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Prototyping of an Arduino Micro-Controlled Digital Display System

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ABSTRACT

Advancement in science and technology has led to the popularity of digital displays (bill boards) for advertisement and public enlightenment as opposed to manually painted bill boards. One advantage of such digital displays is the flexibility of changing the contents without necessarily removing the board. This is made possible mainly through the use of a microcontroller programmed to control the characters displayed on the screen. This paper discusses the design and prototype implementation of an Arduino microcontroller based liquid crystal display (LCD) system that uses a light dependent resistor (LDR). The Arduino microcontroller is a microprocessor embedded circuit board with open source software development environment that allows easy development of microcontroller based devices. It allows for the development of micro-controlled systems that can be adapted to particular needs. The Arduino microcontroller was connected (hard-wired) to the pins of an LCD programmed to display a list of names continuously but one at a time. The developed system was tested and found to meet the required specifications. We intend to extend our work to provide a keypad programmed to allow manipulation of the characters displayed on screen. Our future work will also explore the use of a bigger LCD with suitable hardware to manipulate and display graphics in addition to the characters.

Keywords- *Arduino; liquid-crystal-display; microcontroller; light-dependent-resistor*

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1. INTRODUCTION

Bill boards have traditionally been used to pass information such as adverts, campaign posters and important notices to the general public. However, advancement in technology has led to gradual replacement of manually painted billboards with digital display screens with the advantage of being able to change the screen contents without removing the board. Data displayed on digital screens involves the visual presentation of processed data by specially designed electronic devices. Digital displays are widely used as terminals in several technical devices such as those used in data transmission, diagnostics and signalling/ inspection systems [1][3]. Digital displays make use of cathode ray tube (CRT), light emitting diode (LED) or liquid crystal display (LCD). The LCD is a video display that utilizes the light modulating properties of liquid crystals to display pictures or text on a screen; it is currently the most cost effective technology used in the manufacture of digital displays [3].

Data display units are important part of embedded systems which makes use of microcontrollers. The system designed in this work makes use of an Arduino microcontroller, a tool for making computers that can sense and control more of the physical world than the desktop computer. It's an open-source physical computing platform based on a simple microcontroller board, and a development environment for writing software for the board.

It can be used to develop interactive objects, taking inputs from a variety of switches or sensors, and controlling a variety of lights, motors, and other physical outputs [1][2][4][5]. The boards can be assembled by hand or purchased preassembled.

In this paper, we discuss the design and prototype implementation of an Arduino microcontroller based liquid crystal display (LCD) system that uses a light dependent resistor (LDR). The Arduino microcontroller was connected (hard-wired) to the pins of an LCD programmed to display a list of names continuously but one at a time. Section 2 gives a theoretical background and review of previous works related to our system design and construction while our methodology is explained in Section 3. Evaluation of the prototype is highlighted in Section 4 with Section 5 providing our conclusions with pointers towards future work.

2. THEORETICAL BACKGROUND

Arduino microcontroller has been widely used mostly by researchers and educators to develop low-cost hardware for interaction design and create interface circuits to read sensors that are used to control different devices with minimal effort [2]. Arduino consists of both a physical programmable circuit board (microcontroller) and a piece of software with Integrated Development Environment (IDE) that runs on the system.

The software is used to write and upload computer code to the physical board and is frequently used in most cases to abate programming complexities associated with other types of microcontroller [1]. Arduino can be programmed within the limitations of 32KB memory and processing power of the microcontroller. It can function autonomously without being connected to a computer, or alternatively programmed to respond mainly to commands sent from the computer via various software interfaces [6].

In many cases, users require the display of various outputs of measuring instruments or a sensory system in specific designs. If these systems are hardware controlled, they become inflexible and bulky [3]. However, replacing such circuits with a microcontroller and a few standard chips makes the system smarter, faster, flexible and more accurate. Unlike most previous programmable circuit boards, Arduino does not need a separate piece of hardware in order to load new code into the board; one can simply use Universal Serial Bus (USB) cable [4]. Several researchers have exploited these advantages in designing specific micro-controlled devices [4][8][9][14].

An Arduino based smart energy meter for advanced metering and billing system has previously been proposed [4]. The author integrated Arduino microcontroller with Global system for Mobile (GSM) short messages service to provide automatic metering functions that are predefined. The electronic meter displays the energy used on LCD display. In order to prevent interference, Arduino was used to present the detection program and interface the system components. Similarly, a single phase digital prepaid energy meter based on two Arduino microcontrollers and a single phase energy meter IC was constructed [8]. The digital prepaid meter calculates energy consumption using the output pulses of the energy meter chip and the internal counter of one of the microcontroller. It also used the other microcontroller as a smart card for reading unit recharged by consumer.

The capabilities of an Arduino microcontroller IDE module to load and save special configuration for an intelligent greenhouse system that allows plant to grow through the year has also been previously exploited. Arduino serves as the interface between the system actuator and the sensors, thereby controlling all the operations of components such as control sensor, control actuator among others [5]. Arduino has been employed in various light control applications such as LED light control of an open source multispectral imaging system for rodents [7]. In [6], an inexpensive but effective Arduino-based light emitting diode (LED) simulator system for vision research was developed. The main design goal of this system was to use open-source components as much as possible, and reduce design complexity allowing use of the system by end-users without advanced electronics skills. The core of the system is the USB-connected Arduino microcontroller platform designed with specific emphasis on ease-of-use creating interactive physical computing environment.

An Arduino-based supervision display system for monitoring banana ripening stages was developed [10]. The Arduino system predicts the ripening stages of banana and display the complete process according to the colour changing stages of banana. Also, an Arduino-based positioning system using visible light communication and ultrasound was presented in [15]. All the components of the system, which includes the GPS module, the visible light data receiver, and two ultrasonic sensors, were interfaced and controlled by an Arduino Mega and Arduino Uno microcontroller. The transmitter system consisted of four LED shields each attached to the Arduino Uno which is programmed to transmit the global position relevant to the indoor position of the LED lamp.

This paper shows common similarities with the previous display and measuring systems developed by some researchers, exploiting some of the potentials of Arduino microcontroller such as user friendliness and capability to abate programming complexity. However, unlike these previous researches, we present a generic display system using an LCD (Liquid Crystal Display) with an LDR (Light Dependent Resistor) that controls the backlight of the display unit based on light intensity of the environment.

3. METHODOLOGY

The methods that have been employed in this work include design of circuit diagrams for the prototype as well as development of required firmware into prototype. The system block diagram is shown in Figure 1 and has four main components including power supply unit, sensing unit, controller unit (Microcontroller) and display unit (LCD).

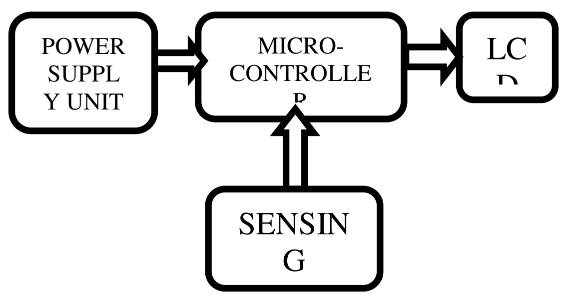

Figure 1: Block Diagram of digital display system

3.1 Sensing Unit

The sensor unit is used to detect the presence of light at certain levels of intensity in the region it is strategically mounted. Here, in order to detect the intensity of light or darkness, a Light Dependent Resistor is used as the sensor. The LDR is a special type of resistor which allows higher voltages to pass through it (low resistance) whenever there is high intensity of light. And passes a low voltage (high resistance) whenever it is dark. We took advantage of this property of the LDR in designing our Arduino microcontroller based LCD data display. The LDR was employed to automatically turn on the backlight of the display system when it is dark or there is no sufficient lighting to view what is being displayed.

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LDRs have a sensitivity that varies with the wavelength of the light applied and are nonlinear devices. Figure 2 shows the LDR circuit diagram. The LDR gives out an analog voltage when connected to a voltage (5V), which varies in magnitude in direct proportion to the input light intensity on it. In other words, the greater the intensity of light, the greater will be the corresponding voltage from the LDR. Since the LDR gives out an analog voltage, it is connected to the analog input pin of the Arduino Microcontroller unit (MCU). The Arduino, with its in-built Analog to Digital Converter (ADC) then converts the analog voltage (0-5V) into a digital value in the range of (0-1023). Thus, when there is sufficient light in its environment or on its surface, the converted digital values read from the LDR through the Arduino will be in the range of 800-1023. The easiest way to use the LDR is in voltage divider configuration. The voltage that appears at the analog input will vary depending on the amount of light hitting the LDR.

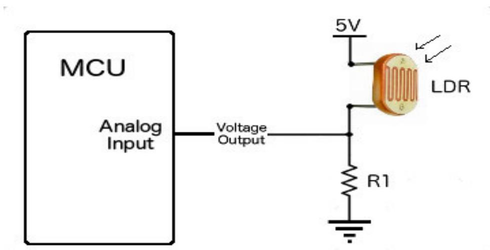

Figure 2: LDR circuitry

3.2 Arduino Microcontroller Unit
The microcontroller used in work is an Arduino Atmega-168 microcontroller kit designed especially for small projects with most of its functions provided on board. It can be connected to computer using USB cable to burn programs in the microcontroller chip. USB connection also provides on board power to the chip and also for any peripherals connected [11][12][13]. Therefore, there is no need to connect separate power source since power is sourced through the USB port of computer.

Nevertheless, it can be powered by external source such as 6-9V DC adapter when the kit is used as a stand-alone device to perform special functions according to the written code. The Arduino Uno board consists of ATmega328 microcontroller, 14 digital input/output pins, 6 analog inputs, a 16 MHz resonator, a USB connection, a power jack, and an ICSP header. The most important features of the board used in this work were the microcontroller, which allows for the building of programs using C++ Programming language, and the digital input/output pins, which allows for the transfer of information between the board and the LCD display.

3.3 Liquid Crystal Display
The LCD module enables the system display a corresponding output based on specific input. In this work, a 16x2 LCD display as shown in Figure 3 was interfaced with an Arduino board and a LDR.

The 16x2 LCD has 32 characters in total with 16 characters on each of the two display lines available and each character occupies a 5x10 (50) pixels box. This LCD can be interfaced with a microcontroller in 8-bit or 4-bit mode. In 8-bit mode, character data encoded with the ASCII standard and LCD commands are sent through the data lines D0 to D7. In other words, the 8 bits data is send at a time and data strobe is given through line E of the LCD. During the 4-bit mode, only 4 data lines D4 to D7 are used. Here, the 8 bits data is divided into two parts and are sent sequentially through the data lines. The idea of the 4 bits communication was introduced to save the pins of microcontroller for other uses. Though the 4-bit mode communication is slower than 8-bit mode, this speed difference has no significance as LCDs are slow speed devices. Thus 4 bit mode data transfer is used in our work.

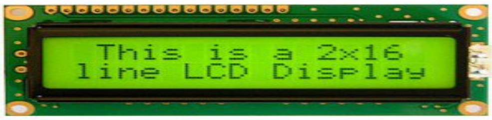

Figure 3: 16x2 LCD Screen

3.4 Power Supply Unit
This is the unit that transfers electric power from a source to a load using electronic circuits as shown in Figure 4. It is required that power supply units in Microcontroller systems are small in size, light, cheap, high power conversion efficiency, possess electrical isolation between the source and load, low harmonic distortion of input/output waveforms and high power factor (PF) from an AC voltage source [8]. Some power supplies require regulation of output voltages, especially conversion of utility AC input power into regulated voltage(s), required for electronic equipment.

In our work, the power supply unit supplies the required amount of electrical energy to system. The voltage requirement for the design is a +5V, hence the power unit is designed such that it delivers a fixed and steady voltage of +5V. It consists of a 24V step down transformer on the input side, which supply the bridge rectifier system with the required energy. The bridge rectifier module has four diodes and converts the AC input voltage from the transformer into DC voltage. The output of the bridge rectifier consisting of ripples is passed through the 4700μF capacitor to filter off the ripples. The LM7805 regulates the voltage and ensure that its output does not exceed +5V at any moment.

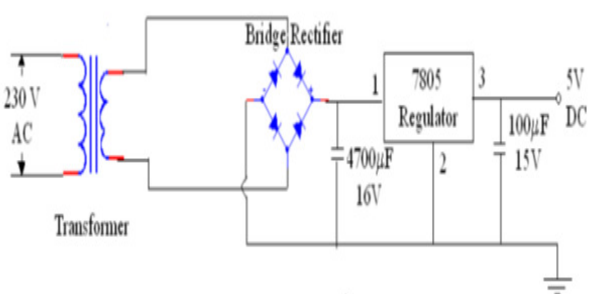

Figure 4: Power Supply Unit Circuit

4. SYSTEM PROTOTYPE CONSTRUCTION

The LCD is connected to the LDR and the microcontroller as shown on the overall circuit diagram in Figure 5.

The microcontroller is programmed to enable the LCD display list of events as stipulated in the programmed firmware embedded on a ROM.

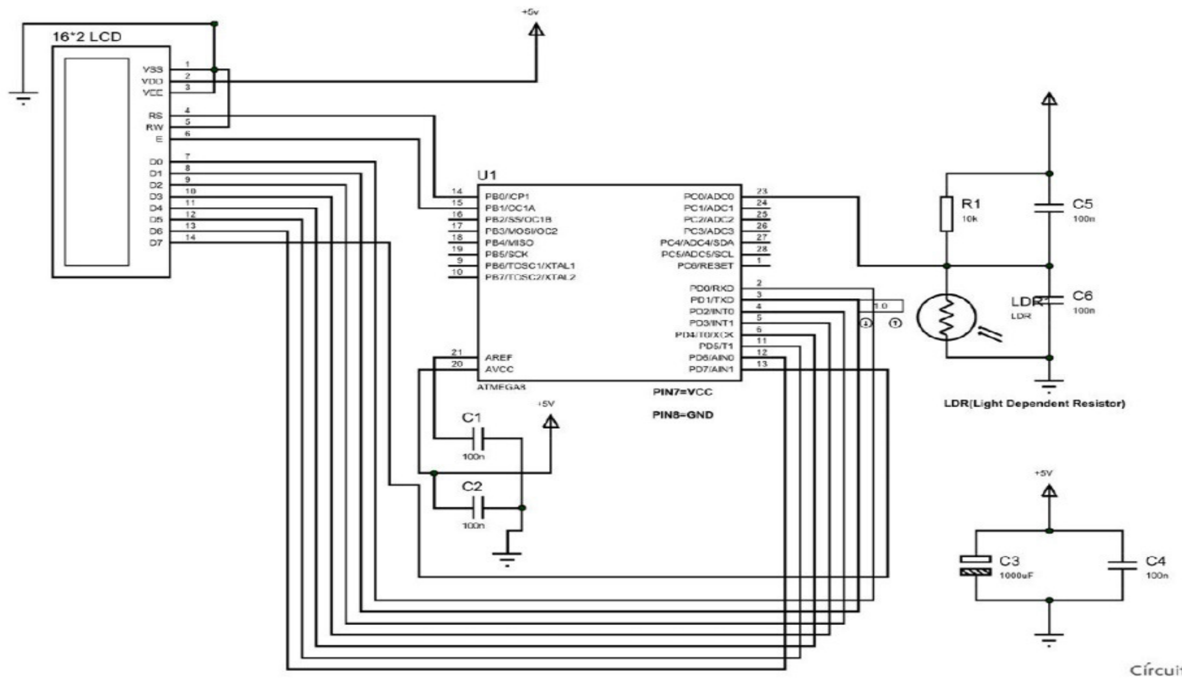

Figure 5: Overall Circuit Diagram of Arduino LDR-controlled LCD

A prototype of the system was made by arranging the components on the breadboard as shown in the circuit diagram in Figure 6. The V_{CC} (5V) and GND (0V) are connected to the breadboard in order to power the Microcontroller IC and the LCD. The power source is not connected until all other connections are done. The pins on LCD are then connected to the microcontroller with V_{EE} to pin2, RS to pin3, R/W to pin4, EN to pin5, DB4 to pin11, DB5 to GND, DB6 to pin12, DB7 to 1K resistor connected to VCC and tapped to connect to two 1K resistors arranged in parallel connected to the GND.The LED+ is also connected to V_{CC} while the LED- pin goes to GND.

The Light Dependent Resistor is connected by placing one terminal on V_{CC} and the other terminal was connected to the analogue pin A0 of the IC, then tapped with a 1K resistor connected to the ground. Figure 6 illustrates the components connection on the breadboard

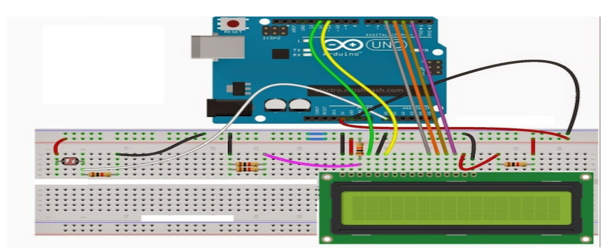

Figure 6: Prototyping on Breadboard

In summary, the system works by the sensory unit triggering the circuit on changes in light intensity. On high light intensity, the sensor is at logic one and the microcontroller executes its programmed instructions by enabling the LCD to display the specified data in a continuous and an attached LED indicator illustrates the status of the sensor. The sensor status is reconfirmed for consistency until the sensor is in an inactive state which leads to the shutting down (switching off) of the system.

5. CONCLUSION

One of the main reasons that LCD displays have become so common in recent years is due to the ease at which they can be interfaced with microcontrollers and other microprocessor based devices. Although an Arduino microcontroller was used to demonstrate this ability in this work, a variety of other microcontrollers can be used to achieve the same result. On a similar note, much more can be accomplished with an Arduino microcontroller and an LCD display than what was demonstrated in this work.

Further hardware can be added to the prototyped circuit such as real time clocks and thermometers thereby allowing the LCD to display the current time and temperature. The simplicity of their design and ease of interface allow for LCD screens to be used in a variety of projects on both a large and small scale. Finally, this design enables the manipulation of the LCD using the Light Dependent resistor as a tool whose voltage variation depends on the light intensity.

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