CHAPTER 1

INTRODUCTION TO EMBEDDED SYSTEMS

Embedded Technology is now in its prime and the wealth of knowledge available is mind blowing. However, most embedded systems engineers have a common complaint. There are no comprehensive resources available over the internet which deal with the various design and implementation issues of this technology. Intellectual property regulations of many corporations are partly to blame for this and also the tendency to keep technical know-how within a restricted group of researchers.

An embedded computer is frequently a computer that is implemented for a particular purpose. In contrast, an average PC computer usually serves a number of purposes: checking email, surfing the internet, listening to music, word processing, etc... However, embedded systems usually only have a single task, or a very small number of related tasks that they are programmed to perform.

Every home has several examples of embedded computers. Any appliance that has a digital clock, for instance, has a small embedded micro-controller that performs no other task than to display the clock. Modern cars have embedded computers onboard that control such things as ignition timing and anti-lock brakes using input from a number of different sensors.

Embedded computers rarely have a generic interface, however. Even if embedded systems have a keypad and an LCD display, they are rarely capable of using many different types of input or output. An example of an embedded system with I/O capability is a security alarm with an LCD status display, and a keypad for entering a password.

An embedded system can be defined as a control system or computer system designed to perform a specific task. Common examples of embedded systems include MP3 players, navigation systems on aircraft and intruder alarm systems. An embedded system can also be defined as a single purpose computer.

Most embedded systems are time critical applications meaning that the embedded system is working in an environment where timing is very important:

the results of an operation are only relevant if they take place in a specific time frame. An autopilot in an aircraft is a time critical embedded system. If the autopilot detects that the plane for some reason is going into a stall then it should take steps to correct this within milliseconds or there would be catastrophic results.

1.1.1 APPLICATIONS OF EMBEDDED SYSTEM

Embedded systems are commonly found in consumer, cooking, industrial, automotive, medical, commercial and military applications.

Telecommunications systems employ numerous embedded systems from telephone switches for the network to cell phones at the end user. Computer networking uses dedicated routers and network bridges to route data.

Consumer electronics include MP3 players, mobile phones, videogame consoles, digital cameras, GPS receivers, and printers. Household appliances, such as microwave ovens, washing machines and dishwashers, include embedded systems to provide flexibility, efficiency and features. Advanced HVAC systems use networked thermostats to more accurately and efficiently control temperature that can change by time of day and season. Home automation uses wired- and wireless-networking that can be used to control lights, climate, security, audio/visual, surveillance, etc., all of which use embedded devices for sensing and controlling.

Transportation systems from flight to automobiles increasingly use embedded systems. New airplanes contain advanced avionics such as inertial guidance systems and GPS receivers that also have considerable safety requirements. Various electric motors brushless DC motors, induction motors and DC and also the DC Various motors use electric/electronic motor controllers. Automobiles, electric vehicles, and hybrid vehicles increasingly use embedded systems to maximize efficiency and reduce pollution. Other automotive safety systems include anti-lock braking system (ABS), Electronic Stability Control (ESC/ESP), traction control (TCS) and automatic four-wheel drive.

Medical equipment uses embedded systems for vital signs monitoring, electronic stethoscopes for amplifying sounds, and various medical imaging (PET, SPECT, CT, and MRI) for non-invasive internal inspections. Embedded systems within medical equipment are often powered by industrial computers.[9]

Embedded systems are used in transportation, fire safety, safety and security, medical applications and life critical systems, as these systems can be isolated from hacking and thus, be more reliable. For fire safety, the systems can be designed to have greater ability to handle higher temperatures and continue to operate. In dealing with security, the embedded systems can be self-sufficient and be able to deal with cut electrical and communication systems.

1.1.2 CHARACTERISTICS OF EMBEDDED SYSTEM

Embedded systems are designed to do some specific task, rather than be a general-purpose computer for multiple tasks. Some also have real-time performance constraints that must be met, for reasons such as safety and usability; others may have low or no performance requirements, allowing the system hardware to be simplified to reduce costs.

Embedded systems are not always standalone devices. Many embedded systems consist of small parts within a larger device that serves a more general purpose. For example, the Gibson Robot Guitar features an embedded system for tuning the strings, but the overall purpose of the Robot Guitar is, of course, to play music. Similarly, an embedded system in an automobile provides a specific function as a subsystem of the car itself.

Embedded systems range from no user interface at all, in systems dedicated only to one task, to complex graphical user interfaces that resemble modern computer desktop operating systems. Simple embedded devices use buttons, LEDs, graphic or character LCDs (HD44780 LCD for example) with a simple menu system.

More sophisticated devices which use a graphical screen with touch sensing or screen-edge buttons provide flexibility while minimizing space used: the meaning of the buttons can change with the screen, and selection involves the natural behavior of pointing at what is desired. Handheld systems often have a screen with a "joystick button" for a pointing device.

Some systems provide user interface remotely with the help of a serial (e.g. RS-232, USB, I²C, etc.) or network (e.g. Ethernet) connection. This approach gives several advantages: extends the capabilities of embedded system, avoids the cost of a display, simplifies BSP and allows one to build a rich user interface on the PC. A good example of this is the combination of an embedded web server running on an embedded device (such as an IP camera) or a network router. The user interface is displayed in a web browser on a PC connected to the device, therefore needing no software to be installed.

1.1.3 PROCESSORS IN EMBEDDED SYSTEMS

Embedded processors can be broken into two broad categories. Ordinary microprocessors Embedded processors can be broken into two broad categories. Ordinary microprocessors (μP) use separate integrated circuits for memory and peripherals. Microcontrollers (μC) have on-chip peripherals, thus reducing power consumption, size and cost. In contrast to the personal computer market, many different basic CPU architectures are used, since software is custom-developed for an application and is not a commodity product installed by the end user. Both Von Neumann as well as various degrees of Harvard architectures are used. RISC as well as non-RISC processors are found. Word lengths vary from 4-bit to 64-bits and beyond, although the most typical remain 8/16-bit. Most architectures come in a large number of different variants and shapes, many of which are also manufactured by several different companies.

Numerous microcontrollers have been developed for embedded systems use. General-purpose microprocessors are also used in embedded systems, but generally require more support circuitry than microcontrollers.

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1.4 DEBUGGING IN EMBEDDED SYSTEMS

Embedded debugging may be performed at different levels, depending on the facilities available. The different metrics that characterize the different forms of embedded debugging are: does it slow down the main application, how close is the debugged system or application to the actual system or application, how expressive are the triggers that I can set for debugging (e.g., I want to inspect the memory when a particular program counter value is reached), and what can I inspect in the debugging process (such as, only memory, or memory and registers, etc.).

From simplest to most sophisticated they can be roughly grouped into the following areas:

Interactive resident debugging, using the simple shell provided by the embedded operating system (e.g. Forth and Basic)

External debugging using logging or serial port output to trace operation using either a monitor in flash or using a debug server like the Remedy Debugger which even works for heterogeneous multicore systems.

An in-circuit debugger (ICD), a hardware device that connects to the microprocessor via a JTAG or Nexus interface. This allows the operation of the microprocessor to be controlled externally, but is typically restricted to specific debugging capabilities in the processor.

An in-circuit emulator (ICE) replaces the microprocessor with a simulated equivalent, providing full control over all aspects of the microprocessor.

A complete emulator provides a simulation of all aspects of the hardware, allowing all of it to be controlled and modified, and allowing debugging on a normal PC. The downsides are expense and slow operation, in some cases up to 100 times slower than the final system.

For SoC designs, the typical approach is to verify and debug the design on an FPGA prototype board. Tools such as Certus[11] are used to insert probes in the FPGA RTL that make signals available for observation. This is used to debug hardware, firmware and software interactions across multiple FPGA with capabilities similar to a logic analyzer.

Unless restricted to external debugging, the programmer can typically load and run software through the tools, view the code running in the processor, and start or stop its operation. The view of the code may be as HLL source-code, assembly code or mixture of both.

Because an embedded system is often composed of a wide variety of elements, the debugging strategy may vary. For instance, debugging a software- (and microprocessor-) centric embedded system is different from debugging an embedded system where most of the processing is performed by peripherals (DSP, FPGA, and co-processor). An increasing number of embedded systems today use more than one single processor core. A common problem with multi-core development is the proper synchronization of software execution. In such a case, the embedded system design may wish to check the data traffic on the busses between the processor cores, which requires very low-level debugging, at signal/bus level, with a logic analyzer, for instance.

1.5 RELIABILITY

Embedded systems often reside in machines that are expected to run continuously for years without errors, and in some cases recover by themselves if an error occurs. Therefore, the software is usually developed and tested more carefully than that for personal computers, and unreliable mechanical moving parts such as disk drives, switches or buttons are avoided.

Specific reliability issues may include:

- The system cannot safely be shut down for repair, or it is too inaccessible to repair. Examples include space systems, undersea cables, navigational beacons, bore-hole systems, and automobiles.
- The system must be kept running for safety reasons. "Limp modes" are less tolerable. Often backups are selected by an operator. Examples include aircraft

navigation, reactor control systems, safety-critical chemical factory controls, train signals.

- The system will lose large amounts of money when shut down: Telephone switches, factory controls, bridge and elevator controls, funds transfer and market making, automated sales and service.

A variety of techniques are used, sometimes in combination, to recover from errors—both software bugs such as memory leaks, and also soft errors in the hardware:

- watchdog timer that resets the computer unless the software periodically notifies the watchdog subsystems with redundant spares that can be switched over to software "limp modes" that provide partial function
- Designing with a Trusted Computing Base (TCB) architecture[12] ensures a highly secure & reliable system environment
- A hypervisor designed for embedded systems, is able to provide secure encapsulation for any subsystem component, so that a compromised software component cannot interfere with other subsystems, or privileged-level system software. This encapsulation keeps faults from propagating from one subsystem to another, improving reliability. This may also allow a subsystem to be automatically shut down and restarted on fault detection.
- Immunity Aware Programming

1.6 TRACING

Real-time operating systems (RTOS) often supports tracing of operating system events. A graphical view is presented by a host PC tool, based on a recording of the system behavior. The trace recording can be performed in software, by the RTOS, or by special tracing hardware. RTOS tracing allows developers to understand timing and performance issues of the software system and gives a good understanding of the high-level system behaviors. Commercial tools like RTXC Quadros or IAR Systems exi

CHAPTER 2

DYNAMIC WIRELESS ELECTRIC VEHICLE CHARGING SYSTEM SOLAR POWERED

INTRODUCTION

The adoption of electric vehicles (EVs) has been steadily increasing as the world seeks sustainable transportation alternatives. However, one of the challenges in the widespread adoption of EVs is the need for efficient and convenient charging infrastructure. To address this challenge, dynamic wireless electric vehicle charging systems, powered by solar energy, have emerged as a promising solution.

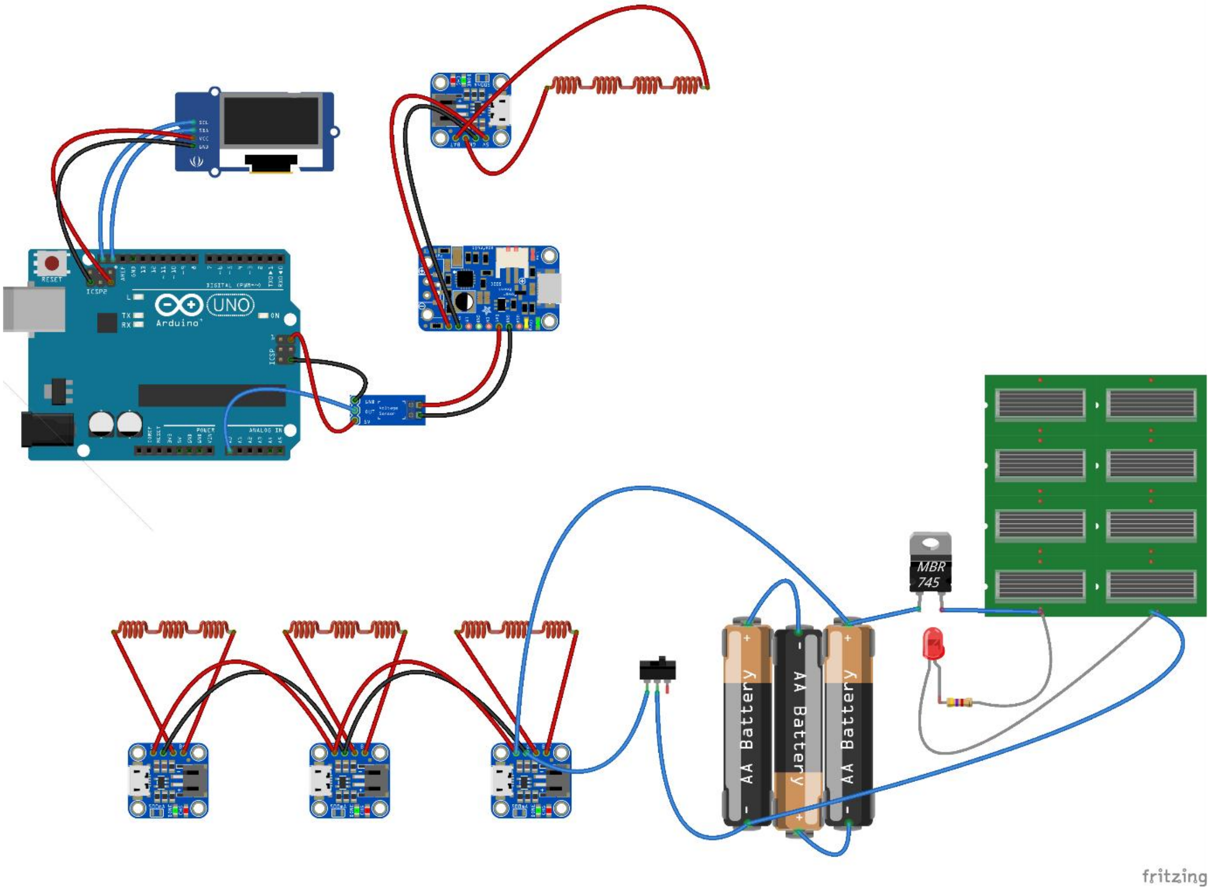
A dynamic wireless electric vehicle charging system utilizes inductive power transfer technology to wirelessly charge EVs while they are in motion. Traditional charging methods require EVs to park and connect to a charging station, leading to limitations in terms of convenience and charging infrastructure availability. In contrast, dynamic wireless charging systems enable continuous charging as EVs drive on specially equipped roads or through charging lanes.

Solar power plays a crucial role in powering these dynamic wireless charging systems. By harnessing energy from the sun, solar panels installed alongside or on top of the charging infrastructure can generate renewable electricity to charge the EVs. This integration of solar power enhances the sustainability and reduces the reliance on the grid for electricity supply, making it an environmentally friendly solution for EV charging.

Furthermore, the dynamic wireless charging system, coupled with solar power, offers several advantages. It eliminates the need for physical charging cables and plugs, providing a seamless and effortless charging experience for EV owners. Drivers can simply enter the designated charging area or lane and have their vehicles automatically charged without any manual intervention.

The integration of solar power also contributes to the overall energy efficiency of the charging system. Excess solar energy generated during peak daylight hours can be stored in batteries and utilized during low-sunlight periods or during high-demand charging periods, ensuring a consistent and reliable power supply for EV charging.

Overall, the combination of dynamic wireless electric vehicle charging systems and solar power represents a significant advancement in the realm of sustainable transportation. It offers convenient and efficient charging options for EV owners while reducing the reliance on fossil fuel-based energy sources. This technology promotes renewable energy integration, reduces greenhouse gas emissions, and accelerates the transition towards a greener and more sustainable transportation future.



CHAPTER 3

SOFTWARE REQUIREMENTS

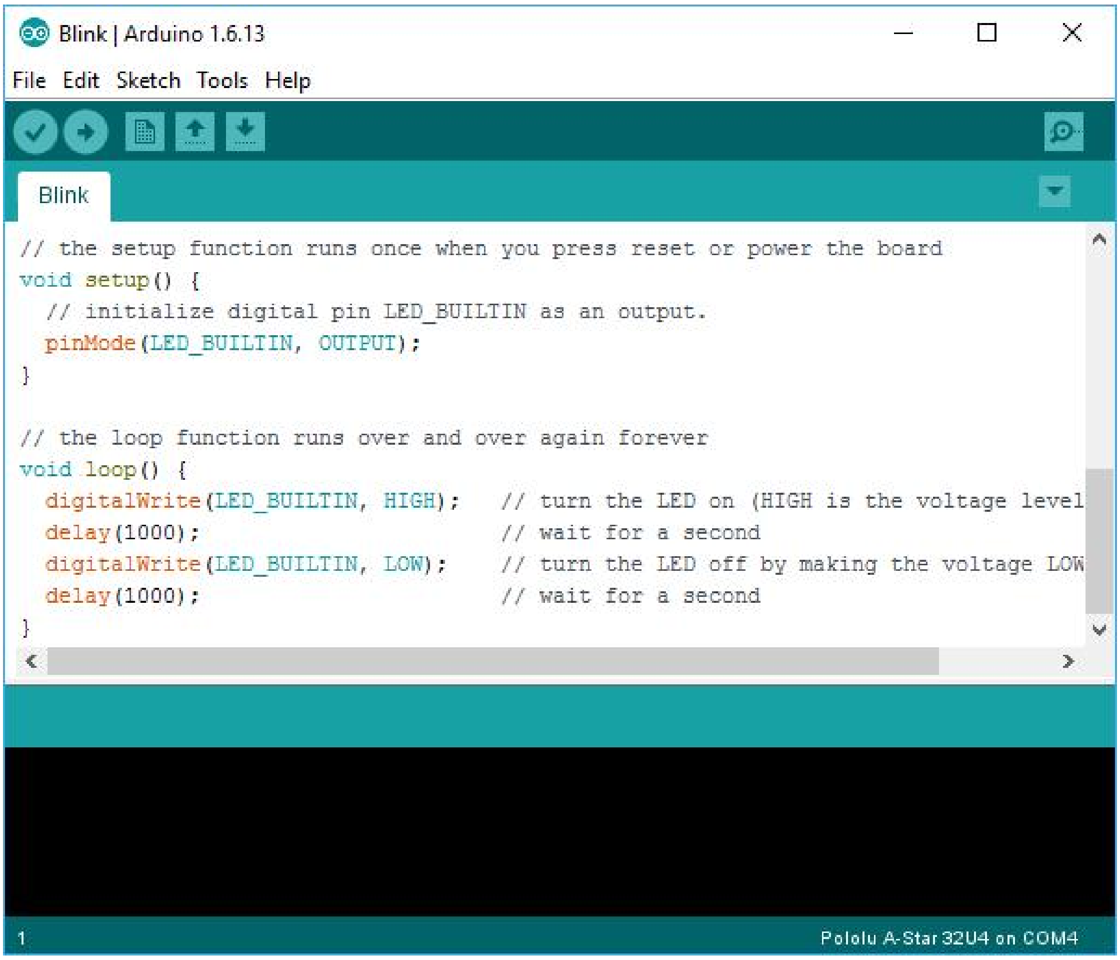
Software used in this project for uploading code onto Arduino is Arduino IDE.

3.1 INTRODUCTION TO ARDUINO IDE

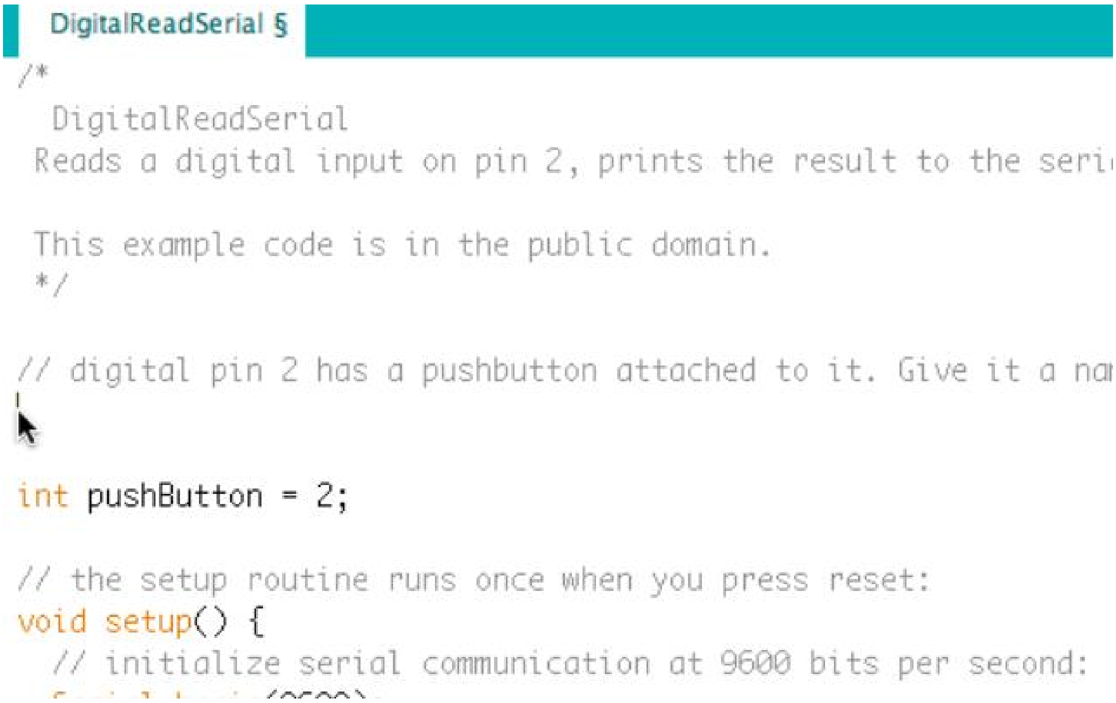
IDE stands for Integrated Development Environment. Pretty fancy sounding, and should make you feel smart any time you use it. The IDE is a text editor-like program that allows you to write Arduino code. When you open the Arduino program, you are opening the IDE. It is intentionally streamlined to keep things as simple and straightforward as possible. When you save a file in Arduino, the file is called a sketch – a sketch is where you save the computer code you have written. The coding language that Arduino uses is very much like C++ ("see plus plus"), which is a common language in the world of computing. The code you learn to write for Arduino will be very similar to the code you write in any other computer language – all the basic concepts remain the same – it is just a matter of learning a new dialect should you pursue other programming languages.

The code you write is "human readable", that is, it will make sense to you (sometimes), and will be organized for a human to follow. Part of the job of the IDE is to take the human readable code and translate it into machine-readable code to be executed by the Arduino. This process is called compiling.

The process of compiling is seamless to the user. All you have to do is press a button. If you have errors in your computer code, the compiler will display an error message at the bottom of the IDE and highlight the line of code that seems to be the issue. The error message is meant to help you identify what you might have done wrong – sometimes the message is very explicit, like saying, "Hey – you forget a semicolon", sometimes the error message is vague. Why be concerned with a semicolon you ask? A semicolon is part of the Arduino language syntax, the rules that govern how the code is written. It is like grammar in writing. Say for example we didn't use periods when we wrote – everyone would have a heck of a time trying to figure out when sentences started and ended. Or



if we didn't employ the comma, how would we convey a dramatic pause to the reader?And let me tell you, if you ever had an English teacher with an overactive red pen, the compiler is ten times worse. In fact – your programs WILL NOT compile without perfect syntax. This might drive you crazy at first because it is very natural to forget syntax. As you gain experience programming



```
DigitalReadSerial §
/*
  DigitalReadSerial
 Reads a digital input on pin 2, prints the result to the seri

 This example code is in the public domain.
 */

// digital pin 2 has a pushbutton attached to it. Give it a na

int pushButton = 2;

// the setup routine runs once when you press reset:
void setup() {
  // initialize serial communication at 9600 bits per second:
```

you will learn to be assiduous about coding grammar.

3.1.1 THE SEMICOLON

A semicolon needs to follow every statement written in the Arduino programming language. For example, …

Int LedPin=9;

In this statement, I am assigning a value to an integer variable (we will cover this later), notice the semicolon at the end. This tells the compiler that you have finished a chunk of code and are moving on to the next piece. A semicolon is to Arduino code, as a period is to a sentence. It signifies a complete statement.

3.1.2 THE DOUBLE BACKSLASH FOR SINGLE LINE COMMENTS //

Comments are what you use to annotate code. Good code is commented well. Comments are meant to inform you and anyone else who might stumble across your code, what the heck you were thinking when you wrote it. A good comment would be something like this…

Now, in 3 months when I review this program, I know where to stick my LED. Comments will be ignored by the compiler – so you can write whatever you like in them. If you have a lot you need to explain, you can use a multi-line comment, shown below…

//This is an example

Comments are like the footnotes of code, except far more prevalent and not at the bottom of the page.

3.1.3 THE CURLY BRACES

Curly braces are used to enclose further instructions carried out by a function (we discuss functions next). There is always an opening curly bracket and a closing curly bracket. If you forget to close a curly bracket, the compiler will not like it and throw an error code.

```
Void loop (){
}
```

Remember – no curly brace may go unclosed!

3.1.4 FUNCTION ( )

Functions are pieces of code that are used so often that they are encapsulated in certain keywords so that you can use them more easily. For example, a function could be the following set of instructions…

This set of simple instructions could be encapsulated in a function that we call WashDog. Every time we want to carry out all those instructions we just type WashDog and voila – all the instructions are carried out. In Arduino, there are certain functions that are used so often they have been built into the IDE. When you type them, the name of the function will appear orange. The function pinMode(), for example, is a common function used to designate the mode of an Arduino pin.

What's the deal with the parentheses following the function pinMode? Many functions require *arguments* to work. An argument is information the function uses when it runs. For our WashDog function, the arguments might be dog name and soap type, or temperature and size of a bucket.

pinMode(13, OUTPUT);

The argument 13 refers to pin 13, and OUTPUT is the mode in which you want the pin to operate. When you enter these arguments the terminology is called passing. You pass the necessary information to the functions. Not all functions require arguments, but opening and closing parentheses will stay regardless though empty.

Notice that the word OUTPUT is blue. There are certain keywords in Arduino that are used frequently and the color blue helps identify them. The IDE turns them blue automatically. Now we won't get into it here, but you can easily make your own functions in Arduino, and you can even get the IDE to color them for you. We will, however, talk about the two functions used in nearly EVERY Arduino program.

3.1.5 VOID SETUP ( )

The function, setup(), as the name implies, is used to set up the Arduino board. The Arduino executes all the code that is contained between the curly braces of setup() only once. Typical things that happen in setup() are setting the modes of pins, starting You might be wondering what void means before the function setup(). Void means that the function does not return information. Some functions do return values – our DogWash function might return the number of buckets it required to clean the dog. The function analogRead() returns an integer value between 0-1023. If this seems a bit odd now, don't worry as we will cover every common Arduino function in depth as we continue the course.

Let us review a couple things you should know about setup()…

1. setup() only runs once.
2. setup() needs to be the first function in your Arduino sketch.
3. setup() must have opening and closing curly braces.

3.1.6 VOID LOOP ( )

You have to love the Arduino developers because the function names are so telling. As the name implies, all the code between the curly braces in loop() is repeated over and over again – in a loop. The loop() function is where the body of your program will reside. As with setup(), the function loop() does not return any values, therefore the word void precedes it.

Does it seem odd to you that the code runs in one big loop? This apparent lack of variation is an illusion. Most of your code will have specific conditions laying in wait which will trigger new actions.

If you have a temperature sensor connected to your Arduino for example, then when the temperature gets to a predefined threshold you might have a fan kick on. The looping code is constantly checking the temperature waiting to trigger the fan. So even though the code loops over and over, not every piece of the code will be executed every iteration of the loop.

3.2 INTRODUCTION ARDUINO LIBRARIES

Libraries are a collection of code that makes it easy for you to connect to a sensor, display, module, etc. For example, the built-in LiquidCrystal library makes it easy to talk to character LCD displays. There are hundreds of additional libraries available on the Internet for download. The built-in libraries and some of these additional libraries are listed in the reference. To use the additional libraries, you will need to install them.

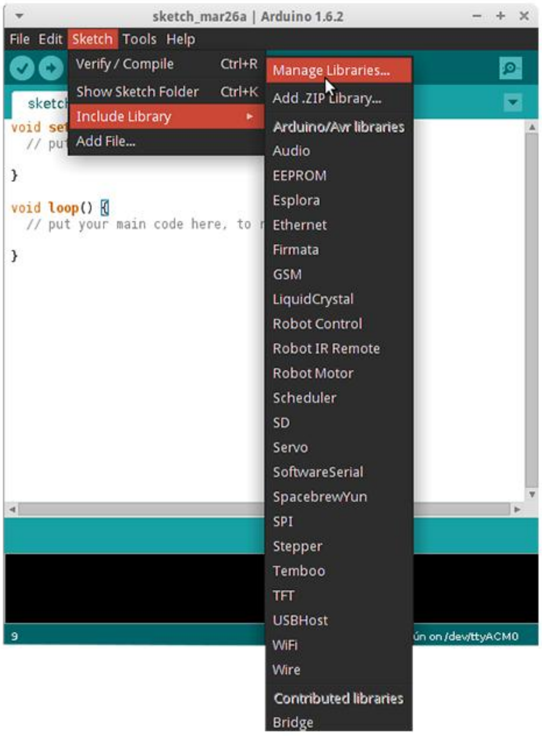
Arduino libraries are managed in three different places: inside the IDE installation folder, inside the core folder and in the libraries folder inside your sketchbook. The way libraries are chosen during compilation is designed to allow the update of libraries present in the distribution. This means that placing a library in the “libraries” folder in your sketchbook overrides the other libraries versions.

The same happens for the libraries present in additional cores installations. It is also important to note that the version of the library you put in your sketchbook may be lower than the one in the distribution or core folders, nevertheless it will be the one used during compilation. When you select a specific core for your board, the libraries present in the core’s folder are used instead of the same libraries present in the IDE distribution folder.

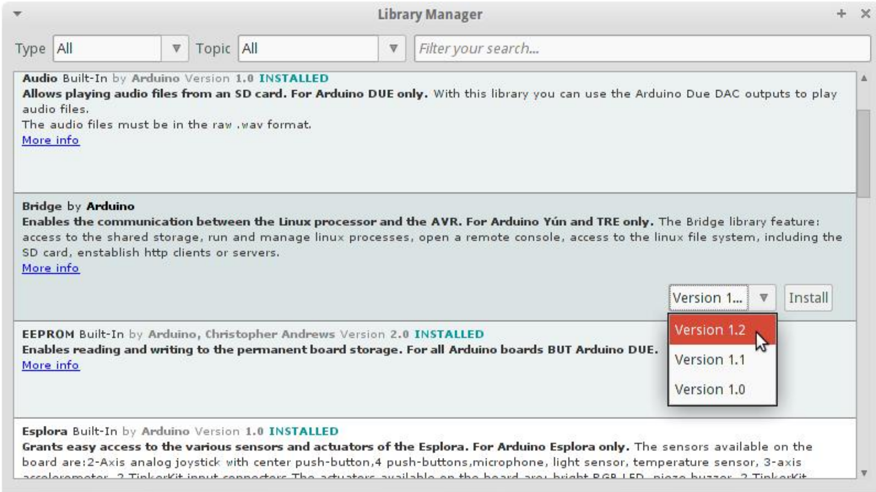
Last, but not least important is the way the Arduino Software (IDE) upgrades itself: all the files in Programs/Arduino (or the folder where you installed the IDE) are deleted and a new folder is created with fresh content. This is why we recommend that you only install libraries to the sketchbook folder so they are not deleted during the Arduino IDE update process.

3.2.1 HOW TO INSTALL A LIBRARY

To install a new library into your Arduino IDE you can use the Library Manager (available from IDE version 1.6.2). Open the IDE and click to the "Sketch" menu and then *Include Library > Manage Libraries*.



Then the Library Manager will open and you will find a list of libraries that are already installed or ready for installation. In this example we will install the Bridge library. Scroll the list to find it, click on it, then select the version of the library you want to install. Sometimes only one version of the library is available. If the version selection menu does not appear, don't worry: it is normal.



Finally click on install and wait for the IDE to install the new library. Downloading may take time depending on your connection speed. Once it has finished, an *Installed* tag should appear next to the Bridge library. You can close the library manager. You can now find the new library available in the *Sketch > Include Library* menu. If you want to add your own library to Library Manager, follow these instructions.

3.3 HOW TO CONNECT ARDUINO BOARD

If you're using a serial board, power the board with an external power supply (6 to 25 volts DC, with the core of the connector positive). Connect the board to a serial port on your computer. On the USB boards, the power source is selected by the jumper between the USB and power plugs. To power the board from the USB port (good for controlling low power devices like LEDs), place the jumper on the two pins closest to the USB plug. To power the board from an external power supply (needed for motors and other high current devices), place the jumper on the two pins closest to the power plug. Either way, connect the board to a USB port on your computer. On Windows, the Add New Hardware wizard will open; tell it you want to specify the location to search for drivers and point to the folder containing the USB drivers you unzipped in the previous step.

The power LED should go on.

3.4 HOW TO UPLOAD A PROGRAM

The content of circuits and Arduino sketches can vary greatly. Before you get started, there is one simple process for uploading a sketch to an Arduino board that you can refer back to.

Follow these steps to upload your sketch:

1. Connect your Arduino using the USB cable.

   The square end of the USB cable connects to your Arduino and the flat end connects to a USB port on your computer.

2. Choose Tools→Board→Arduino Uno to find your board in the Arduino menu.

   You can also find all boards through this menu, such as the Arduino MEGA 2560 and Arduino Leonardo.

3. Choose the correct serial port for your board.

   You find a list of all the available serial ports by choosing Tools→Serial Port→ comX or /dev/tty.usbmodemXXXXX. X marks a sequentially or randomly assigned number. In Windows, if you have just connected your Arduino, the COM port will normally be the highest number, such as com 3 or com 15.

   Many devices can be listed on the COM port list, and if you plug in multiple Arduinos, each one will be assigned a new number. On Mac OS X, the /dev/tty.usbmodem number will be randomly assigned and can vary in length, such as /dev/tty.usbmodem1421 or /dev/tty.usbmodem262471. Unless you have another Arduino connected, it should be the only one visible.

4. Click the Upload button.

   This is the button that points to the right in the Arduino environment. You can also use the keyboard shortcut Ctrl+U for Windows or Cmd+U for Mac OS X.

CHAPTER 4

HARDWARE REQUIREMENTS

Hardware Components of this project are

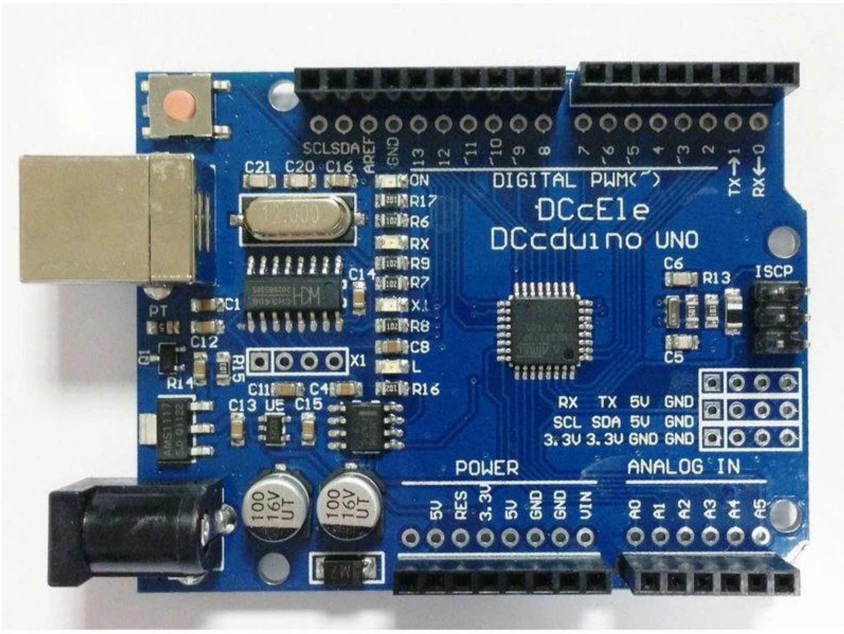
1. ARDIUNO UNO
2. OLED SSD1306
3. VOLTAGE SENSOR
4. BOOST CONVERTOR
5. HW BATTERY
6. WIRELESS CHARGING MODULE
7. LI-ION BATTERY
8. SOLAR PANEL
9. LED

4.1 INTRODUCTION TO ARDUINO UNO

Arduino is an open-source electronics platform based on easy-to-use hardware and software. Arduino boards are able to read inputs - light on a sensor, a finger on a button, or a Twitter message - and turn it into an output - activating a motor, turning on an LED, publishing something online. You can tell your board what to do by sending a set of instructions to the microcontroller on the board. To do so you use the Arduino programming language (based on Wiring), and the Arduino Software (IDE), based on Processing.

Over the years Arduino has been the brain of thousands of projects, from everyday objects to complex scientific instruments. A worldwide community of makers - students, hobbyists, artists, programmers, and professionals - has gathered around this open-source platform, their contributions have added up to an incredible amount of accessible knowledge that can be of great help to novices and experts alike.

Arduino was born at the Ivrea Interaction Design Institute as an easy tool for fast prototyping, aimed at students without a background in electronics and programming. As soon as it reached a wider community, the Arduino board started changing to adapt to new needs and challenges, differentiating its offer from simple 8-bit boards to products for IoT applications, wearable, 3D printing, and embedded environments. All Arduino boards are completely open-source, empowering users to build them independently and eventually adapt them to their particular needs. The software, too, is open-source, and it is growing through the contributions of users worldwide.



4.1.1 WHY ARDUINO

Thanks to its simple and accessible user experience, Arduino has been used in thousands of different projects and applications. The Arduino software is easy-to-use for beginners, yet flexible enough for advanced users. It runs on Mac, Windows, and Linux. Teachers and students use it to build low cost scientific instruments, to prove chemistry and physics principles, or to get started with programming and robotics. Designers and architects build interactive prototypes, musicians and artists use it for installations and to experiment with new musical instruments. Makers, of course, use it to build many of the projects exhibited at the Maker Faire, for example. Arduino is a key tool to learn new things. Anyone - children, hobbyists, artists, programmers - can start tinkering just following the step by step instructions of a kit, or sharing ideas online with other members of the Arduino community.

4.1.2 ADVANTAGES OF ARDUINO

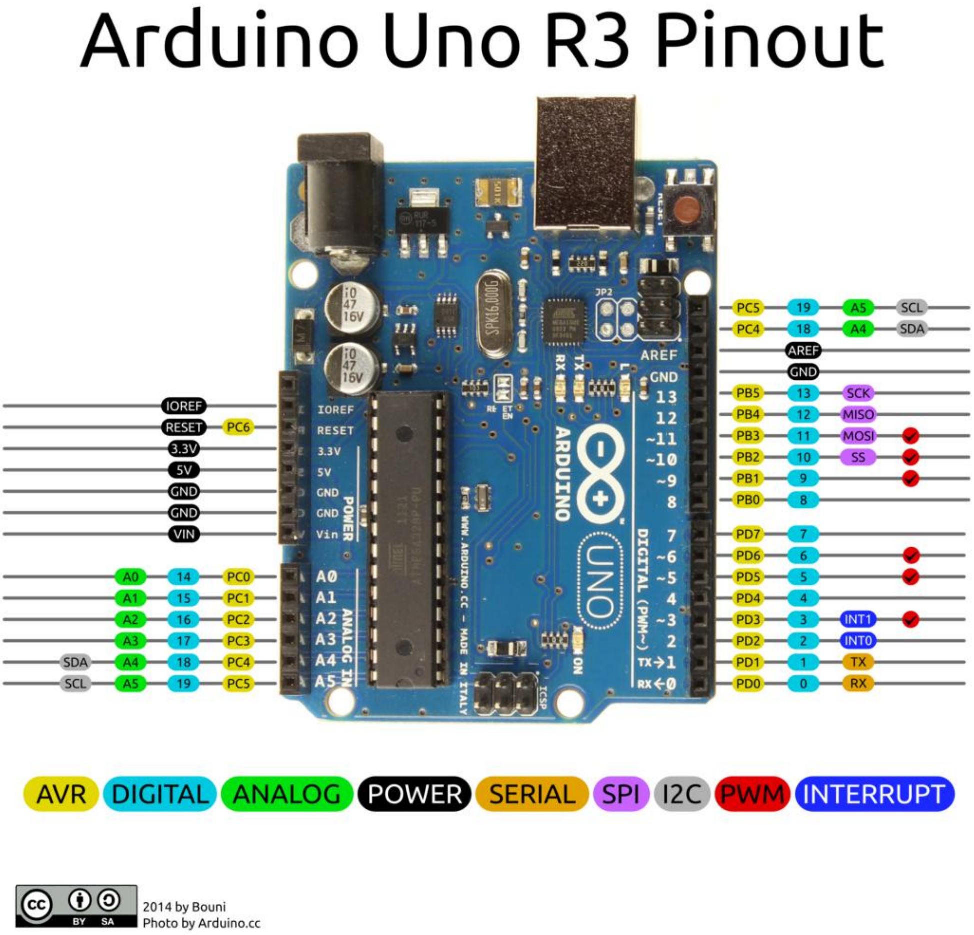
- **Inexpensive** - Arduino boards are relatively inexpensive compared to other microcontroller platforms. The least expensive version of the Arduino module can be assembled by hand, and even the pre-assembled Arduino modules cost less than $50
- **Cross-platform** - The Arduino Software (IDE) runs on Windows, Macintosh OSX, and Linux operating systems. Most microcontroller systems are limited to Windows.
- **Simple, clear programming environment** - The Arduino Software (IDE) is easy-to-use for beginners, yet flexible enough for advanced users to take advantage of as well. For teachers, it's conveniently based on the Processing programming environment, so students learning to program in that environment will be familiar with how the Arduino IDE works.
- **Open source and extensible software** - The Arduino software is published as open source tools, available for extension by experienced programmers. The language can be expanded through C++ libraries, and people wanting to understand the technical details can make the leap from Arduino to the AVR C programming language on which it's based. Similarly, you can add AVR-C code directly into your Arduino programs if you want to.
- **Open source and extensible hardware** - The plans of the Arduino boards are published under a Creative Commons license, so experienced circuit designers can make their own version of the module, extending it and improving it. Even relatively inexperienced users can build the breadboard version of the module in order to understand how it works and save money.

4.1.3 FEATURES OF ARDUINO UNO

The **Arduino Uno** is a microcontroller board based on the ATmega328. Arduino is an open-source, prototyping platform and its simplicity makes it ideal for hobbyists to use as well as professionals. The Arduino Uno has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with a AC-to-DC adapter or battery to get started.

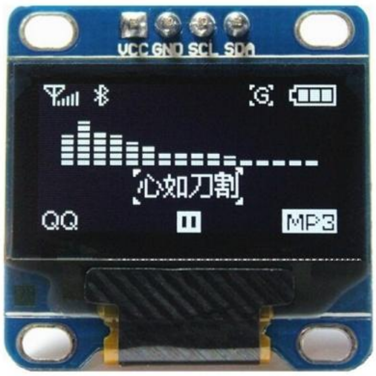
Features of the Arduino UNO:

- Microcontroller: ATmega328
- Operating Voltage: 5V
- Input Voltage (recommended): 7-12V
- Input Voltage (limits): 6-20V
- Digital I/O Pins: 14 (of which 6 provide PWM output)
- Analog Input Pins: 6
- DC Current per I/O Pin: 40 mA
- DC Current for 3.3V Pin: 50 mA
- Flash Memory: 32 KB of which 0.5 KB used by bootloader
- SRAM: 2 KB (ATmega328)
- EEPROM: 1 KB (ATmega328)
- Clock Speed: 16 MHz



INTRODUCTION TO SSD1306 OLED DISPLAY

SSD1306 is a single-chip CMOS OLED/PLED driver with controller for organic / polymer light emitting diode dot-matrix graphic display system. It consists of 128 segments and 64commons. This IC is designed for Common Cathode type OLED panel. The SSD1306 embeds with contrast control, display RAM and oscillator, which reduces the number of external components and power consumption. It has 256-step brightness control. Data/Commands are sent from general MCU through the hardware selectable 6800/8000 series compatible Parallel Interface, I 2 C interface or Serial Peripheral Interface. It is suitable for many compact portable applications, such as mobile phone sub-display, MP3 player and calculator, etc.



4.2.1 FEATURES

Resolution: 128 x 64 dot matrix panel

• Power supply o VDD = 1.65V to 3.3V for IC logic o VCC = 7V to 15V for Panel driving

• For matrix display o OLED driving output voltage, 15V maximum o Segment maximum source current: 100uA o Common maximum sink current: 15mA o 256 step contrast brightness current control

• Embedded 128 x 64 bit SRAM display buffer

• Pin selectable MCU Interfaces: o 8-bit 6800/8080-series parallel interface o 3 /4 wire Serial Peripheral Interface o I 2 C Interface

• Screen saving continuous scrolling function in both horizontal and vertical direction

• RAM write synchronization signal

• Programmable Frame Rate and Multiplexing Ratio

• Row Re-mapping and Column Re-mapping

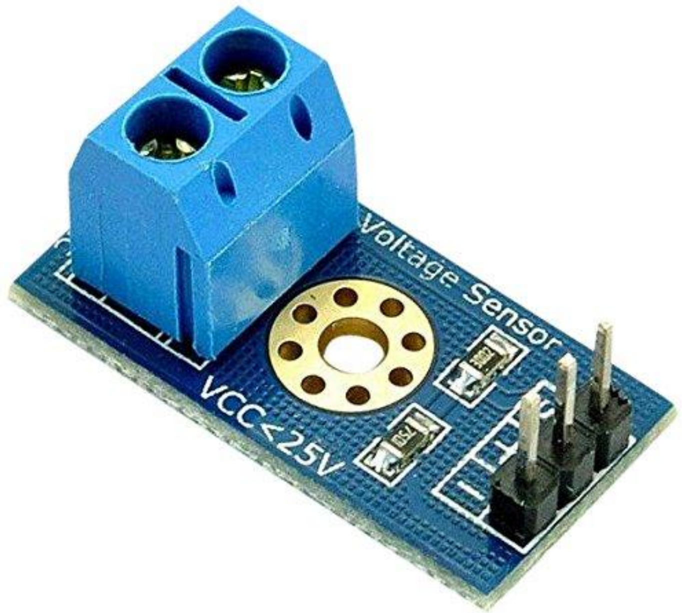
• On-Chip Oscillator • Chip layout for COG & COF

• Wide range of operating temperature: -40°C to 85°C

4.3 INTRODUCTION TO VOLTAGE SENSOR

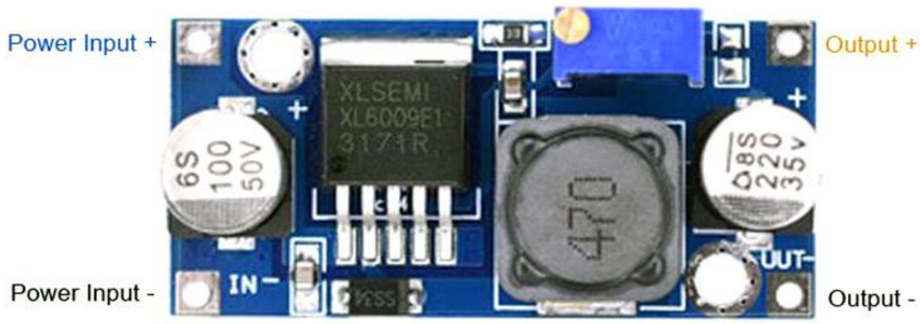
A voltage sensor is a sensor used to calculate and monitor the amount of voltage in an object. Voltage sensors can determine the AC voltage or DC voltage level. The input of this sensor is the voltage, whereas the output is the switches, analog voltage signal, a current signal, or an audible signal.

Sensors are devices that can sense or identify and react to certain types of electrical or optical signals. The implementation of a voltage sensor and current sensor techniques have become an excellent choice for the conventional current and voltage measurement methods.



4.4 INTRODUCTION TO BOOST CONVERTOR

A **boost converter** (**step-up converter**) is a DC-to-DC power converter that steps up voltage (while stepping down current) from its input (supply) to its output (load). It is a class of switched-mode power supply (SMPS) containing at least two semiconductors (a diode and a transistor) and at least one energy storage element: a capacitor, inductor, or the two in combination. To reduce voltage ripple, filters made of capacitors (sometimes in combination with inductors) are normally added to such a converter's output (load-side filter) and input (supply-side filter).



4.5 INTRODUCTION 9V BATTERY

The nine-volt battery, or 9-volt battery, is a common size of battery that was introduced for the early transistor radios. It has a rectangular prism shape with rounded edges and a polarized snap connector at the top. This type is commonly used in walkie-talkies, clocks and smoke detectors.

The nine-volt battery format is commonly available in primary carbon-zinc and alkaline chemistry, in primary lithium iron disulfide, and in rechargeable form in nickel-cadmium, nickel-metal hydride and lithium-ion. Mercury-oxide batteries of this format, once common, have not been manufactured in many years due to their mercury content. Designations for this format include *NEDA 1604* and *IEC 6F22* (for zinc-carbon) or *MN1604 6LR61* (for alkaline). The size, regardless of chemistry, is commonly designated *PP3* - a designation originally reserved solely for carbon-zinc or in some countries, *E* or *E-block*.

Most nine-volt alkaline batteries are constructed of six individual 1.5 V LR61 cells enclosed in a wrapper. These cells are slightly smaller than LR8D425 AAAA cells and can be used in their place for some devices, even though they are 3.5 mm shorter. Carbon-zinc types are made with six flat cells in a stack, enclosed in a moisture-resistant wrapper to prevent drying. Primary lithium types are made with three cells in series.

In 2007, 9-volt batteries accounted for 4% of alkaline primary battery sales in the US. In Switzerland in 2008, 9-volt batteries totalled 2% of primary battery sales and 2% of secondary battery sales

4.5.1 TECHNICAL SPECIFICATIONS

The most common type of 9V battery is commonly referred to simply as *9-volt*, although there are less common 9V batteries of different sizes. Codes for the usual size include PP3 (for size and voltage, any technology), 6LR61 (IEC code for alkaline batteries), and in Japan 006P.[1]

The PP3 size battery has height 48.5 mm, width 26.5 mm, depth 17.5 mm (or 1.9 in × 1.0 in × 0.68 in). Both terminals are at one end and their centers are ½ inch (12.7 mm) apart.

Inside an alkaline or carbon-zinc 9-volt battery there are six cylindrical or flat cells connected in series. Some brands use welded tabs internally to attach to the cells, others press foil strips against the ends of the cells.

Rechargeable nickel–cadmium (NiCd) and Nickel–metal hydride (NiMH) batteries of nominal 9V rating have between six and eight 1.2 volt cells. Lithium ion versions typically use two cells (3.7-4.2V nominal each). There are also lithium polymer and low self-discharge NiMHversions.

Mercury batteries were formerly made in this size. They had higher capacity than the then-standard carbon-zinc types, a nominal voltage of 8.4

volts, and very stable voltage. Once used in photographic and measuring instruments or long-life applications, they are no longer manufactured as mercury is an environmental pollutant.

4.5.2 CONNECTORS

The battery has both terminals in a snap connector on one end. The smaller circular (male) terminal is positive, and the larger hexagonal or octagonal (female) terminal is the negative contact. The connectors on the battery are the same as on the connector itself; the smaller one connects to the larger one and vice versa. The same snap-style connector is used on other battery types in the Power Pack (PP) series. Battery polarization is normally obvious since mechanical connection is usually only possible in one configuration. A problem with this style of connector is that it is very easy to connect two batteries together in a short circuit, which quickly discharges both batteries, generating heat and possibly a fire. Because of this hazard, 9-volt batteries should be kept in the original packaging until they are going to be used. An advantage is that several nine-volt batteries can be connected to each other in series to provide higher voltages.

Introduction: Wireless Charging Module

The proliferation of electronic devices in our daily lives has created a growing demand for convenient and efficient charging solutions. In response to this need, wireless charging technology has emerged as a game-changing innovation, eliminating the reliance on cables and enabling the seamless charging of devices through the use of wireless charging modules.

A wireless charging module, also known as an inductive charging module, utilizes electromagnetic fields to transfer power between the charging station and compatible devices. It employs the principles of electromagnetic induction, where an alternating current in the charging station generates a magnetic field, which is then picked up by a receiver coil in the device, converting it back into electrical energy for charging.

The introduction of wireless charging modules has revolutionized the way we power our devices. No longer bound by the constraints of physical connectors and cables, wireless charging offers a more convenient and clutter-free charging experience. Users can simply place their compatible devices, such as smartphones, tablets, or wearables, on a wireless charging pad or dock, and the charging process initiates automatically.

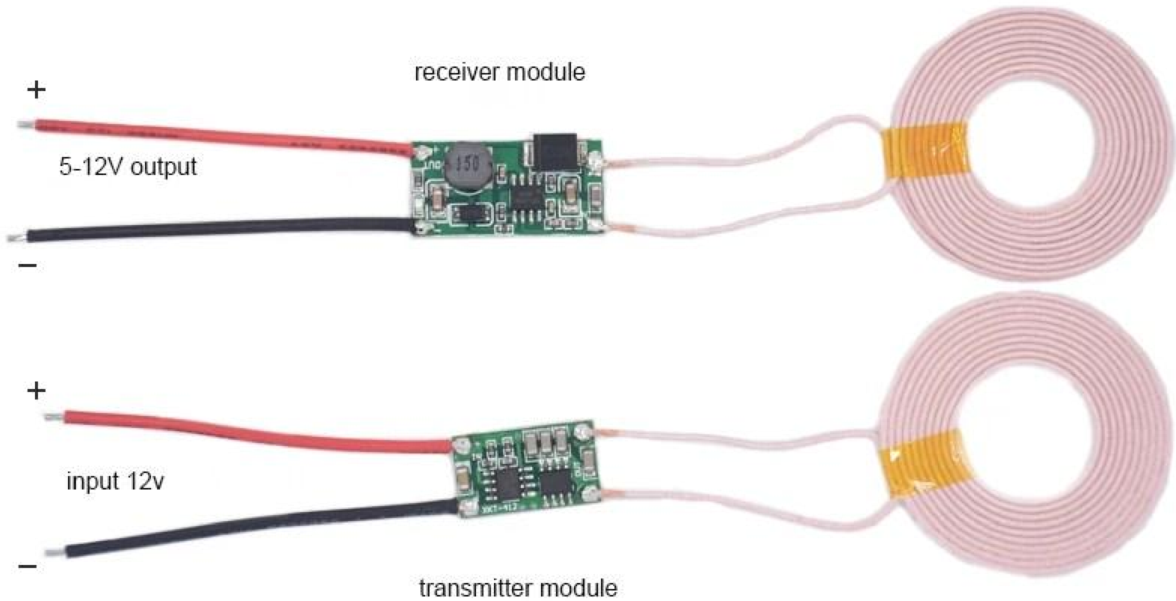
One of the key advantages of wireless charging modules is their versatility and compatibility. Many modern smartphones and other electronic devices come equipped with wireless charging capabilities, enabling seamless integration with wireless charging pads or modules. Additionally, wireless charging modules are designed to support various device types, making them suitable for a wide range of consumer electronics, including smartwatches, headphones, and even electric vehicles.

Wireless charging modules also offer the benefit of safety and durability. With no exposed charging ports or connectors, there is a reduced risk of damage caused by repeated plugging and unplugging of cables. Additionally, wireless charging modules employ safety mechanisms such as foreign object detection, which prevents charging if any non-compatible object is placed on the charging pad, ensuring a safe charging environment.

Another advantage of wireless charging modules is their potential for future advancements. As technology evolves, wireless charging capabilities are expected to improve in terms of charging speed and efficiency. The development of higher power wireless charging modules allows for faster charging times, while ongoing research focuses on extending the range and expanding the charging footprint, enabling charging from a distance without direct contact with the charging pad.

Furthermore, wireless charging modules contribute to the reduction of electronic waste. With traditional charging methods that involve disposable cables and connectors, there is a significant accumulation of electronic waste over time. Wireless charging eliminates the need for disposable cables, promoting a more sustainable and environmentally friendly charging solution.

In conclusion, wireless charging modules have revolutionized the way we charge our electronic devices, providing a convenient, versatile, and clutter-free charging experience. With their compatibility, safety features, and potential for future advancements, wireless charging modules are poised to become the standard charging method for a wide range of consumer electronics. As technology continues to evolve, wireless charging modules hold the promise of faster charging speeds, extended range, and a more sustainable approach to power our devices wirelessly.



4.6 INTRODUCTION TO 18650 BATTERY

A **lithium-ion battery** or **Li-ion battery** is a type of rechargeable battery in which lithium ions move from the negative electrode through an electrolyte to the positive electrode during discharge, and back when charging. Li-ion batteries use an intercalated lithium compound as the material at the positive electrode and typically graphite at the negative electrode.

Li-ion batteries have a high energy density, no memory effect (other than LFP cells)[9] and low self-discharge. Cells can be manufactured to either prioritize energy or power density. [10] They can however be a safety hazard since they contain flammable electrolytes, and if damaged or incorrectly charged can lead to explosions and fires. Samsung was forced to recall Galaxy Note 7 handsets following lithium-ion fires,[11] and there have been several incidents involving batteries on Boeing 787s.

A prototype Li-ion battery was developed by Akira Yoshino in 1985, based on earlier research by John Goodenough, M. Stanley Whittingham, Rachid Yazami and Koichi Mizushima during the 1970s–1980s,[12][13][14] and then a commercial Li-ion battery was developed by a Sony and Asahi Kasei team led by Yoshio Nishi in 1991.[15]

Lithium-ion batteries are commonly used for portable electronics and electric vehicles and are growing in popularity for military and aerospace applications.[16]

Chemistry, performance, cost and safety characteristics vary across types of lithium-ion batteries. Handheld electronics mostly use lithium polymer batteries (with a polymer gel as electrolyte), a lithium cobalt oxide ($LiCoO_3$-based lithium rich layered materials, LMR-NMC), and lithium nickel manganese cobalt oxide ($LiNiMnCoO_2$ or NMC) may offer longer lives and may have better rate capability. Such batteries are widely used for electric tools, medical equipment, and other roles. NMC and its derivatives are widely used in electric vehicles.

Research areas for lithium-ion batteries include extending lifetime, increasing energy density, improving safety, reducing cost, and increasing charging speed,[19] among others. Research has been under way in the area of non-flammable electrolytes as a pathway to increased safety based on the flammability and volatility of the organic solvents used in the typical electrolyte.

Strategies include aqueous lithium-ion batteries, ceramic solid electrolytes, polymer electrolytes, ionic liquids, and heavily fluorinated systems

4.7 INTRODUCTION TO SOLAR PANELS

Solar panels absorb the sunlight as a source of energy to generate electricity or heat.

A photovoltaic (PV) module is a packaged, connect assembly of typically 6x10 photovoltaic solar cells. Photovoltaic modules constitute the photovoltaic array of a photovoltaic system that generates and supplies solar electricity in commercial and residential applications. Each module is rated by its DC output power under standard test conditions (STC), and typically ranges from 100 to 365 Watts (W). The efficiency of a module determines the area of a module given the same rated output – an 8% efficient 230 W module will have twice the area of a 16% efficient 230 W module. There are a few commercially available solar modules that exceed efficiency of 22%[1] and reportedly also exceeding 24%. A single solar module can produce only a limited amount of power; most installations contain multiple modules. A photovoltaic system typically includes an array of photovoltaic modules, an inverter, a battery pack for storage, interconnection wiring, and optionally a solar tracking mechanism.

4.7.1 THEORY AND CONSTRUCTION

Photovoltaic modules use light energy (photons) from the Sun to generate electricity through the photovoltaic effect. The majority of modules use wafer-based crystalline silicon cells or thin-film cells. The structural (load carrying) member of a module can either be the top layer or the back layer. Cells must also be protected from mechanical damage and moisture. Most modules are rigid, but semi-flexible ones are available, based on thin-film cells. The cells must be connected electrically in series, one to another. Externally, most of photovoltaic modules use MC4 connectors type to facilitate easy weatherproof connections to the rest of the system.

Modules electrical connections are made in series to achieve a desired output voltage or in parallel to provide a desired current capability. The conducting wires that take the current off the modules may contain silver, copper or other non-magnetic conductive transition metals. Bypass diodes may be incorporated or used externally, in case of partial module shading, to maximize the output of module sections still illuminated.

Some special solar PV modules include concentrators in which light is focused by lenses or mirrors onto smaller cells. This enables the use of cells with a high cost per unit area (such as gallium arsenide) in a cost-effective way.

4.7.2 EFFIENCIES

Depending on construction, photovoltaic modules can produce electricity from a range of frequencies of light, but usually cannot cover the entire solar range (specifically, ultraviolet, infrared and low or diffused light). Hence, much of the incident sunlight energy is wasted by solar modules, and they can give far higher efficiencies if illuminated with monochromatic light. Therefore, another design concept is to split the light into different wavelength ranges and direct the beams onto different cells tuned to those ranges.[*citation needed*] This has been projected to be capable of raising efficiency by 50%. Scientists from Spectrolab, a subsidiary of Boeing, have reported development of multi-junction solar cells with an efficiency of more than 40%, a new world record for solar photovoltaic cells.[6] The Spectrolab scientists also predict that concentrator solar cells could achieve efficiencies of more than 45% or even 50% in the future, with theoretical efficiencies being about 58% in cells with more than three junctions.

Currently, the best achieved sunlight conversion rate (solar module efficiency) is around 21.5% in new commercial products[7] typically lower than the efficiencies of their cells in isolation. The most efficient mass-produced solar modules[*disputed – discuss*] have power density values of up to 175 W/m^2 (16.22 W/ft^2).[8] Research by Imperial College, London has shown that the efficiency of a solar panel can be improved by studding the light-receiving semiconductor surface with aluminum nanocylinders similar to the ridges on Lego blocks. The scattered light then travels along a longer path in the semiconductor which means that more photons can be absorbed and converted into current. Although these nanocylinders have been used previously (aluminum was preceded by gold and silver), the light scattering occurred in the near infrared region and visible light was absorbed strongly. Aluminum was found to have absorbed the ultraviolet part of the spectrum, while the visible and near infrared parts of the spectrum were found to be scattered by the aluminum surface. This, the research argued, could bring down the cost significantly and improve the efficiency as aluminum is more abundant and less costly than gold and silver. The research also noted that the increase in current makes thinner film solar panels technically feasible without "compromising power conversion efficiencies, thus reducing material consumption"

4.7.3 TECHNOLOGY

Most solar modules are currently produced from crystalline silicon (c-Si) solar cells made of multicrystalline and monocrystalline silicon. In 2013, crystalline silicon accounted for more than 90 percent of worldwide PV production, while the rest of the overall market is made up of thin-film technologies using cadmium telluride, CIGS and amorphous silicon[11] Emerging, third generation solar technologies use advanced thin-film cells. They produce a relatively high-efficiency conversion for the low cost compared to other solar technologies. Also, high-cost, high-efficiency, and close-packed rectangular multi-junction (MJ) cells are preferably used in solar panels on spacecraft, as they offer the highest ratio of generated power per kilogram lifted into space. MJ-cells are compound semiconductors and made of gallium arsenide (GaAs) and other semiconductor materials. Another emerging PV technology using MJ-cells is concentrator photovoltaics (CPV).

4.7.4 MAINTAINENCE

Solar panel conversion efficiency, typically in the 20% range, is reduced by dust, grime, pollen, and other particulates that accumulate on the solar panel. "A dirty solar panel can reduce its power capabilities by up to 30% in high dust/pollen or desert areas", says Seamus Curran, associate professor of physics at the University of Houston and director of the Institute for NanoEnergy, which specializes in the design, engineering, and assembly of nanostructures.[23] Paying to have solar panels cleaned is often not a good investment; researchers found panels that had not been cleaned, or rained on, for 145 days during a summer drought in California, lost only 7.4% of their efficiency. Overall, for a typical residential solar system of 5 kW, washing panels halfway through the summer would translate into a mere $20 gain in electricity production until the summer drought ends—in about 2 ½ months. For larger commercial rooftop systems, the financial losses are bigger but still rarely enough to warrant the cost of washing the panels. On average, panels lost a little less than 0.05% of their overall efficiency per day.

4.8 INTRODUCTION TO LEDS

A **light-emitting diode** (**LED**) is a two-lead semiconductor light source. It is a p–n junction diode that emits light when activated. When a suitable current is applied to the leads, electrons are able to recombine with electron holes within the device, releasing energy in the form of photons. This effect is called electroluminescence, and the color of the light (corresponding to the energy of the photon) is determined by the energy band gap of the semiconductor. LEDs are typically small (less than 1 mm^2) and integrated optical components may be used to shape the radiation pattern.

Appearing as practical electronic components in 1962, the earliest LEDs emitted low-intensity infrared light. Infrared LEDs are still frequently used as transmitting elements in remote-control circuits, such as those in remote controls for a wide variety of consumer electronics. The first visible-light LEDs were of low intensity and limited to red. Modern LEDs are available across the visible, ultraviolet, and infrared wavelengths, with very high brightness.

Early LEDs were often used as indicator lamps for electronic devices, replacing small incandescent bulbs. They were soon packaged into numeric readouts in the form of seven-segment displays and were commonly seen in digital clocks. Recent developments have produced LEDs suitable for environmental and task lighting. LEDs have led to new displays and sensors, while their high switching rates are useful in advanced communications technology.

4.8.1 WORKING PRINCIPLE

A P-N junction can convert absorbed light energy into a proportional electric current. The same process is reversed here (i.e. the P-N junction emits light when electrical energy is applied to it). This phenomenon is generally called electroluminescence, which can be defined as the emission of light from a semiconductor under the influence of an electric field. The charge carriers recombine in a forward-biased P-N junction as the electrons cross from the N-region and recombine with the holes existing in the P-region. Free electrons are in the conduction band of energy levels, while holes are in the valence energy band. Thus the energy level of the holes is less than the energy levels of the electrons. Some portion of the energy must be dissipated to recombine the electrons and the holes. This energy is emitted in the form of heat and light.

The electrons dissipate energy in the form of heat for silicon and germanium diodes but in gallium arsenide phosphide (GaAsP) and gallium phosphide (GaP) semiconductors, the electrons dissipate energy by emitting photons. If the semiconductor is translucent, the junction becomes the source of light as it is emitted, thus becoming a light-emitting diode. However, when the junction is reverse biased, the LED produces no light and—if the potential is great enough, the device is damaged.

4.8.2 TECHNOLOGY

The LED consists of a chip of semiconducting material doped with impurities to create a p-n junction. As in other diodes, current flows easily from the p-side, or anode, to the n-side, or cathode, but not in the reverse direction. Charge-carriers—electrons and holes—flow into the junction from electrodes with different voltages. When an electron meets a hole, it falls into a lower energy level and releases energy in the form of a photon.

The wavelength of the light emitted, and thus its color, depends on the band gap energy of the materials forming the p-n junction. In silicon or germanium diodes, the electrons and holes usually recombine by a non-radiative transition, which produces no optical emission, because these are indirect band gap materials. The materials used for the LED have a direct band gap with energies corresponding to near-infrared, visible, or near-ultraviolet light.

LED development began with infrared and red devices made with gallium arsenide. Advances in materials science have enabled making devices with ever-shorter wavelengths, emitting light in a variety of colors.

LEDs are usually built on an n-type substrate, with an electrode attached to the p-type layer deposited on its surface. P-type substrates, while less common, occur as well. Many commercial LEDs, especially GaN/InGaN, also use sapphire substrate.

4.8.3 ADVANTAGES

- **Efficiency:** LEDs emit more lumens per watt than incandescent light bulbs.[150] The efficiency of LED lighting fixtures is not affected by shape and size, unlike fluorescent light bulbs or tubes.
- **Color:** LEDs can emit light of an intended color without using any color filters as traditional lighting methods need. This is more efficient and can lower initial costs.
- **Size:** LEDs can be very small (smaller than 2 mm^2) and are easily attached to printed circuit boards.
- **Warmup time:** LEDs light up very quickly. A typical red indicator LED achieves full brightness in under a microsecond. LEDs used in communications devices can have even faster response times.
- **Cycling:** LEDs are ideal for uses subject to frequent on-off cycling, unlike incandescent and fluorescent lamps that fail faster when cycled often, or high-intensity discharge lamps(HID lamps) that require a long time before restarting.
- **Dimming:** LEDs can very easily be dimmed either by pulse-width modulation or lowering the forward current.[153] This pulse-width modulation is why LED lights, particularly headlights on cars, when viewed on camera or by some people, appear to be flashing or flickering. This is a type of stroboscopic effect.
- **Cool light:** In contrast to most light sources, LEDs radiate very little heat in the form of IR that can cause damage to sensitive objects or fabrics. Wasted energy is dispersed as heat through the base of the LED.
- **Slow failure:** LEDs mostly fail by dimming over time, rather than the abrupt failure of incandescent bulbs.[72]
- **Lifetime:** LEDs can have a relatively long useful life. One report estimates 35,000 to 50,000 hours of useful life, though time to complete failure may be longer.[154] Fluorescent tubes typically are rated at about 10,000 to 15,000 hours, depending partly on the conditions of use, and incandescent light bulbs at 1,000 to 2,000 hours. Several DOEdemonstrations have shown that reduced maintenance costs from this extended lifetime, rather than energy savings, is the primary factor in determining the payback period for an LED product.
-

4.8.4 DISADVANTAGES

- **Initial price:** LEDs are currently slightly more expensive (price per lumen) on an initial capital cost basis, than other lighting technologies. As of March 2014, at least one manufacturer claims to have reached $1 per kilolumen.[156] The additional expense partially stems from the relatively low lumen output and the drive circuitry and power supplies needed.
- **Temperature dependence:** LED performance largely depends on the ambient temperature of the operating environment – or thermal management properties. Overdriving an LED in high ambient temperatures may result in overheating the LED package, eventually leading to device failure. An adequate heat sink is needed to maintain long life. This is especially important in automotive, medical, and military uses where devices must operate over a wide range of temperatures, which require low failure rates. Toshiba has produced LEDs with an operating temperature range of −40 to 100 °C, which suits the LEDs for both indoor and outdoor use in applications such as lamps, ceiling lighting, street lights, and floodlights.
- **Voltage sensitivity:** LEDs must be supplied with a voltage above their threshold voltage and a current below their rating. Current and lifetime change greatly with a small change in applied voltage. They thus require a current-regulated supply (usually just a series resistor for indicator LEDs).
- **Color rendition:** Most cool-white LEDs have spectra that differ significantly from a black body radiator like the sun or an incandescent light. The spike at 460 nm and dip at 500 nm can cause the color of objects to be perceived differently under cool-white LED illumination than sunlight or incandescent sources, due to metamerism,[158] red surfaces being rendered particularly poorly by typical phosphor-based cool-white LEDs.
- **Area light source:** Single LEDs do not approximate a point source of light giving a spherical light distribution, but rather a lambertian distribution. So LEDs are difficult to apply to uses needing a spherical light field; however, different fields of light can be manipulated by the application of different optics or "lenses". LEDs cannot provide divergence below a few degrees. In contrast, lasers can emit beams with divergences of 0.2 degrees or less

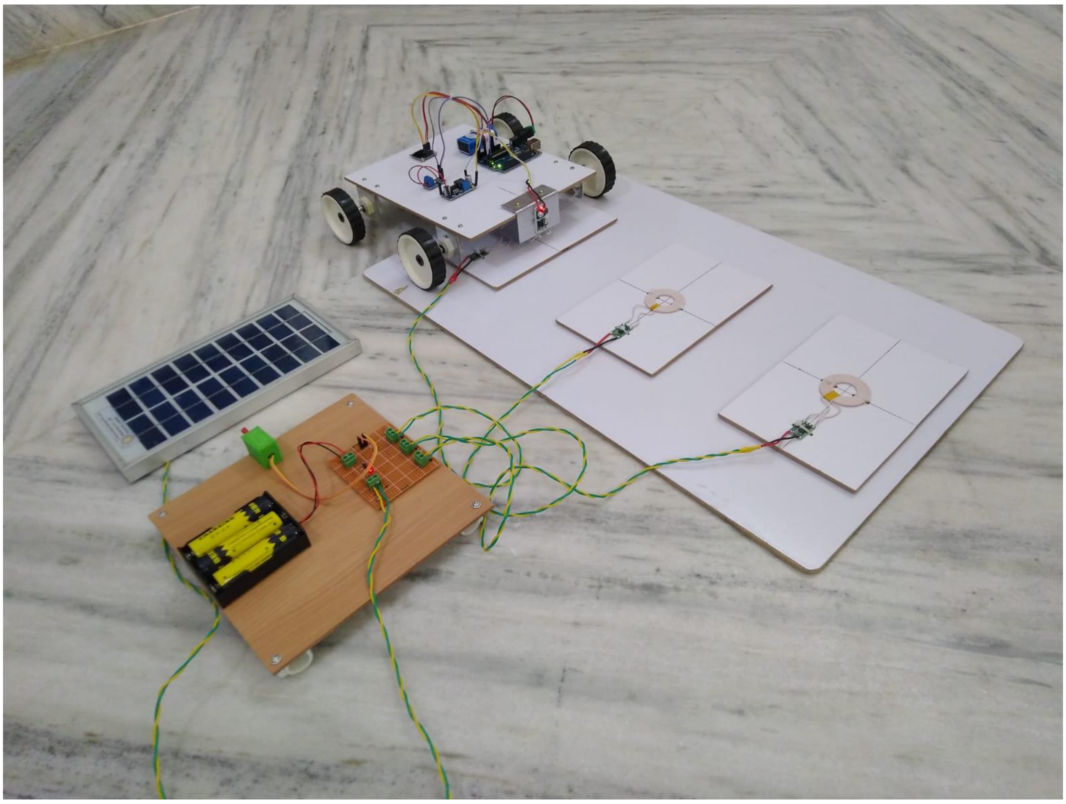
4.8.5 APPLICATIONS

LED uses fall into four major categories:

- Visual signals where light goes more or less directly from the source to the human eye, to convey a message or meaning
- Illumination where light is reflected from objects to give visual response of these objects
- Measuring and interacting with processes involving no human vision
- Narrow band light sensors where LEDs operate in a reverse-bias mode and respond to incident light, instead of emitting light.

CHAPTER 5

RESULT



A small dynamic wireless electric vehicle (EV) charging system, powered by solar energy, offers a compact and sustainable solution for EV charging needs. Solar panels capture sunlight and convert it into electricity, which is wirelessly transferred to EVs equipped with receiving coils. This eliminates the need for physical connections, making charging convenient for residential areas and urban streets. With the ability to charge while in motion, EVs can extend their range without frequent stops. This system optimizes energy transfer and reduces costs, all while promoting environmental sustainability by using renewable energy sources and lowering emissions.

In conclusion, a small dynamic wireless EV charging system powered by solar energy offers a practical and sustainable solution for charging electric vehicles in residential and urban environments, contributing to the widespread adoption of clean transportation options.

CHAPTER 6

CONCLUSION

The integration of dynamic wireless electric vehicle charging systems with solar power holds tremendous potential for revolutionizing the charging infrastructure of electric vehicles. By enabling EVs to charge while in motion, these systems provide a convenient and seamless charging experience, eliminating the need for physical connections and reducing the limitations posed by stationary charging stations.

The use of solar power as the energy source for these dynamic wireless charging systems further enhances their sustainability and environmental benefits. By harnessing the sun's energy, these systems reduce reliance on the grid and decrease greenhouse gas emissions associated with fossil fuel-based electricity generation. Solar power also contributes to the overall energy efficiency of the charging system, with excess energy being stored and utilized during low-sunlight periods or high-demand charging periods.

The combination of dynamic wireless charging and solar power represents a significant step forward in promoting sustainable transportation and reducing carbon emissions. It offers the potential for widespread adoption of electric vehicles by addressing charging infrastructure limitations and providing an environmentally friendly and efficient charging solution. Continued research, development, and deployment of these systems will be crucial in realizing a future of sustainable transportation powered by renewable energy sources.

In conclusion, a small dynamic wireless EV charging system powered by solar energy offers a practical and sustainable solution for charging electric vehicles in residential and urban environments, contributing to the widespread adoption of clean transportation options.

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