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AN INNOVATIVE DESIGN OF AN ELECTRONIC DATA ACQUISITION MEASUREMENT SYSTEM

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Abstract

In this research work, an innovative design of an electronic data acquisition measurement system is developed. The system consists of measuring voltage, resistance, capacitance and temperature. The unique feature of this system is that it can be measured three types of voltages simultaneously and display them on the liquid crystal display (LCD). The measurement result data are displayed on the LCD and stored in the micro secure digital (SD) card. The system is constructed using an Arduino mega 2560 development board, resistors, capacitors, temperature sensor and other electronic components. The system is innovatively designed to measure the electrical characteristics and electronic components.

Keywords: Data acquisition, Arduino ATmega2560, LM 35 sensor, micro SD card, measuring voltage, measuring resistance, measuring capacitance

Introduction

The process of collecting and measuring electrical data in a specific way is called data acquisition. To operate a control system or drive a prototype design for electronics studies, a data acquisition system is essential to obtain various parameters of electrical and physical properties. It is very important to develop or analyses an electronic circuit or to develop material science, thin film technology, developing solar cells and study of semiconductor researches. Data acquisition applications are usually controlled by software programs developed using various general-purpose programming languages such as Assembly, BASIC, C, C++, Fortran, Java, Lab VIEW, Pascal, etc. Data acquisition system is the process of sampling signals into digital numeric values to measure real world physical conditions. Data acquisition system convert analog waveforms into digital values for processing [Floyd, (2006)].

Materials and Method

Arduino Mega 2560 Microcontroller

Arduino microcontroller is a microcontroller built on a single printed circuit board. This board provides all the necessary circuitry for control work, including a microprocessor, I/O circuits; clock generator, random-access memory (RAM) that Stored program memory and required support ICs. The Arduino Mega 2560 includes multiple digital and analog I/O pins and selects the microcontroller used in the circuit for uploading of program code to larger program memory on Arduino developer boards. This code can be created in a high-level programming language. The Arduino mega is the heart of the circuit, a program code to operate the data acquisition system [John, **(**2013)]. Arduino mega includes 54 digital I/O pins and 16 analog input pins. The Arduino mega board works with a 16 MHz crystal oscillator.

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The Arduino mega board 2560 can be connected to a computer with a USB cable and powered via the USB connection or with a AC-to-DC adapter or battery to get started. The adapter can be connected by plugging a 2.1 mm center-positive plug into the board's power jack. The recommended range is 7 to 12 volts. If voltage supplied with less than 5 V, the board may become unstable. If using more than 12 V, the voltage regulator may overheat and damage the board. The whole circuit power supply can be obtained from the dc barrel jack by connecting with two lithium-ion batteries of 3.7 V rechargeable batteries. The component of Arduino mega microcontroller is shown in Figure 1**.**

Rotary Encoder Module

A rotary encoder-based menu is created to choose different measuring quantities by rotating the rotary encoder. A rotary encoder is a type of position sensor which is used for determining the angular position of a rotating shaft. It generates an electrical signal, either analog or digital, according to the rotational movement. Turning the rotor will change the menu and pressing the rotor will enter the selected menu and pressing again will return to start of the menu selection. Component of rotary encoder module is shown in Figure 2.

Micro SD Card Module

In some data acquisition, micro-SD card is required to log the measuring results [Jack, (2015)]. Logging data to the micro-SD card and exporting data to excel worksheet are at the time for measuring physical quantities. The terms SD card stands for “Secure Digital” Card, there are many types of SD cards. The SD cards can work in two operating modes, one is using the SD mode commands and the other is serial peripheral interface (SPI) mode. The SPI module consists of six pins and they are four SPI pins and two power pins. The data logging on SD memory card can be stored measuring data. While the data is logging on the micro-SD card, the data can be exported to the excel worksheet by connecting the circuit using USB cable [Harold, (2011)]. The Parallax Data Acquisitions (PLX-DAQ) tool software is an add-in tool for Microsoft excel. The component of micro-SD card module is as shown in Figure 3.

Temperature Sensor

Temperature is one of the most commonly measured parameters in the world. They are used in daily household devices from microwave, fridges, air conditional and all fields of engineering. The LM35 series are precision integrated-circuit temperature devices with an output voltage linearly-proportional to the centigrade temperature. The LM35 device has an advantage over linear temperature sensors calibrated in Kelvin, as the user is not required to subtract a large constant voltage from the output to obtain convenient Centigrade scaling. The LM35 device does not require any external calibration [10]. LM35 has very low self-heating of less than 0.1°C in still air. The LM35 device is rated to operate over a -55° C to 150° C temperature range. LM35 can be operated from a 5 V supply and the stand by current is less than 60 uA. The sensitivity of LM35 is 10 mV/degree Celsius. As temperature increases, output voltage also increases (E.g., 250 mV means 25°C). Temperature sensor LM35 is as shown in Figure 4.

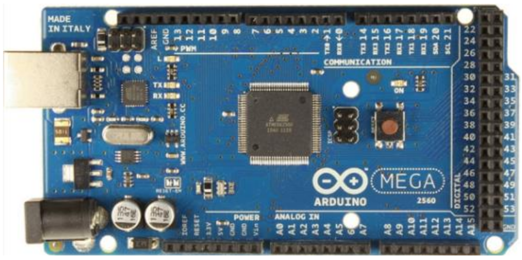

Figure 1: The component of Arduino mega 2560 microcontroller

Figure 2: Component of rotary encoder module

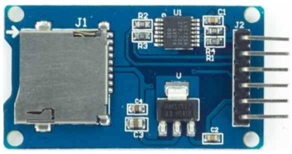

Figure 3: Component of micro-SD card module

Figure 4: Temperature sensor LM35

Development and Operation of the System

The flow chart of an electronic data acquisition measurement system is shown in Figure 5. The circuit diagram of an electronic data acquisition measurement system is shown in Figure 6. The main circuit board consisted of Arduino Mega 2560 board, rotary encoder, alphanumeric liquid crystal display (LCD 20×4), a micro-SD card module and temperature sensor.

Measuring of voltage was made by selecting the menu of rotary encoder to V1 or V2 or V3 or three voltages. The voltage level of three different test points could be measured at the same time. The voltage divider circuit utilized 4.7k Ω, 47k Ω and a 10k Ω variable resistor.

The variable resistor 10kΩ was used to calibrate. The voltage divider ratio was the maximum input 50 V divided 10 times. Therefore, Arduino microcontroller input pins (A0, A1, A2) got maximum 5 V. Similarly, the other two pairs of volt meters were constructed using voltage divider circuits. In the program coding, the resolution of analog input was 10-bit resolution. Arduino microcontroller resolution value was 4.88 mV (5000mV/1024) on each digital reading because of reference voltage 5 V. The real input voltage was 10 times decreased by voltage divider circuit. Therefore, the voltage was again multiplied with 10 to obtain the real value. Then the value was printed on the LCD as volt meter 1 or volt meter 2 or volt meter 3 or three-volts meter. The voltage measuring was for higher voltage level 50 V.

The unknown resistor Rx was connected between the analog input pin and ground line. Therefore, one of the resistors on digital pin and unknown resistor become a voltage divider circuit. There was a specific voltage drop at the junction. The digital output 7 pins (pin 35,37,39,41, 43, 45, 49) and an analog input pin A3 pin were used to measure the resistance of an unknown resistor Rx. Seven different values of resistors are connected in parallel between each digital I/O pins and analog input pin. Arduino microcontroller read at analog input pin A3 pin. But the circuit was designed auto ranging, therefore, various resistors were added to achieve accurate reading in the program. But, switching diodes were added to protect reverse bias on the I/O pins, which would encounter incorrect reading of the unknown resistor value. Since the voltage divider output was a simple ratio of the input voltage. Simple ratio impedance through to the ADC input. If the relative impedance was low, unknown resistance could be measured in the low mega-ohm range. Then the unknown resistor could be obtained simple ratio of voltage divider calculation. To achieve measuring very high resistances, a buffer is required for the ADC through a voltage follower with a very high (tens or hundreds of tetra-ohms) impedance input.

The value of an unknown capacitor could be investigated by using resistor capacitor (RC) circuits, known as the time constant (TC). (TC = R * C) where TC was the time constant in seconds, R was the resistance in ohms, and C was the capacitance in farads. According to the RC time constant, charging and discharging resistors were connected. The charging pin was pin 31 and discharge pin was pin 33. The discharge pin is to prevent discharging the capacitor. The charging pin was HIGH for charging the capacitor. The junction of two resistor and capacitor was feed to analog A4 pin to check whether the voltage level of capacitor becomes 63.2% of the total voltage. The initial charging time was recorded by the Arduino. If charging voltage was under 63.2%, the charging, time counting and analog reading are looping again and again. If the analog reading is larger than 63.2%, time difference is made for current time and recorded start time. The charging voltage of 63.2% equals 1 TC. Using time constant equation, unknown capacitor value could be obtained. When the rotary encoder is selected to measure the unknown capacitor. Unknown capacitor value could be measured in micro farad, nano farad and pico farad range.

Temperature sensor basically measures heat or cold generated by an object. The semiconductor temperature sensor LM35 was used in the circuit. The power pin 1 of temperature sensor was connected with the 5 V power supply. The output pin 2 generated analog voltage according the variation of temperature. The 10-ohm resistor and 1uF capacitor were connected in series between the output of LM35 and ground line to protect the external interferences of electrical noises. The output voltage changed 10mV for 1° C. The resolution of analog reading was 10bit value (0 to 1023), the reference voltage of LM35 is 5 V (5000 mV). Then the resolution was 5000 mV was divided by1024 and obtained 4.88mV. The program operation of the thermometer was chosen ºC or ºF by rotating the rotary encoder. Then the program jumps to temperature reading routine by reading the analog voltage on A5 pin and converted to temperature in degree Celsius.

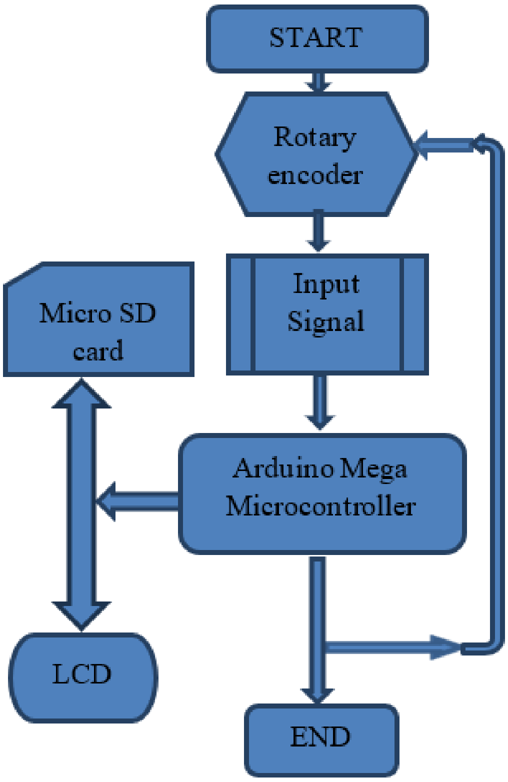

Figure 5: The flow chart of an electronic data acquisition measurement system

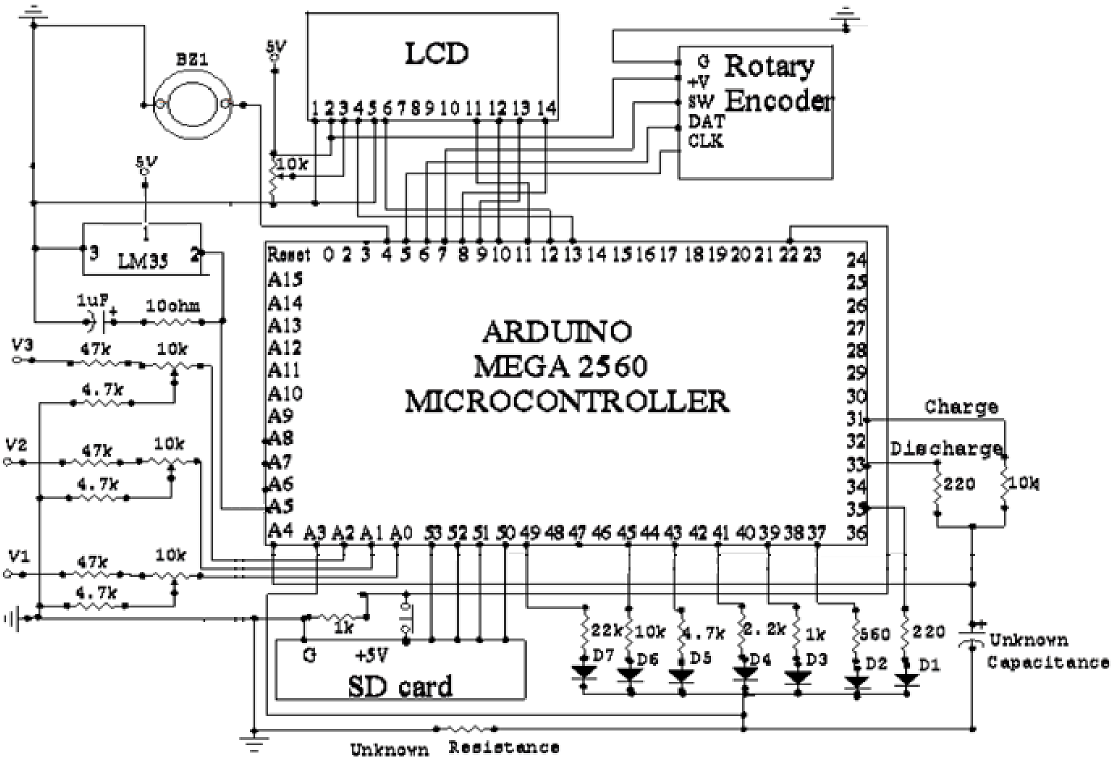

Figure 6: The circuit diagram of an electronic data acquisition measurement system

Results and Discussion

For measuring voltage, rotary encoder could be chosen four categories which were “volt meter one”, “volt meter two”, “volt meter three” and “three volt meter”. The volt meter circuit was an application of analog to digital converter. The voltage divider circuit was used to measure high voltage level because Arduino microcontroller of reference analog input voltage was maximum 5 V. The measuring voltage range is 0 to 50 Vdc. Circuit operation for measuring voltage was shown in Figure 7.

For measuring unknown resistor Rx, the value of unknown resistor could be calculated using voltage divider circuit. Unknown resistor Rx was connected between the analog input pin and ground line. The voltage on the detection point was read to measure voltage using the ADC on the microcontroller. The circuit operation for measuring resistance was shown in Figure 8.

For measuring unknown capacitor Cx, known resistor and unknown capacitor were connected in series. The analog input A4 pin was repeatedly reading the voltage level of unknown capacitor Cx. If the charging was less than 63.2% of total charge, the time counting and analog reading were looping again and again. The unknown capacitance could be calculated using known resistor and time constant. The circuit operation for measuring of capacitance is as shown in Figure 9.

For measuring temperature circuit, output voltage of temperature sensor LM35 was connected to input A6 pin of microcontroller. The value was calculated by microcontroller and displayed on LCD in degree Celsius or Fahrenheit. To protect the external interferences of electrical noises, 10 Ω resistor and 1 uF capacitor were connected in series between the output of LM35 and ground line. The circuit operation for measuring temperature was shown in Figure 10.

Conclusion

The measurement of maximum dc voltage could be measured from 10 mV to 50 V. Each voltage divider circuit was connected adjusting small trimmer resistor to calibration. The measuring resistances results were nearly the same value of color code reading within tolerance. The maximum resistance value can be measured 20 MΩ. The capacitance values could be measured range from microfarad to picofarad. The measuring temperature range is from −55° C to 150° C.

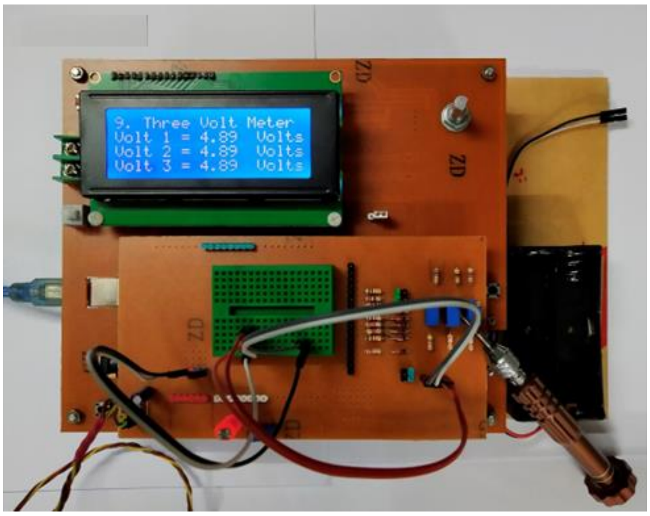

Figure 7: Photograph of measuring voltage results

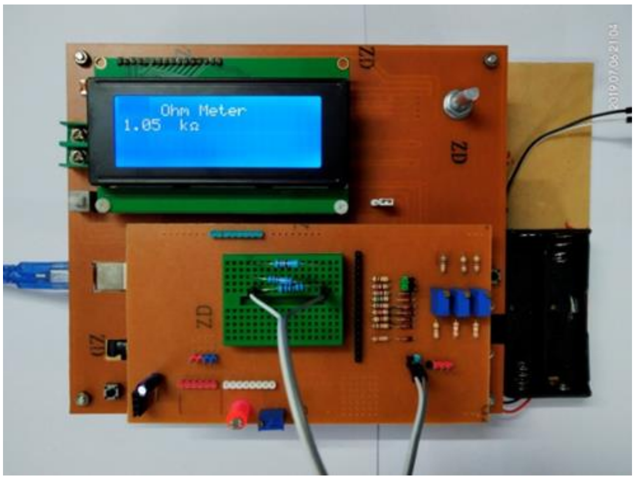

Figure 8: Photograph of measuring results for resistance circuit

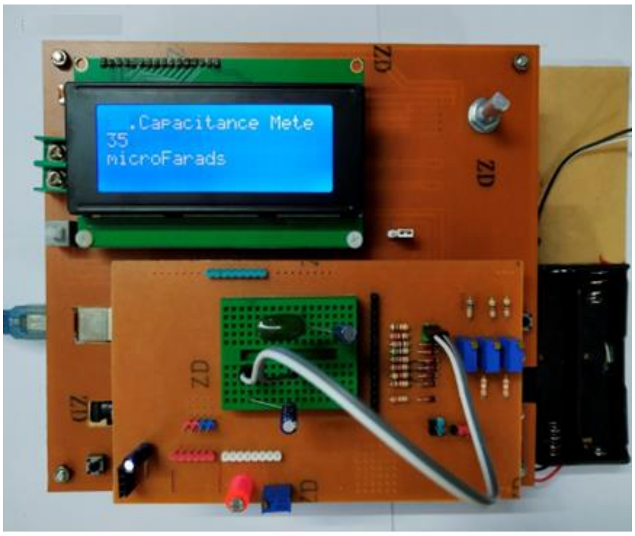

Figure 9: Photograph of measuring results for capacitance circuit

Figure 10: Photograph of measuring results for temperature

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