UNIVERSITI TEKNIKAL MALAYSIA MELAKA

TEMPERATURE CONTROL DEVICE DESIGN FOR ELECTRIC KETTLE USING BANG-BANG CONTROLLER

This report is submitted in accordance with the requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor of Electrical Engineering Technology (Industrial Automation & Robotics) with Honours.

by

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FACULTY OF ENGINEERING TECHNOLOGY
2016

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

BORANG PENGESAHAN STATUS LAPORAN PROJEK SARJANA MUDA

TAJUK: **TEMPERATURE CONTROL DEVICE DESIGN FOR ELECTRIC KETTLE USING BANG-BANG CONTROLLER**

SESI PENGAJIAN: **2015/16 Semester 2**

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APPROVAL

This report is submitted to the Faculty of Engineering Technology of UTeM as a partial fulfillment of the requirements for the degree of Bachelors of Electrical Engineering Technology (Industrial Automation and Robotics). The member of the supervisory is as follow:

……

(DR. MOHD BADRIL BIN NOR SHAH)

ABSTRAK

Cerek elektrik biasanya bertujuan untuk mendidihkan air dan sebahagian besar tidak memberi paparan suhu dan keupayaan kawalan suhu diilhamkan daripada kekangan ini, litar peranti kawalan suhu untuk cerek elektrik dan pengawal yang dapat mengawal suhu air pada tahap yang dikehendaki akan dibangunkan dalam projek ini. Litar utama dibangunkan dengan menggunakan mikropengawal Arduino. Pengubah penurun dan penerus litar digunakan untuk mengawal sehingga litar pengawalmikro. Geganti keadaan pepejal akan digunakan untuk antara muka antara bekalan kuasa 240V untuk cerek elektrik. Untuk reka bentuk pengawal, sistem kawalan bang-bang dipilih kerana ia adalah mudah untuk direkabentuk dan teguh kepada gangguan dan ketidaktentuan parameter. Keberkesanan litar dan pengawal direka dinilai melalui Online Arduino Simulator. Model prototaip perkakasan dicipta untuk merealisasikan litar direka dan pengawal, yang juga dilengkapi dengan kawalan suhu dan paparan suhu. Peranti kawalan suhu yang dibangunkan diuji dengan disambungkan ke beberapa cerek elektrik untuk mengesahkan keberkesanannya. Pada akhir projek ini, peranti yang menyediakan antara muka pengguna asas untuk mengawal suhu air di dalam cerek elektrik telah berjaya dibangunkan.

ABSTRACT

An electric kettle normally intended to boil water and for the most part does not give temperature display and temperature control capability. Inspired from this constraint, a circuit of temperature control device for electric kettle and a controller that able to regulate water temperature at the desired level will be developed in this project. The main circuit is developed by utilizing Arduino microcontroller. A step down transformer and rectifier circuit is utilized to control up the microcontroller circuit. Solid state relay will be utilized for interfacing between 240V power supply to electric kettle. For controller design, bang-bang control system is chosen since it is easy to design and robust to disturbance and parameter uncertainties. The effectiveness of the designed circuit and controller is assessed through Online Arduino Simulator. The hardware prototype model is created to realize the designed circuit and controller, which is also equipped with temperature adjust and temperature display. The developed temperature control device is tested by interfacing with a few electric kettle to verify the efficiency. In the end of this project, a device that gives basic user interface of controlling water temperature inside electric kettle is successfully delivered.

DEDICATION

To my beloved parents

To my kind lecturers

And not to forget all my fellow friends

Thank you for all their love, sacrifice, encouragement, and best wishes.

ACKNOWLEDGEMENT

Before, while and after I doing my job to complete this project, I have received so many help from my supervisors, lecturers, researchers, family members and also my fellow friends.

First and foremost, I want to give my thanks to my supervisor, Dr Mohd Badril Bin Nor Shah who gave me a lot of encouragement, a true guidance and very supportive.

Besides, I also thankful to my parents for supporting me on mentally and financially for almost part for this project. It's the most things that I need.

Not forget also to my fellow friends, very kind housemates of "Rumah Ukhwah Fillah", that help me constantly with support, advices and technical skills.

Last but not least, thanks to all people those help me directly or indirectly. Without all of them that I appreciate, this project would not been successful.

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CHAPTER 1
INTRODUCTION

1.0 Project Background

An electric kettle normally intended to boil water. The main component that responsible to heat-up the water is a heat element which is powered by electrical energy. When the water inside kettle is reached at the boiling point (100^{o}C), the generated steam pressure will induce a cut-off switch to stop the heating process. Figure 1.1 shows the common internal structure of an electric kettle.

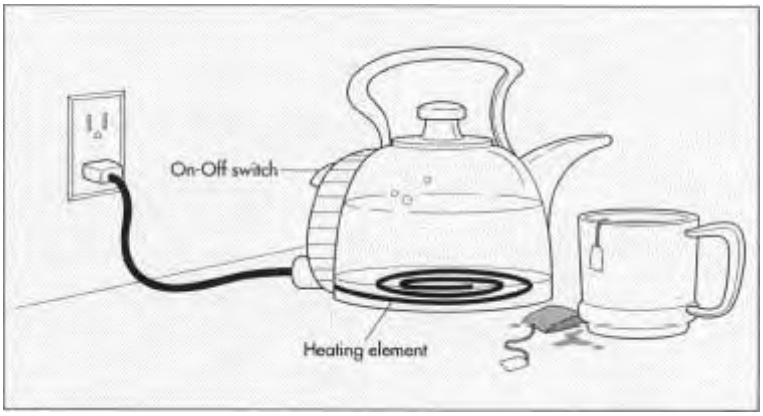

Figure 1.1: Common internal structure of an electric kettle

An electric kettle usually does not equipped with temperature display and temperature control capability. These contraints has prevent for those who want warm-up the water at specific temperature. For such temperature control purpose, a bang-bang controller can be used to control the electrical energy that supplied to heat elemet of kettle.

Bang-bang controller is also known as on-off controller. It is the simplest and basic form of controller and used in many applications such as temperature and

power supply control. The advantages of this controller are ease to design and also robust to disturbance and parameter uncertainties.

1.1 Problem Statement

An electric kettle regularly intended to boil water. It generally does not give temperature display and temperature control capability. Because of their constrained abilities, an electric kettle just can fill one purpose; to produce boiled water. There would be a great favorable circumstances if an electric kettle has ability to set and keep up at the water temperature set by user.

There are many applications can be adopted if an electric kettle is able to produce warm water at desired level temperature. For example, at 40^{o}C water temperature, a guardian can prepare formula milk for their babies or toddlers. A coffee enthusiast always required heated water of 92^{o}C for brewing a delicious coffee drink. For cookies or cakes maker, warm water at 60^{o}C will help them to prepare perfecly mixed dough.

By having an external device that can control temperature at the desired level, user does not have to buy an expensive water warmer or similar device to obtain their preferred warm water. By using a cheap electric kettle and the proposed device that is developed in this project, user is able to obtain the warm water as they intended.

1.2 Objectives

The objective of this project are :

a) To design a circuit of temperature control device for electric kettle
b) To design a controller that capable to maintain water temperature at the desired level

c) To develop temperature control device complete with user interface and temperature display

1.3 Work Scope

The scopes of this project are :

a) **Circuit design**

Microcontroller – based circuit that will be designed for this project, where it will be connected to electric kettle. A rectifier – based power supply circuit is also included in the design.

b) **Controller design**

To provide precise temperature control of water in electric kettle based on desired temperature set by user, closed loop control design is required.

c) **Simulation**

The performance of the designed closed-loop control of temperature control for electric kettle is analyzed through simulation.

d) **Hardware prototype**

A hardware prototype of this project will be developed to verify the efficiency of the designed controller and the circuit.

e) **Electric kettle type**

A cheap and metal body electric kettle will be used in this project, and will be connected to the developed device.

1.4 Thesis Outline

This thesis consists of five chapter and are organized as follows. Chapter 2 provides a literature review on information that is related in developing this project. The review of hardware components and several related previous works are also included in this chapter.

Chapter 3 provides the details methodology of process development. It covers the circuit design, hardware and programming development.

Chapter 4 discussed the results from simulation model circuit and hardware prototype. The analysis of results are also explained in this chapter.

Finally, Chapter 5 presents the conclusion of this project. The recommendation for future works is also included.

CHAPTER 2
LITERETURE REVIEW

2.0 Introduction

Literature review is the critical strategy for engineers before they build up their task. Literature review expect to scrutinize the same number of as source to helping engineers to inspire thought to build up the undertaking. The movement included looking, gathering, investigating and reaching inference from all level headed discussions and issues brought up in pertinent assortment of writing. For create temperature control device project, it have to do research and gather related data of this anticipate with past undertakings. From that can make correlation between past project and project need to create. There are numerous approaches to lead writing survey, for example, from web, journal, books, specialized reports, continuing referens, unknown reference, and e-book.

Before expressing any undertaking, a few thoughts from different researcher are exceptionally valuable. The thoughts can be taken from their exploration likes mechanical outline, control system, program advancement and procedure. Consequently, literature review is the starting stride to comprehend the thoughts to build up this temperature control device. In this part, detail outlines of the temperature control device advancement from past scientists are resolved and the present task will be looked at and talked about. This literature review clarifies about all parts and circuits which are utilized for the framework including specification of them.

2.1 Microcontroller

PIC 16F877A microcontroller enhances the execution of the temperature control by making significant change in rising also, settling time, moreover, diminishing overshoot and consistent state mistake contrasted with a customary PID controller proposed by Mimura, K., & Shiotsuki, T. (2007). Consolidated technique of criticism control, iterative learning encourage forward technique firmly around the set point amid ordinary operation is tried. Perfect condition of the machine and move kill the inhomogeneous issue for the responding screw infusion forming machine by Somesh, B. S., Mukherjee, A., Sen, S., & Karmakar, P. (2014).

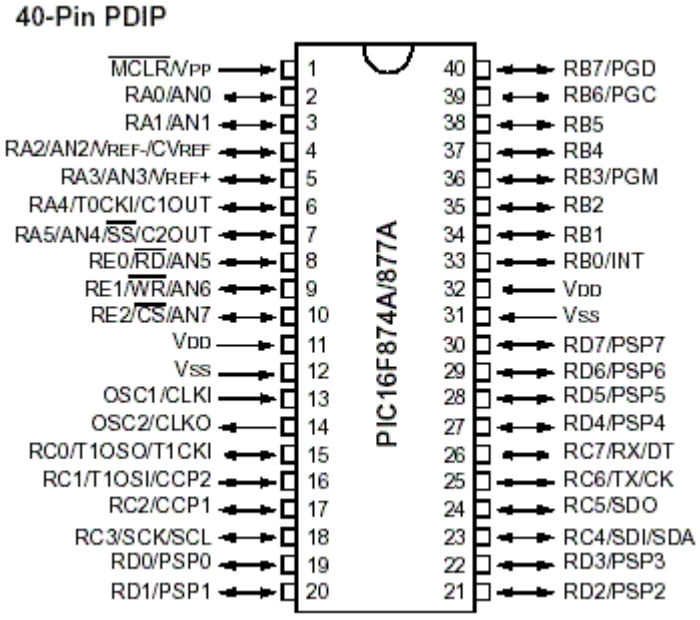

Figure 2.1: PIC 16F877A

According to Miah et al. (2015), Arduino is laid out as open-source devices prototyping stage giving schematics and versatile progression packs for enthusiastic customers who intend to convey natural things or circumstances. The Arduino Uno board is a microcontroller in light of the ATmega328. It comprises of 14 computerized input/output pins out of which there are 6 pins that can be utilized as PWM yields, a 16 MHz artistic resonator, an ICSP header, a USB association, there are 6 analog inputs pins, a power jack and a reset button. This contains all the needed help required for microcontroller. For the associating with a PC it utilizes a USB link. Additionally with an AC-to-DC connector or battery it can be fueled on. Arduino Uno Board shifts from all different sheets and they won't utilize the FTDI USB-to-serial driver chip in them. It is highlighted by the Atmega16U2 (Atmega8U2 up to form R2) modified as a USB-to-serial converter. According to Weeks, M. (2015), Arduino is an open prototyping stage in view of ATmega processor records and dialect, for example, C programming environment change, and could be connected with an assortment of COTS sensors.

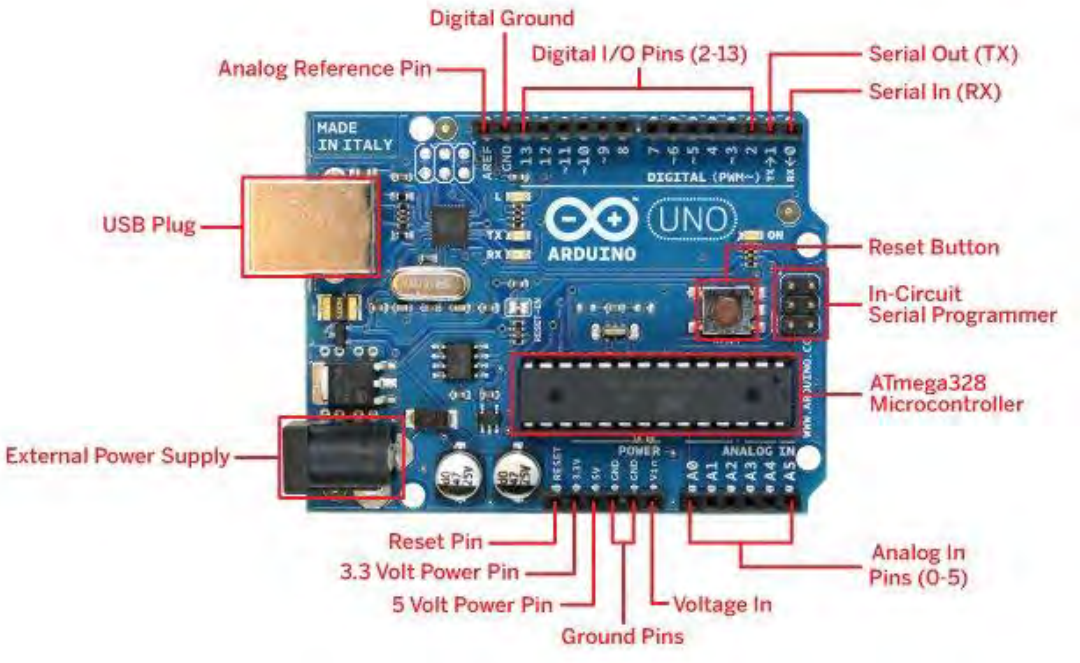

Figure 2.2: Arduino UNO board

Technical Specification

- 14 digital input/output pins (6 pins can be used as pwm output)
- 6 analog inputs, a 16 MHz crystal oscillator
- USB connection
- Power jack
- ICSP header
- Reset button
- Serial Out (TX), Serial In (RX)

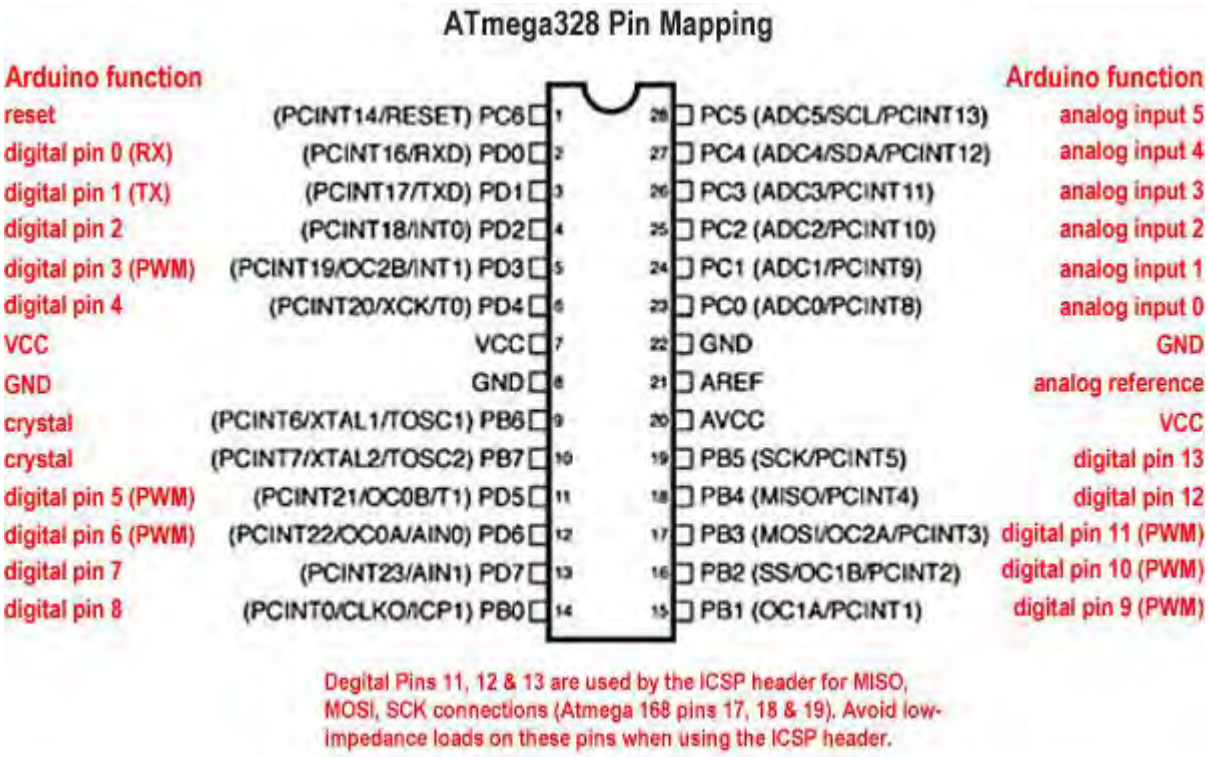

Figure 2.3: Atmega328 mapping

Technical specification

- Microcontroller : ATmega328P
- Operating Voltage : 5V
- Input Voltage (recommended) : 7-12V
- Input Voltage (limit) : 6-20V
- Digital I/O Pins : 14 (of which 6 provide PWM output)
- PWM Digital I/O Pins : 6
- Analog Input Pins : 6
- DC Current per I/O Pin : 20 mA
- DC Current for 3.3V Pin : 50 mA
- Flash Memory : 32 KB (ATmega328P) of which 0.5 KB used by bootloader
- SRAM : 2 KB (ATmega328P)
- EEPROM : 1 KB (ATmega328P)
- Clock Speed : 16 MHz
- Length : 68.6 mm
- Width : 53.4 mm
- Weight : 25 g

Arduino is quick getting to be a standout amongst the most well known microcontrollers utilized as a part of studies. Significantly of the general population feels that Arduino UNO is a microcontroller, however it is marginally off base. This Arduino board really is another particularly created signal board expected for advancement with prototyping utilizing Atmel microcontrollers. Arduino can be open-source PC equipment notwithstanding programming bundle firm, undertaking adding to purchaser nearby group in which new model to organizations' bundles planned for building electronic hardware to expand the intelligent things that can inspire to charge the substantial globe. It can be modified and control any device. It goes about as the inside controller that offers order to device, however ought to physically plan the equipment base on inventiveness.

Utilizing an Arduino streamlines the use of equipment and programming advancement need to do keeping in mind the end goal to get the system running and can control effectively.

The Arduino equipment stage as of now elements power and reset hardware setup and also hardware to handle and speak with the microcontroller over USB. Furthermore, ones I/O pins of any microcontroller are normally as of now encouraged out to attachments/headers expected for simple openness (This may differ a bit with the particular model).

For the product side, Arduino gives various libraries to make programming for the microcontroller less demanding. The most straightforward connected with these is to control and read the I/O pins. More valuable are things, for example, having the capacity to set I/O pins to PWM certain obligation cycle utilizing a solitary order or doing Serial correspondence.

Arduino UNO additionally is an open source, so people groups that need to utilized it does not have to purchase the first, yet the clones version which are produced by merchants can be purchased. Table 2.1 demonstrates the Arduino UNO board detail. Figure 2.4 demonstrates the Arduino UNO board depiction.

Table 2.1: Technical specification of Arduino UNO board

Microcontroller	ATmega328
Operating Voltage	5V
Input voltage (recommended	7-12V
Input voltage (limit)	6-20V
Digital I/O pins	14 (of which 6 provide PWM output)
Analog Input Pins	6
DC current I/O pins	40mA
DC Current for 3.3V Pin	50mA
Flash Memory	32KB of which 0.5KB used by bootloader
SRAM	2KB

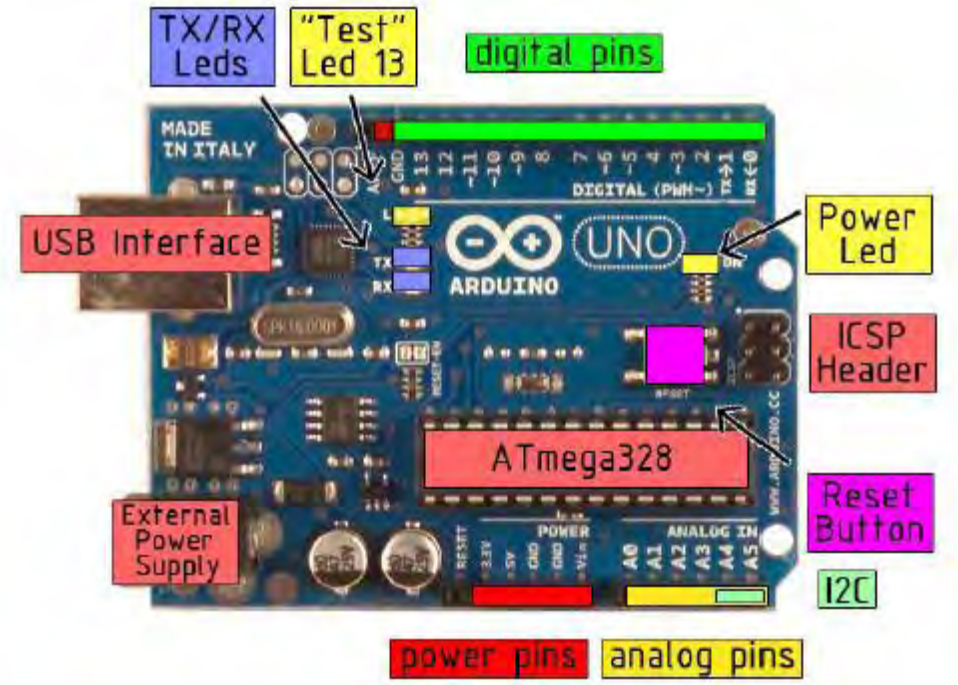

Figure 2.4: Arduino UNO board description

There are a few strategies to control up ones Arduino. As a matter of first importance by means of USB association, furthermore utilizing outside force supply. Ones force source chose consequently. Outside (non-USB) force can come either by an AC-to-DC connector (divider wart) or battery. The connector is generally associated from connecting 2.1mm focus positive fitting to current board's energy jack. Current battery will be embedded with the GND and Vin pin headers of a force connector. The board will most likely perform towards outer force supply 6-20 volts. whether gave less when contrasted with 7 volts, however 5 volts pin can be taken less when contrasted with 5 volts in addition to the board is generally flimsy. Regardless of whether applying in abundance of 12 volts, the voltage controller will most likely overheat and perilous spot. Determined assortment is 7 to 12 volts.`

The ATmega328 has 32 KB flash memory to put away the code (where 0.5 KB used for the boot loader), it has an additional 2 KB of SRAM and 1 KB of EEPROM (which can be read and composed with the EEPROM library).

Each of the 14 propelled sticks towards the Arduino UNO might be utilized as a conceivable data or even yield, applying pinMode (), digitalWrite (), and digitalRead () limits. They work from a couple of volts. Each pin will unquestionably offer or even make application for a most huge including 40mA and has the internal draw up resistor (confined obviously) associated with 20-50kOhms. Moreover, some pins have customized limits:

- Serial: 0 (RX) and 1 (TX). Used to get (RX) and transmit (TX) TTL serial information. These pins are associated with the relating pins of the ATmega8U2 USB-to-TTL Serial chip.

- External Interrupts: 2 and 3. These pins can be designed to trigger a hinder on a low esteem, a rising or falling edge, or an adjustment in quality. See the attachInterrupt () capacity for subtle elements.
- PWM: 3, 5, 6, 9, 10, and 11. Give 8-bit PWM yield with the analogWrite() capacity.
- SPI: 10 (SS), 11 (MOSI), 12 (MISO), 13 (SCK). These pins bolster SPI correspondence, which, in spite of the fact that gave by the hidden equipment, is not as of now incorporated into the Arduino dialect
- LED: 13. There is an implicit LED associated with advanced pin 13. At the point when the pin is HIGH esteem, the LED is on, when the pin is LOW, it's off.

Arduino UNO gives six inputs, each of which gives 10 bits with respect to determination (i.e. 1024 special qualities). From default the measure originating from ground to have the capacity to every one of the 5 volts, however is really possible to change ones upper end associated with the degree applying ones AREF pin in