ARDUINO-BASED EMBEDDED SYSTEM FOR GREENHOUSE MONITORING

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Abstract : Today embedded systems are replacing various systems that used to be designed with a set of complex electronic circuits. Usually the heart of the embedded system is a microcontroller. One example of a microcontroller is Arduino. Arduino is an open source based prototyping platform used to sense and control physical devices. The purpose of this thesis was to create a microcontroller-based embedded system for monitoring green-house environmental variables. The user can control the greenhouse environment through a website. The website displays monitoring data to the user on a 24-hour line chart. Theory explains the use of Arduino microcontroller and how it is used in embedded systems. The practical part of the project introduces which hardware components are used and how they are used to build the system. Theory of the thesis is used as a base for designing the software layer. Software section of the practical part ex-plains how the software was designed and implemented on top of the hardware layer .

Index Terms- Arduino, embedded systems, sensors, webserver

I.INTRODUCTION

In 2008 the number of devices on the internet exceeded the number of people on the internet. It is esti-mated in 2020 there would be over 50 billion devices connected. Internet of Things (IOT) is starting to support the process connecting real-world to the Internet. Sensors and microprocessors are recording and transmitting data to the Internet. Rapidly increasing Internet-connected sensors means that new clas-ses of technical capabilities and applications are being created. Constant monitoring is deepening the understanding of the internal and external worlds encountered by humans. High-frequency data pro-cessing is developing how humans adapt to the different kinds of data flows enabled by the IOT. In this paper, microcontroller-based embedded system is designed to monitor greenhouse environmental variables. In addition to monitoring temperature and moisture, the user can control greenhouse environ-ment through relays. The system was designed using Arduino Due microcontroller and its development environment. Arduino webserver monitoring system was programmed using the C programming lan-guage. The sensor data is read and processed by Arduino and it is displayed to the user through the web interface. Website programming is designed with AJAX, HTML and CSS languages. The main aspects of designing the system were the simple usability and the low cost of manufacturing. User interface is designed to be used by people who have no prior computer knowledge. The whole design process is divided to four sections: design model, architecture model, implementation and testing. System design theory is applied when designing the practical part. Theory describes the use of the Arduino microcontroller and how it is utilized in the embedded systems. Practical part of the project is divided into two parts: Hardware and Software. Practical part describes manufacturing of the green-house monitoring system. The wiring diagram is explained such a way that someone without practical experience can replicate the process of creating the system. The source code of the user interface and the system are published in appendices.

.II. PROPOSED SYSTEM

(i) EMBEDDED SYSTEM

An embedded system is an applied computer system that is built to control a range of functions. Because of rapidly evolving technology the meaning of embedded systems is a vastly fluctuating definition. Ad-vancing technology causes decrease in the cost of manufacturing and allows implementation of various hardware and software components to embedded systems. Embedded system is dedicated to a specific task. Systems normally consists of inputs, outputs and a small processing unit. Most of the devices used in our everyday life are some kind of embedded systems. Devices like mobile phones, watches, and elevators are all embedded systems. Most of the embedded systems are reactive systems, which means that the information received by the system is constantly processed and the system acts based on the information. The information changes according the interaction system and the environment. The example of a reactive embedded system is the car-braking system. Car brakes need to react instantly to a user input. System needs to react in a split second to prevent collision. (Karvinen & Karvinen 2009, 8-11.) Below figure 1 shows are different embedded systems inside of a car.

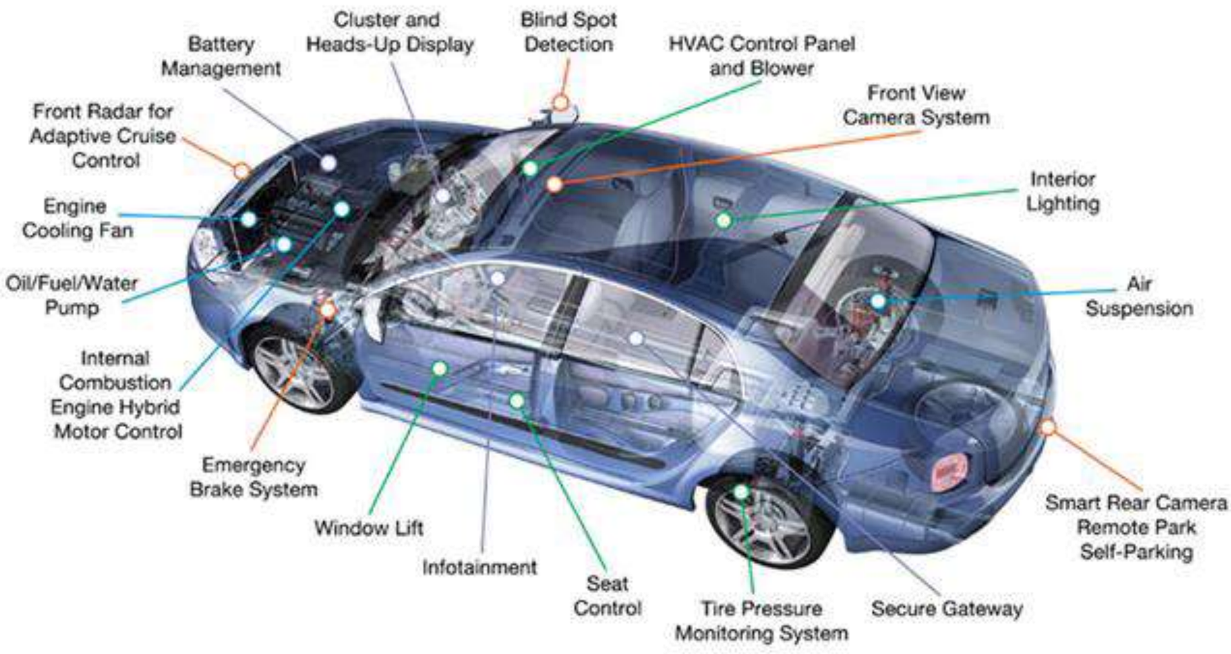

Fig1 : Embedded Systems Inside Of A Car

(ii)ARDUINO

Arduino is an open source tool for developing computers that can sense and control more of the physical world than desktop computer. It is an open-source physical computing platform based on a simple microcontroller board, and a development environment for writing software for the board. The software is written in C or C++ programming language. The Arduino development board is an implementation of wiring, a similar physical computing platform, which is based on the processing multimedia programming environment. (Arduino 2011a.)

This single chip microcontroller has a microprocessor, which comes from a company called Atmel. The chip is known as an AVR. The AVR chip is running at only 16 MHz with an 8-bit core, and has a very limited amount of available memory, with 32 kilobytes of storage and 2 kilobytes of random access memory. Basic model of Arduino is shown in below figure 2. Arduino setup build around Atmel microprocessor causes it to be easy and popular to be used in all different kinds of DIY projects. (Evans 2011, 2-3; Banzi 2011, 17-18.)

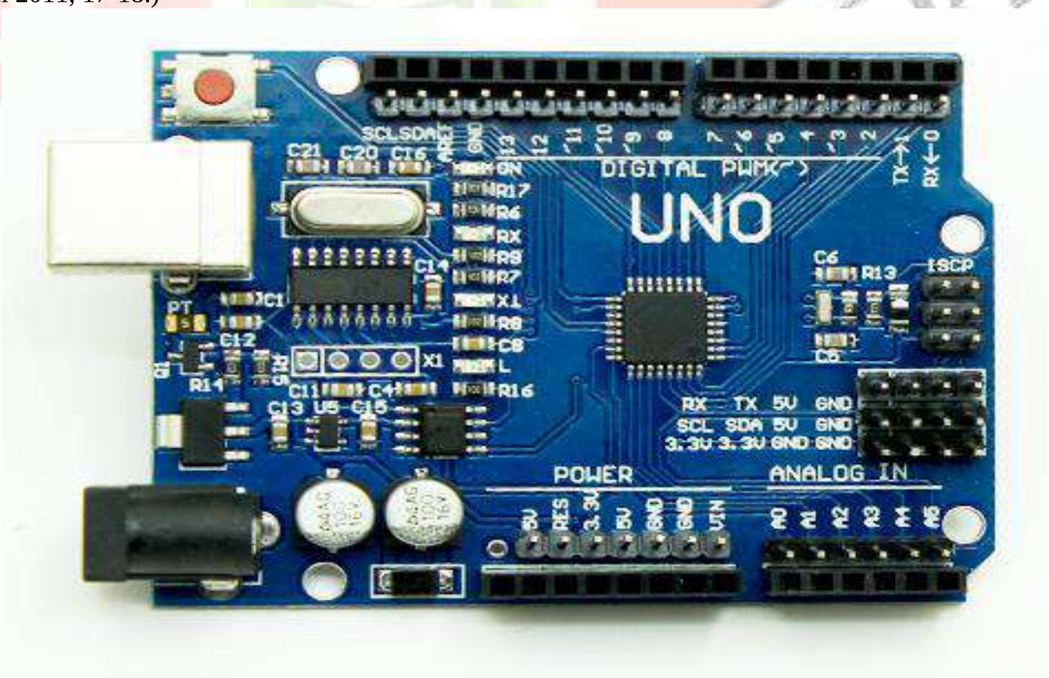

Fig2 Arduino Uno microcontroller

(iii)Arduino Due

Arduino Due is the Arduino Microcontroller family's first development board based on the Atmel SAM3X8E ARM Cortex-M3 CPU that is shown in fig3. It has 54 digital input/output pins, 12 analog inputs, an 84 MHz clock, an USB OTG capable connection, 2 DAC (digital to analog), 2 TWI, a power jack, an SPI header, a JTAG header, a reset button and an erase button. Arduino Due has extended memory capabilities with 512kb of FLASH memory and 96kb or SRAM. The difference to other Arduino family boards is that the logical level voltage is 3.3v, the most of the Arduino boards run 5v on logical level. Arduino Due is the extended version of the Arduino family and it has all the basic func-tionalities of an Arduino. The microcontroller does not lack its usability because it has good compatibil-ity with different module boards (shields). (Arduino 2011c.)

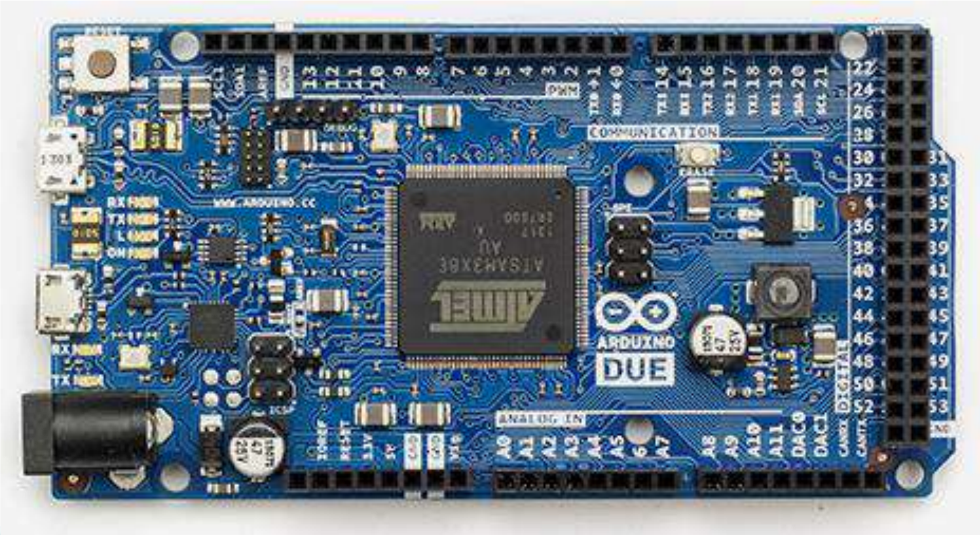

Fig3-Arduino Due microcontroller (Arduino 2011c).

III.GREENHOUSE MONITORING SYSTEM

Important factors for the quality and productivity of plant growth are temperature, humidity, light and the level of the carbon dioxide. Monitoring of these environmental variables gives better understanding on how efficiently plants are growing and how to achieve maximal plant growth. The optimal green-house climate adjustment can enable us to improve productivity and to achieve remarkable energy savings - especially during the winter in northern countries. (Aarons Creek Farms 2012.) Difference between consumer and corporate level greenhouse monitoring system is that the accuracy of sensing environment is on a small area. Consumer level greenhouses are smaller so total cost of the system can be kept low. It used to be in the past that greenhouses had one cabled measurement point in the middle to measure information from the greenhouse automation system. Modern greenhouses are larger and more adjustable. Lights, ventilation, heating and other support systems can be more precisely controlled, which requires increased amount of sensors and better accuracy of locations. Increased number of meas-urement points should not dramatically increase the automation system cost. (Timmerman & Kamp 2003.)

Requirements

Before beginning to design the monitoring system for the greenhouse, certain requirements were set. The system is needed to be easy to use and the user could remotely monitor environmental changes inside the greenhouse. Sensor data required to be collected and stored for showing long period changes in the environment variables. Hardware requirements were set so that the cost of the system would be low as possible. To narrow down the cost of the system only three environment variables were chosen to be tracked: air humidity, soil moisture and temperature.

Design

Embedded system design is divided into three layers: Hardware, Software and Application layer. Hardware layer consists of electrical specifications of the design. Layer describes wiring of sensors, shield, RTC and Relays to Arduino Due. Software layer has the programming design of the system. Software describes functions to control relays and technique used to read sensor data. Application layer introduces the design of web-based user interface and the way data is transferred between software and the application layer.

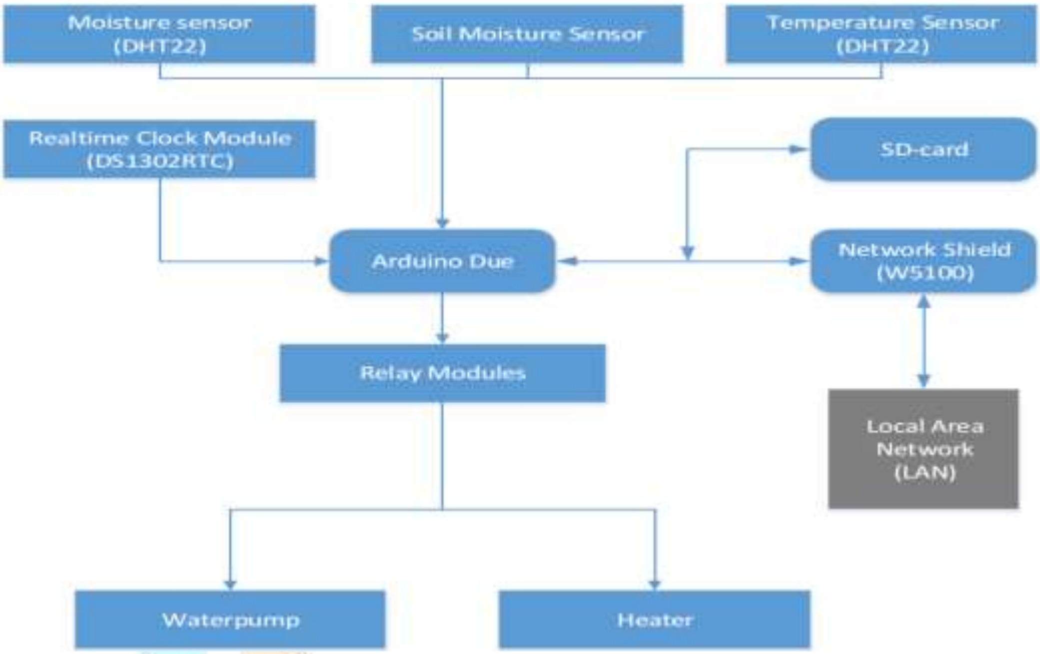

Fig4-Block diagram

IV.HARDWARE DESCRIPTION

Arduino Due microcontroller is the heart of the greenhouse monitoring system. Due provides enough processing power and memory to run the webserver and it can read multiple sensors simultaneously. To add network connectivity to the project, network shield W5100 is added on top of the main board. Arduino network shield enables website hosting to local area network (LAN). W5100 network shield included SD card slot, which was used for long term data storage. Network shield is visible on top of Arduino in Graph 8. Real-time clock module is introduced to the system to keep up time and date, even on power loss. The real time clock module DS1302 is connected to Due through I2C bus. RTC module's data line (SDA) is connected to pin 20 and clock line (SCL) is connected to pin 21 on the Arduino. Digital humidity and temperature sensor DHT22 is connected to digital pin 12 of the microcontroller.

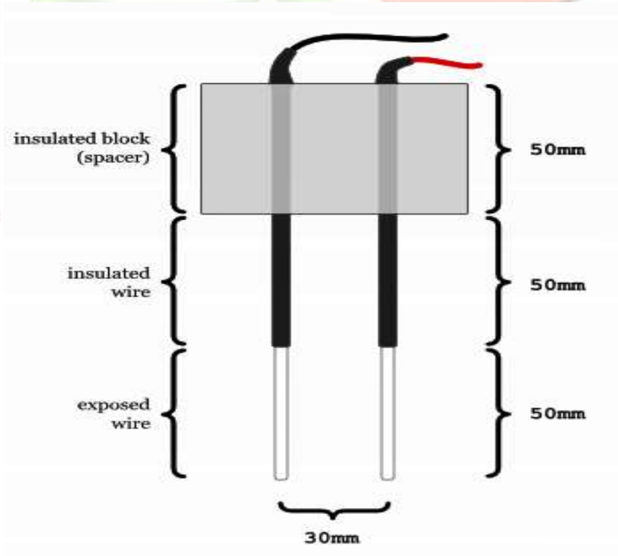

fig 5 Soil moisture control

Two soil moisture sensors shown in fig5 are connected to pins A0 and A1. Current is driven from Arduino to one of the poles in the soil moisture sensor (fig 5). The second pole on the sensor fig5 is connected to Arduino analog pin. Analog pin is used to sense amount of conductivity of the soil. Moisture in a ground increases the conductivity of the soil.

V.CONCLUSION

A systematic approach in designing the microcontroller based system for measurement and control of the three essential parameters for plant growth, temperature, humidity and soil moisture, has been fol-lowed. The system has successfully overcome of the existing systems by reducing the power consumption, complexity and the cost at the same time providing a precise form of maintaining the environment. The results obtained from the measurement have shown that the system performance is quite reliable and accurate. Arduino microcontrollers are constantly evolving development platform. Vastly advancing technology can easily bypass technology used in Arduino Due and make the technology outdated. Growing open-source community is constantly developing. More advanced software is programmed to work similarly with monitoring environment variables. Environment variable monitoring DIY projects are common in open-source communities. Multiple greenhouse or household plant monitoring projects can be found online. The key factor that sets this greenhouse-monitoring project apart from other DIY monitoring systems is that the user can easily ac-cess the data through the web interface and the user can affect the environment inside the greenhouse through the interface. Usually web interfacing monitoring systems require multiple hardware to handle hosting services. To narrow down the cost of hosting and monitoring system was combined to one de-vice. For further research, the system could be designed to operate in a wireless environment. Wi-Fi technology would be considerable option to provide free access to user interface. Alternatively, even further taken option can be 3G or 4G cellular connectivity. Accessing the monitoring data regardless of distance to the location of the greenhouse would make monitoring more efficient and less time consuming. Data could be accessed via internet with the handheld device.

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