using MSP430F5529 launchpad, Node MCU section, a RTD circuit and a power supply has been successfully done in the paper. Energia and Arduino software has been used for developing and uploading the code on the MSP430F5529 microcontroller and on Node MCU respectively. The ADC values have been taken and caliberated using variable potentiometer and a RTD sensor. The inbuilt RTC in the microcontroller has been activated and caliberated using a wifi module ESP8266 which gets the current time and date using NTP and UDP protocol.It has been found that the current consumption of battery used by microcontroller decreases from 10mA to 6mA during the sleep mode of the microcontroller and thus battery can be used for longer duration of time with higher efficiency. In the paper ADC value of the RTD sensor taken by the microcontroller has been sent to cloud named Thingspeak using Wi-Fi module (ESP8266) so that anyone can access output of data logger anywhere around the world.

VI. ACKNOWLEDGMENT

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AUTHORS PROFILE

Ashima is a B.E. student of Electronics (Instrumentation & Control) engineering (2015-19) batch at Thapar Institute of Engineering & Technology (Deemed to be University), Patiala, Punjab. She has received Certificate of Merit from C.B.S.E for obtaining 10.0 C.G.P.A in class 10th examination.

Dr. Sangeeta Kamboj is currently Assistant Professor and ISO Coordinator in the Electrical and Instrumentation Engineering Department, Thapar Institute of Engineering and Technology (Deemed to be University), Patiala, Punjab. Dr. Kamboj obtained her Ph.D. from NIT, Kurukshetra, Haryana on Application of Signal Processing in Power System in 2014. Dr. Kamboj has about sixteen years of teaching experience.Her current area of research interest includes Signal Processing, Electronic Circuits & Devices, Communication and Control in Power system. She is member of professional societies such as IETE, IAENG and MSI. She has published papers in reputed international journals on her area of research interest.