Temperature data logger for Industrial Process

Ivan Imonigie
14034, Utopia Drive
Sugarland, TX 77498
United State
Tel: 1-713-397-2609 E-mail: ivanimonigie@gmail.com[1]

Ebenezer John (Corresponding author)
1127, McMurtry Ridge Dr,
Katy, Tx 77494
United State
Tel: 1-832-841-7234 E-mail: ebenezergabe@gmail.com[2]

Bamidele Idiong (Corresponding author)
21519, Crainfeld Drive,
Richmond, TX 77407
United State
Tel: 1-281-684-2555 E-mail: idiongbamidele@yahoo.com[3]

Abstract
One of the challenges in industrial process monitoring is the ability to take accurate measurement of variables. In today's world where industries are sited remotely due to proximity to raw materials or for the purpose of safety of human habitation, there's needed to infer measurement of variables and store data for retrieval at convenience or transmitted through telemetry for the purpose of control and automation. This is made possible using data acquisition system. A multi-channel data logging system is crucial and valuable in many Engineering applications especially where the environmental monitoring plays a substantial role. Implementation of a low cost, universal data logger based on the AVR Atmega328 and the DFRobot SD Module is described in this work. Test implementation was performed at the technology center of one of the world's leading oilfield service companies to demonstrate industrial application. The design and implementation of the portable low-cost data-logger was achieved using few electronic components. The hardware part includes power supply, temperature sensor, SD card, and an Arduino micro-controller which contain the program used in the data logging. The system is ideal for battery operated low power data logging applications.
Keywords: Logging, data, Atmega328, Module, Arduino, System.
DOI: 10.7176/CEIS/13-3-04
Publication date: July 31st 2022

1.0 Introduction

A data logger is an electronic instrument that records measurements at set intervals over a period. Data logging is much more than collecting information electronically about a physical quantity. Depending on the data logger, such measurements can include Temperature, AC/DC current and voltage, Relative humidity, Differential pressure, Light intensity, Soil moisture, Rainfall, Wind speed and direction, Pulse signals, etc. Data loggers are typically compact, battery-powered devices equipped with an internal microprocessor, data storage device example micro-SD card, and one or more sensors (https://www.onsetcomp.com/files/data-logger-basics.pdf). They can be deployed indoors, outdoors, and underwater, and can record data for a long period of time unattended, depending on the storage capacity. A data logger may be a single-unit, stand-alone device with internal sensors, which fits in the palm of a hand, or it may be a multi-channel data collection instrument equipped with one or more external sensors.

2.0 Researched Related Works

(Sumon et al., Nov 2006) in their project, "Design of a Low Cost Multi Channel Data Logger" developed a low-cost multi-channel (eight to twenty-two channels) data logger used in converting analog signal of physical parameters into digital form by a suitable program code. Their actual aim was to provide a module with a software package when installed in a computer, one can remotely acquire and monitor different types of signals sequentially at a time. Signals obtained from the various sensors have been successfully conditioned. Interfacing these signals using an ADC with the parallel port of a computer satisfies the very goal of data acquisition. The user friendliness and consistency in using a PC and channel selector multiplexers further add to the flexibility of their data logger. However, the major limitation in the design and implementation of such equipment was the cost which was as high as US$30. Also, the design uses about eight different ADC channel for the eight sensor nodes. Furthermore, (Bello et al, 2015) in their work designed a Standalone General Purpose Data Logger which is compatible with a variety of transducers, permitting the measurement and recording of a wide range of phenomena. The recorded data can be retrieved to a PC via an RS-232 serial port. His design was centered on a single microcontroller unit, and the output of the logged data is displayed on an LCD during the logging process. Also, the data can be retrieved to a computer via the RS-232 serial port.

However, there seems to be major setbacks in their design, apart from the high cost of implementation due to the numerous number of components used, the increased power consumption by the device which can be optimized either by reducing the number of components like eliminating the LCD display which consumes much power from the backlight or by implementing a few conservation practices such as automatic backlight control and employing the power-managed modes supported by the PIC18F4520.

3.0 System Design

3.1 HARDWARE SETUP

The hardware setup of the multichannel universal data logger comprises of three different electronic circuitries, the power supply, the microcontroller unit, and the SD Module. These three units were connected and properly biased according to the pin mapping specified by the datasheet.
The following electronic components were used to actualize the design:

- Microcontroller (Atmega328)
- Voltage regulators (LM7805)
- Capacitors
- Resistors
- The SD Module

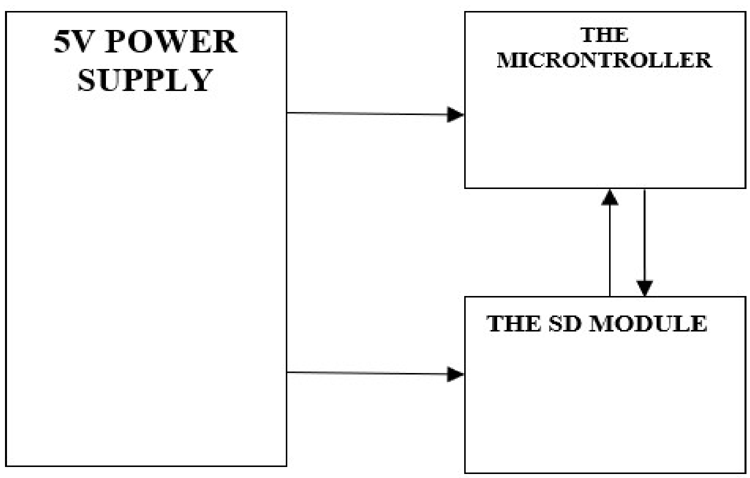


Figure 1: The System block diagram

3.2 System Modules Implementation

A. Power Supply Unit

The SD Module and the Atmega328 microcontroller require a 5V power supply for effective operation of the device. The LM7805 which is a 5V regulator was used to achieve this design. The voltage from a 9V battery was fed into the input of the voltage regulator (LM7805) by using a 10uF capacitor (C1) to buffer the input signal; the 5V of the output was also filtered with a 10uF capacitor (C2) to smoothen the output. The complete circuit of the power supply is shown in Figure 2

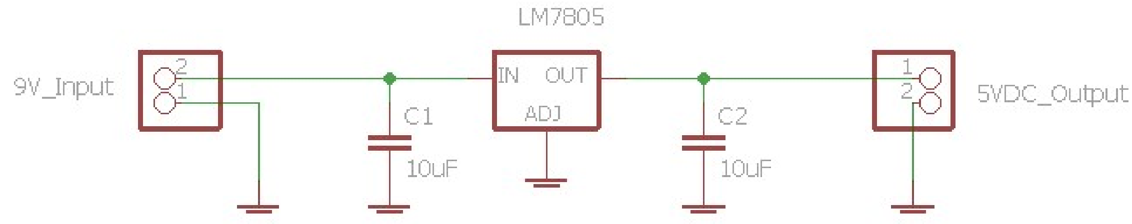


Figure 2: Eagles schematic for the power supply

B. The Microcontroller Unit

Arduino boards are deceptively small, but they have many of the computational capabilities of a "real" computer. The size of the allowed code is smaller than that allowed on a bigger computer, with extensive computational capabilities. The major difference between microcontroller programming and "conventional" programming (for scientific and engineering computation, for example) is that the essential purpose of microcontroller programming is to control hardware. In this Project, the hardware of interest is restricted mostly just to those devices needed to construct a datalogger which include the SD Module and the analog input of the sensors.

The Arduino Uno R3 was first tested for proper functionality by connecting it to the USB serial port of a computer and the LED blink sketch on the Arduino, example sketch from the Arduino IDE was uploaded. Since there was a proper connection between the microcontroller and the computers' serial port, the LED on Pin13 of the Uno board blinked which indicates that the sketch was successfully uploaded.

The code for the data logger found on Appendix A was then uploaded to the board, this code controls the different hardware by logging data from any sensor plugged into the any of the two analog pins (A0 or A1) into the SD Module as shown in figure 3.

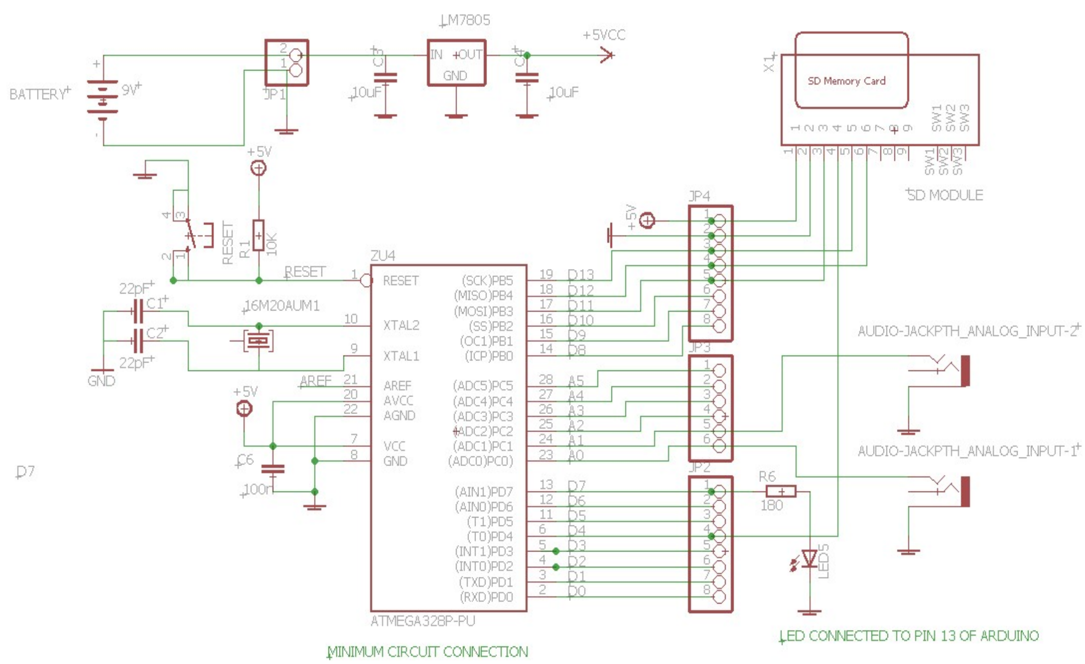


Figure 3: Eagles schematic of the data logger circuit

C. Temperature Sensor LM35

The LM35 is a precision integrated-circuit temperature-sensing element. Its output voltage is linearly proportional to the Celsius temperature. It offers precision of ±1/4°C at room temperature and ±3⁄4°C, over a full −55 to +150°C temperature range. It issues output of 10millivolts per degree centigrade. LM35 senses temperature and sends analog output to the analog to digital converter (ADC) for further processing.

D. SD Card Module

The SD Module was first connected to the Arduino board and tested. The dfrobot SD Module has the following pin mapping:

- Pin1 - 5V Supply
- Pin2 - GND
- Pin3 - (MOSI)
- Pin4 - SS
- Pin5 - SCK
- Pin6 - MISO

The SD module was connected according to the schematic (Figure 4) following the under listed steps:

- The VCC was connected to the 5V supply
- The GND was connected to the ground pin of the 5V supply
- The Chip select pin (SS) was connected to Pin D4 on the Arduino board which is equivalent to Pin6 of the Atmega328.
- The MOSI was connected to Pin D11 on the Arduino board which is equivalent to Pin17 of the Atmega328.
- The SCK was connected to Pin D13 on the Arduino board which is equivalent to Pin19 of the Atmega328.
- The MISO was connected to Pin D12 on the Arduino board which is equivalent to Pin18 of the Atmega328.

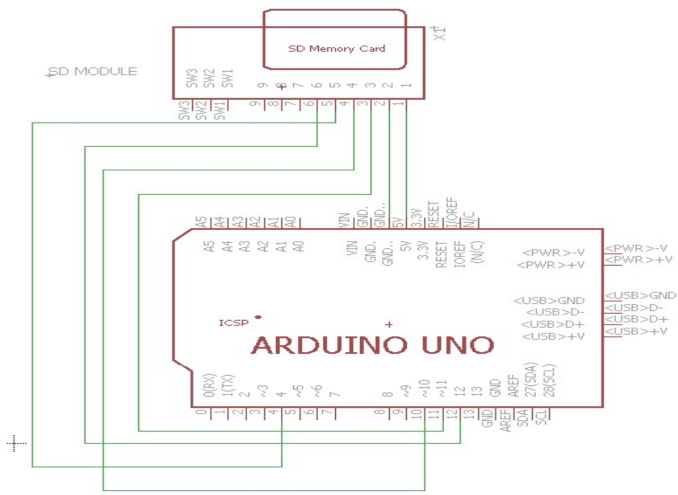


Figure 4: Eagles schematic for wiring up the SD Module

3. 3 System Software Design

The Arduino integrated development environment (IDE) is a free download for Windows, Mac, or Linux systems from http://arduino.cc/en/main/software.

The software was first downloaded and installed on the computer. After the installation was completed and the program was launched, a blank sketch was open (Figure 5).

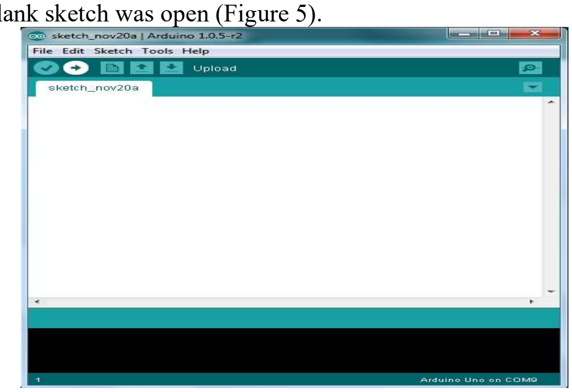


Figure 5: The Arduino IDE software

INSTALLING THE USB DRIVER

The Arduino Uno R3 which is an Atmega328 compatible board requires its USB driver to be installed on one of the serial ports of the computer. The USB driver comes with the Arduino IDE installed on the computer. The Arduino board was plugged into the computer via a USB cable which got the required USB driver for the Uno board installed on COM9 of the computer serial communication port.

UPLOADING THE SOURCE CODE

The source code for logging data into SD card is found on the Example sketch of the Arduino IDE under the SD library. The programming logic was tweaked a little to give the required result.

The sketch was then compiled and uploaded. The source code for the universal data logger is found on Appendix A.

4.0 System Result

The system was used to monitor heating process of an electrical oven during high temperature operation of stator induction motor, which is the device under test (DUT) for qualification purpose. A temperature sensor was inserted into an electrical oven, routed out and connected to the data logger. The oven power supply was switched ON, the heater turned ON, the thermostat was set to maintain oven temperature at 150degC. The device under test (DUT) was maintained at 125degC by keeping the oven temperature at the set point. This is because it takes the DUT longer time to attain the oven air temperature. Temperature data was logged into the SD card, saved in a .csv file format and retrieved to computer via USB drive.

Table 1: Extract of Data from SD card

Time (Hr:min:sec)	Temperature (degC)
7:07:00 AM	22.7
7:10:00 AM	42.9
7:11:00 AM	65.2
7:16:00 AM	108.7
7:17:00 AM	111.6
7:28:00 AM	148.4
7:29:00 AM	149.7

Result is graphically represented as shown in figure 6.

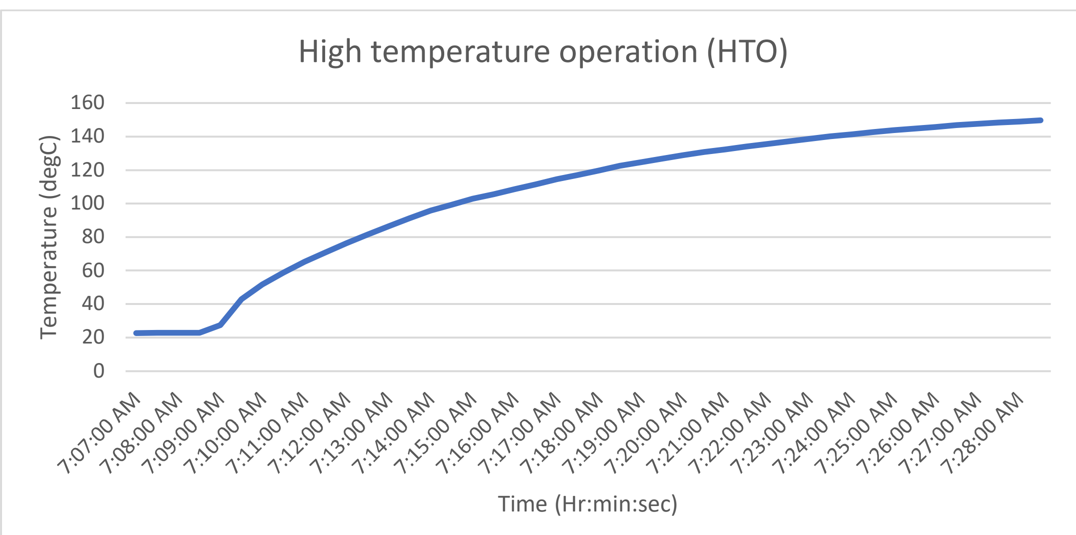


Figure 6: Heating process of electrical oven

From the graph (figure 6), the heating process commenced at 7:07a.m, after 2 minutes oven temperature started rising exponentially till it got to 150degC, 21 minutes from the time the heater was switched ON. A thermocouple was connected on the DUT to multimeter to monitor the DUT's temperature and ensure it's maintained at 125degC.

5. Conclusion

The temperature data logger using Arduino Uno and the Arduino compatible SD Module was designed and constructed to log digital output of any sensor plugged into the sensor input via the audio jag. It is flexible to incorporate more sensors into the multichannel microcontroller, by tweaking the source codes to suit whatever variables that are connected to it. This project has exposed the team to the use of electronic components, microcontroller programming and embedded systems to a large extent that one has come to appreciate the theories learned over the years. The solution was developed and implemented as a low cost and efficient option for logging analog data during downhole tool validation and verification testing that is commonplace in the Energy industry. Future direction of the project involves exploring the possibility of integrating measurement of other types of variables into the same data acquisition system and transmit the data through telemetry system for ease of automation.

References

Bader M. O. Al-thobaiti, Iman I. M. Abosolaiman, Mahdi H. M. Alzahrani, Sami H. A. Almalki, Mohamed S. Soliman. (JULY 2014). Design and Implementation of a Reliable Wireless Real-Time Home Automation System Based on Arduino Uno Single-Board Microcontroller. INTERNATIONAL JOURNAL OF CONTROL, AUTOMATION AND SYSTEMS VOL.3 NO.3.

Onset Computer Corporation (2016), "Data Logger Basics". [Online] Available from: (https://www.onsetcomp.com/files/data-logger-basics.pdf) [Accessed 20th June 2022].

Bello N., M. Ghraizi and S. O. Adetona. (Vol. 34 No. 2, April 2015). STANDALONE GENERAL PURPOSE DATA LOGGER DESIGN AND. Nigerian Journal of Technology (NIJOTECH).

Divakar, V. (ISSN: 2249 – 8958, Volume-3, Issue-2, December - 2013). Design and Implementation of Microcontroller Based Temperature Data Logging System. International Journal of Engineering and Advanced Technology (IJEAT).

Dr. Ovidiu Vermesan, D. P. (2013). Internet of Things: Converging Technologies for Smart Environments and Integrated Ecosystems. Denmark: River Publishers.

Evans, D. (2011). The Internet of Things How the Next Evolution of the Internet Is Changing Everything. Cisco Internet Business Solutions Group (IBSG).

LiuYing M.J.S.R.D.L, "Design of USB Multi-channel and Humidity Acquisition System Based on Wireless Communication" ICEMI'2009.

Perez S. J. et al. "A microcontroller-based data logging System" Instrumentation and Development Vol. 3(8), copyright 1997, Journal of the Mexican Society of Instrumentation.

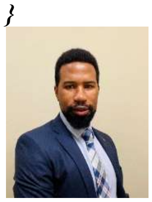
Sumon Saha, Md. Tofiqul Islam and M Zakir Hossain. (VOL.1, NO.1, JUNE 2006). Design of a Low Cost Multi Channel Data Logger. ARPN Journal of Engineering and Applied Sciences

Appendix A
Project source code

```
#include <SD.h>
const int chipSelect = 4;
int led = 5;
int led2 = 6;
int led3 = 7;
int val;
int tempPin = 1;
int Cen, mv;
void setup()
{
 //Initialize LED pins
 pinMode(led, OUTPUT);
   pinMode(led2, OUTPUT);
     pinMode(led3, OUTPUT);
  // Open serial communications and wait for port to open:
 Serial.begin(9600);
 digitalWrite(led, HIGH);
  while (!Serial) {
   ; // wait for serial port to connect. Needed for Leonardo only
 }
 Serial.print("Initializing SD card...");
 // make sure that the default chip select pin is set to
 // output, even if you don't use it:
 pinMode(10, OUTPUT);

 // see if the card is present and can be initialized:
 while (!SD.begin(chipSelect)) {
   Serial.println("Card failed, or not present");
   digitalWrite(led, LOW);
   delay(1000);
   digitalWrite(led, HIGH);
   delay(1000);
   digitalWrite(led, LOW);
   delay(1000);
 }
 Serial.println("card initialized.");
 delay(3000);
 digitalWrite(led2, HIGH);
 digitalWrite(led, HIGH);
}
void loop()
{
  //Main sensing routine
     val = analogRead(tempPin);
   float mv = ( val/1024.0)*5000;
   float  Cen = (mv/10) + 3.12;
  //   float farh = (cel*9)/5 + 32;
  Serial.println("Logging.....");
 //String Temperature_Centigrade = String(Cen);
float Temperature_Centigrade = Cen;
 File dataFile = SD.open("datalog.csv", FILE_WRITE);
 // if the file is available, write to it:
 if (dataFile) {
   dataFile.println(Cen);
    digitalWrite(led3, HIGH);
    delay(2500);
```

```
    digitalWrite(led3, LOW);
    delay(2500);
   dataFile.close();
   // print to the serial port too:
   Serial.println(Temperature_Centigrade);
  }
  // if the file isn't open, pop up an error:
  else {
   Serial.println("error opening datalog.csv");
  }
}
```


Ivan Imonigie was born on 28th May, at Auchi Edo State Nigeria. He obtained his Bachelors in Engineering degree in Electrical Electronic Engineering with a First Class Honor Division from the University of Benin City, Edo state Nigeria in 2007.

He has over 12years experience in the Energy industry and has been part of the development and deployment of numerous innovative techniques employed in the industry in the area of wireline logging and data acquisition. He currently works as Field Service Quality Engineer for one of the world's leading oilfield service companies and his job role entails, ensuring the operability of downhole electronic tools which comprises; analysing equipment performance, providing expert support on service quality investigations, developing and deployment of design improvement, and dissemination of technical solutions to keep critical downhole electronic assets working at optimum performance. He is a professional member of the Institute of Electrical and Electronics Engineering (IEEE) and his research interest is to promote cost-effective engineering solutions for the Energy industry and the engineering community at large.


Bamidele Idiong was born on 10th November, at Surulere in lagos State, Nigeria. He obtained a Higher National Diploma in Instrumentation and Control Engineering from Petroleum Training Institute, Effurun, Delta State in 2004. After his National Service in 2006, he joined one of the world's leading oilfield service companies same year. In the course of his service in the industry, he received technological trainings in major cities in the world including Houston Texas, Fuchinobe in Japan, Scotland, Paris and United Arab Emirates. Due to his zeal in academic pursuits, he moved to the United Kingdom where he obtained a bachelor's degree in electrical and Electronics Engineering from the University of Sunderland in 2012, with a first-class honor of 4.0/4.0 CGPA and later obtained master's degree in Electronics and Telecommunication Engineering from the University of Port Harcourt, Rivers State, Nigeria, in 2017. He's currently working as an Electrical Engineer in the technology center of one of the world's leading oilfield services companies. His research interest is Automation and Embedded Systems. He is a registered Engineer with the Council for the Regulation of Engineering in Nigeria (COREN) and a member of Institute of Electrical and Electronics Engineering (IEEE).


Ebenezer John was born on 22nd April, at Abak in Akwa Ibom State, Nigeria. He obtained a Bachelors degree in Physics and Electronics with a Second Class Upper Division from the University of Port Harcourt, Rivers State in 2015. In the course of his studies, he was trained in advanced Embedded Systems Design. Due to his interest in IoT and Embedded Systems, this had led him to partner with a private research laboratory to conduct and participate in several researches in the field of IoT and Embedded Systems. After his National Service in 2017, he joined the United Bank for Africa Plc, a top global African bank with offices in Africa and Europe where he delivers excellently as a Digital Banking Officer. His passion for scientific researches has led him to build different IoT solutions for clients, starting from the design through to simulation, and product prototyping.