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Smart Solar Energy System with Inverter and Mobile Application Integration

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ABSTRACT:

This project focuses on the development of a smart solar monitoring system using solar inverters integrated with a mobile application. The system utilizes solar PV panels, a hybrid inverter, sensors, an IoT gateway, and a mobile app for real-time energy data tracking and control. Energy data is captured from the inverter and sensors and sent to the cloud using an IoT-enabled communication interface. The mobile app allows users to visualize power generation, monitor battery storage, control energy flows, and receive alerts. This project promotes sustainable energy usage and empowers users with datadriven decision-making tools. So, to prevent further outages, we have incorporated renewable sources of energy as a backup.. The Energy Audit System gives you the best amount you can save with respect to your household. an auto-switching circuit is being designed for the day-to-day purpose using a relay

CHAPTER 1: INTRODUCTION

With the growing need for renewable energy and smart technology, solar power systems have become an essential part of sustainable energy solutions. However, traditional solar inverters often lack intelligent monitoring features that provide real-time insights into system performance. This project aims to bridge that gap by integrating Internet of Things (IoT) technology into a solar inverter system. By using sensors and a Wi-Fi-enabled microcontroller, critical parameters such as solar panel output, battery status, and inverter performance can be continuously monitored and uploaded to the ThingSpeak cloud platform. This allows users to remotely access and analyze system data from anywhere, promoting better energy management, fault detection, and overall system efficiency. The project not only demonstrates the practical application of IoT in renewable energy but also encourages the development of smart, connected, and eco-friendly energy solutions.

CHAPTER 2: EMBEDDED SYSTEMS

2.1 Embedded Systems:

An embedded system is a computer system designed to perform one or a few dedicated functions often with real-time computing constraints. It is embedded as part of a complete device often including hardware and mechanical parts. By contrast, a general-purpose computer, such as a personal computer (PC), is designed to be flexible and to meet a wide range of end-user needs. Embedded systems control many devices in common use today.

Embedded systems are controlled by one or more main processing cores that are typically either microcontrollers or digital signal processors (DSP). The key characteristic, however, is being dedicated to handle a particular task, which may require very powerful processors. For example, air traffic control systems may usefully be viewed as embedded, even though they involve mainframe computers and dedicated regional and national networks between airports and radar sites. (Each radar probably includes one or more embedded systems of its own.)

Since the embedded system is dedicated to specific tasks, design engineers can optimize it to reduce the size and cost of the product and increase the reliability and performance. Some embedded

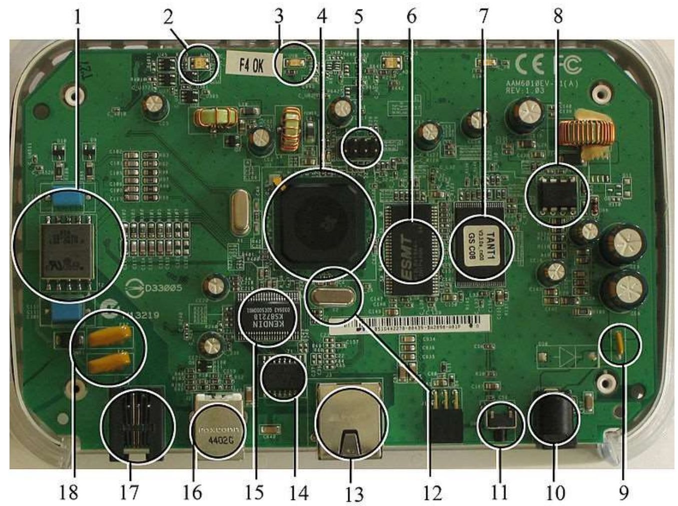

Fig 2.1:A modern example of embedded system

2.1.1 History:

In the earliest years of computers in the 1930–40s, computers were sometimes dedicated to a single task, but were far too large and expensive for most kinds of tasks performed by embedded computers of today. Over time however, the concept of programmable controllers evolved from traditional electromechanical sequencers, via solid state devices, to the use of computer technology. main memory. When the Minuteman II went into production in 1966, the D-17 was replaced with a new computer that was the first high-volume use of integrated circuits.

2.1.2 Tools:

Embedded development makes up a small fraction of total programming. There's also a large number of embedded architectures, unlike the PC world where 1 instruction set rules, and the Unix world where there's only 3 or 4 major ones. This means that the tools are more expensive. It also means that they're lower featured, and less developed. On a major embedded project, at some point you will almost always find a compiler bug of some sort.

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2.1.3 Resources:

To save costs, embedded systems frequently have the cheapest processors that can do the job. This means your programs need to be written as efficiently as possible. When dealing with large data sets, issues like memory cache misses that never matter in PC programming can hurt you. Luckily, this won't happen too often- use reasonably efficient algorithms to start, and optimize only when necessary. Of course, normal profilers won't work well, due to the same reason debuggers don't work well.

Memory is also an issue. For the same cost savings reasons, embedded systems usually have the least memory they can get away with. That means their algorithms must be memory efficient (unlike in PC programs, you will frequently sacrifice processor time for memory, rather than the reverse). It also means you can't afford to leak memory. Embedded applications generally use deterministic memory techniques and avoid the default "new" and "malloc" functions, so that leaks can be found

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and eliminated more easily. Other resources programmers expect may not even exist. For example, most embedded processors do not have hardware FPUs (Floating-Point Processing Unit). These resources either need to be emulated in software, or avoided altogether.

2.1.4 Real Time Issues:

Embedded systems frequently control hardware, and must be able to respond to them in real time. Failure to do so could cause inaccuracy in measurements, or even damage hardware such as motors. This is made even more difficult by the lack of resources available. Almost all embedded systems need to be able to prioritize some tasks over others, and to be able to put off/skip low priority tasks such as UI in favor of high priority tasks like hardware control.

2.2 Need For Embedded Systems:

The uses of embedded systems are virtually limitless, because every day new products are introduced to the market that utilizes embedded computers in novel ways. In recent years, hardware such as microprocessors, microcontrollers, and FPGA chips have become much cheaper. So when implementing a new form of control, it's wiser to just buy the generic chip and write your own custom software for it. Producing a custom-made chip to handle a particular task or set of tasks costs far more time and money. Many embedded computers even come with extensive libraries, so that "writing your own software" becomes a very trivial task indeed. From an implementation viewpoint, there is a major difference between a computer and an embedded system. Embedded systems are often required to provide Real-Time response. The main elements that make embedded systems unique are its reliability and ease in debugging.

2.2.1 Debugging:

Embedded debugging may be performed at different levels, depending on the facilities available. From simplest to most sophisticate 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 multi core systems.

2.2.2 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.

2.3 Explanation of Embedded Systems:

2.3.1 Software Architecture:

There are several different types of software architecture in common use.

- Simple Control Loop:

In this design, the software simply has a loop. The loop calls subroutines, each of which manages a part of the hardware or software.

- Interrupt Controlled System:

Some embedded systems are predominantly interrupt controlled. This means that tasks performed by the system are triggered by different kinds of events. An interrupt could be generated for example by a timer in a predefined frequency, or by a serial port controller receiving a byte. These kinds of systems are used if event handlers need low latency and the event handlers are short and simple.

2.3.3 Real-time embedded systems:

Embedded systems which are used to perform a specific task or operation in a specific time period those systems are called as real-time embedded systems. There are two types of real-time embedded systems.

- Hard Real-time embedded systems:

These embedded systems follow an absolute dead line time period i.e.., if the tasking is not done in a particular time period then there is a cause of damage to the entire equipment.

Eg: consider a system in which we have to open a valve within 30 milliseconds. If this valve is not opened in 30 ms this may cause damage to the entire equipment. So in such cases we use embedded systems for doing automatic operations.

- Soft Real Time embedded systems:

These embedded systems follow a relative dead line time period i.e.., if the task is not done in a particular time that will not cause damage to the equipment.

Eg: Consider a TV remote control system, if the remote control takes a few milliseconds delay it will not cause damage either to the TV or to the remote control. These systems which will not cause damage when they are not operated at considerable time period those systems comes under soft real-time embedded systems.

2.3.4 Network communication embedded systems:

A wide range network interfacing communication is provided by using embedded systems.

Eg:

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Fig 2.2: Network communication embedded systems

2.3.5 Different types of processing units:

The central processing unit (c.p.u) can be any one of the following microprocessor, microcontroller, digital signal processing.

- Among these Microcontroller is of low cost processor and one of the main advantage of microcontrollers is, the components such as memory, serial communication interfaces, analog to digital converters etc.., all these are built on a single chip. The numbers of external components that are connected to it are very less according to the application.

2.4.3. Industrial automation:

Today a lot of industries are using embedded systems for process control. In industries we design the embedded systems to perform a specific operation like monitoring temperature, pressure, humidity ,voltage, current etc.., and basing on these monitored levels we do control other devices, we can send information to a centralized monitoring station.The input coil is called the PRIMARY WINDING; the output coil is the SECONDARY WINDING. Fig: 3.3.4 shows step-down transformer.

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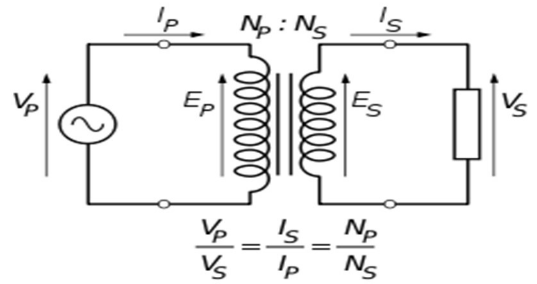

Fig 3.3.4: Step-Down Transformer

The voltage induced in the secondary is determined by the TURNS RATIO.

$$\frac{\text{primary voltage}}{\text{secondary voltage}} = \frac{\text{number of primary turns}}{\text{number of secondary turns}}$$

For example, if the secondary has half the primary turns; the secondary will have half the primary voltage.

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Rectifiers:

A rectifier is an electrical device that converts alternating current (AC) to direct current (DC), a process known as rectification. Rectifiers have many uses including as components of power supplies and as detectors of radio signals. Rectifiers may be made of solid-state diodes, vacuum tube diodes, mercury arc valves, and other components.

A device that it can perform the opposite function (converting DC to AC) is known as an inverter.

When only one diode is used to rectify AC (by blocking the negative or positive portion of the waveform), the difference between the term diode and the term rectifier is merely one of usage, i.e., the term rectifier describes a diode that is being used to convert AC to DC. Almost all rectifiers comprise a number of diodes in a specific arrangement for more efficiently converting AC to DC than is possible with only one diode. Before the development of silicon semiconductor rectifiers, vacuum tube diodes and copper (I) oxide or selenium rectifier stacks were used.

Bridge full wave rectifier:

The Bridge rectifier circuit is shown in fig: 3.3.7, which converts an ac voltage to dc voltage using both half cycles of the input ac voltage. The Bridge rectifier circuit is shown in the figure. The circuit has four diodes connected to form a bridge. The ac input voltage is applied to the diagonally opposite ends of the bridge. The load resistance is connected between the other two ends of the bridge.

Input

Output

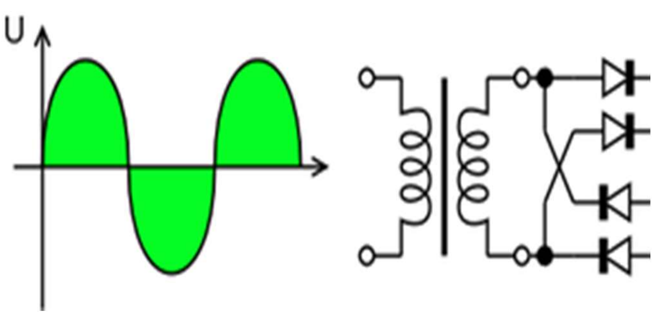

Fig 3.3.7: Bridge rectifier: a full-wave rectifier using 4 diodes

DB107:

Features:

- Good for automation insertion
- Surge overload rating - 30 amperes peak
- Ideal for printed circuit board
- Reliable low cost construction utilizing molded
- Glass passivated device
- Polarity symbols molded on body
- Mounting position: Any
- Weight: 1.0 gram

Fig 3.3.8: DB107

Filtration:

The process of converting a pulsating direct current to a pure direct current using filters is called as filtration.

Filters:

Electronic filters are electronic circuits, which perform signal-processing functions, specifically to remove unwanted frequency components from the signal, to enhance wanted ones.

Introduction to Capacitors:

The Capacitor or sometimes referred to as a Condenser is a passive device, and one which stores energy in the form of an electrostatic field which produces a potential (static voltage) across its plates. In its basic form a capacitor consists of two parallel conductive plates that are not connected but are electrically separated either by air or by an insulating material called the Dielectric. When a voltage is applied to these plates, a current flows charging up the plates with electrons giving one plate a positive charge and the other plate an equal and opposite negative charge This flow of electrons to the plates is known as the Charging Current and continues to flow until the voltage across the plates (and hence the capacitor) is equal to the applied voltage Vcc

Voltage Regulator:

A voltage regulator (also called a 'regulator') with only three terminals appears to be a simple device, but it is in fact a very complex integrated circuit. It converts a varying input voltage into a constant 'regulated' output voltage. Voltage Regulators are available in a variety of outputs like 5V, 6V, 9V, 12V and 15V. The LM78XX series of voltage regulators are designed for positive input. For applications requiring negative input, the LM79XX series is used. Using a pair of 'voltage-divider' resistors can increase the output voltage of a regulator circuit.

It is not possible to obtain a voltage lower than the stated rating. You cannot use a 12V regulator to make a 5V power supply. Voltage regulators are very robust. These can withstand over-current draw due to short circuits and also over-heating. In both cases, the regulator will cut off before any damage occurs. The only way to destroy a regulator is to apply reverse voltage to its input. Reverse polarity destroys the regulator almost instantly. Fig: 3.3.11 shows voltage regulator.

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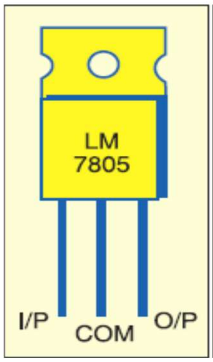


Fig 3.3.11: Voltage Regulator

Resistors:

A resistor is a two-terminal electronic component that produces a voltage across its terminals that is proportional to the electric current passing through it in accordance with Ohm's law:

$$V = IR$$

Resistors are elements of electrical networks and electronic circuits and are ubiquitous in most electronic equipment. Practical resistors can be made of various compounds and films, as well as resistance wire (wire made of a high-resistivity alloy, such as nickel/chrome). Resistors can be made to control the flow of current, to work as Voltage dividers, to dissipate power and it can shape electrical waves when used in combination of other components. Basic unit is ohms.

Theory of operation:

Ohm's law:

The behavior of an ideal resistor is dictated by the relationship specified in Ohm's law:

$$V = IR$$

Ohm's law states that the voltage (V) across a resistor is proportional to the current (I) through it where the constant of proportionality is the resistance (R).

Power dissipation:

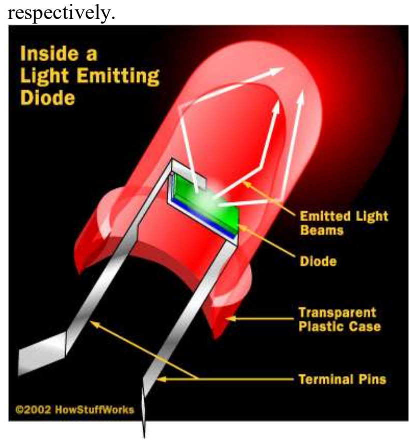
The power dissipated by a resistor (or the equivalent resistance of a resistor network) is calculated using the following:

$$P = I^2R = IV = \frac{V^2}{R}$$

Fig 3.3.12: Resistor Fig 3.3.13: Color Bands In Resistor

3.3. LED:

A light-emitting diode (LED) is a semiconductor light source. LED's are used as indicator lamps in many devices, and are increasingly used for lighting. Introduced as a practical electronic component in 1962, early LED's emitted low-intensity red light, but modern versions are available across the visible, ultraviolet and infrared wavelengths, with very high brightness. The internal structure and parts of a led are shown in figures 3.4.1 and 3.4.2 respectively.



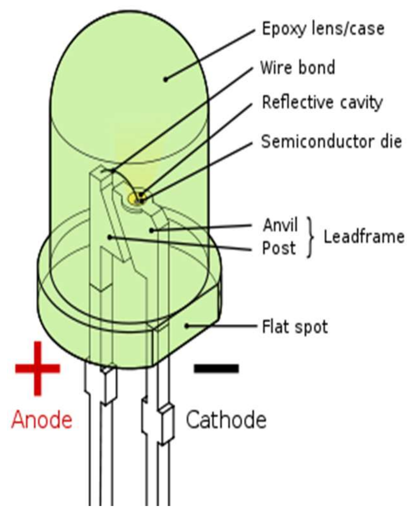


Fig 3.4.1: Inside a LED Fig 3.4.2: Parts of a LED

Working:

The electrical symbol and polarities of led are shown in fig: 3.4.3.

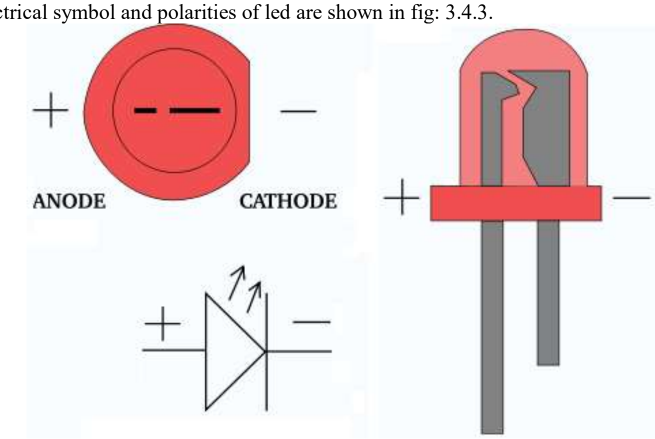


Fig 3.4.3: Electrical Symbol & Polarities of LED

LED lights have a variety of advantages over other light sources:

- High-levels of brightness and intensity

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- High-efficiency
- Low-voltage and current requirements
- Low radiated heat
- High reliability (resistant to shock and vibration)
- No UV Rays
- Long source life
- Can be easily controlled and programmed

Applications of LED fall into three major categories:

- Visual signal application where the light goes more or less directly from the LED to the human eye, to convey a message or meaning.
- Illumination where LED light is reflected from object to give visual response of these objects.
- Generate light for measuring and interacting with processes that do not involve the human visual system.

3.2 ARDUINO (MICRO CONTROLLER)

3.3.**1 Introduction to the Arduino Board**

The Arduino is a family of microcontroller boards to simplify electronic design, prototyping and experimenting for artists, hackers, hobbyists, but also many professionals. People use it as brains for their robots, to build new digital music instruments, or to build a system that lets your house plants tweet you when they're dry. Arduinos (we use the standard Arduino Uno) are built around an ATmega microcontroller — essentially a complete computer with CPU, RAM, Flash memory, and input/output pins, all on a single chip. Unlike, say, a Raspberry Pi, it's designed to attach all kinds of sensors, LEDs, small motors and speakers, servos, etc

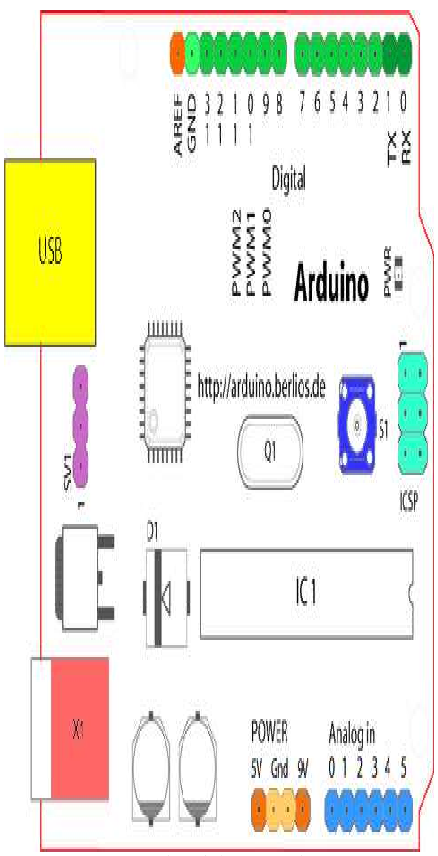

Figure 3.3.1 Structure of Arduino Board

Looking at the board from the top down, this is an outline of what you will see (parts of the board you might interact with in the course of normal use are highlighted)

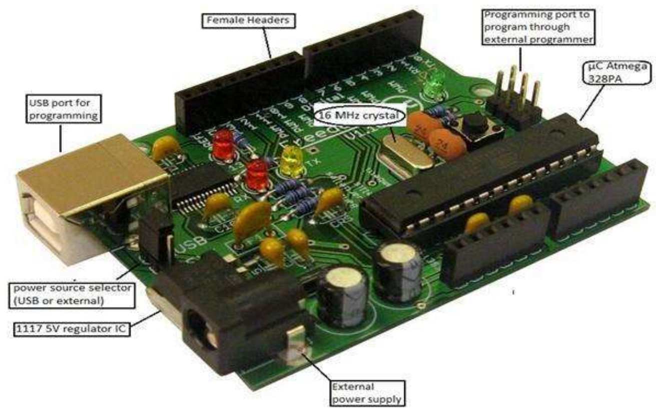

Figure 3.3.2 Arduino Board

Starting clockwise from the top center:

- ➢ Analog Reference pin (orange)
- ➢ Digital Ground (light green)
- ➢ Digital Pins 2-13 (green)
- ➢ Digital Pins 0-1/Serial In/Out - TX/RX (dark green) - These pins cannot be used for digital i/o (Digital Read and Digital Write) if you are also using serial communication (e.g. Serial.begin).
- ➢ Reset Button - S1 (dark blue)
- ➢ In-circuit Serial Programmer (blue-green)
- ➢ Analog In Pins 0-5 (light blue)
- ➢ Power and Ground Pins (power: orange, grounds: light orange)
- ➢ External Power Supply In (9-12VDC) - X1 (pink)
- ➢ Toggles External Power and USB Power (place jumper on two pins closest to desired supply) - SV1 (purple)
- ➢ USB (used for uploading sketches to the board and for serial communication between the board and the computer; can be used to power the board) (yellow)

3.3.2 Pin diagram

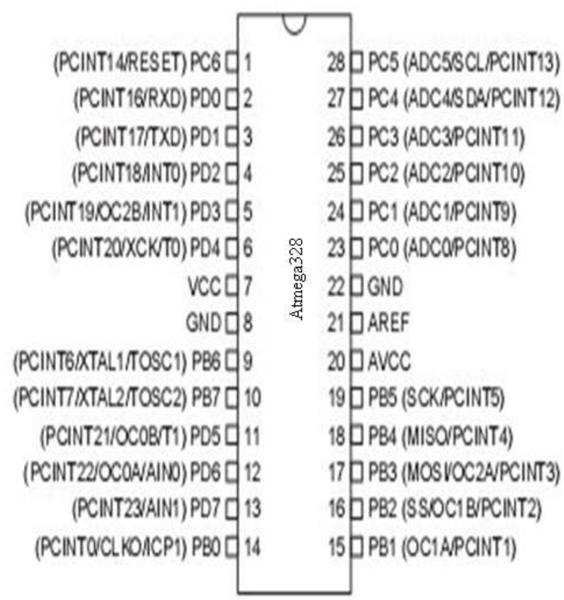

Figure 3.3.3 Pin Configuration of Atmega328

Features

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- 1.8-5.5V operating range
- Up to 20MHz
- Part: ATMEGA328P-AU
- 32kB Flash program memory
- 1kB EEPROM
- 2kB Internal SRAM
- 2 8-bit Timer/Counters
- 16-bit Timer/Counter
- RTC with separate oscillator
- Master/Slave SPI interface
- 2-wire (I2C) interface
- Watchdog timer
- 23 IO lines
- Data retention: 20 years at 85C/ 100 years at 25C
- Digital I/O Pins are 14 (out of which 6 provide PWM output)
- Analog Input Pins are 6.
- DC Current per I/O is 40 mA
- DC Current for 3.3V Pin is 50mA

3.3.3 AVR CPU Core

The AVR core combines a rich instruction set with 32 general purpose working registers. All the 32 registers are directly connected to the Arithmetic Logic Unit (ALU), allowing two independent registers to be accessed in one single instruction executed in one clock cycle.

3.4 VOLTAGE SENSOR

VOLTAGE SENSOR

VOLTAGE SENSOR:

In practice a voltage transformer can be used as a voltage sensor. The voltage transformer must be connected across the transmission lines. The primary of the transformer must be connected to the transmission lines and the secondary must be given to the microcontroller. A step down voltage transformer is used.

Illustration of a voltage senso

Fig: Diagram of voltage sensor

In the project we have made use of a potentiometer in place of a voltage sensor. A **potentiometer** (colloquially known as a "**pot**") is a three-terminal resistor with a sliding contact that forms an adjustable voltage divider. It is a measuring device which measures the voltage or current at the output by comparing it with the known input voltage. Varying the input voltage is a difficult process and requires advanced equipments. In the potentiometer the input is fixed at some maximum and minimum value. By turning the notch of the potentiometer the output voltage is varied, whenever the output voltage exceeds the bounds it indicates the occurrence of fault. After the fault is indicated the microcontroller gives trip signals to the relay which in turn operates the circuit breaker.

3.9 WIFI MODULE:

ESP 8266 Description:

The ESP8266 Wi-Fi Module is a self-contained SOC with integrated TCP/IP protocol stack that can give any microcontroller access to your Wi-Fi network. The ESP8266 is capable of either hosting an application or offloading all Wi-Fi networking functions from another application processor. Each ESP8266 module comes pre-programmed with an AT command set firmware, meaning, you can simply hook this up to your Arduino device and get about as much Wi-Fi-ability as a Wi-Fi Shield offers (and that's just out of the box)! The ESP8266 module is an extremely cost-effective board with a huge, and ever growing, community.

Note: This new version of the ESP8266 Wi-Fi Module has increased the flash disk size from 512k to 1MB.

3.10 Solar Panel:

Photovoltaic Cells: Converting Photons to Electrons

The solar cells that you see on calculators and satellites are also called photovoltaic (PV) cells, which as the name implies (photo meaning "light" and voltaic meaning "electricity"), convert sunlight directly into electricity. A module is a group of cells connected electrically and packaged into a frame (more commonly known as a solar panel), which can then be grouped into larger solar arrays.

Photovoltaic cells are made of special materials called semiconductors such as silicon, which is currently used most commonly. Basically, when light strikes the cell, a certain portion of it is absorbed within the semiconductor material. This means that the energy of the absorbed light is transferred to the semiconductor. The energy knocks electrons loose, allowing them to flow freely.

PV cells also all have one or more electric field that acts to force electrons freed by light absorption to flow in a certain direction. This flow of electrons is a current, and by placing metal contacts on the top and bottom of the PV cell, we can draw that current off for external use, say, to power a calculator. This current, together with the cell's voltage (which is a result of its built-in electric field or fields), defines the power (or wattage) that the solar cell can produce.

Solar Panel Setup:

Reverse charging

Subjecting a discharged cell to a current in the direction which tends to discharge it further, rather than charge it, is called reverse charging; this damages cells. Reverse charging can occur under a number of circumstances, the two most common being:

- When a battery or cell is connected to a charging circuit the wrong way around.
- When a battery made of several cells connected in series is deeply discharged.

Depth of discharge

Main article: Depth of discharge

Depth of discharge (DOD) is normally stated as a percentage of the nominal ampere-hour capacity; 0% DOD means no discharge. Seeing as the usable capacity of a battery system depends on the rate of discharge and the allowable voltage at the end of discharge, the depth of discharge must be qualified to show the way it is to be measured. Due to variations during manufacture and aging, the DOD for complete discharge can change over time

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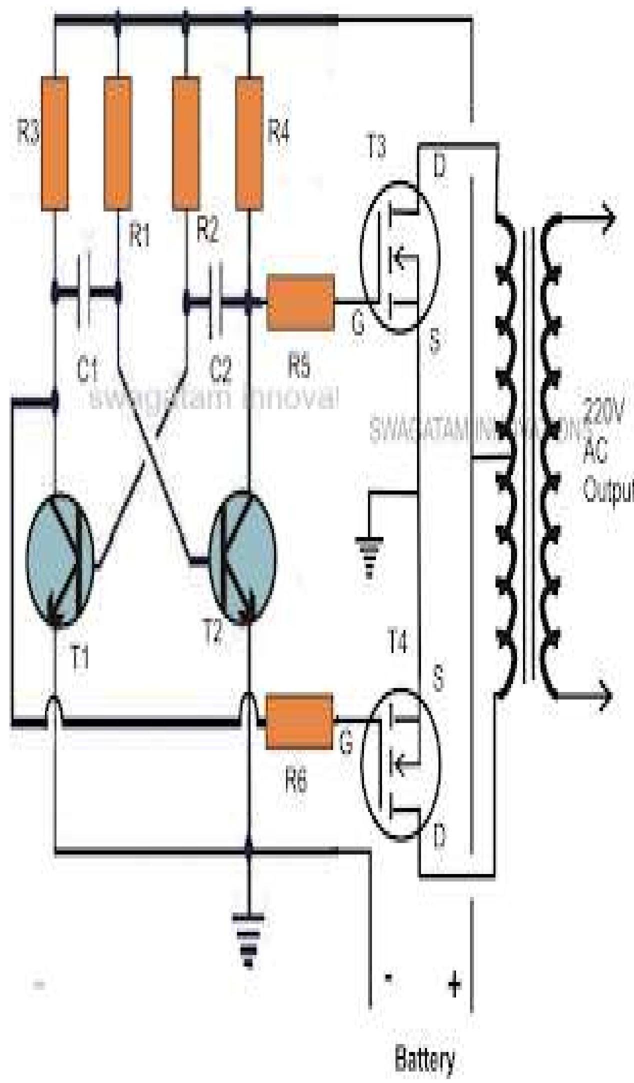
or number of charge cycles. Generally a rechargeable battery system will tolerate more charge/discharge cycles if the DOD is lower on each cycle.[5]

Table of rechargeable battery types

Type	Voltage[a]	Energy density[b]			Power[c]	Effi.[d]	E/$[e]	Disch.[f]	Cycles[g]	Life[h]
	(V)	(MJ/kg)	(Wh/kg)	(Wh/L)	(W/kg)	(%)	(Wh/$)	(%/month)	(#)	(years)
Lead–acid	2.1	0.11-0.14	30-40	60-75	180	70%-92%	5-8	3%-4%	500-800	5-8 (automotive battery), 20 (stationary)
Alkaline	1.5	0.31	85	250	50	--	7.7	<0.3	100-1000	<5
Nickel–iron	1.2	0.18	50		100	65%	5-7.3[6]	20%-40%		50+
Nickel–cadmium	1.2	0.14-0.22	40-60	50-150	150	70%-90%	1.25-2.5[6]	20%	1500	
Nickel–hydrogen	1.5	0.27	75	60	220	85%			20,000+	15+ (satellite application with frequent charge-discharge cycles)
Nickel–metal hydride	1.2	0.11-0.29	30-80	140-300	250-1000	66%	2.75	30%	500-1000	
Nickel–zinc	1.7	0.22	60	170	900		2-3.3		100-500	
Lithium-air (organic)[7]	2.7	7.2	2000	2000	400				~100	
Lithium-ion	3.6	0.58	150-250	250-360	1800	99%+[citation needed]	2.8-5[8]	5%-10%	1200-10000	2-6

Less common types:

Lithium sulfur battery:



SOFTWARE DESCRIPTION

This project is implemented using following software's:

- Arduino IDE compiler - for compilation part

4.1 Arduino IDE Compiler:

This instructable adds to any of the Arduino on a Breadboard instructables.

1. We need a microcontroller with a pre-loaded Bootloader, or must load your own
2. Not all ATmega328's are equal

(A bootloader, very simply, is a programme that sits on the chip and manages the upload of your sketches onto the chip)

4.2 Procedural steps for compilation, simulation and dumping:

Learn the basics of uploading a sketch in Arduino IDE:

1. Open Arduino IDE
2. Connect the board to your computer
3. Board package installation
4. Select board and port
5. Upload a sketch

What you'll need:

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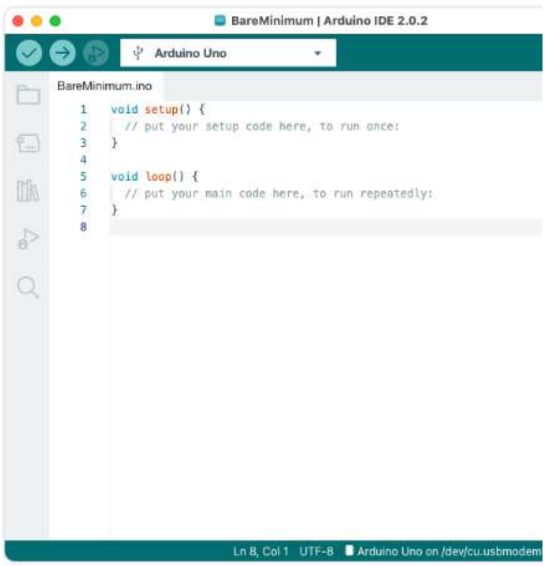
- A computer running Windows, macOS or Linux
- Arduino IDE
- An Arduino board
- A compatible data USB cable

1. Open Arduino IDE

If you haven't done so already, download Arduino IDE from the software page. You can find installation instructions here.

2. Connect the board to your computer



2. Connect the board to your computer

Next, connect to board to your computer with a USB cable. This will both power the board and allow the IDE to send instructions to the board. You'll need a data USB cable (a charge-only cable will not work), with connectors that fit both the board and your computer.

3. Install board package

To compile and upload sketches for your board Arduino IDE needs a collection of files for that board called a **board package**.

When Arduino IDE detects a board with a missing board package, it may ask you to install the missing files:

- In IDE 2, click **Yes**.

If no prompt appears, proceed with the next step. If you at any point need to manually find and add a missing board package, see Add boards to Arduino IDE.

4. Select board and port

Port and board selection can be managed in two ways:

- Using the board selector (requires IDE 2)
- Using the Tools menu

Using the board selector

CHAPTER 5: PROJECT DESCRIPTION

In this chapter, schematic diagram and interfacing Copper coils with each module is considered.

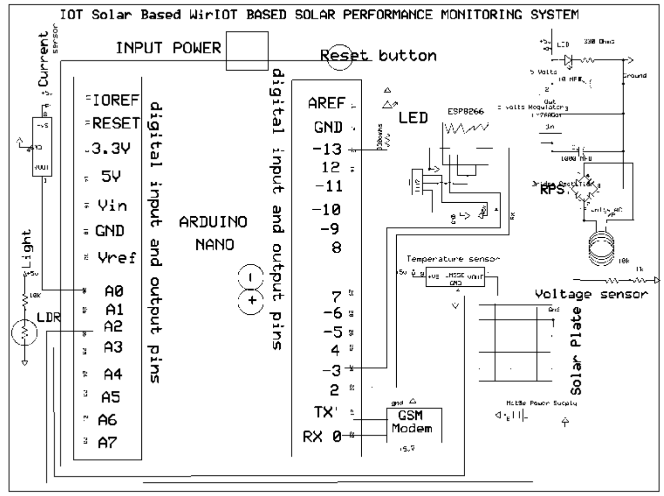


Fig 5.1: schematic diagram of IOT BASED SOLAR PERFORMANCE MONITORING SYSTEM

The above schematic diagram of **IOT BASED SOLAR PERFORMANCE MONITORING SYSTEM** explains the interfacing section of each component.

CHAPTER 6: ADVANTAGES AND DISADVANTAGES

Advantages:

- Monitoring of solar parameters values into the thingspeak cloud.
- Wireless monitoring using IOT technology.
- Solar energy is obtained stored into the rechargeable battery.
- Battery power is used to switch ON the LEDs.
- SMS alerts under abnormal conditions of sunlight using GSM modem
- Sunlight intensity detection using light sensor and voltage sensor
- Reduces dependency on plug-in charging stations.
- Uses renewable solar energy for sustainability.
- GSM based monitoring ensures efficient power management.
- Minimizes wear and tear of charging ports.

Disadvantages:

1. Limited distance.
2. Interfacing section of the Arduino NANO microcontroller is sensitive.

Applications:

Residential Solar Systems

- Monitor individual home solar panel performance.
- Track daily energy production and consumption.
- Detect faults or inefficiencies in real-time.
- Remote monitoring via smartphone or web dashboards.

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2. Commercial & Industrial Solar Installations

- Manage and monitor large-scale solar farms or rooftop systems.
- Improve ROI by maximizing panel efficiency and reducing downtime.
- Predictive maintenance alerts using sensor data.
- Centralized data management for multiple sites.

3. Educational Institutions & Campuses

- Real-time energy dashboards for awareness and learning.
- Analyze solar data trends as part of sustainability programs.
- Encourage energy-efficient practices among students/staff.

4. Smart Cities

- Integrate solar performance data with city energy management systems.
- Support green infrastructure by ensuring optimal solar usage.
- Monitor environmental impact (e.g., CO_2 savings).

5. Remote & Rural Areas

- Monitor off-grid solar power systems.
- Provide early warnings of system failures to avoid power loss.
- Enable technicians to troubleshoot remotely.

CHAPTER 7: RESULTS

7.1 Result:

The project **IOT BASED SOLAR PERFORMANCE MONITORING SYSTEM** was designed a solar energy measurement system using IOT for measuring solar cell parameters such as voltage, current and temperature through multiple sensors and upload this parameter values into the thingspeak webpage along with date and time..

7.2 Conclusion:

Integrating features of all the hardware components used have been developed in it. Presence of every module has been reasoned out and placed carefully, thus contributing to the best working of the unit. Secondly, using highly advanced IC's with the help of growing technology, the project has been successfully implemented. Thus the project has been successfully designed and tested.

7.3 Future Scope:

- **Expansion to highways** for long-distance EV travel.
- **Integration with AI** for automated charging optimization.
- **Higher efficiency coils** for improved power transfer.
- **Fast charging capability** for reduced charging time.
- **Implementation in public transport** for buses and taxis.
- **Smart grid integration** for better energy management.
- **Battery health monitoring** using advanced IoT analytics.
- **Scaling for industrial and military EV applications.**

REFERENCES

The sites which were used while doing this project:
1. www.wikipedia.com
2. www.allaboutcircuits.com
3. www.microchip.com
4. www.howstuffworks.com

References books:
1. Mohan, N., Undeland, T. M., & Robbins, W. P. (2018). *Power Electronics: Converters, Applications, and Design* (3rd ed.). Wiley.
2. Budhia, M., Covic, G. A., & Boys, J. T. (2013). *Design and Optimization of Magnetic Structures for Lumped Inductive Power Transfer Systems*. Springer.
3. Kurs, A., Karalis, A., Moffatt, R., Joannopoulos, J. D., Fisher, P., & Soljačić, M. (2007). *Wireless Power Transfer via Strongly Coupled Magnetic Resonances*. Science.
4. Sukhatme, S. P., & Nayak, J. K. (2017). *Solar Energy: Principles of Thermal Collection and Storage* (4th ed.). McGraw Hill.
5. Keysan, O., & McDonald, A. (2020). *Wireless Power Transfer for Electric Vehicles and Industrial Applications*. IET.
6. Valenzuela, J., & Kumar, P. (2019). *IoT and Smart Cities: Advances in Green Energy and Sustainable Technologies*. Springer.
7. Tesla, N. (2007). *The Inventions, Researches and Writings of Nikola Tesla*. Cosimo Classics. (Original work published in 1894). segmentation,'' in Proc. IEEE Conf. Comput. Vis. Pattern Recognit., Jun. 2014.

[6] R. Girshick, ''Fast R-CNN,'' in Proc. IEEE Int. Conf. Comput. Vis. (ICCV), Dec. 2015, pp. 1440–1448.

[7] S. Ren, K. He, R. Girshick, and J. Sun, ''Faster R-CNN: Towards real-time object detection with region proposal networks,'' in Proc. Adv. Neural Inf. Process. Syst., vol. 28, 2015.

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