IJCRT.ORG ISSN : 2320-2882
INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)
An International Open Access, Peer-reviewed, Refereed Journal

AN IOT BASED HEDGE SYSTEM FOR SOLAR POWER GENERATION

1K.Sindhu priya, 2L.Raju, 3M.Nikitha, 4R.Akhil, 5Shiva ramakrishna

1student, 2student, 3Student, 4Student, 5Professor

1JB Institute of Engineering and Technology,

2JB Institute of Engineering and Technology,

3JB Institute of Engineering and Technology,

4JB Institute of Engineering and Technology,

5JB Institute of Engineering and Technology

ABSTRACT

Environmental protection is an important issue in recent decades, and renewable energy is an ideal solution for eco-friendly power generation. Solar-power generation is a popular renewable energy with low cost and small environmental footprint, which leads to exponential growth and high industrial investment. A mature solar business model has been established, but some uncertainties hinder the development, especially when focusing on the lack of solar-radiation. To address these issues, in this article we propose a hedging system to hedge the low-radiation risk for solar-investors through the designed IoT-based data, edge-based models for predicting solar-radiation as well as hedging options. Our experimental results show that the edge-based predictive models can obtain an R-squared value of 0.841 and a correlation coefficient of 0.917. For binary options designed in the hedging system, the broker can obtain stable payoffs with the highest Sharpe ratio of 3.354, and the investors can obtain large payoffs during low-radiation. Our simulation results show the effectiveness of the proposed hedging system for investors (buyer-side), simultaneously, present the motivation of the broker (seller-side) to join the designed hedging system utilized in solar-power generation.

CHAPTER -1

INTRODUCTION

Environmental protection is an important and thought-provoking issue for researchers and industry alike in recent decades. Due to global warming and climate change, the means to generate electricity has become a major topic of research and development in recent years. Currently most electricity comes from thermal power which produces large amounts of carbon dioxide (CO2, greenhouse gases) and other harmful gases. These pollutants are the prime culprits for global warming. Furthermore, pollutants from thermal energy have residual effects on the body including harming the lungs. Renewable green energy is an ideal solution for environmentally friendly (eco-friendly) power generation, which can include wind-power, hydropower, and solar-power. Wind, as well as hydropower, utilizes kinetic energy and water respectively to drive power generators. However, they are location-dependent, require high cost, and need ample space to operate. Conversely, solar-power generation has low cost and small footprint characteristics, and only a few square feet of power generation panels are needed to collect solar energy and generate a usable amount of electricity. These advantages make solar-power generation a viable option for green energy which has seen an increase in investment interest for companies and investors. Simultaneously, many governments encourage investment and the construction of solar power generation, as well as provide substantial subsidies and guarantees to maintain a stable purchase price for green energy. Lei et al. showed that 40% of global electricity growth comes from renewable energy sources, mainly from solar-power (40:7%), and wind- power (58:2%). This shows that solar-power generation is an emerging topic. With the unremitting efforts of both government and entrepreneurs, numerous people may invest in solar-power generation, and a mature solar business model has been established, as shown in Fig. 1. Companies that run solar- power plants are known to construct power generation infrastructure, which divides the power plant into shares to investors. Then, the generated electricity is sold to the government at a guaranteed stable price. For solar-power investors, they provide funds (investments) to build power plants and obtain shares. A share represents several units of power panels, and the electricity (profit) generated by these panels are distributed to investors with shares. With a tremendous amount of information in various regions and interaction between parties, techniques for the Internet of Things (IoT), data mining, and edge computing are suitable technologies to utilize in these circumstances. One of the main concepts behind IoT is to exchange virtual information and interact with physical objects and smart devices through sensing, control, mining, and the concern of security. Data mining and machine learning are usually adopted in IoT systems to analyze information. Data mining aims to discover structures, patterns, as well as information within datasets through data- and demand-driven mode. In contrast, machine learning aims to build algorithms for classification and regression through sampled data and pas experiences to predict and assist decision-making. Since IoT-based data is usually located in various regions, edge computing can be implemented to distribute computational efforts to the edges of IoT systems, while attempting to address known concerns at the edge of networks success response time, data privacy, throughput, and energy efficiency. Through ubiquitous embedded and edge systems and data mining techniques, IoT systems can make atto the ease with which we live today by establishing smart cities, smart healthcare, smart agriculture and many other technologically advanced infrastructures. Although the above business model can give some level of guarantee for earned profits from the government, there are still some uncertainties including natural disasters and lack of solar-radiation. Damages caused by natural disasters can be compensated through insurance (property insurance has been well-developed. The only uncertainty and uncontrollable factor in the solar business model is solar-radiation, which completely dominates the electricity generated by solar panels. Less solar-radiation will produce less electricity and profits, which may not be able to cover the depreciation and result in investment losses. To address these issues, we propose a novel hedging system utilized in the solar-power business, which adopts the edge-based predictive models with IoT data f solar radiation, and the hedging binary option. IoT-based datcontains information from solar panels and weather sensors. The designed two edge-based predictive models are constructed with four well-developed machine learning technique to achieve distributed computing with low hesitation and less computation. The binary options act as an intermediary for the hedging service In the developed hedging system, binary options act as an intermediary to hedge against low solar-radiation risk. Nesters can purchase options in our hedging system (for example, bet that the radiation is less than 20 J=m2, joule per square meter) to hedge low-radiation risk. If solar-radiation is less than 20 J=m2, the investors may have losses in a solar power investment but can earn a payoff from the options. If tradition is greater than 20 J=m2, investors only need to spend a small number of finances for hedging and obtain more profits from their solar-power generation. The broker (seller-side of the option) must accurately determine the odds of each option, which is determined by predictive solar-radiation and the probability of binary outcomes. Therefore, a precise prediction is required in the proposed system to accurately predict solar radiation, which is called the precise predictive model (PPM) To further process real-time information and solve low-latency issues on our edge-based model, a light predictive model (LPM) is developed that to speed up the runtime performance with fewer features on the edge-computing model. Our in-depth experimental results show that the prediction algorithm of random forest regression has the best performance, which obtains an R-squared of 0:841 (0:828) and correlation coefficient of 0:917 (0:910) within PPM (LPM). Robustness results on different datasets and comparing with state-of-art works also present the outstanding performance of the predictive models (PPM and LPM). Besides, the experimental results of hedging options show stable payoffs (with the highest Sharpe ratio of 3:354) for the broker and effective hedging services for investors. These results demonstrate the effectiveness of the proposed hedging system. Thus, the major contributions of this paper are then summarized as:

1) Developed an IoT-based data-driven system utilized in solar-power generation and prediction.

2) Adopted four machine learning algorithms into the two edge-computing models (PPM and LPM) to respectively predict solar-radiation accurately, and with low-latency and less computation.

3) Showed that the designed PPM and LPM obtained better performance in terms of mean square error and R-squared compare to the existing models.

4) Proposed hedging system provides hedging services for solar-power investors and generates fix-income for the broker in the simulation.

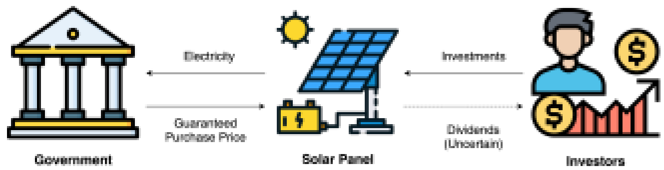


Fig: 1 The existing business model of solar-power generation

In this section, the background of solar-power generation and prediction are first introduced. Then, we survey the literature and machine learning algorithms used. Furthermore, the binary option is stated and discussed.

A. Solar-Power Generation and Prediction

Solar-power generation converts solar-radiation into electricity through the photovoltaic effect. A single photovoltaic cell generates only a few watts of energy. By connecting an array of photovoltaic cells, the photovoltaic system (solar panel) can generate about 150 to 180 Watts per square meter. The commonly photovoltaic system is the flat solar panel deployed in our daily lives (rooftop or bus station). Large solar-power plants may be implemented by solar trackers and concentrated solar power, which can rotate panels or concentrate sunlight to improve efficiency.

Illustrated that the cumulative capacity of solar power could be doubled every two years. Swanson's law stated that the price per watt of solar photovoltaic modules drops by half for every 10 times the capacity increases [31]. These pieces of evidence show that solar-power generation is the fast-growing renewable energy and is cost-competitive to the other thermal powers (e.g., coal, crude oil, and natural gas).

Adopted a least-square support vector machine model (SVM) for predicting solar-power, which utilized features of historical atmospheric transmissivity and meteorological variables (e.g., sky cover, relative humidity, and wind speed). Compared with the models based on auto-regressive and neural networks, the SVM-based model achieved better results. Jang et al. designed a model to predict the solar-power by atmospheric motion vectors from satellite images, which can be used to determine the motion vectors of clouds and affected the solar-radiation. They also adopted SVM as the prediction model and defeated the models with non-linear autoregressive and artificial neural networks.

Long et al. developed daily solar-power prediction mod else using data-driven approaches, and the artificial neural network-based model had the highest accuracy when pre dieting present and multivariate linear regression-based and k-nearest neighbor-based models outperformed other models when predicting multi-steps.

TABLE I: Description and characteristics of the observations

Observation	Abbreviation	Description	Unit
Observation month	*Month*	the month of observation	Dummy, 1,...,12
Observation time	*Hour*	the time (which hour) of observation	Dummy, 1,...,24
Solar-radiation	*SRad*	the radiant energy of sunshine	MJ/m^2
Sun duration	*SDur*	the length of sunshine	hour
Temperature	*Temp*	average temperature during the observation	°C
Relative humidity	*RH*	relative humidity during the observation	%
Wind speed	*WS*	average speed of wind during the observation	m/s
Cloud amount	*CA*	the amount (region) of cloud cover the sky	0,...,10

IN "ALTERNATIVES TO THE GLOBAL WARMING POTENTIAL FOR COMPARING CLIMATE IMPACTS OF EMISSIONS OF GREENHOUSE GASES,".

The Global Warming Potential (GWP) is used within the Kyoto Protocol to the United Nations Framework Convention on Climate Change as a metric for weighting the climatic impact of emissions of different greenhouse gases. The GWP has been subjected to many criticisms because of its formulation, but nevertheless it has retained some favors because of the simplicity of its design and application, and its transparency compared to proposed alternatives. Here, two new metrics are proposed, which are based on a simple analytical climate model. The first metric is called the Global Temperature Change Potential and represents the temperature change at a given time due to a pulse emission of a gas (GTPP); the second is similar but represents the effect of a sustained emission change (hence GTPS). Both GTPP and GTPS are presented as relative to the temperature change due to a similar emission change of a reference gas, here taken to be carbon dioxide. Both metrics are compared against an upwelling-diffusion energy balance model that resolves land and ocean and the hemispheres. The GTPP does not perform well, compared to the energy balance model, except for long-lived gases. By contrast, the GTPS is shown to perform well relative to the energy balance model, for gases with a wide variety of lifetimes. It is also shown that for time horizons in excess of about 100 years, the GTPS and GWP produce very similar results, indicating an alternative interpretation for the GWP. The GTPS retains the advantage of the GWP in terms of transparency, and the relatively small number of input parameters required for calculation. However, it has an enhanced relevance, as it is further down the cause–effect chain of the impacts of greenhouse gases emissions and has an unambiguous interpretation. It appears to be robust to key uncertainties and simplifications in its derivation and may be an attractive alternative to the GWP. The Intergovernmental Panel on Climate Change (IPCC) has, since its first scientific assessment in 1990, used the Global Warming Potential (GWP) as a method for comparing the potential climate impact of emissions of different greenhouse gases (IPCC, 1990; IPCC, 2001). The GWP is the time-integrated radioactive forcing due to a pulse emission of a given gas, over some given time period (or horizon) relative to a pulse emission of carbon dioxide (see Appendix A). The GWP has been adopted as an instrument in the Kyoto Protocol of the United Nations Framework Convention on Climate Change (UNFCCC). Emission targets are set in terms of equivalent emissions of carbon dioxide, where the carbon dioxide equivalence of emissions of other greenhouse gases (methane, nitrous oxide, the hydro fluorocarbons, the per fluorocarbons and sulphur hexafluoride) is determined using the GWP with a 100-year time horizon (henceforth GWP (100)). Since its introduction, the GWP has been subject to scrutiny and criticism (e.g. Wrigley, 1998; Fuglestvedt et al., 2000; O'Neill, 2000; Smith and Wigley, 2000a, b; Manne and Rachel, 2001). One criticism relates to the fact that, despite its name, the global warming potential does not purport to represent the impact of gas emissions on temperature. The GWP uses the time-integrated radioactive forcing and this does not give a unique indication of the effect of pulse emissions on temperature, because of large differences in the time constants of the various greenhouse gases. Although a strong greenhouse gas with a short lifetime could have the same GWP as a weaker greenhouse gas with a longer lifetime, identical (in mass terms) pulse emissions of the two gases could cause a different temperature change at a given time. Economists have also criticized the GWP concept for not being based on an analysis of damages caused by the emissions (e.g. Schmalensee, 1993; Kandlikar, 1995; Hammitt et al., 1996). Although within this paper we restrict the discussion to possible alternative physically based metrics, the new metrics could feed into the development of damage-based indices. However, despite these criticisms and the suggestion of many alternatives, the GWP seems to have retained its attractiveness and widespread use, mainly because of the simplicity of its definition, the small number of required input parameters and the relative ease of calculation, compared to some of the alternatives. Additionally, the "transparency" and ease of application appear to be important aspects of acceptability amongst policymakers. Preparations for the Fourth Assessment Report of the IPCC (due out in 2007) will begin soon as might negotiations over the second commitment period of the Kyoto Protocol (i.e. the period beyond 2012). This raises the question as to whether a metric can be designed that addresses some of the problems with the GWP, while at the same time maintaining its transparency and ease of use. This paper explores the use of two related metrics as a contribution to the growing debate (e.g. O'Neill, 2000; Smith and Wiggly, 2000a, b; Gödel, 2003; O'Neill, 2003; Smith, 2003) over whether, and how, the GWP could be superseded for use within international climate agreements and in other applications of climate change metrics.

IN "RESIDENCE IN PROXIMITY OF A COAL-OIL-FIRED THERMAL POWER PLANT AND RISK OF LUNG AND BLADDER CANCER IN NORTH-EASTERN ITALY. A POPULATION-BASED STUDY: 1995–2009"

This study investigated the risk of lung and bladder cancers in people residing in proximity of a coal-oil-fired thermal power plant in an area of north-eastern Italy, covered by a population-based cancer registry. Incidence rate ratios (IRR) by sex, age, and histology were computed according to tertiles of residential exposure to benzene, nitrogen dioxide (NO2), particular matter, and sulfur dioxide (SO2) among 1076 incident cases of lung and 650 cases of bladder cancers. In men of all ages and in women under 75 years of age, no significant associations were observed. Conversely, in women aged ≥75 years significantly increased risks of lung and bladder cancers were related to high exposure to benzene (IRR for highest vs.

lowest tertile: 2.00 for lung cancer and 1.94 for bladder cancer) and NO2 (IRR: 1.72 for lung cancer; and 1.94 for bladder cancer). In these women, a 1.71-fold higher risk of lung cancer was also related to a high exposure to SO2. Acknowledging the limitations of our study, in particular that we did not have information regarding cigarette smoking habits, the findings of this study indicate that air pollution exposure may have had a role with regard to the risk of lung and bladder cancers limited to women aged ≥75 years. Such increased risk warrants further analytical investigations. Agents classified as Group 1 lung carcinogens by the International Agency for Research on Cancer (IARC) include personal habits and occupational and environmental exposures. Although in many populations cigarette smoking is the main cause of lung cancer, other recognized risk factors may have a relevant impact under local circumstances. Such factors include exposure to identify physical and chemical agents and their mixtures and occupational and environmental activities. The latter may entail exposures occurred in or in proximity of some industrial facilities, air pollution due to road traffic and home heating. Sufficient or convincing evidence about causes of bladder cancer is associated with cigarette smoking, radiation, exposure to aromatic amines, arsenic and inorganic arsenic compounds, Schist soma haematobium, and work in occupations such as aluminum production, painting, and rubber production. However, a positive association between bladder cancer and outdoor air pollution has recently emerged .With specific reference to the carcinogenic effect of combustion of coal, burning coal inside the home for the purpose of heating or cooking produces particulate and gas emissions that are lung carcinogens (IARC Group I). Additional substances derived from coal, also recognized as carcinogens, are: coal-tar pitch, soot, diesel engine exhaust, and related occupations (i.e., coal gasification, coke production, iron and steel founding). However, the extension and impact of the carcinogenic effects of emissions from coal and coal-oil-fired plants is a matter of debate, especially when such effects are compared with other local sources of air pollution and with alternative modes of energy production

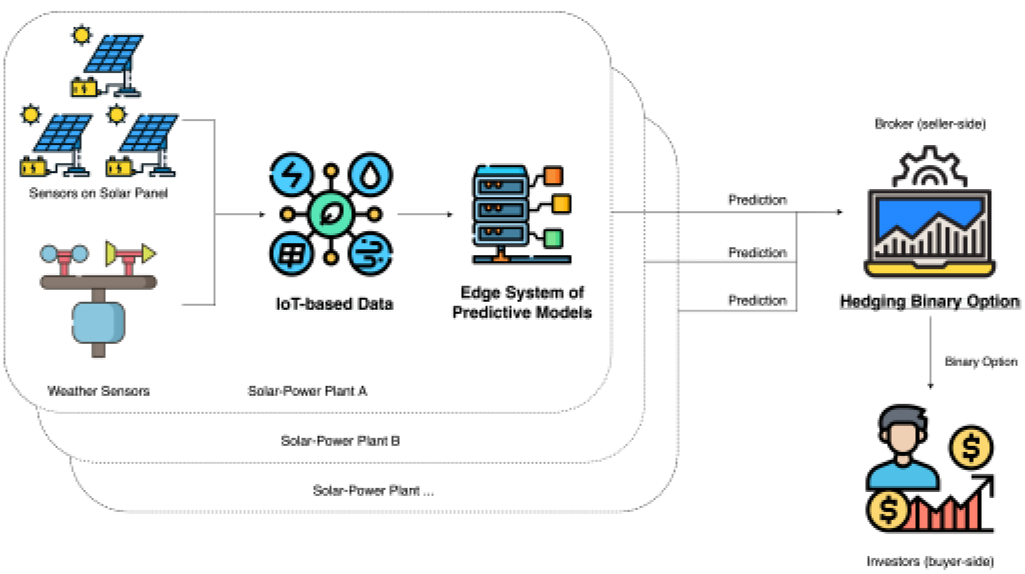
IN "RENEWABLE ENERGY RESOURCES: CURRENT STATUS, FUTURE PROSPECTS AND THEIR ENABLING TECHNOLOGY"

Electric energy security is essential, yet the high cost and limited sources of fossil fuels, in addition to the need to reduce greenhouse gasses emission, have made renewable resources attractive in world energy based economies. The potential for renewable energy resources is enormous because they can, in principle, exponentially exceed the world's energy demand; therefore, these types of resources will have a significant share in the future global energy portfolio, much of which is now concentrating on advancing their pool of renewable energy resources. Accordingly, this paper presents how renewable energy resources are currently being used, scientific developments to improve their use, their future prospects, and their deployment. Additionally, the paper represents the impact of power electronics and smart grid technologies that can enable the proportionate share of renewable energy resources Conventional energy sources based on oil, coal, and natural gas have proven to be highly effective drivers of economic progress. However, with the rapid depletion of conventional energy sources and increasing energy demand, worldwide primary energy consumption has grown by 1.8% in 2012 [1]. Due to certain environmental issues, many related organizations have encouraged intensive research for more efficient and green power plants utilizing advanced technology. Since environmental protection concerns are increasing, both clean fuel technologies and new energies are being intensively pursued and investigated. In fact, fossil fuel and renewable energy prices, social and environmental costs are moving in opposite directions and the economic and policy mechanisms needed to support the widespread dissemination of sustainable markets for renewable energy systems are rapidly evolving. It is clear that future growth in the energy sector is primarily in the new regime of renewable. Therefore, shifting to renewable energy can help us meet the dual goals of reducing greenhouse gas emissions, thereby limiting future extreme weather and climate impacts, and ensuring reliable, timely, and cost-efficient delivery of energy. Investing in renewable energy can have significant dividends for our energy security. Renewable energies are energy sources that are continually replenished by nature and derived directly from the sun (such as thermal, photo-chemical, and photo-electric), indirectly from the sun (such as wind, hydropower, and photosynthetic energy stored in biomass), or from other natural movements and mechanisms of the environment (such as geothermal and tidal energy). Renewable energy does not include energy resources derived from fossil fuels, waste products from fossil sources, or waste products from inorganic sources. Fig. 1 shows an overview of renewable energy sources . Renewable energy technologies turn these natural energy sources into usable forms of energy—electricity, heat and fuels. Fig. 2 illustrates the ability of renewable energy sources to provide over 3000 times the current global energy needs. Renewable energy markets – electricity, heating and transportation – have been growing sharply over the last five years. The deployment of established technologies, such as hydro, as well as newer technologies such as wind and solar photovoltaic, has risen quickly, which has increased confidence in the technologies, reduced costs and opened up new opportunities. Global electricity generation from renewable energy sources is expected to grow 2.7 times between 2010 and 2035, as indicated by Table 1. Consumption of bio fuels is projected to more than triple over the same period to reach 4.5 million barrels of oil equivalent per day (mboe/d), up from 1.3 mboe/d in 2010. Almost all bio fuels are used in road transport, but the consumption of aviation bio fuels will make an inroad towards 2035. The use of modern renewable to produce heat will almost double, from 337 Mtoe in 2010 to 604 Mtoe in 2035. The share of renewable in electricity generation is higher than in heat production or Transportation road, as shown in Fig. 3. The goal of the paper is to present an overview of the different types of renewable energy resources, their current and future states, their share in different end use applications, and their benefits, growth, investment and deployment. Furthermore, power electronics and smart grid will be discussed as enabling technologies for different renewable energy resources.

Table 1
World renewable energy use by type [7].

	2010	2020	2035
Electricity generation (TW h)	**4206**	**6999**	**11,342**
Bioenergy	331	696	1,487
Hydro	3431	4513	5,677
Wind	342	1272	2,681
Geothermal	68	131	315
Solar PV	32	332	846
Concentrating solar power	2	50	278
Marine	1	5	57
Share of total generation	**20%**	**25%**	**31%**
Heat demand (Mtoe)	**337**	**447**	**604**
Industry	207	263	324
Buildings and agriculture	131	184	280
Share of total production	**10%**	**12%**	**14%**
Biofuels (mboe/d)	**1.3**	**2.4**	**4.5**
Road transport	1.3	2.4	4.4
Aviation	–	–	0.1
Share of total transport	**2%**	**4%**	**6%**

IMPLEMENTATION



CHAPTER 2

INTRODUCTION TO EMBEDDED SYSTEMS

Many embedded systems have substantially different design constraints than desktop computing applications. No single characterization applies to the diverse spectrum of embedded systems. However, some combination of cost pressure, long life-cycle, real-time requirements, reliability requirements, and design culture dysfunction can make it difficult to be successful applying traditional computer design methodologies and tools to embedded applications. Embedded systems in many cases must be optimized for life-cycle and business-driven factors rather than for maximum computing throughput. There is currently little *tool* support for expanding embedded computer design to the scope of holistic embedded system design. However, knowing the strengths and weaknesses of current approaches can set expectations appropriately, identify risk areas to tool adopters, and suggest ways in which tool builders can meet industrial needs. If we look around us, today we see numerous appliances which we use daily, be it our refrigerator, the microwave oven, cars, PDAs etc. Most appliances today are powered by something beneath the sheath that makes them do what they do. These are tiny microprocessors, which respond to various keystrokes or inputs. These tiny microprocessors, working on basic assembly languages, are the heart of the appliances. We call them embedded systems. Of all the semiconductor industries, the embedded systems market place is the most conservative, and engineering decisions here usually lean towards established, low risk solutions. Welcome to the world of embedded systems, of computers that will not look like computers and won't function like anything we are familiar with.

2.1 CLASSIFICATION

Embedded systems are divided into autonomous, real-time, networked & mobile categories.

Autonomous systems

They function in standalone mode. Many embedded systems used for process control in manufacturing units& automobiles fall under this category.

Real-time embedded systems

These are required to carry out specific tasks in a specified amount of time. These systems are extensively used to carry out time critical tasks in process control.

Networked embedded systems

They monitor plant parameters such as temperature, pressure and humidity and send the data over the network to a centralized system for on line monitoring.

Mobile gadgets

Mobile gadgets need to store databases locally in their memory. These gadgets imbibe powerful computing & communication capabilities to perform realtime as well as nonrealtime tasks and handle multimedia applications. The embedded system is a combination of computer hardware, software, firmware and perhaps additional mechanical parts, designed to perform a specific function. A good example is an automatic washing machine or a microwave oven. Such a system is in direct contrast to a personal computer, which is not designed to do only a specific task. But an embedded system is designed to do a specific task with in a given timeframe, repeatedly, endlessly, with or without human interaction.

Hardware

Good software design in embedded systems stems from a good understanding of the hardware behind it. All embedded systems need a microprocessor, and the kinds of microprocessors used in them are quite varied. A list of some of the common microprocessors families are: ARM family, The Zilog Z8 family, Intel 8051/X86 family, Motorola 68K family and the power PC family. For processing of information and execution of programs, embedded system incorporates microprocessor or micro- controller. In an embedded system the microprocessor is a part of final product and is not available for reprogramming to the end user. An embedded system also needs memory for two purposes, to store its program and to store its data. Unlike normal desktops in which data and programs are stored at the same place, embedded systems store data and programs in different memories. This is simply because the embedded system does not have a hard drive and the program must be stored in memory even when the power is turned off. This type of memory is called ROM. Embedded applications commonly employ a special type of ROM that can be programmed or reprogrammed with the help of special devices.

2.2 OTHER COMMON PARTS FOUND ON MANY EMBEDDED SYSTEMS

- UART& RS232
- PLD
- ASIC's& FPGA's
- Watch dog timer etc.

2.3 DESIGN PROCESS

Embedded system design is a quantitative job. The pillars of the system design methodology are the separation between function and architecture, is an essential step from conception to implementation. In recent past, the search and industrial community has paid significant attention to the topic of hardware-software (HW/SW) codesign and has tackled the problem of coordinating the design of the parts to be implemented as software and the parts to be implemented as hardware avoiding the HW/SW integration problem marred the electronics system industry so long. In any large scale embedded systems design methodology, concurrency must be considered as a first class citizen at all levels of abstraction and in both hardware and software. Formal models & transformations in system design are used so that verification and synthesis can be applied to advantage in the design methodology. Simulation tools are used for exploring the design space for validating the functional and timing behaviors of embedded systems. Hardware can be simulated at different levels such as electrical circuits, logic gates, RTL e.t.c. using VHDL description. In some environments software development tools can be coupled with hardware simulators, while in others the software is executed on the simulated hardware. The later approach is feasible only for small parts of embedded systems. Design of an embedded system using Intel's 80C188EB chip is shown in the figure. In order to reduce complexity, the design process is divided in four major steps: specification, system synthesis, implementation synthesis and performance evaluation of the prototype.

2.3.1 SPECIFICATION

During this part of the design process, the informal requirements of the analysis are transformed to formal specification using SDL.

2.3.2 SYSTEM-SYNTHESIS

For performing an automatic HW/SW partitioning, the system synthesis step translates the SDL specification to an internal system model switch contains problem graph& architecture graph. After system synthesis, the resulting system model is translated back to SDL.

2.3.3 IMPLEMENTATION-SYNTHESIS

SDL specification is then translated into conventional implementation languages such as VHDL for hardware modules and C for software parts of the system.

2.3.4 PROTOTYPING

On a prototyping platform, the implementation of the system under development is executed with the software parts running on multiprocessor unit and the hardware part running on a FPGA board known as phoenix, prototype hardware for Embedded Network Interconnect Accelerators.

2.3.5 APPLICATIONS

Embedded systems are finding their way into robotic toys and electronic pets, intelligent cars and remote controllable home appliances. All the major toy makers across the world have been coming out with advanced interactive toys that can become our friends for life. 'Furby' and 'AIBO' are good examples at this kind. Furbish have a distinct life cycle just like human beings, starting from being a baby and growing to an adult one. In AIBO first two letters stands for Artificial Intelligence. Next two letters represents robot. The AIBO is robotic dog. Embedded systems in cars also known as Telemetric Systems are used to provide navigational security communication & entertainment services using GPS, satellite. Home appliances are going the embedded way. LG electronics digital DIOS refrigerator can be used for surfing the net, checking e-mail, making video phone calls and watching TV.IBM is developing an air conditioner that we can control over the net. Embedded systems cover such a broad range of products that generalization is difficult. Here are some broad categories.

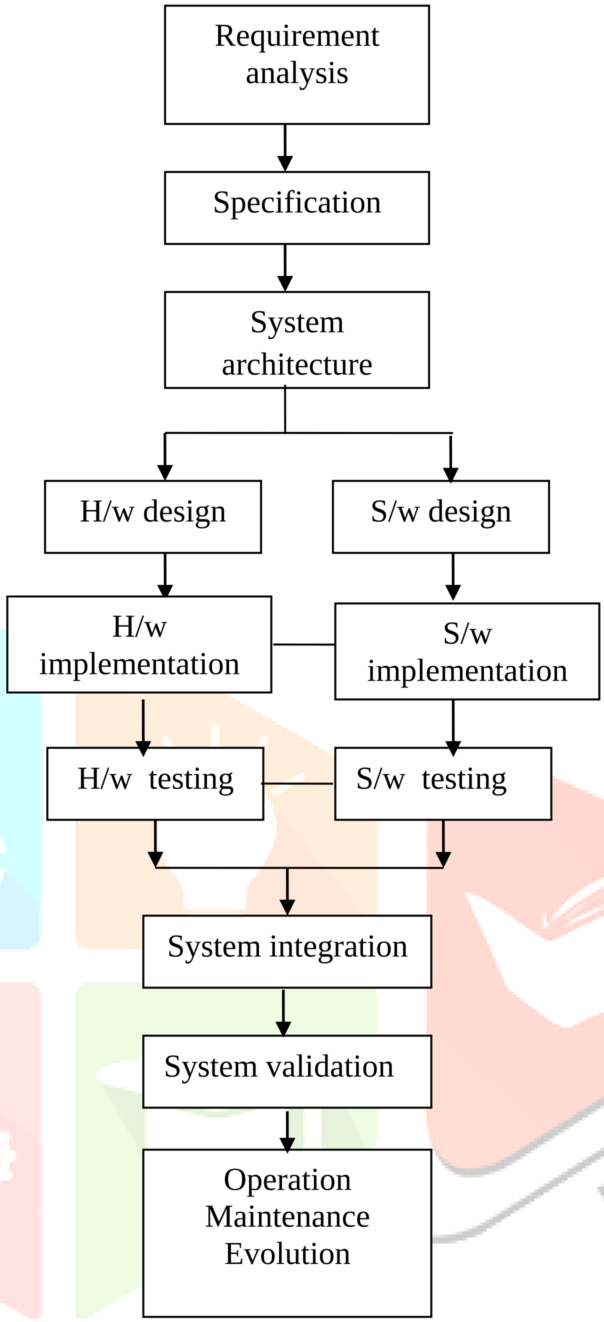


Fig 2.1: Embedded Development Life Cycle

- **Aerospace and defence electronics**: Fire control, radar, robotics/sensors, sonar.
- **Automotive**: Autobody electronics, auto power train, auto safety, car information systems.
- **Broadcast & entertainment**: Analog and digital sound products, camaras, DVDs, Set top boxes, virtual reality systems, graphic products.
- **Consumer/internet appliances**: Business handheld computers, business network computers/terminals, electronic books, internet smart handheld devices, PDAs.

- **Data communications:** Analog modems, ATM switches, cable modems, XDSL modems, Ethernet switches, concentrators.
- **Digital imaging**: Copiers, digital still cameras, Fax machines, printers, scanners.
- **Industrial measurement and control:** Hydro electric utility research & management traffic management systems, train marine vessel management systems.
- **Medical electronics:** Diagnostic devices, real time medical imaging systems, surgical devices, critical care systems.
- **Server I/O:** Embedded servers, enterprise PC servers, PCI LAN/NIC controllers, RAID devices, SCSI devices.
- **Telecommunications**: ATM communication products, base stations, networking switches, SONET/SDH cross connect, multiplexer.
- **Mobile data infrastructures**: Mobile data terminals, pagers, VSATs, Wireless LANs, Wireless phones.

CHAPTER 3

ARDUINO NANO (Micro controller)

Introduction to the Arduino NANO Board

The Arduino Nano, as the name suggests is a compact, complete and bread-board friendly microcontroller board. The Nano board weighs around 7 grams with dimensions of 4.5 cms to 1.8 cms (L to B). This article discusses about the technical specs most importantly the pinout and functions of each and every pin in the Arduino Nano board.

Arduino Nano has similar functionalities as Arduino Duemilanove but with a different package. The Nano is inbuilt with the ATmega328P microcontroller, same as the Arduino UNO. The main difference between them is that the UNO board is presented in PDIP (Plastic Dual-In-line Package) form with 30 pins and Nano is available in TQFP (plastic quad flat pack) with 32 pins. The extra 2 pins of Arduino Nano serve for the ADC functionalities, while UNO has 6 ADC ports but Nano has 8 ADC ports. The Nano board doesn't have a DC power jack as other Arduino boards, but instead has a mini-USB port. This port is used for both programming and serial monitoring. The fascinating feature in Nano is that it will choose the strongest power source with its potential difference, and the power source selecting jumper is invalid.

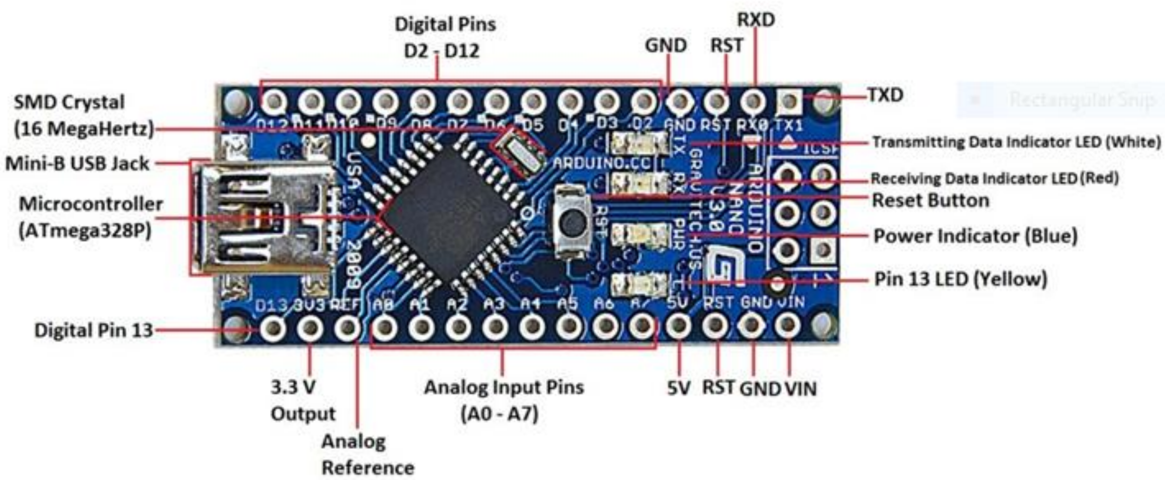


Figure 3.3.2 Arduino nano Board

Arduino Nano – Specification

Arduino Nano	Specifications
Analog I/O Pins	8
Architecture	AVR
Clock Speed	16 MHz
DC Current per I/O Pins	40 milliAmps
Digital I/O Pins	22
EEPROM	1 KB
Flash Memory	32 KB of which 2 KB used by Bootloader
Input Voltage	(7-12) Volts
Microcontroller	ATmega328P
Operating Voltage	5 Volts
PCB Size	18 x 45 mm
Power Consumption	19 milliAmps
PWM Output	6
SRAM	2KB
Weight	7 gms

3.2 Pin diagram

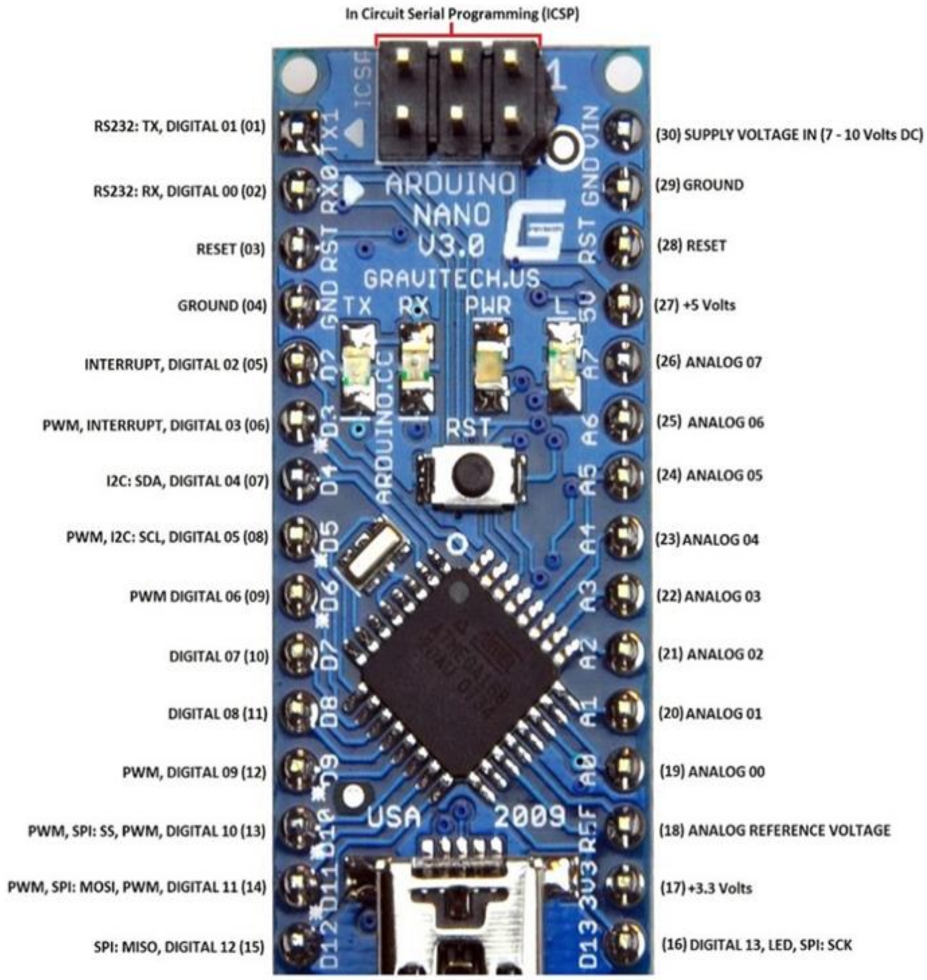


Figure 3.3.3 Pin Configuration of Atmega328

Pin Description

Arduino Nan0 – Pin Description

Pins 1 to 30

Arduino Nano Pin	Pin Name	Type	Function
1	D1/TX	I/O	Digital I/O Pin Serial TX Pin
2	D0/RX	I/O	Digital I/O Pin Serial RX Pin
3	RESET	Input	Reset (Active Low)

Arduino Nano Pin	Pin Name	Type	Function
4	GND	Power	Supply Ground
5	D2	I/O	Digital I/O Pin
6	D3	I/O	Digital I/O Pin
7	D4	I/O	Digital I/O Pin
8	D5	I/O	Digital I/O Pin
9	D6	I/O	Digital I/O Pin
10	D7	I/O	Digital I/O Pin
11	D8	I/O	Digital I/O Pin
12	D9	I/O	Digital I/O Pin
13	D10	I/O	Digital I/O Pin
14	D11	I/O	Digital I/O Pin
15	D12	I/O	Digital I/O Pin
16	D13	I/O	Digital I/O Pin
17	3V3	Output	+3.3V Output (from FTDI)
18	AREF	Input	ADC reference

Arduino Nano Pin	Pin Name	Type	Function
19	A0	Input	Analog Input Channel 0
20	A1	Input	Analog Input Channel 1
21	A2	Input	Analog Input Channel 2
22	A3	Input	Analog Input Channel 3
23	A4	Input	Analog Input Channel 4
24	A5	Input	Analog Input Channel 5
25	A6	Input	Analog Input Channel 6
26	A7	Input	Analog Input Channel 7
27	+5V	Output or Input	+5V Output (From On-board Regulator) or +5V (Input from External Power Supply
28	RESET	Input	Reset (Active Low)
29	GND	Power	Supply Ground
30	VIN	Power	Supply voltage

ICSP Pins

Arduino Nano ICSP Pin Name	Type	Function
MISO	Input or Output	Master In Slave Out
Vcc	Output	Supply Voltage
SCK	Output	Clock from Master to Slave
MOSI	Output or Input	Master Out Slave In
RST	Input	Reset (Active Low)
GND	Power	Supply Ground

Arduino Nano Digital Pins

Pins - 1, 2, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, and 16

As mentioned earlier, Arduino Nano has 14 digital I/O pins that can be used either as digital input or output. The pins work with 5V voltage as maximum, i.e., digital high is 5V and digital low is 0V. Each pin can provide or receive a current of 20mA, and has a pull-up resistance of about 20-50k ohms. Each of the 14 digital pins on the Nano pinout can be used as an input or output, using pin Mode(), digital Write(), and digital Read() functions.

Other than the digital input and output functions, the digital pins have some additional functionality as well.

Serial Communication Pins

Pins - 1, 2

1 - RX and 2 - TX

These two pins RX- receive and TX- transmit are used for TTL serial data communication. The pins RX and TX are connected to the corresponding pins of the USB-to-TTL Serial chip.

PWM Pins

Pins - 6, 8, 9, 12, 13, and 14

Each of these digital pins provide a Pulse Width Modulation signal of 8-bit resolution. The PWM signal can be generated using analogWrite () function.

External Interrupts

Pins - 5, 6

When we need to provide an external interrupt to other processor or controller we can make use of these pins. These pins can be used to enable interrupts INT0 and INT1 respectively by using the attach Interrupt () function. These pins can be used to trigger three types of interrupts such as interrupt on a low value, a rising or falling edge interrupt and a change in value interrupt.

SPI Pins

Pins - 13, 14, 15, and 16

When you don't want the data to be transmitted asynchronously you can use these Serial Peripheral Interface pins. These pins support synchronous communication with SCK as the synchronizing clock. Even though the hardware has this feature, the Arduino software doesn't have this by default. So you have to include a library called SPI Library for using this feature.

LED

Pin - 16

If you remember your first Arduino code, blinking LED, then you'll definitely came across this Pin16. The pin 16 is being connected to the blinking LED on the board.

Arduino Nano Analog Pins

Pins - 18, 19, 20, 21, 22, 23, 24, 25, and 26

As mentioned earlier UNO got 6 analog input pins but Arduino Nano has 8 analog inputs (19 to 26), marked A0 through A7. This means you can connect *8 channel analog sensor inputs for processing. Each of these analog pins has a inbuilt ADC of resolution of 1024 bits (so it will give 1024 values). By default, the pins are measured from ground to 5V. If you want the reference voltage to be 0V to 3.3V, we can give 3.3V to AREF pin (18^{th} Pin) by using the analog Reference () function.

Similar to digital pins in Nano, analog pins also got some other functions as well.

I2C

Pins 23, 24 as A4 and A5

Since SPI communication also has its disadvantages such as 4 essential pins and limited within a device. For long distance communication we use the I2C protocol. I2C supports multi master and multi slave with only two wires. One for clock (SCL) and another for data (SDA). For using this I2C feature we need to import a library called Wire library.

AREF

Pin 18

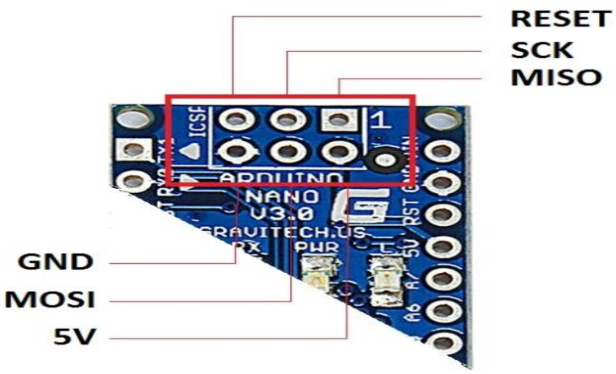
As mentioned already the AREF- Analog Reference pin is used as a reference voltage for analog input for the ADC conversion.

Reset

Pin 28

Reset pins in Arduino are active low pins which means if we make this pin value as LOW i.e., 0v, it will reset the controller. Usually used to be connected with switches to use as reset button.

ICSP



Arduino Nano ISCP

ICSP stands for *In Circuit Serial Programming*, which represents one of the several methods available for programming Arduino boards. Ordinarily, an Arduino bootloader program is used to program an Arduino board, but if the boot loader is missing or damaged, ICSP can be used instead. ICSP can be used to restore a missing or damaged boot loader.

Each ICSP pin usually is cross-connected to another Arduino pin with the same name or function. For example, MISO on Nano's ICSP header is connected to MISO / digital pin 12 (Pin 15); MOSI on the ISCP header is connected to MOSI / digital pin 11 (Pin 16); and so forth. Note, MISO, MOSI, and SCK pins taken together make up most of an SPI interface.

We can use one Arduino to program another Arduino using this ICSP.

Arduino as ISP	**ATMega328**
Vcc/5V	Vcc
GND	GND
MOSI/D11	D11
MISO/D12	D12
SCK/D13	D13
D10	Reset

RESET

Pins 3, 28 and 5 in ICSP

Power

Pins 4, 17, 27, 28, 30 and 2 & 6 in ICSP

Features

- 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. The resulting architecture is more code efficient while achieving throughputs up to ten times faster than conventional CISC microcontrollers.

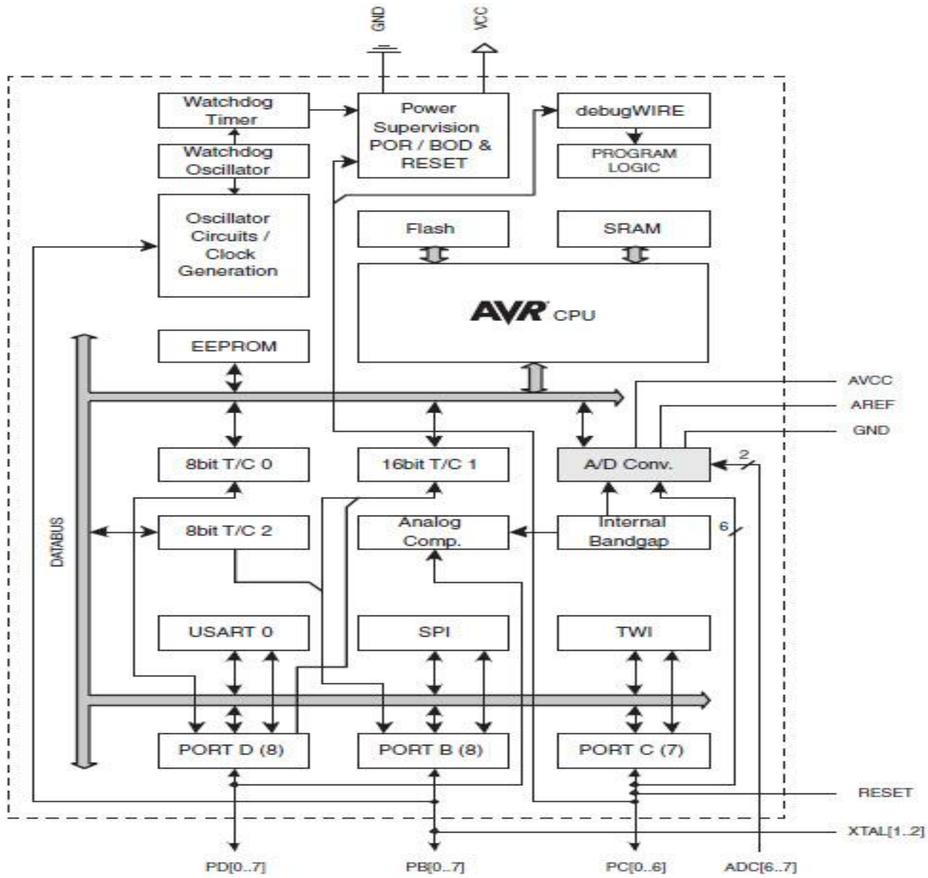


Figure 3.3.3 AVR Block Diagram

Overview

This section discusses the AVR core architecture in general. The main function of the CPU core is to ensure correct program execution. The CPU must therefore be able to access memories, perform calculations,control peripherals, and handle interrupts.

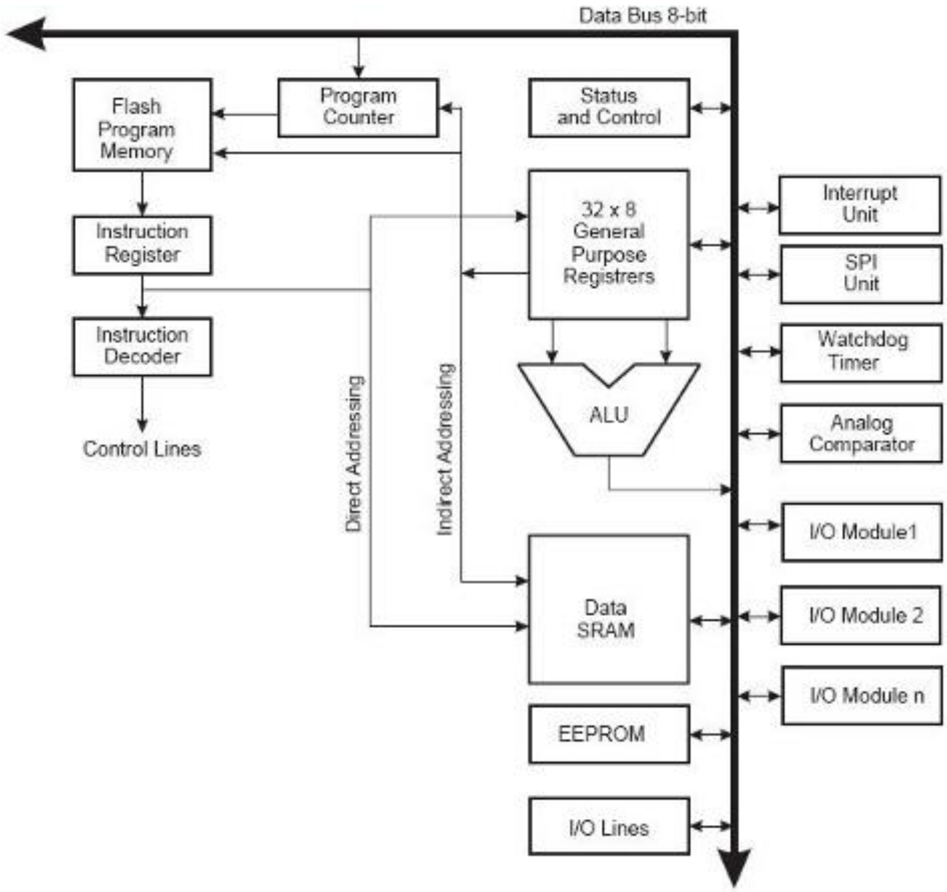


Figure 3.3.4 AVR core architecture

In order to maximize performance and parallelism, the AVR uses a Harvard architecture – with separate memories and buses for program and data. Instructions in the program memory are executed with a single level pipelining. While one instruction is being executed, the next instruction is pre-fetched from the program memory. This concept enables instructions to be executed in every clock cycle. The program memory is In-System Reprogrammable Flash memory. The fast-access Register File contains 32 x 8-bit general purpose working registers with a single clock cycle access time. This allows single-cycle Arithmetic Logic Unit (ALU) operation. In a typical ALU operation, two operands are output from the Register File, the operation is executed, and the result is stored back in the Register File– in one clock cycle.

Six of the 32 registers can be used as three 16-bit indirect address register pointers for Data Space addressing – enabling efficient address calculations. One of these address pointers can also be used as an address pointer for look up tables in Flash program memory. These added function registers are the 16-bit X-, Y-, and Z-register, described later in this section. The ALU supports arithmetic and logic operations between registers or between a constant and a register. Single register operations can also be executed in the ALU. After an arithmetic operation, the Status Register is updated to reflect information about the result of the operation. Program flow is provided by conditional and unconditional jump and call instructions, able to directly address the whole address space. Most AVR instructions have a single 16-bit word format. Every program memory address contains a 16- or 32-bit instruction.

3.2.4 Arduino with ATmega328

The Arduino Uno is a microcontroller board based on the ATmega328 (datasheet). It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz ceramic resonator, 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.

The Uno differs from all preceding boards in that it does not use the FTDI USB-to-serial driver chip. Instead, it features the Atmega16U2 (Atmega8U2 up to versionR2) programmed as a USB-to-serial converter.

- Pin out: Added SDA and SCL pins that are near to the AREF pin and two other new pins placed near to the RESET pin, the IOREF that allow the shields to adapt to the voltage provided from the board. In future, shields will be compatible with both the board that uses the AVR, which operates with 5V and with the Arduino. Due that operates with 3.3V. The second one is a not connected pin that is reserved for future purposes.
- Stronger RESET circuit.
- Atmega 16U2 replace the 8U2.

"Uno" means one in Italian and is named to mark the upcoming release of Arduino 1.0. The Uno and version 1.0 will be the reference versions of Arduino, moving forward. The Uno is the latest in a series of USB Arduino boards, and thereference model for the Arduino platform; for a comparison with previous versions, see the index of Arduino boards.

Arduino Characteristics

The Arduino Uno can be powered via the USB connection or with an external power supply. The power source is selected automatically. External (non-USB) power can come either from an AC-to-DC adapter (wall-wart) or battery. The adapter can be connected by plugging a 2.1mm center-positive plug into the board's power jack. Leads from a battery can be inserted in the Gnd and Vin pin headers of the POWER connector. The board can operate on an external supply of 6 to 20 volts. If supplied with less than 7V, however, the 5V pin may supply less than five volts and the board may be unstable. If using more than 12V, the voltage regulator may overheat and damage the board. The recommended range is 7 to 12 volts.

The power pins are as follows:

- **VIN:** The input voltage to the Arduino board when it's using an external power source (as opposed to 5 volts from the USB connection or other regulated power source). You can supply voltage through this pin, or, if supplying voltage via the power jack, access it through this pin.

- **5V:** This pin outputs a regulated 5V from the regulator on the board. The board can be supplied with power either from the DC power jack (7 - 12V), the USB connector (5V), or the VIN pin of the board (7-12V). Supplying voltage via the 5V or 3.3V pins bypasses the regulator, and can damage your board. We don't advise it.
- **3V3.** A 3.3 volt supply generated by the on-board regulator. Maximum current draw is 50 mA.
- **GND.** Ground pins.
- **IOREF.** This pin on the Arduino board provides the voltage reference with which the microcontroller operates. A properly configured shield can read the IOREF pin voltage and select the appropriate power source or enable voltage translators on the outputs for working with the 5V or 3.3V.

Memory:

The ATmega328 has 32 KB (with 0.5 KB used for the boot loader). It also has 2 KB of SRAM and 1 KB of EEPROM (which can be read and written with the EEPROM library).

Serial Communication:

The Arduino Uno has a number of facilities for communicating with a computer, another Arduino, or other microcontrollers. The ATmega328 provides UART TTL (5V) serial communication, which is available on digital pins 0 (RX) and 1 (TX). An ATmega16U2 on the board channels this serial communication over USB and appears as a virtual com port to software on the computer. The '16U2 firmware uses the standard USB COM drivers, and no external driver is needed. However, **on Windows, a .inf file is required**. The Arduino software includes a serial monitor which allows simple textual data to be sent to and from the Arduino board. The RX and TX LEDs on the board will flash when data is being transmitted via the USB-to-serial chip and USB connection to the computer (but not for serial communication on pins 0 and 1).

A Software Serial library allows for serial communication on any of the Uno's digital pins. The ATmega328 also supports I2C (TWI) and SPI communication. The Arduino software includes a Wire library to simplify use of the I2C bus. For SPI communication, use the SPI library.

CHAPTER 4

HARDWARE COMPONENTS

LCD (Liquid Cristal Display)

Introduction:

A liquid crystal display (LCD) is a thin, flat display device made up of any number of color or monochrome pixels arrayed in front of a light source or reflector. Each pixel consists of a column of liquid crystal molecules suspended between two transparent electrodes, and two polarizing filters, the axes of polarity of which are perpendicular to each other. Without the liquid crystals between them, light passing through one would be blocked by the other. The liquid crystal twists the polarization of light entering one filter to allow it to pass through the other.

A program must interact with the outside world using input and output devices that communicate directly with a human being. One of the most common devices attached to an controller is an LCD display. Some of the most common LCDs connected to the controllers are 16X1, 16x2 and 20x2 displays. This means 16 characters per line by 1 line 16 characters per line by 2 lines and 20 characters per line by 2 lines, respectively.

Many microcontroller devices use 'smart LCD' displays to output visual information. LCD displays designed around LCD NT-C1611 module, are inexpensive, easy to use, and it is even possible to produce a readout using the 5X7 dots plus cursor of the display. They have a standard ASCII set of characters and mathematical symbols. For an 8-bit data bus, the display requires a +5V supply plus 10 I/O lines (RS RW D7 D6 D5 D4 D3 D2 D1 D0). For a 4-bit data bus it only requires the supply lines plus 6 extra lines(RS RW D7 D6 D5 D4). When the LCD display is not enabled, data lines are tri-state and they do not interfere with the operation of the microcontroller.

Features:

(1) Interface with either 4-bit or 8-bit microprocessor.

(2) Display data RAM

(3) 80x8 bits (80 characters).

(4) Character generator ROM

(5). 160 different 57 dot-matrix character patterns.

(6). Character generator RAM

(7) Different user programmed 57 dot-matrix patterns.

(8).Display data RAM and character generator RAM may be

Accessed y the microprocessor.

(9) Numerous instructions

(10) .Clear Display, Cursor Home, Display ON/OFF, Cursor ON/OFF,

Blink Character, Cursor Shift, Display Shift.

(11). Built-in reset circuit is triggered at power ON.

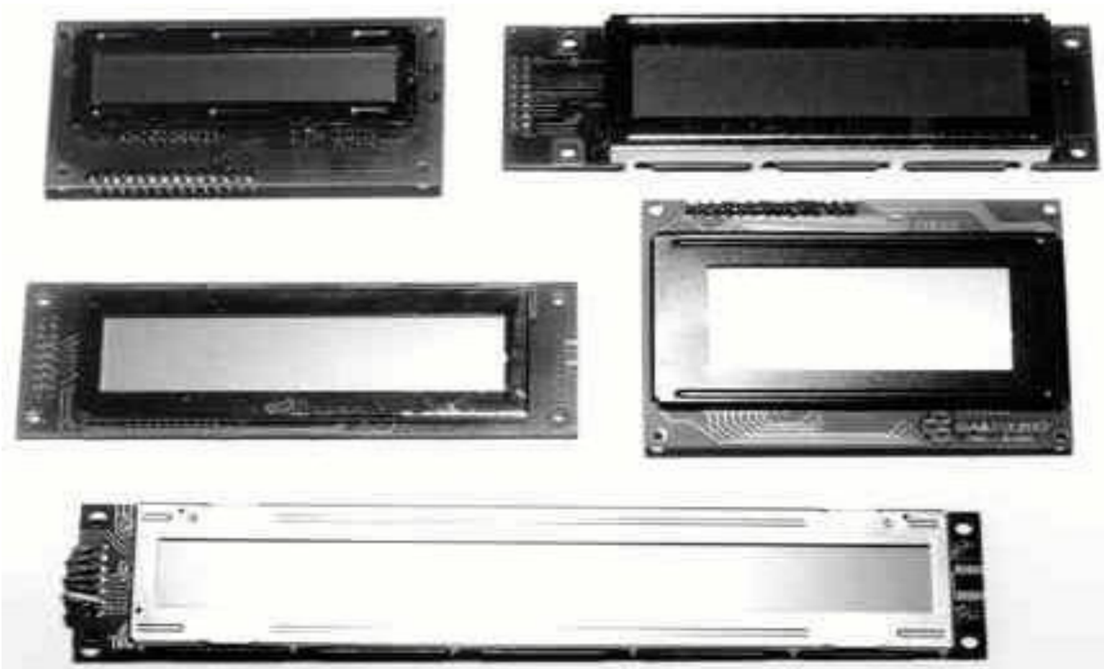
(12). Built-in oscillator.

Data can be placed at any location on the LCD. For 16×1 LCD, the address locations are:

POSITION		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
ADDRESS	LINE1	00	01	02	03	04	05	06	07	40	41	42	43	44	45	46	47

Fig: Address locations for a 1x16 line LCD

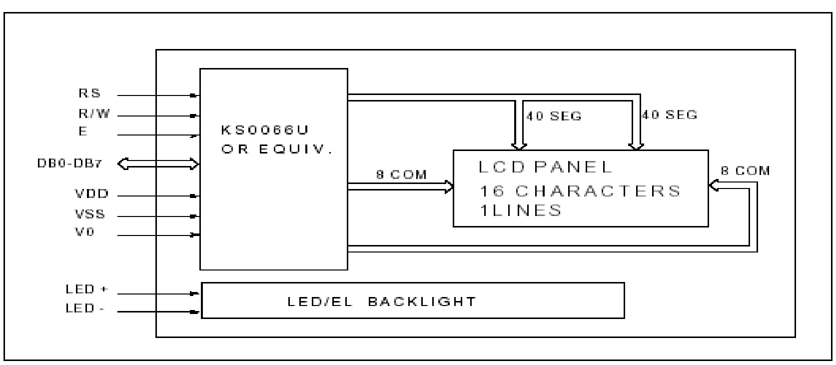
Shapes and sizes:



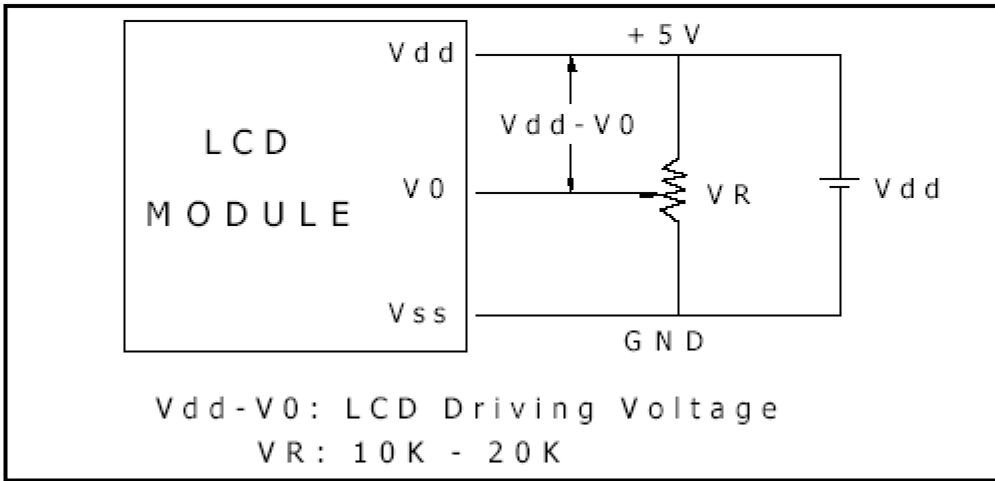
Even limited to character based modules,there is still a wide variety of shapes and sizes available. Line lenghs of 8,16,20,24,32 and 40 charecters are all standard, in one, two and four line versions.

Several different LC technologies exists. “supertwist” types, for example, offer Improved contrast and viewing angle over the older “twisted nematic” types. Some modules are available with back lighting, so so that they can be viewed in dimly-lit conditions. The back lighting may be either “electro-luminescent”, requiring a high voltage inverter circuit, or simple LED illumination.

Electrical blockdiagram:



Power supply for lcd driving:



PIN DESCRIPTION:

Most LCDs with 1 controller has 14 Pins and LCDs with 2 controller has 16 Pins (two pins are extra in both for back-light LED connections).

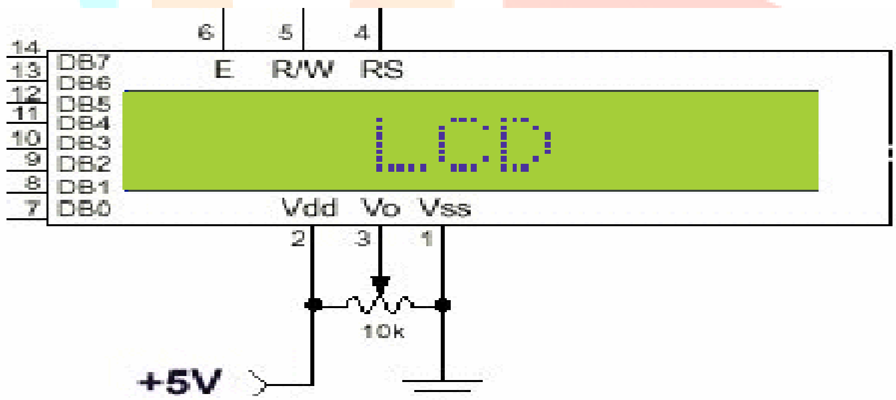


Fig: pin diagram of 1x16 lines lcd

PIN	SYMBOL	FUNCTION
1	Vss	Power Supply(GND)
2	Vdd	Power Supply(+5V)
3	Vo	Contrast Adjust
4	RS	Instruction/Data Register Select
5	R/W	Data Bus Line
6	E	Enable Signal
7-14	DB0-DB7	Data Bus Line
15	A	Power Supply for LED B/L(+)
16	K	Power Supply for LED B/L(-)

CONTROL LINES:

EN: Line is called "Enable." This control line is used to tell the LCD that you are sending it data. To send data to the LCD, your program should make sure this line is low (0) and then set the other two control lines and/or put data on the data bus. When the other lines are completely ready, bring EN high (1) and wait for the minimum amount of time required by the LCD datasheet (this varies from LCD to LCD), and end by bringing it low (0) again.

RS: Line is the "Register Select" line. When RS is low (0), the data is to be treated as a command or special instruction (such as clear screen, position cursor, etc.). When RS is high (1), the data being sent is text data which should be displayed on the screen. For example, to display the letter "T" on the screen you would set RS high.

RW: Line is the "Read/Write" control line. When RW is low (0), the information on the data bus is being written to the LCD. When RW is high (1), the program is effectively querying (or reading) the LCD. Only one instruction ("Get LCD status") is a read command. All others are write commands, so RW will almost always be low.

Finally, the data bus consists of 4 or 8 lines (depending on the mode of operation selected by the user). In the case of an 8-bit data bus, the lines are referred to as DB0, DB1, DB2, DB3, DB4, DB5, DB6, and DB7.

Logic status on control lines:

• E - 0 Access to LCD disabled

- 1 Access to LCD enabled

• R/W - 0 Writing data to LCD

- 1 Reading data from LCD

• RS - 0 Instructions

- 1 Character

Writing data to the LCD:

1) Set R/W bit to low

2) Set RS bit to logic 0 or 1 (instruction or character)

3) Set data to data lines (if it is writing)

4) Set E line to high

5) Set E line to low

Read data from data lines (if it is reading) on LCD:

1) Set R/W bit to high

2) Set RS bit to logic 0 or 1 (instruction or character)

3) Set data to data lines (if it is writing)

4) Set E line to high

5) Set E line to low

Entering Text:

First, a little tip: it is manually a lot easier to enter characters and commands in hexadecimal rather than binary (although, of course, you will need to translate commands from binary couple of sub-miniature hexadecimal rotary switches is a simple matter, although a little bit into hex so that you know which bits you are setting). Replacing the dial. switch pack with a of re-wiring is necessary.

The switches must be the type where On = 0, so that when they are turned to the zero position, all four outputs are shorted to the common pin, and in position "F", all four outputs are open circuit.

All the available characters that are built into the module are shown in Table 3. Studying the table, you will see that codes associated with the characters are quoted in binary and hexadecimal, most significant bits ("left-hand" four bits) across the top, and least significant bits ("right-hand" four bits) down the left.

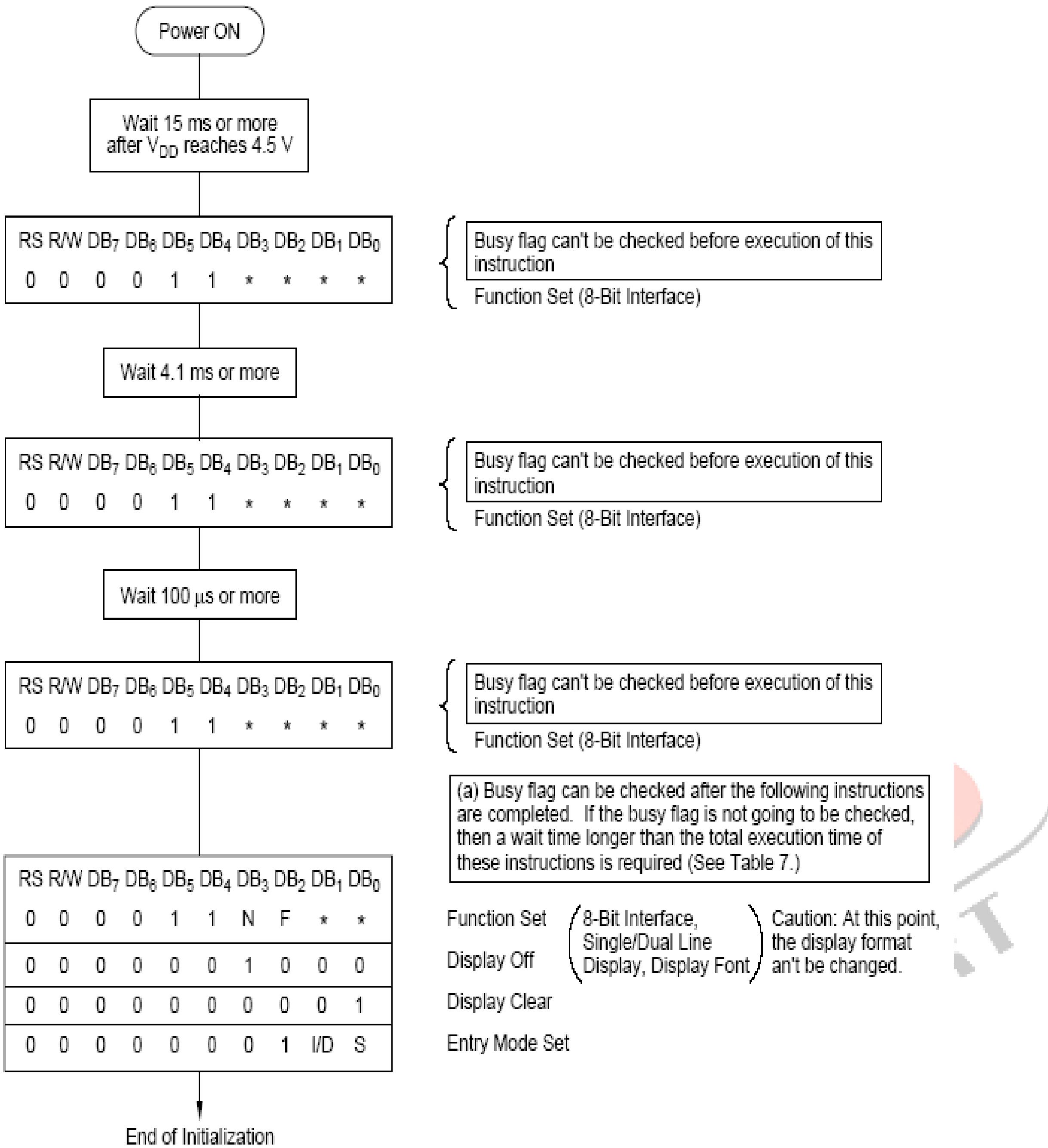
Most of the characters conform to the ASCII standard, although the Japanese and Greek characters (and a few other things) are obvious exceptions. Since these intelligent modules were designed in the "Land of the Rising Sun," it seems only fair that their Katakana phonetic symbols should also be incorporated. The more extensive Kanji character set, which the Japanese share with the Chinese, consisting of several thousand different characters, is not included!

Using the switches, of whatever type, and referring to Table 3, enter a few characters onto the display, both letters and numbers. The RS switch (S10) must be "up" (logic 1) when sending the characters, and switch E (S9) must be pressed for each of them. Thus the operational order is: set RS high, enter character, trigger E, leave RS high, enter another character, trigger E, and so on.

The first 16 codes in Table 3, 00000000 to 00001111, ($00 to $0F) refer to the CGRAM. This is the Character Generator RAM (random access memory), which can be used to hold user-defined graphics characters. This is where these modules really start to show their potential, offering such capabilities as bar graphs, flashing symbols, even animated characters. Before the user-defined characters are set up, these codes will just bring up strange looking symbols.

Codes 00010000 to 00011111 ($10 to $1F) are not used and just display blank characters. ASCII codes "proper" start at 00100000 ($20) and end with 01111111 ($7F). Codes 10000000 to 10011111 ($80 to $9F) are not used, and 10100000 to 11011111 ($A0 to $DF) are the Japanese characters.

Initialization by Instructions:



If the power conditions for the normal operation of the internal reset circuit are not satisfied, then executing a series of instructions must initialize LCD unit. The procedure for this initialization process is as above show.

REGULATED POWER SUPPLY:

Introduction:

Power supply is a supply of electrical power. A device or system that supplies electrical or other types of energy to an output load or group of loads is called a power supply unit or PSU. The term is most commonly applied to electrical energy supplies, less often to mechanical ones, and rarely to others.

A power supply may include a power distribution system as well as primary or secondary sources of energy such as

- Conversion of one form of electrical power to another desired form and voltage, typically involving converting AC line voltage to a well-regulated lower-voltage DC for electronic devices. Low voltage, low power DC power supply units are commonly integrated with the devices they supply, such as computers and household electronics.
- Batteries.
- Chemical fuel cells and other forms of energy storage systems.
- Solar power.
- Generators or alternators.

Block Diagram:

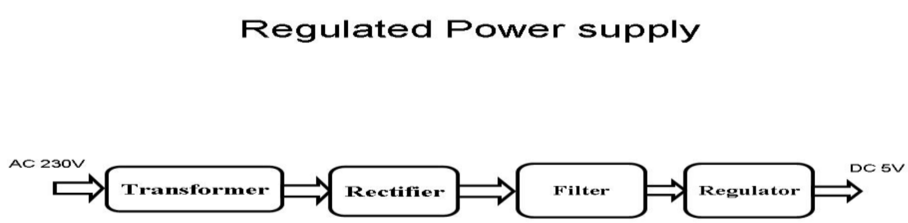


Fig .Regulated Power Supply

The basic circuit diagram of a regulated power supply (DC O/P) with led connected as load is shown in fig:

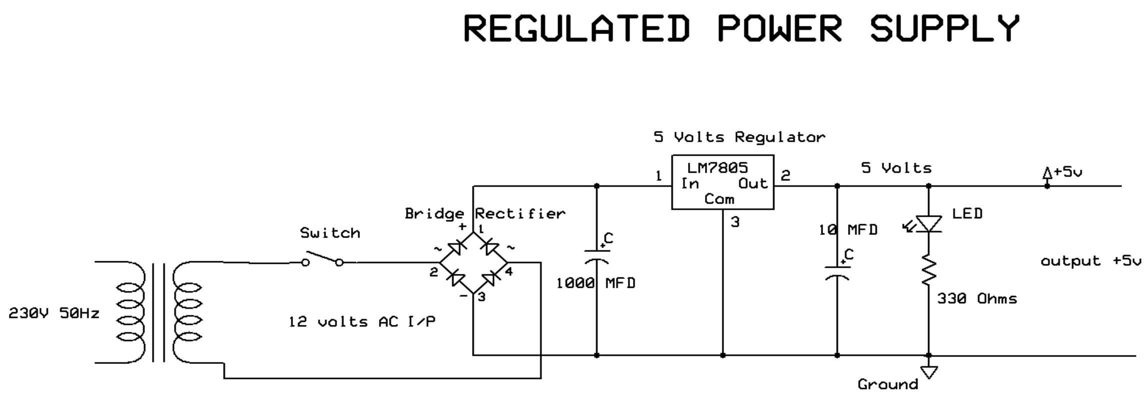


Fig Circuit diagram of Regulated Power Supply with Led connection

The components mainly used in above figure are

- 230V AC MAINS
- TRANSFORMER
- BRIDGE RECTIFIER(DIODES)
- CAPACITOR
- VOLTAGE REGULATOR(IC 7805)
- RESISTOR
- LED(LIGHT EMITTING DIODE)

The detailed explanation of each and every component mentioned above is as follows:

Step 1: Transformation: The process of transforming energy from one device to another is called transformation. For transforming energy we use transformers.

Transformers:

A transformer is a device that transfers electrical energy from one circuit to another through inductively coupled conductors without changing its frequency. A varying current in the first or primary winding creates a varying magnetic flux in the transformer's core, and thus a varying magnetic field through the secondary winding. This varying magnetic field induces a varying electromotive force (EMF) or "voltage" in the secondary winding. This effect is called mutual induction.

If a load is connected to the secondary, an electric current will flow in the secondary winding and electrical energy will be transferred from the primary circuit through the transformer to the load. This field is made up from lines of force and has the same shape as a bar magnet.

If the current is increased, the lines of force move outwards from the coil. If the current is reduced, the lines of force move inwards.

If another coil is placed adjacent to the first coil then, as the field moves out or in, the moving lines of force will "cut" the turns of the second coil. As it does this, a voltage is induced in the second coil. With the 50 Hz AC mains supply, this will happen 50 times a second. This is called MUTUAL INDUCTION and forms the basis of the transformer.

The input coil is called the PRIMARY WINDING; the output coil is the SECONDARY WINDING. Fig: 3.3.4 shows step-down transformer.

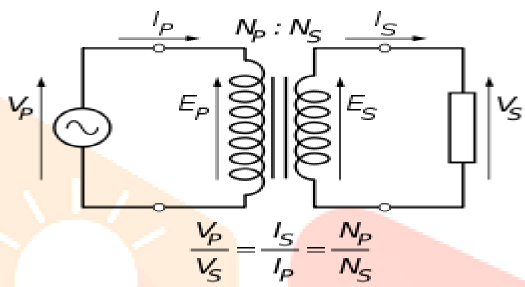


Fig 3.3.3: Step-Down Transformer

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.

Another example is if the primary has 5000 turns and the secondary has 500 turns, then the turn's ratio is 10:1.

If the primary voltage is 240 volts then the secondary voltage will be x 10 smaller = 24 volts. Assuming a perfect transformer, the power provided by the primary must equal the power taken by a load on the secondary. If a 24-watt lamp is connected across a 24 volt secondary, then the primary must supply 24 watts.

To aid magnetic coupling between primary and secondary, the coils are wound on a metal CORE. Since the primary would induce power, called EDDY CURRENTS, into this core, the core is

LAMINATED. This means that it is made up from metal sheets insulated from each other. Transformers to work at higher frequencies have an iron dust core or no core at all.

Note that the transformer only works on AC, which has a constantly changing current and moving field. DC has a steady current and therefore a steady field and there would be no induction.

Some transformers have an electrostatic screen between primary and secondary. This is to prevent some types of interference being fed from the equipment down into the mains supply, or in the other direction. Transformers are sometimes used for IMPEDANCE MATCHING.

We can use the transformers as step up or step down.

Step Up transformer:

In case of step up transformer, primary windings are every less compared to secondary winding.

Because of having more turns secondary winding accepts more energy, and it releases more voltage at the output side.

Step down transformer:

Incase of step down transformer, Primary winding induces more flux than the secondary winding, and secondary winding is having less number of turns because of that it accepts less number of flux, and releases less amount of voltage.

Battery power supply:

A battery is a type of linear power supply that offers benefits that traditional line-operated power supplies lack: mobility, portability and reliability. A battery consists of multiple electrochemical cells connected to provide the voltage desired. Fig: 3.3.4 shows Hi-Watt 9V battery

Fig: Hi-Watt 9V Battery

The most commonly used dry-cell battery is the carbon-zinc dry cell battery. Dry-cell batteries are made by stacking a carbon plate, a layer of electrolyte paste, and a zinc plate alternately until the desired total voltage is achieved. The most common dry-cell batteries have one of the following voltages: 1.5, 3, 6, 9, 22.5, 45, and 90. During the discharge of a carbon-zinc battery, the zinc metal is converted to a zinc salt in the electrolyte, and magnesium dioxide is reduced at the carbon electrode. These actions establish a voltage of approximately 1.5 V.

The lead-acid storage battery may be used. This battery is rechargeable; it consists of lead and lead/dioxide electrodes which are immersed in sulfuric acid. When fully charged, this type of battery has a 2.06-2.14 V potential (A 12 volt car battery uses 6 cells in series). During discharge, the lead is converted to lead sulfate and the sulfuric acid is converted to water. When the battery is charging, the lead sulfate is converted back to lead and lead dioxide A nickel-cadmium battery has become more popular in recent years. This battery cell is completely sealed and rechargeable. The electrolyte is not involved in the electrode reaction, making the voltage constant over the span of the batteries long service life. During the charging process, nickel oxide is oxidized to its higher oxidation state and cadmium oxide is reduced. The nickel-cadmium batteries have many benefits. They can be stored both charged and uncharged. They have a long service life, high current availabilities, constant voltage, and the ability to be recharged. Fig: 3.3.5 shows pencil battery of 1.5V.

Fig: Pencil Battery of 1.5V

Step 2: Rectification

The process of converting an alternating current to a pulsating direct current is called as rectification. For rectification purpose we use rectifiers.

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 figure, 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.

For the positive half cycle of the input ac voltage, diodes D1 and D3 conduct, whereas diodes D2 and D4 remain in the OFF state. The conducting diodes will be in series with the load resistance R_L and hence the load current flows through R_L.

For the negative half cycle of the input ac voltage, diodes D2 and D4 conduct whereas, D1 and D3 remain OFF. The conducting diodes D2 and D4 will be in series with the load resistance R_L and hence the current flows through R_L in the same direction as in the previous half cycle. Thus a bi-directional wave is converted into a unidirectional wave.

Input Output

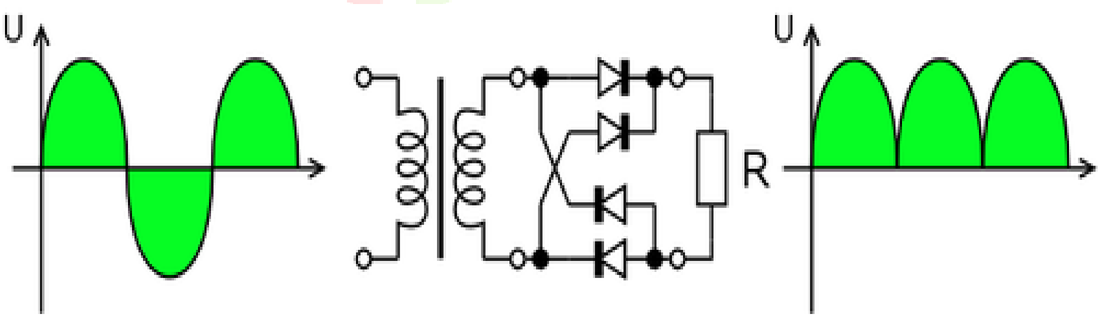


Fig : Bridge rectifier: a full-wave rectifier using 4 diodes

DB107:

Now -a –days Bridge rectifier is available in IC with a number of DB107. In our project we are using an IC in place of bridge rectifier.

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 : DB107

Step 3: Filtration

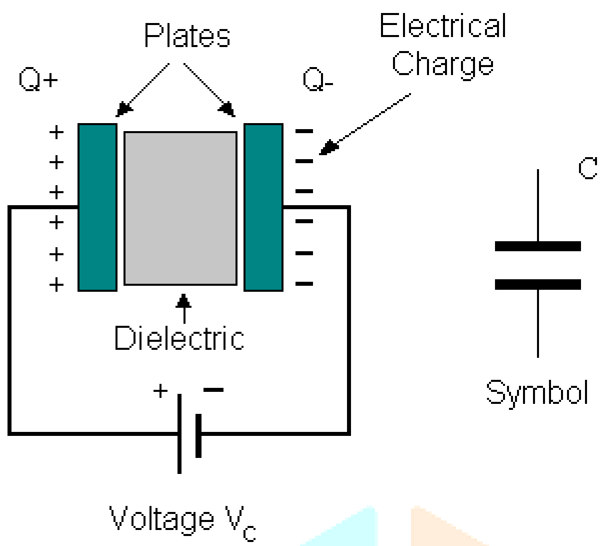
The process of converting a pulsating direct current to a pure direct current using filters is called as filtration.

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. At this point the capacitor is said to be fully charged and this is illustrated below.



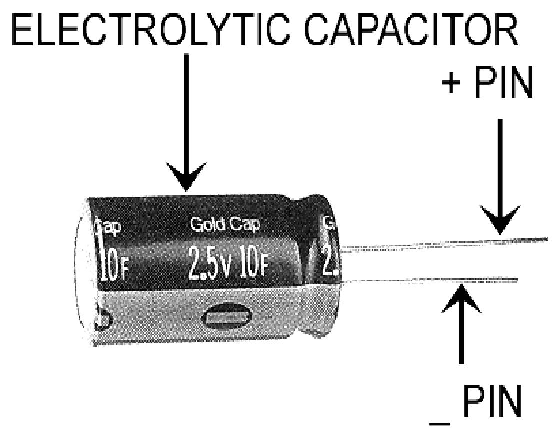


Fig:Construction Of a Capacitor **Fig :Electrolytic Capaticor**

Units of Capacitance:

Microfarad (µF) 1µF = 1/1,000,000 = 0.000001 = 10^{-6} F

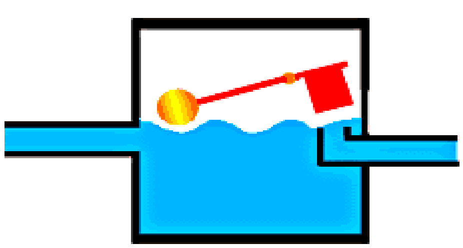
Nanofarad (nF) 1nF = 1/1,000,000,000 = 0.000000001 = 10^{-9} F

Pico farad (pF) 1pF = 1/1,000,000,000,000 = 0.000000000001 = 10^{-12} F

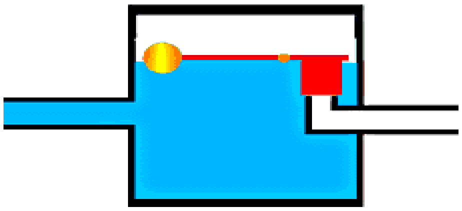
Operation of Capacitor:

Think of water flowing through a pipe. If we imagine a capacitor as being a storage tank with an inlet and an outlet pipe, it is possible to show approximately how an electronic capacitor works.

First, let's consider the case of a "coupling capacitor" where the capacitor is used to connect a signal from one part of a circuit to another but without allowing any direct current to flow.



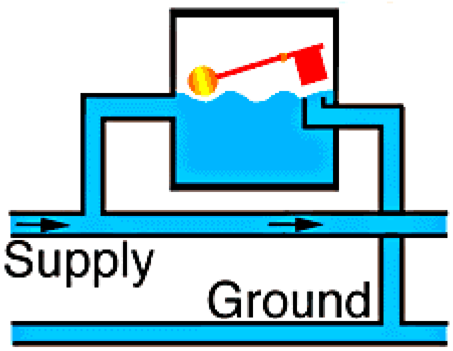
If the current flow is alternating between zero and a maximum, our "storage tank" capacitor will allow the current waves to pass through.



However, if there is a steady current, only the initial short burst will flow until the "floating ball valve" closes and stops further flow.

So a coupling capacitor allows "alternating current" to pass through because the ball valve doesn't get a chance to close as the waves go up and down. However, a steady current quickly fills the tank so that all flow stops.

A capacitor will pass alternating current but (apart from an initial surge) it will not pass d.c.



Where a capacitor is used to decouple a circuit, the effect is to "smooth out ripples". Any ripples, waves or pulses of current are passed to ground while d.c. Flows smoothly.

Step 4: Regulation

The process of converting a varying voltage to a constant regulated voltage is called as regulation. For the process of regulation we use voltage regulators.

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: 3.3.10 shows voltage regulator.

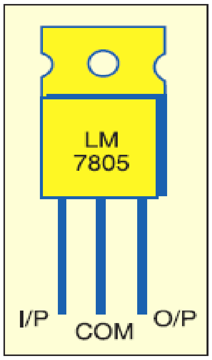


Fig : Voltage Regulator

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).

The primary characteristics of a resistor are the resistance, the tolerance, maximum working voltage and the power rating. Other characteristics include temperature coefficient, noise, and inductance. Less well-known is critical resistance, the value below which power dissipation limits the maximum permitted current flow, and above which the limit is applied voltage. Critical resistance is determined by the design, materials and dimensions of the resistor.

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:

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

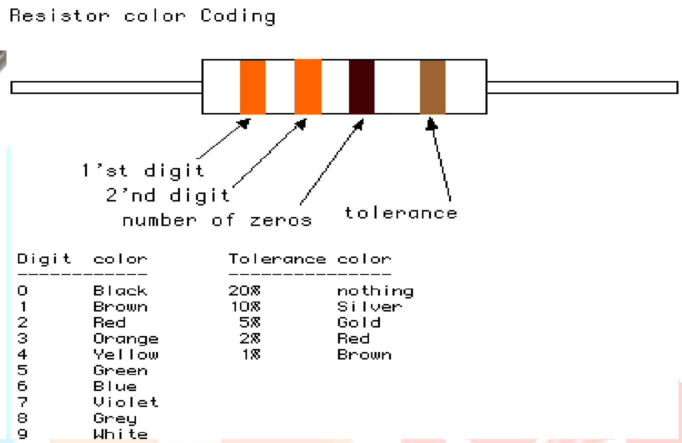
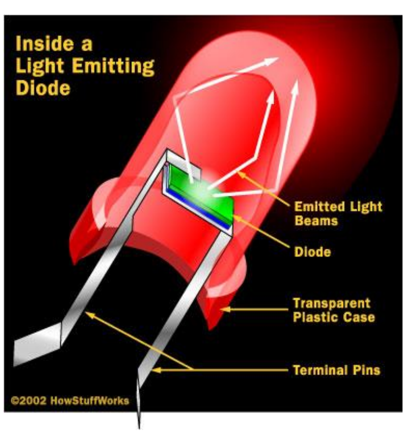


Fig : Resistor **Fig : Color Bands In Resistor**

LED:

A light-emitting diode (LED) is a semiconductor light source. LEDs are used as indicator lamps in many devices, and are increasingly used for lighting. Introduced as a practical electronic component in 1962, early LEDs 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 below.



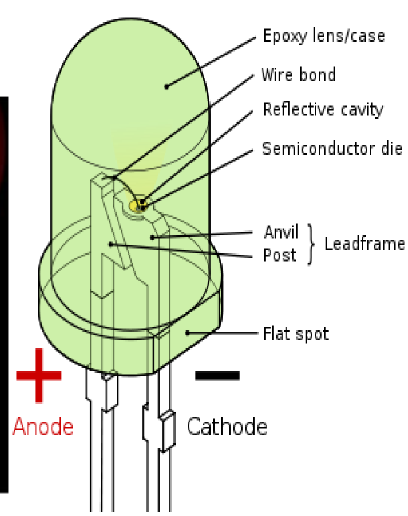


Fig : Inside a LED **Fig : Parts of a LED**

Working:

The structure of the LED light is completely different than that of the light bulb. Amazingly, the LED has a simple and strong structure. The light-emitting semiconductor material is what determines the LED's color. The LED is based on the semiconductor diode.

When a diode is forward biased (switched on), electrons are able to recombine with 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 gap of the semiconductor. An LED is usually small in area (less than 1 mm^2), and integrated optical components are used to shape its radiation pattern and assist in reflection. LEDs present many advantages over incandescent light sources including lower energy consumption, longer lifetime, improved robustness, smaller size, faster switching, and greater durability and reliability. However, they are relatively expensive and require more precise current and heat management than traditional light sources. Current LED products for general lighting are more expensive to buy than fluorescent lamp sources of comparable output. They also enjoy use in applications as diverse as replacements for traditional light sources in automotive lighting (particularly indicators) and in traffic signals. The compact size of LEDs has allowed new text and video displays and sensors to be developed, while their high switching rates are useful in advanced communications technology. The electrical symbol and polarities of led are shown in fig:

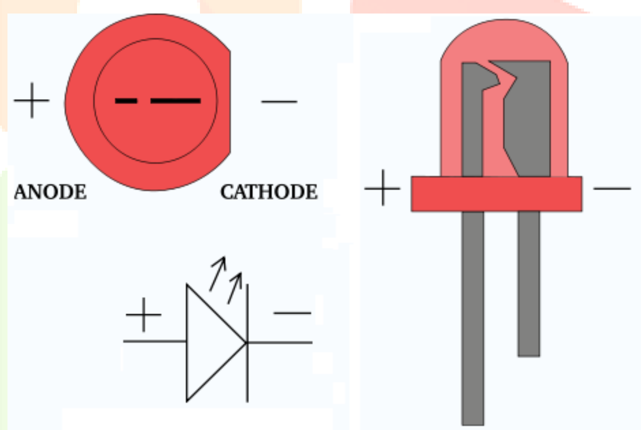


Fig : Electrical Symbol & Polarities of LED

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

- High-levels of brightness and intensity
- 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.

SOLAR ENERGY

Solar energy is radiant light and heat from the Sun that is harnessed using a range of technologies such as solar power to generate electricity, solar thermal energy including solar water heating, and solar architecture.

It is an essential source of renewable energy, and its technologies are broadly characterized as either passive solar or active solar depending on how they capture and distribute solar energy or convert it into solar power. Active solar techniques include the use of photovoltaic systems, concentrated solar power, and solar water heating to harness the energy. Passive solar techniques include orienting a building to the Sun, selecting materials with favorable thermal mass or light-dispersing properties, and designing spaces that naturally circulate air.

The large magnitude of solar energy available makes it a highly appealing source of electricity. Solar energy has been cheaper than fossil fuels since 2021.

In 2011, the International Energy Agency said that "the development of affordable, inexhaustible and clean solar energy technologies will have huge longer-term benefits. It will increase countries' energy security through reliance on an indigenous, inexhaustible, and mostly import-independent resource, enhance sustainability, reduce pollution, lower the costs of mitigating global warming .... These advantages are global.

The Earth receives 174 pet watts (PW) of incoming solar radiation (isolation) at the upper atmosphere. Approximately 30% is reflected back to space while the rest is absorbed by clouds, oceans and land masses. The spectrum of solar light at the Earth's surface is mostly spread across the visible and near-infrared ranges with a small part in the near-ultraviolet. Most of the world's population live in areas with isolation levels of 150–300 watts/m2, or 3.5–7.0 kWh/m2 per day.

Solar radiation is absorbed by the Earth's land surface, oceans – which cover about 71% of the globe – and atmosphere. Warm air containing evaporated water from the oceans rises, causing atmospheric circulation or convection. When the air reaches a high altitude, where the temperature is low, water vapor condenses into clouds, which rain onto the Earth's surface, completing the water cycle. The latent heat of water condensation amplifies convection, producing atmospheric phenomena such as wind, cyclones and anticyclones. Sunlight absorbed by the oceans and land masses keeps the surface at an average temperature of 14 °C. By photosynthesis, green plants convert solar energy into chemically stored energy, which produces food, wood and the biomass from which fossil fuels are derived.

The total solar energy absorbed by Earth's atmosphere, oceans and land masses is approximately 3,850,000 exajoules (EJ) per year. In 2002, this was more energy in one hour than the world used in one year. Photosynthesis captures approximately 3,000 EJ per year in biomass. The amount of solar energy reaching the surface of the planet is so vast that in one year it is about twice as much as will ever be obtained from all of the Earth's non-renewable resources of coal, oil, natural gas, and mined uranium combined,

Yearly solar fluxes & human consumption1

Solar 3,850,000

Wind 2,250

Biomass potential ~200

Primary energy use2 539

Electricity2 ~67

1 Energy given in Exajoule (EJ) = 1018 J = 278 TWh

2 Consumption as of year 2010

The potential solar energy that could be used by humans differs from the amount of solar energy present near the surface of the planet because factors such as geography, time variation, cloud cover, and the land available to humans limit the amount of solar energy that we can acquire. In 2021, Carbon Tracker Initiative estimated the land area needed to generate all our energy from solar alone was 450,000 km2- or about the same as the area of Sweden, or the area of Morocco, or the area of California (0.3% of the Earth's total land area).

Geography affects solar energy potential because areas that are closer to the equator have a higher amount of solar radiation. However, the use of photovoltaic that can follow the position of the Sun can significantly increase the solar energy potential in areas that are farther from the equator. Time variation effects the potential of solar energy because during the nighttime, there is little solar radiation on the surface of the Earth for solar panels to absorb. This limits the amount of energy that solar panels can absorb in one day. Cloud cover can affect the potential of solar panels because clouds block incoming light from the Sun and reduce the light available for solar cells.

Besides, land availability has a large effect on the available solar energy because solar panels can only be set up on land that is otherwise unused and suitable for solar panels. Roofs are a suitable place for solar cells, as many people have discovered that they can collect energy directly from their homes this way.

Other areas that are suitable for solar cells are lands that are not being used for businesses where solar plants can be established.

Solar technologies are characterized as either passive or active depending on the way they capture, convert and distribute sunlight and enable solar energy to be harnessed at different levels around the world, mostly depending on the distance from the equator. Although solar energy refers primarily to the use of solar radiation for practical ends, all renewable energies, other than geothermal power and Tidal power, derive their energy either directly or indirectly from the Sun.

Active solar techniques use photovoltaic, concentrated solar power, solar thermal collectors, pumps, and fans to convert sunlight into useful outputs. Passive solar techniques include selecting materials with favorable thermal properties, designing spaces that naturally circulate air, and referencing the position of a building to the Sun. Active solar technologies increase the supply of energy and are considered supply side technologies, while passive solar technologies reduce the need for alternate resources and are generally considered demand-side technologies.

In 2000, the United Nations Development Programmer, UN Department of Economic and Social Affairs, and World Energy Council published an estimate of the potential solar energy that could be used by humans each year that took into account factors such as insolation, cloud cover, and the land that is usable by humans. The estimate found that solar energy has a global potential of 1,600 to 49,800 exajoules (4.4×1014 to 1.4×1016 kWh) per year (see table below).[21]

Annual solar energy potential by region (Exajoules) [21]

Region	North America	Latin America and Caribbean	Western Europe	Central and Eastern Europe	Former Soviet Union	Middle East and North Africa	Sub-Saharan Africa	Pacific Asia	South Asia	Centrally planned Asia	Pacific OECD
Minimum	181.1	112.6	25.1	4.5	199.3	412.4	371.9	41.0	38.8	115.5	72.6
Maximum	7,410	3,385	914	154	8,655	11,060	9,528	994	1,339	4,135	2,263

Note:

Total global annual solar energy potential amounts to 1,575 EJ (minimum) to 49,837 EJ (maximum)

Data reflects assumptions of annual clear sky irradiance, annual average sky clearance, and available land area. All figures given in Exajoules.

Quantitative relation of global solar potential vs. the world's primary energy consumption:

Ratio of potential vs. current consumption (402 EJ) as of year: 3.9 (minimum) to 124 (maximum)

Ratio of potential vs. projected consumption by 2050 (590–1,050 EJ): 1.5–2.7 (minimum) to 47–84 (maximum)

Ratio of potential vs. projected consumption by 2100 (880–1,900 EJ): 0.8–1.8 (minimum) to 26–57 (maximum)

Source: United Nations Development Programmer – World Energy Assessment (2000)[21]

Thermal energy

Main article: Solar thermal energy

Solar thermal technologies can be used for water heating, space heating, space cooling and process heat generation.

Early commercial adaptation

In 1878, at the Universal Exposition in Paris, Augustin Mouchot successfully demonstrated a solar steam engine, but couldn't continue development because of cheap coal and other factors.

1917 Patent drawing of Shuman's solar collector

In 1897, Frank Shuman, a US inventor, engineer and solar energy pioneer built a small demonstration solar engine that worked by reflecting solar energy onto square boxes filled with ether, which has a lower boiling point than water and were fitted internally with black pipes which in turn powered a steam engine. In 1908 Shuman formed the Sun Power Company with the intent of building larger solar power plants. He, along with his technical advisor A.S.E. Ackermann and British physicist Sir Charles Vernon Boys,[citation needed] developed an improved system using mirrors to reflect solar energy upon collector boxes, increasing heating capacity to the extent that water could now be used instead of ether. Shuman then constructed a full-scale steam engine powered by low-pressure water, enabling him to patent the entire solar engine system by 1912.

Shuman built the world's first solar thermal power station in Maida, Egypt, between 1912 and 1913. His plant used parabolic troughs to power a 45–52 kilowatts (60–70 hp) engine that pumped more than 22,000 liters (4,800 imp gal; 5,800 US gal) of water per minute from the Nile River to adjacent cotton fields. Although the outbreak of World War I and the discovery of cheap oil in the 1930s discouraged the advancement of solar energy, Shuman's vision, and basic design were resurrected in the 1970s with a new wave of interest in solar thermal energy. In 1916 Shuman was quoted in the media advocating solar energy's utilization, saying:

We have proved the commercial profit of sun power in the tropics and have more particularly proved that after our stores of oil and coal are exhausted the human race can receive unlimited power from the rays of the Sun.

— Frank Shuman, New York Times, 2 July 1916

Water heating

Main articles: Solar hot water and Solar comb system

Solar water heaters facing the Sun to maximize gain

Solar hot water systems use sunlight to heat water. In middle geographical latitudes (between 40 degrees north and 40 degrees south), 60 to 70% of the domestic hot water use, with water temperatures up to 60 °C (140 °F), can be provided by solar heating systems. The most common types of solar water heaters are evacuated tube collectors (44%) and glazed flat plate collectors (34%) generally used for domestic hot water; and unglazed plastic collectors (21%) used mainly to heat swimming pools.

As of 2015, the total installed capacity of solar hot water systems was approximately 436 thermal gigawatt (GWth), and China is the world leader in their deployment with 309 GWth installed, taken up 71% of the market. Israel and Cyprus are the per capita leaders in the use of solar hot water systems with over 90% of homes using them. In the United States, Canada, and Australia, heating swimming pools is the dominant application of solar hot water with an installed capacity of 18 GWth as of 2005.

Heating, cooling and ventilation

Main articles: Solar heating, Thermal mass, Solar chimney, and Solar air conditioning

In the United States, heating, ventilation and air conditioning (HVAC) systems account for 30% (4.65 EJ/yr) of the energy used in commercial buildings and nearly 50% (10.1 EJ/yr) of the energy used in residential buildings. Solar heating, cooling and ventilation technologies can be used to offset a portion of this energy. Use of solar for heating can roughly be divided into passive solar concepts and active solar concepts, depending on whether active elements such as sun tracking and solar concentrator optics are used.

MIT's Solar House #1, built in 1939 in the US, used seasonal thermal energy storage for year-round heating.

Thermal mass is any material that can be used to store heat—heat from the Sun in the case of solar energy. Common thermal mass materials include stone, cement, and water. Historically they have been used in arid climates or warm temperate regions to keep buildings cool by absorbing solar energy during the day and radiating stored heat to the cooler atmosphere at night. However, they can be used in cold temperate areas to maintain warmth as well. The size and placement of thermal mass depend on several factors such as climate, day lighting, and shading conditions. When duly incorporated, thermal mass maintains space temperatures in a comfortable range and reduces the need for auxiliary heating and cooling equipment.

A solar chimney (or thermal chimney, in this context) is a passive solar ventilation system composed of a vertical shaft connecting the interior and exterior of a building. As the chimney warms, the air inside is heated, causing an updraft that pulls air through the building. Performance can be improved by using glazing and thermal mass materials in a way that mimics greenhouses.

Deciduous trees and plants have been promoted as a means of controlling solar heating and cooling. When planted on the southern side of a building in the northern hemisphere or the northern side in the southern hemisphere, their leaves provide shade during the summer, while the bare limbs allow light to pass during the winter. Since bare, leafless trees shade 1/3 to 1/2 of incident solar radiation, there is a balance between the benefits of summer shading and the corresponding loss of winter heating. In climates with significant heating loads, deciduous trees should not be planted on the Equator-facing side of a building because they will interfere with winter solar availability. They can, however, be used on the east and west sides to provide a degree of summer shading without appreciably affecting winter solar gain.

Main article: Solar cooker

Parabolic dish produces steam for cooking, in Auroville, India.

Solar cookers use sunlight for cooking, drying, and pasteurization. They can be grouped into three broad categories: box cookers, panel cookers, and reflector cookers. The simplest solar cooker is the box cooker first built by Horace de Saussure in 1767. A basic box cooker consists of an insulated container with a transparent lid. It can be used effectively with partially overcast skies and will typically reach temperatures of 90–150 °C (194–302 °F). Panel cookers use a reflective panel to direct sunlight onto an insulated container and reach temperatures comparable to box cookers. Reflector cookers use various concentrating geometries (dish, trough, Fresnel mirrors) to focus light on a cooking container. These cookers reach temperatures of 315 °C (599 °F) and above but require direct light to function properly and must be repositioned to track the Sun.

Process heat

Main articles: Solar pond, Salt evaporation pond, and Solar furnace

Solar concentrating technologies such as parabolic dish, trough and Scheffler reflectors can provide process heat for commercial and industrial applications. The first commercial system was the Solar Total Energy Project (STEP) in Shenandoah, Georgia, US where a field of 114 parabolic dishes provided 50% of the process heating, air conditioning and electrical requirements for a clothing factory. This grid-connected cogeneration system provided 400 kW of electricity plus thermal energy in the form of 401 kW steam and 468 kW chilled water, and had a one-hour peak load thermal storage. Evaporation ponds are shallow pools that concentrate dissolved solids through evaporation. The use of evaporation ponds to obtain salt from seawater is one of the oldest applications of solar energy. Modern uses include concentrating brine solutions used in leach mining and removing dissolved solids from waste streams.

Clothes lines, clotheshorses, and clothes racks dry clothes through evaporation by wind and sunlight without consuming electricity or gas. In some states of the United States legislation protects the "right to dry" clothes. Unglazed transpired collectors (UTC) are perforated sun-facing walls used for preheating ventilation air. UTCs can raise the incoming air temperature up to 22 °C (40 °F) and deliver outlet temperatures of 45–60 °C (113–140 °F). The short payback period of transpired collectors (3 to 12 years) makes them a more cost-effective alternative than glazed collection systems. As of 2003, over 80 systems with a combined collector area of 35,000 square metres (380,000 sq ft) had been installed worldwide, including an 860 m2 (9,300 sq ft) collector in Costa Rica used for drying coffee beans and a 1,300 m2 (14,000 sq ft) collector in Coimbatore, India, used for drying marigolds.[needs update]

Water treatment

Main articles: Solar still, Solar water disinfection, Solar desalination, and Solar Powered Desalination Unit

Solar water disinfection in Indonesia

Solar distillation can be used to make saline or brackish water potable. The first recorded instance of this was by 16th-century Arab alchemists. A large-scale solar distillation project was first constructed in 1872 in the Chilean mining town of Las Salinas. The plant, which had solar collection area of 4,700 m2 (51,000 sq ft), could produce up to 22,700 L (5,000 imp gal; 6,000 US gal) per day and operate for 40 years. Individual still designs include single-slope, double-slope (or greenhouse type), vertical, conical, inverted absorber, multi-wick, and multiple effect. These stills can operate in passive, active, or hybrid modes. Double-slope stills are the most economical for decentralized domestic purposes, while active multiple effect units are more suitable for large-scale applications.

Solar water disinfection (SODIS) involves exposing water-filled plastic polyethylene terephthalate (PET) bottles to sunlight for several hours. Exposure times vary depending on weather and climate from a minimum of six hours to two days during fully overcast conditions. It is recommended by the World Health Organization as a viable method for household water treatment and safe storage. Over two million people in developing countries use this method for their daily drinking water.

Solar energy may be used in a water stabilization pond to treat waste water without chemicals or electricity. A further environmental advantage is that algae grow in such ponds and consume carbon dioxide in photosynthesis, although algae may produce toxic chemicals that make the water unusable.

Molten salt technology

Molten salt can be employed as a thermal energy storage method to retain thermal energy collected by a solar tower or solar trough of a concentrated solar power plant so that it can be used to generate electricity in bad weather or at night. It was demonstrated in the Solar Two project from 1995 to 1999. The system is predicted to have an annual efficiency of 99%, a reference to the energy retained by storing heat before turning it into electricity, versus converting heat directly into electricity. The molten salt mixtures vary. The most extended mixture contains sodium nitrate, potassium nitrate and calcium nitrate. It is non-flammable and non-toxic, and has already been used in the chemical and metals industries as a heat-transport fluid. Hence, experience with such systems exists in non-solar applications.

The salt melts at 131 °C (268 °F). It is kept liquid at 288 °C (550 °F) in an insulated "cold" storage tank. The liquid salt is pumped through panels in a solar collector where the focused irradiance heats it to 566 °C (1,051 °F). It is then sent to a hot storage tank. This is so well insulated that the thermal energy can be usefully stored for up to a week.

When electricity is needed, the hot salt is pumped to a conventional steam-generator to produce superheated steam for a turbine/generator as used in any conventional coal, oil, or nuclear power plant. A 100-megawatt turbine would need a tank about 9.1 metres (30 ft) tall and 24 metres (79 ft) in diameter to drive it for four hours by this design.

Several parabolic trough power plants in Spain and solar power tower developer Solar Reserve use this thermal energy storage concept. The Solana Generating Station in the U.S. has six hours of storage by molten salt. The María Elena plant is a 400 MW thermo-solar complex in the northern Chilean region of Antofagasta employing molten salt technology.

Electricity production

These paragraphs are an excerpt from Solar power.[edit]

Solar power is the conversion of renewable energy from sunlight into electricity, either directly using photovoltaics (PV), indirectly using concentrated solar power, or a combination. Concentrated solar power systems use lenses or mirrors and solar tracking systems to focus a large area of sunlight into a small beam. Photovoltaic cells convert light into an electric current using the photovoltaic effect.

Photovoltaic’s were initially solely used as a source of electricity for small and medium-sized applications, from the calculator powered by a single solar cell to remote homes powered by an off-grid rooftop PV system. Commercial concentrated solar power plants were first developed in the 1980s. Since then, as the cost of solar electricity has fallen, grid-connected solar PV systems have grown more or less exponentially. Millions of installations and gigawatt-scale photovoltaic power stations have been and are being built. Solar PV has rapidly become an inexpensive, low-carbon technology.

The International Energy Agency said in 2021 that under its "Net Zero by 2050" scenario solar power would contribute about 20% of worldwide energy consumption, and solar would be the world's largest source of electricity. China has the most solar installations. In 2020, solar power generated 3.5% of the world's electricity, compared to under 3% the previous year. In 2020 the unsubsidisedlevelised cost of electricity for utility-scale solar power was around $36/MWh, and installation cost about a dollar per DC watt.

Photovoltaic

This section is an excerpt from Photovoltaic.[edit]

The Solar Settlement, a sustainable housing community project in Freiburg, Germany.

Photovoltaic SUDI shade is an autonomous and mobile station in France that provides energy for electric cars using solar energy.

Solar panels on the International Space Station

Photovoltaic (PV) is the conversion of light into electricity using semiconducting materials that exhibit the photovoltaic effect, a phenomenon studied in physics, photochemistry, and electrochemistry. The photovoltaic effect is commercially utilized for electricity generation and as photo sensors.

A photovoltaic system employs solar modules, each comprising a number of solar cells, which generate electrical power. PV installations may be ground-mounted, rooftop-mounted, wall-mounted or floating. The mount may be fixed or use a solar tracker to follow the sun across the sky.

Some hope that photovoltaic technology will produce enough affordable sustainable energy to help mitigate global warming caused by CO2. Solar PV has specific advantages as an energy source: once installed, its operation generates no pollution and no greenhouse gas emissions, it shows simple scalability in respect of power needs and silicon has large availability in the Earth's crust, although other materials required in PV system manufacture such as silver will eventually constrain further growth in the technology. Other major constraints identified are competition for land use and lack of labor in making funding applications. The use of PV as a main source requires energy storage systems or global distribution by high-voltage direct current power lines causing additional costs, and also has a number of other specific disadvantages such as unstable power generation and the requirement for power companies to compensate for too much solar power in the supply mix by having more reliable conventional power supplies in order to regulate demand peaks and potential undersupply. Production and installation does cause pollution and greenhouse gas emissions and there are no viable systems for recycling the panels once they are at the end of their lifespan after 10 to 30 years.

Photovoltaic systems have long been used in specialized applications as stand-alone installations and grid-connected PV systems have been in use since the 1990s.[65] Photovoltaic modules were first mass-produced in 2000, when German environmentalists and the Eurosolar organization received government funding for a ten thousand roof program.

Decreasing costs has allowed PV to grow as an energy source. This has been partially driven by massive Chinese government investment in developing solar production capacity since 2000, and achieving economies of scale. Much of the price of production is from the key component polysilicon, and most of the world supply is produced in China, especially in Xinjiang. Beside the subsidies, the low prices of solar panels in the 2010s has been achieved through the low price of energy from coal and cheap labor costs in Xinjiang, as well as improvements in manufacturing technology and efficiency. Advances in technology and increased manufacturing scale have also increased the efficiency of photovoltaic installations. Net metering and financial incentives, such as preferential feed-in tariffs for solar-generated electricity, have supported solar PV installations in many countries. Panel prices dropped by a factor of 4 between 2004 and 2011. Module prices dropped 90% of over the 2010s, but began increasing sharply in 2021.

In 2019, worldwide installed PV capacity increased to more than 635 gigawatts (GW) covering approximately two percent of global electricity demand. After hydro and wind powers, PV is the third renewable energy source in terms of global capacity. In 2019 the International Energy Agency expected a growth by 700 - 880 GW from 2019 to 2024. In some instances, PV has offered the cheapest source of electrical power in regions with a high solar potential, with a bid for pricing as low as 0.01567 US$/kWh in Qatar in 2020.

Concentrated solar power

Main article: Concentrated solar power

Concentrating Solar Power (CSP) systems use lenses or mirrors and tracking systems to focus a large area of sunlight into a small beam. The concentrated heat is then used as a heat source for a conventional power plant. A wide range of concentrating technologies exists; the most developed are the parabolic trough, the concentrating linear fresnel reflector, the Stirling dish, and the solar power tower. Various techniques are used to track the Sun and focus light. In all of these systems, a working fluid is heated by the concentrated sunlight, and is then used for power generation or energy storage. Designs need to account for the risk of a dust storm, hail, or another extreme weather event that can damage the fine glass surfaces of solar power plants. Metal grills would allow a high percentage of sunlight to enter the mirrors and solar panels while also preventing most damage.

Architecture and urban planning

Main articles: Passive solar building design and Urban heat island

Darmstadt University of Technology, Germany, won the 2007 Solar Decathlon in Washington, DC with this passive house designed for humid and hot subtropical climate.

Sunlight has influenced building design since the beginning of architectural history. Advanced solar architecture and urban planning methods were first employed by the Greeks and Chinese, who oriented their buildings toward the south to provide light and warmth.

The common features of passive solar architecture are orientation relative to the Sun, compact proportion (a low surface area to volume ratio), selective shading (overhangs) and thermal mass. When these features are tailored to the local climate and environment, they can produce well-lit spaces that stay in a comfortable temperature range. Socrates' Megaron House is a classic example of passive solar design. The most recent approaches to solar design use computer modeling tying together solar lighting, heating and ventilation systems in an integrated solar design package. Active solar equipment such as pumps, fans, and switchable windows can complement passive design and improve system performance.

Urban heat islands (UHI) are metropolitan areas with higher temperatures than that of the surrounding environment. The higher temperatures result from increased absorption of solar energy by urban materials such as asphalt and concrete, which have lower albedos and higher heat capacities than those in the natural environment. A straightforward method of counteracting the UHI effect is to paint buildings and roads white and to plant trees in the area. Using these methods, a hypothetical "cool communities" program in Los Angeles has projected that urban temperatures could be reduced by approximately 3 °C at an estimated cost of US$1 billion, giving estimated total annual benefits of US$530 million from reduced air-conditioning costs and healthcare savings.

Agriculture and horticulture

Greenhouses like these in the Westland municipality of the Netherlands grow vegetables, fruits and flowers.

Agriculture and horticulture seek to optimize the capture of solar energy to optimize the productivity of plants. Techniques such as timed planting cycles, tailored row orientation, staggered heights between rows and the mixing of plant varieties can improve crop yields. While sunlight is generally considered a plentiful resource, the exceptions highlight the importance of solar energy to agriculture. During the short growing seasons of the Little Ice Age, French and English farmers employed fruit walls to maximize the collection of solar energy. These walls acted as thermal masses and accelerated ripening by keeping plants warm. Early fruit walls were built perpendicular to the ground and facing south, but over time, sloping walls were developed to make better use of sunlight. In 1699, Nicolas Fatio de Duillier even suggested using a tracking mechanism which could pivot to follow the Sun. Applications of solar energy in agriculture aside from growing crops include pumping water, drying crops, brooding chicks and drying chicken manure.

More recently the technology has been embraced by vintners, who use the energy generated by solar panels to power grape presses.

Greenhouses convert solar light to heat, enabling year-round production and the growth (in enclosed environments) of specialty crops and other plants not naturally suited to the local climate. Primitive greenhouses were first used during Roman times to produce cucumbers year-round for the Roman emperor Tiberius. The first modern greenhouses were built in Europe in the 16th century to keep exotic plants brought back from explorations abroad. Greenhouses remain an important part of horticulture today. Plastic transparent materials have also been used to similar effect in polytonal and row covers.

Transport

Main articles: Solar vehicle, Solar-charged vehicle, Electric boat, and solar balloon

Winner of the 2013 World Solar Challenge in Australia

Solar electric aircraft circumnavigating the globe in 2015

Development of a solar-powered car has been an engineering goal since the 1980s. The World Solar Challenge is a biannual solar-powered car race, where teams from universities and enterprises compete over 3,021 kilometres (1,877 mi) across central Australia from Darwin to Adelaide. In 1987, when it was founded, the winner's average speed was 67 kilometres per hour (42 mph) and by 2007 the winner's average speed had improved to 90.87 kilometres per hour (56.46 mph). The North American Solar Challenge and the planned South African Solar Challenge are comparable competitions that reflect an international interest in the engineering and development of solar powered vehicles.

Some vehicles use solar panels for auxiliary power, such as for air conditioning, to keep the interior cool, thus reducing fuel consumption.

In 1975, the first practical solar boat was constructed in England. By 1995, passenger boats incorporating PV panels began appearing and are now used extensively. In 1996, Kenichi Horie made the first solar-powered crossing of the Pacific Ocean, and the Sun21 catamaran made the first solar-powered crossing of the Atlantic Ocean in the winter of 2006–2007. There were plans to circumnavigate the globe in 2010.

In 1974, the unmanned AstroFlight Sunrise airplane made the first solar flight. On 29 April 1979, the Solar Riser made the first flight in a solar-powered, fully controlled, man-carrying flying machine, reaching an altitude of 40 ft (12 m). In 1980, the Gossamer Penguin made the first piloted flights powered solely by photovoltaics. This was quickly followed by the Solar Challenger which crossed the English Channel in July 1981. In 1990 Eric Scott Raymond in 21 hops flew from California to North Carolina using solar power. Developments then turned back to unmanned aerial vehicles (UAV) with the Pathfinder (1997) and subsequent designs, culminating in the Helios which set the altitude record for a non-rocket-propelled aircraft at 29,524 metres (96,864 ft) in 2001. The Zephyr, developed by BAE Systems, is the latest in a line of record-breaking solar aircraft, making a 54-hour flight in 2007, and month-long flights were envisioned by 2010.[100] As of 2016, Solar Impulse, an electric aircraft, is currently circumnavigating the globe. It is a single-seat plane powered by solar cells and capable of taking off under its own power. The design allows the aircraft to remain airborne for several days.

A solar balloon is a black balloon that is filled with ordinary air. As sunlight shines on the balloon, the air inside is heated and expands, causing an upward buoyancy force, much like an artificially heated hot air balloon. Some solar balloons are large enough for human flight, but usage is generally limited to the toy market as the surface-area to payload-weight ratio is relatively high.

Fuel production

Concentrated solar panels are getting a power boost. Pacific Northwest National Laboratory (PNNL) will be testing a new concentrated solar power system – one that can help natural gas power plants reduce their fuel usage by up to 20 percent.[needs update]

Main articles: Solar chemical, solar fuel, and Artificial photosynthesis

Solar chemical processes use solar energy to drive chemical reactions. These processes offset energy that would otherwise come from a fossil fuel source and can also convert solar energy into storable and transportable fuels. Solar induced chemical reactions can be divided into thermochemical or photochemical. A variety of fuels can be produced by artificial photosynthesis. The multielectron catalytic chemistry involved in making carbon-based fuels (such as methanol) from reduction of carbon dioxide is challenging; a feasible alternative is hydrogen production from protons, though use of water as the source of electrons (as plants do) requires mastering the multielectron oxidation of two water molecules to molecular oxygen. Some have envisaged working solar fuel plants in coastal metropolitan areas by 2050 – the splitting of seawater providing hydrogen to be run through adjacent fuel-cell electric power plants and the pure water by-product going directly into the municipal water system.

Hydrogen production technologies have been a significant area of solar chemical research since the 1970s. Aside from electrolysis driven by photovoltaic or photochemical cells, several thermo chemical processes have also been explored. One such route uses concentrators to split water into oxygen and hydrogen at high temperatures (2,300–2,600 °C or 4,200–4,700 °F). Another approach uses the heat from solar concentrators to drive the steam reformation of natural gas thereby increasing the overall hydrogen yield compared to conventional reforming methods.[108] Thermo chemical cycles characterized by the decomposition and regeneration of reactants present another avenue for hydrogen production. The Sol zinc process under development at the Weizmann Institute of Science uses a 1 MW solar furnace to decompose zinc oxide (ZnO) at temperatures above 1,200 °C (2,200 °F). This initial reaction produces pure zinc, which can subsequently be reacted with water to produce hydrogen.

Energy storage methods

Main articles: Energy storage, Seasonal thermal energy storage, Phase change material, Grid energy storage, and V2G

Thermal energy storage. The Andasol CSP plant uses tanks of molten salt to store solar energy.

Thermal mass systems can store solar energy in the form of heat at domestically useful temperatures for daily or interpersonal durations. Thermal storage systems generally use readily available materials with high specific heat capacities such as water, earth and stone. Well-designed systems can lower peak demand, shift time-of-use to off-peak hours and reduce overall heating and cooling requirements.

Phase change materials such as paraffin wax and Glauber's salt are another thermal storage medium. These materials are inexpensive, readily available, and can deliver domestically useful temperatures (approximately 64 °C or 147 °F). The "Dover House" (in Dover, Massachusetts) was the first to use a Glauber's salt heating system, in 1948. Solar energy can also be stored at high temperatures using molten salts. Salts are an effective storage medium because they are low-cost, have a high specific heat capacity, and can deliver heat at temperatures compatible with conventional power systems. The Solar Two project used this method of energy storage, allowing it to store 1.44 terajoules (400,000 kWh) in its 68 m³ storage tank with an annual storage efficiency of about 99%.

Off-grid PV systems have traditionally used rechargeable batteries to store excess electricity. With grid-tied systems, excess electricity can be sent to the transmission grid, while standard grid electricity can be used to meet shortfalls. Net metering programs give household systems credit for any electricity they deliver to the grid. This is handled by 'rolling back' the meter whenever the home produces more electricity than it consumes. If the net electricity use is below zero, the utility then rolls over the kilowatt-hour credit to the next month. Other approaches involve the use of two meters, to measure electricity consumed vs. electricity produced. This is less common due to the increased installation cost of the second meter. Most standard meters accurately measure in both directions, making a second meter unnecessary.

Pumped-storage hydroelectricity stores energy in the form of water pumped when energy is available from a lower elevation reservoir to a higher elevation one. The energy is recovered when demand is high by releasing the water, with the pump becoming a hydroelectric power generator.

Development, deployment and economics

Participants in a workshop on sustainable development inspect solar panels at Monterrey Institute of Technology and Higher Education, Mexico City on top of a building on campus.

Further information: Deployment of solar power to energy grids

See also: Cost of electricity by source and Renewable energy by country

Cost development of solar PV modules per watt

Beginning with the surge in coal use, which accompanied the Industrial Revolution, energy consumption has steadily transitioned from wood and biomass to fossil fuels. The early development of solar technologies starting in the 1860s was driven by an expectation that coal would soon become scarce. However, development of solar technologies stagnated in the early 20th century in the face of the increasing availability, economy, and utility of coal and petroleum.

The 1973 oil embargo and 1979 energy crisis caused a reorganization of energy policies around the world. It brought renewed attention to developing solar technologies. Deployment strategies focused on incentive programs such as the Federal Photovoltaic Utilization Program in the US and the Sunshine Program in Japan. Other efforts included the formation of research facilities in the US (SERI, now NREL), Japan (NEDO), and Germany (Fraunhofer Institute for Solar Energy Systems ISE).

Commercial solar water heaters began appearing in the United States in the 1890s. These systems saw increasing use until the 1920s but were gradually replaced by cheaper and more reliable heating fuels. As with photovoltaic, solar water heating attracted renewed attention as a result of the oil crises in the 1970s, but interest subsided in the 1980s due to falling petroleum prices. Development in the solar water heating sector progressed steadily throughout the 1990s, and annual growth rates have averaged 20% since 1999. Although generally underestimated, solar water heating and cooling is by far the most widely deployed solar technology with an estimated capacity of 154 GW as of 2007.

The International Energy Agency has said that solar energy can make considerable contributions to solving some of the most urgent problems the world now faces.

The development of affordable, inexhaustible, and clean solar energy technologies will have huge longer-term benefits. It will increase countries' energy security through reliance on an indigenous, inexhaustible, and mostly import-independent resource, enhance sustainability, reduce pollution, lower the costs of mitigating climate change, and keep fossil fuel prices lower than otherwise. These advantages are global. Hence the additional costs of the incentives for early deployment should be considered learning investments; they must be wisely spent and need to be widely shared.

In 2011, a report by the International Energy Agency found that solar energy technologies such as photovoltaic, solar hot water, and concentrated solar power could provide a third of the world's energy by 2060 if politicians commit to limiting climate change and transitioning to renewable energy. The energy from the Sun could play a key role in de-carbonizing the global economy alongside improvements in energy efficiency and imposing costs on greenhouse gas emitters. "The strength of solar is the incredible variety and flexibility of applications, from small scale to big scale".

We have proved ... that after our stores of oil and coal are exhausted the human race can receive unlimited power from the rays of the Sun.

— Frank Shuman, The New York Times, 2 July 1916.

In 2021 Lazard estimated the levelized cost of new build unsubsidized utility scale solar electricity at less than 37 dollars[clarification needed] and existing coal-fired power above that amount. The 2021 report also said that new solar was also cheaper than new gas-fired power, but not generally existing gas power.

SOFTWARE DESCRIPTION

The Arduino Nano is a small, complete, and breadboard-friendly board based on the ATmega328P. It offers the same connectivity and specs of the UNO board in a smaller form factor.

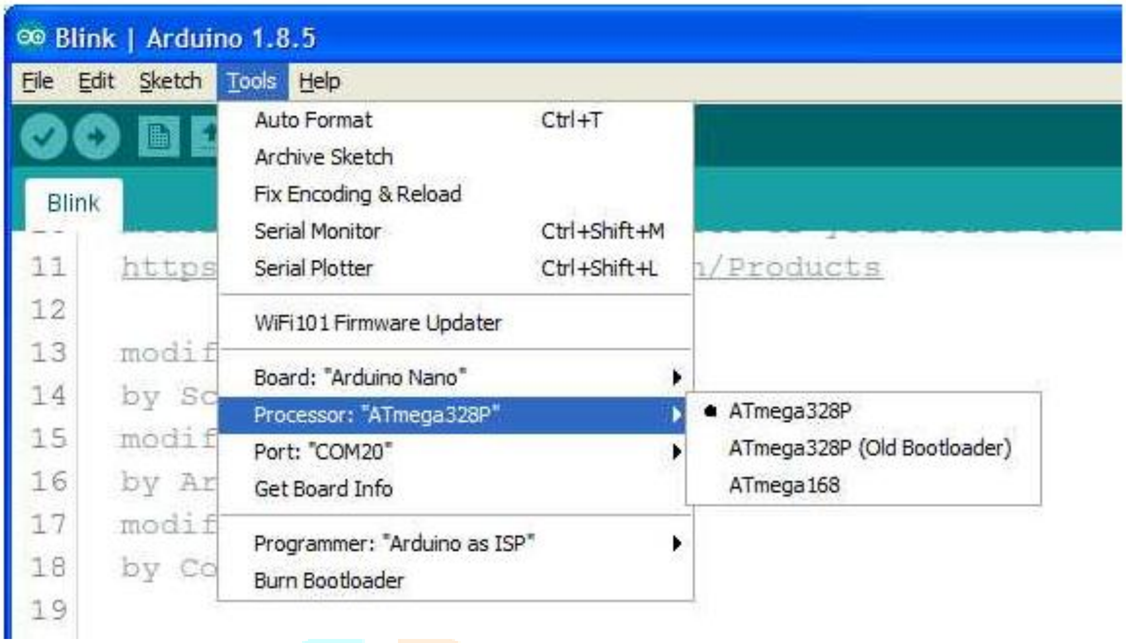
The Arduino Nano is programmed using the Arduino Software (IDE), our Integrated Development Environment common to all our boards

Use your Arduino Nano on the Arduino Desktop IDE

If you want to program your Arduino Nano while offline you need to install the Arduino Desktop IDE To connect the Arduino Nano to your computer, you'll need a Mini-B USB cable. This also provides power to the board, as indicated by the blue LED (which is on the bottom of the Arduino Nano 2.x and the top of the Arduino Nano.

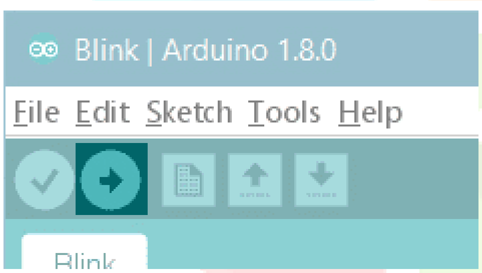
Select your board type and port

Select **Tools > Board > Arduino AVR Boards > Arduino Nano**.



Upload and Run your first Sketch

To upload the sketch to the Arduino Nano, click the **Upload** button in the upper left to load and run the sketch on your board:



Wait a few seconds - you should see the RX and TX LEDs on the board flashing. If the upload is successful, the message "Done uploading." will appear in the status bar

Conclusion

Due to the shortage of inexhaustible resources, and environmental problems caused by the emissions, traditional power generation based on fossil fuels are generally considered to be unsustainable in the long term. As a result, many efforts are made worldwide for introducing more renewable energies in the energy mix.

Renewable energy resources are innovative options for electricity generation and their potential is enormous as they can, in principle, meet the world's energy demand many times over. This paper presents an up-to-date and detailed current status and future projection of major renewable energy resources, as well as their benefits, growth, investment and deployment. In addition, the role of power electronics converters as enabling technology for using different renewable energy resources is illustrated. Furthermore, integration of renewable energy resources into smart grid system, keeping in mind all challenges, will help in meeting ever-increasing electric energy demands effectively.

REFERENCES:

[1] A. Qazi et al., "Towards Sustainable Energy: A Systematic Review of Renewable Energy Sources, Technologies, and Public Opinions," IEEE Access, vol. 7, pp. 6383763851, 2019.

[2] K.Saritha Rani, ”Environmental Effects Of Burning Fossil Fuels’, Journal of Chemical and Pharmaceutical Sciences, Special Issue 3: October 2014.

[3] A. Jahid, M. K. H. Monju, M. E. Hossain and M. F. Hossain, "Renewable Energy Assisted Cost Aware Sustainable Off-Grid Base Stations with Energy Cooperation," IEEE Access, vol. 6, pp. 60900-60920, 2018. [4] BP Statistical Review of World Energy, 68th edition, June, 2019, pp. 1- 64.

[5] Renewable Capacity Statistics,International Renewable Energy Agency, March, 2019, pp.1-60.

[6] Rajasekhar Gorthi, K. Giribabu, Dr. S. Shiva Prasad: Simulink model for cost-effective analysis at Hybrid System: International Journal of Modern Engineering Research (volume:4, Issue:2, Feb 2014)

[7] Dr. Rajesh Thipparaju, Suddala Janardhan, Rajashekar Gorthi: PV array based BLDC motor driven water pump using solar Technology: The International journal of analytical and experimental model analysis (volume:12, Issue:7, July 2020)

[8] Renewables Information, International Energy Agency, August 2019. [9] Wind Power Capacity Worldwide Reaches 597 GW, 50,1 GW added in 2018, World Wind Energy Agency, 25 Feb, 2019. [10] Clean Energy Australia Report 2019, Clean Energy Council, 4 April, 2019, pp. 1- 82.