

DISTRIBUTED REALTIME IOT FOR AUTONOMOUS VEHICLES

ABSTRACT

Artificial Intelligence (AI) is a machine intelligence tool providing enormous possibilities for smart industrial revolution. Internet of Things (IoT) is the axiom of industry 4.0 revolution, including a worldwide infrastructure for collecting and processing of the data/information from storage, actuation, sensing, advanced services and communication technologies. The combination of high-speed, resilient, low-latency connectivity, and technologies of AI and IoT will enable the transformation towards fully smart Autonomous Vehicle (AV) that illustrate the complementary between real world and digital knowledge for industry 4.0. The purpose of this article is to examine how the latest approaches in AI and IoT can assist in the search for the Autonomous Vehicles. It has been shown that human errors are the source of 90% of automotive crashes, and the safest drivers drive ten times better than the average (Wu et al. Accident Analysis and Prevention, 117, 21–31, 2018). The automated vehicle safety is significant, and users are requiring 1000 times smaller acceptable risk level. Some of the incredible benefits of AVs are: (1) increasing vehicle safety, (2) reduction of accidents, (3) reduction of fuel consumption, (4) releasing of driver time and business opportunities, (5) new potential market opportunities, and (6) reduced emissions and dust particles. However, AVs must use large-scale data/information from their sensors and devices.

INTRODUCTION

Imagine a bus carrying passengers on its own, driving better than any bus driver could do. Imagine a taxi, which can be called through an app installed in your smartphone, which carries you to your destination as fast and economically for you as possible. Imagine vehicles dedicating to agriculture on their own and without having to rest. Imagine vehicles travelling by themselves, mapping all the places they go by, not only on earth, but also on any rock out there in the universe. Imagine that your own car drives for you and you don't need to care about, while it drives better than you could ever do. Imagine the possibilities in a world where the vehicles are autonomously driven. We are about to reach to that future, a future in which our elder and disabled loved ones will be able to maintain their independence, where time spent commuting will be time spent doing what you want to do and where deaths from traffic accidents (over 2 million worldwide every year) will be reduced dramatically, since 94% of the accidents are due to human error. Autonomous vehicles don't drink alcohol nor take drugs, they are never tired or sick, they never take medicines, they never lose their concentration or talk by phone, they know how to drive since the first moment and don't need to learn, they never act recklessly when driving. On the other hand, they will drive much more smoothly, they will pollute less and, if they have an accident, they will ask for help autonomously

CHAPTER 2: EMBEDDED SYSTEMS

2.1 Embedded Systems:

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

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

Since the embedded system is dedicated to specific tasks, design engineers can optimize it to reduce the size and cost of the product and increase the reliability and performance. Some embedded systems are mass-produced, benefiting from economies of scale.

Physically embedded systems range from portable devices such as digital watches and MP3 players, to large stationary installations like traffic lights, factory controllers, or the systems controlling nuclear power plants. Complexity varies from low, with a single microcontroller chip, to very high with multiple units, peripherals and networks mounted inside a large chassis or enclosure.

In general, "embedded system" is not a strictly definable term, as most systems have some element of extensibility or programmability. For example, handheld computers share some elements with embedded systems such as the operating systems and microprocessors which power them, but they allow different applications to be loaded and peripherals to be connected. Moreover, even systems which don't expose programmability as a primary feature generally need to support software updates. On a continuum from "general purpose" to "embedded", large

application systems will have subcomponents at most points even if the system as a whole is "designed to perform one or a few dedicated functions", and is thus appropriate to call "embedded". A modern example of embedded system is shown in fig: 2.1.

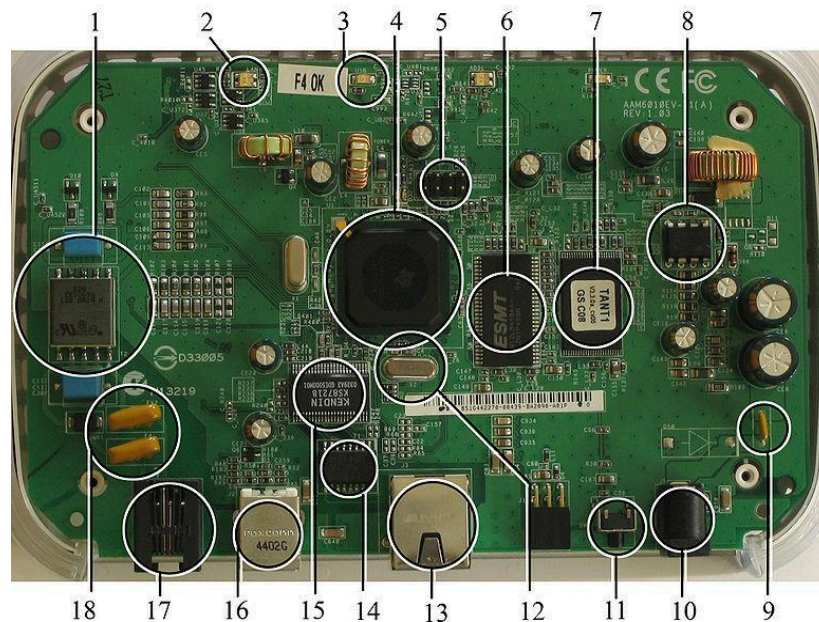


Fig 2.1:A modern example of embedded system

Labeled parts include microprocessor (4), RAM (6), flash memory (7). Embedded systems programming is not like normal PC programming. In many ways, programming for an embedded system is like programming PC 15 years ago. The hardware for the system is usually chosen to make the device as cheap as possible. Spending an extra dollar a unit in order to make things easier to program can cost millions. Hiring a programmer for an extra month is cheap in comparison. This means the programmer must make do with slow processors and low memory, while at the same time battling a need for efficiency not seen in most PC applications. Below is a list of issues specific to the embedded field.

2.1.1 History:

In the earliest years of computers in the 1930–40s, computers were sometimes dedicated to a single task, but were far too large and expensive for most kinds of tasks performed by embedded computers of today. Over time however, the concept of programmable

controller evolved from traditional electromechanical sequencers, via solid state devices, to the use of computer technology.

One of the first recognizably modern embedded systems was the Apollo Guidance Computer, developed by Charles Stark Draper at the MIT Instrumentation Laboratory. At the project's inception, the Apollo guidance computer was considered the riskiest item in the Apollo project as it employed the then newly developed monolithic integrated circuits to reduce the size and weight. An early mass-produced embedded system was the Autonetics D-17 guidance computer for the Minuteman missile, released in 1961. It was built from transistor logic and had a hard disk for main memory. When the Minuteman II went into production in 1966, the D-17 was replaced with a new computer that was the first high-volume use of integrated circuits.

2.1.2 Tools:

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

Debugging tools are another issue. Since you can't always run general programs on your embedded processor, you can't always run a debugger on it. This makes fixing your program difficult. Special hardware such as JTAG ports can overcome this issue in part. However, if you stop on a breakpoint when your system is controlling real world hardware (such as a motor), permanent equipment damage can occur. As a result, people doing embedded programming quickly become masters at using serial IO channels and error message style debugging.

2.1.3 Resources:

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

optimize only when necessary. Of course, normal profilers won't work well, due to the same reason debuggers don't work well.

Memory is also an issue. For the same cost savings reasons, embedded systems usually have the least memory they can get away with. That means their algorithms must be memory efficient (unlike in PC programs, you will frequently sacrifice processor time for memory, rather than the reverse). It also means you can't afford to leak memory. Embedded applications generally use deterministic memory techniques and avoid the default "new" and "malloc" functions, so that leaks can be found and eliminated more easily. Other resources programmers expect may not even exist. For example, most embedded processors do not have hardware FPUs (Floating-Point Processing Unit). These resources either need to be emulated in software, or avoided altogether.

2.1.4 Real Time Issues:

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

2.2 Need For Embedded Systems:

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

2.2.1 Debugging:

Embedded debugging may be performed at different levels, depending on the facilities available. From simplest to most sophisticated they can be roughly grouped into the following areas:

- Interactive resident debugging, using the simple shell provided by the embedded operating system (e.g. Forth and Basic)
- External debugging using logging or serial port output to trace operation using either a monitor in flash or using a debug server like the Remedy Debugger which even works for heterogeneous multi core systems.
- An in-circuit debugger (ICD), a hardware device that connects to the microprocessor via a JTAG or Nexus interface. This allows the operation of the microprocessor to be controlled externally, but is typically restricted to specific debugging capabilities in the processor.
- An in-circuit emulator replaces the microprocessor with a simulated equivalent, providing full control over all aspects of the microprocessor.
- A complete emulator provides a simulation of all aspects of the hardware, allowing all of it to be controlled and modified and allowing debugging on a normal PC.
- Unless restricted to external debugging, the programmer can typically load and run software through the tools, view the code running in the processor, and start or stop its operation. The view of the code may be as assembly code or source-code.

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

2.2.2 Reliability:

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

Specific reliability issues may include:

- The system cannot safely be shut down for repair, or it is too inaccessible to repair. Examples include space systems, undersea cables, navigational beacons, bore-hole systems, and automobiles.
- The system must be kept running for safety reasons. "Limp modes" are less tolerable. Often backup s are selected by an operator. Examples include aircraft navigation, reactor control systems, safety-critical chemical factory controls, train signals, engines on single-engine aircraft.
- The system will lose large amounts of money when shut down: Telephone switches, factory controls, bridge and elevator controls, funds transfer and market making, automated sales and service.

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

- Watchdog timer that resets the computer unless the software periodically notifies the watchdog
- Subsystems with redundant spares that can be switched over to
- software "limp modes" that provide partial function
- Designing with a Trusted Computing Base (TCB) architecture[6] ensures a highly secure & reliable system environment
- An Embedded Hypervisor is able to provide secure encapsulation for any subsystem component, so that a compromised software component cannot interfere with other subsystems, or privileged-level system software. This encapsulation keeps faults from propagating from one subsystem to another, improving reliability. This may also allow a subsystem to be automatically shut down and restarted on fault detection.
- Immunity Aware Programming

2.3 Explanation of Embedded Systems:

2.3.1 Software Architecture:

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

- **Simple Control Loop:**

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

- **Interrupt Controlled System:**

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

Usually these kinds of systems run a simple task in a main loop also, but this task is not very sensitive to unexpected delays. Sometimes the interrupt handler will add longer tasks to a queue structure. Later, after the interrupt handler has finished, these tasks are executed by the main loop. This method brings the system close to a multitasking kernel with discrete processes.

- **Cooperative Multitasking:**

A non-preemptive multitasking system is very similar to the simple control loop scheme, except that the loop is hidden in an API. The programmer defines a series of tasks, and each task gets its own environment to “run” in. When a task is idle, it calls an idle routine, usually called “pause”, “wait”, “yield”, “nop” (stands for no operation), etc. The advantages and disadvantages are very similar to the control loop, except that adding new software is easier, by simply writing a new task, or adding to the queue-interpreter.

- **Primitive Multitasking:**

In this type of system, a low-level piece of code switches between tasks or threads based on a timer (connected to an interrupt). This is the level at which the system is generally considered to have an "operating system" kernel. Depending on how much functionality is required, it introduces more or less of the complexities of managing multiple tasks running conceptually in parallel.

As any code can potentially damage the data of another task (except in larger systems using an MMU) programs must be carefully designed and tested, and access to shared data must be controlled by some synchronization strategy, such as message queues, semaphores or a non-blocking synchronization scheme.

Because of these complexities, it is common for organizations to buy a real-time operating system, allowing the application programmers to concentrate on device functionality rather than operating system services, at least for large systems; smaller systems often cannot afford the overhead associated with a generic real time system, due to limitations regarding memory size, performance, and/or battery life.

- **Microkernels And Exokernels:**

A microkernel is a logical step up from a real-time OS. The usual arrangement is that the operating system kernel allocates memory and switches the CPU to different threads of execution. User mode processes implement major functions such as file systems, network interfaces, etc.

In general, microkernels succeed when the task switching and intertask communication is fast, and fail when they are slow. Exokernels communicate efficiently by normal subroutine calls. The hardware and all the software in the system are available to, and extensible by application programmers. Based on performance, functionality, requirement the embedded systems are divided into three categories:

2.3.2 Stand Alone Embedded System:

These systems takes the input in the form of electrical signals from transducers or commands from human beings such as pressing of a button etc., process them and produces

desired output. This entire process of taking input, processing it and giving output is done in standalone mode. Such embedded systems comes under stand alone embedded systems

Eg: microwave oven, air conditioner etc..

2.3.3 Real-time embedded systems:

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

- Hard Real-time embedded systems:

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

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

- Soft Real Time embedded systems:

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

2.3.4 Network communication embedded systems:

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

Eg:

- Consider a web camera that is connected to the computer with internet can be used to spread communication like sending pictures, images, videos etc., to another computer with internet connection throughout anywhere in the world.

- Consider a web camera that is connected at the door lock.

Whenever a person comes near the door, it captures the image of a person and sends to the desktop of your computer which is connected to internet. This gives an alerting message with image on to the desktop of your computer, and then you can open the door lock just by clicking the mouse. Fig: 2.2 show the network communications in embedded systems.



Fig 2.2: Network communication embedded systems

2.3.5 Different types of processing units:

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

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

- Microprocessors are more powerful than microcontrollers. They are used in major applications with a number of tasking requirements. But the microprocessor requires many external components like memory, serial communication, hard disk, input output ports etc..., so the power consumption is also very high when compared to microcontrollers.
- Digital signal processing is used mainly for the applications that particularly involved with processing of signals

2.4 APPLICATIONS OF EMBEDDED SYSTEMS:

2.4.1 Consumer applications:

At home we use a number of embedded systems which include microwave oven, remote control, vcd players, dvd players, camera etc....



Fig2.3: Automatic coffee makes equipment

2.4.2 Office automation:

We use systems like fax machine, modem, printer etc...



Fig2.4: Fax machine



Fig2.5: Printing machine

2.4.3. Industrial automation:

Today a lot of industries are using embedded systems for process control. In industries we design the embedded systems to perform a specific operation like monitoring temperature, pressure, humidity ,voltage, current etc., and basing on these monitored levels we do control other devices, we can send information to a centralized monitoring station.



Fig2.6: Vehicle

In critical industries where human presence is avoided there we can use vehicles which are programmed to do a specific operation.

2.4.5 Computer networking:

Embedded systems are used as bridges routers etc..



Fig2.7: Computer networking

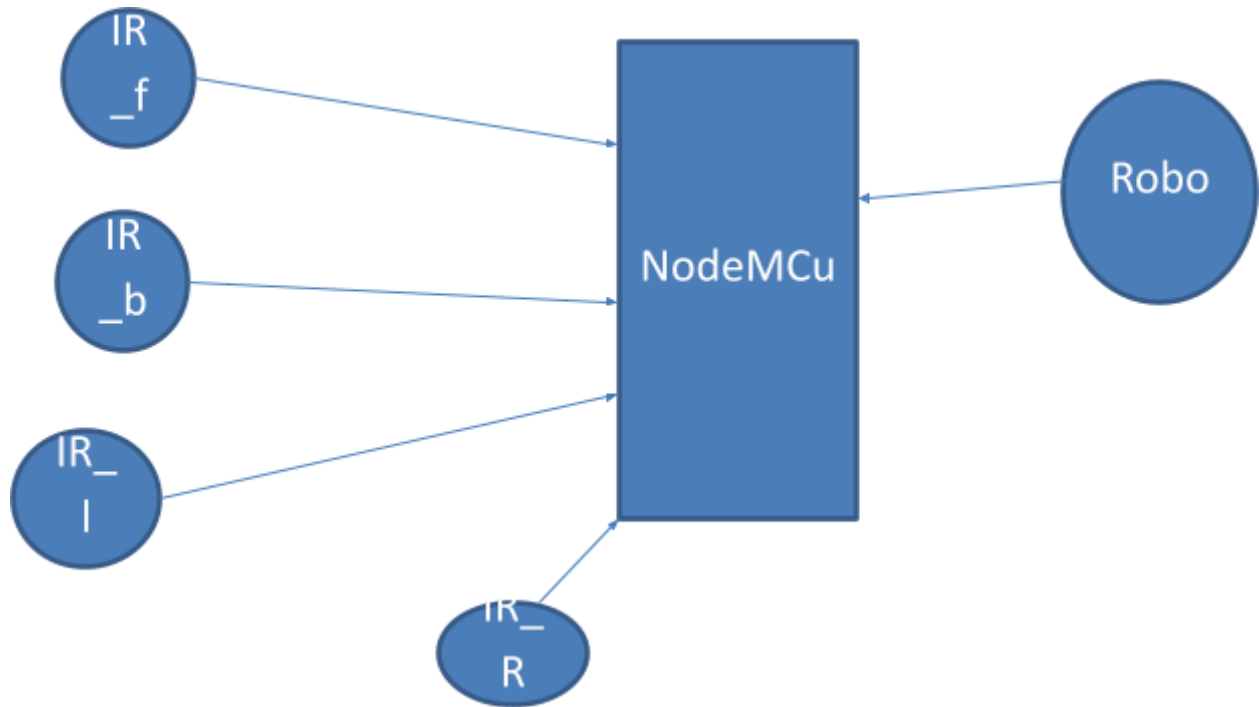
2.4.6 Tele communications:

Cell phones, web cameras etc.



Fig2.8: Cell Phone Fig2.9: Web camera

BLOCK DIAGRAM



POWER SUPPLY

All digital circuits require regulated power supply. In this article we are going to learn how to get a regulated positive supply from the mains supply.

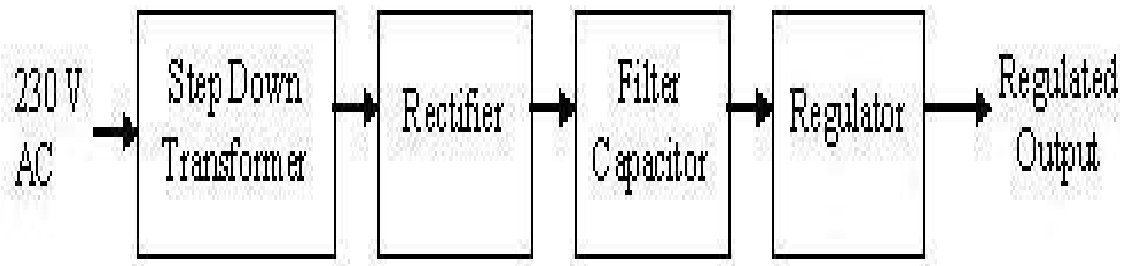
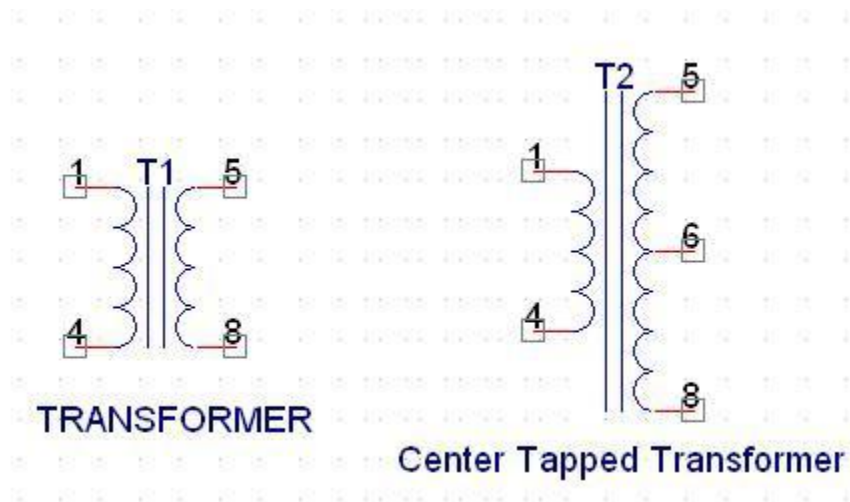


Figure 1 shows the basic block diagram of a fixed regulated power supply. Let us go through each block.

2.2.1 TRANSFORMER



A transformer consists of two coils also called as “WINDINGS” namely PRIMARY & SECONDARY.

They are linked together through inductively coupled electrical conductors also called as CORE. A changing current in the primary causes a change in the Magnetic Field in the core & this in turn induces an alternating voltage in the secondary coil. If load is applied to the secondary then an alternating current will flow through the load. If we consider an ideal condition then all the energy from the primary circuit will be transferred to the secondary circuit through the magnetic field.

$$P_{\text{primary}} = P_{\text{secondary}}$$

So

$$I_p V_p = I_s V_s$$

The secondary voltage of the transformer depends on the number of turns in the Primary as well as in the secondary.

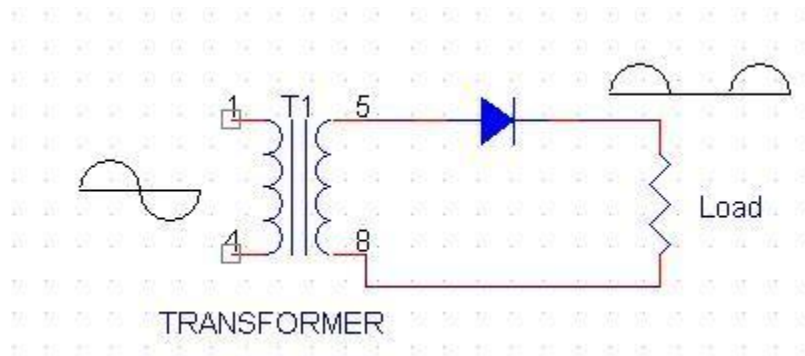
$$\frac{V_s}{V_p} = \frac{N_s}{N_p}$$

2.2.2 Rectifier

A rectifier is a device that converts an AC signal into DC signal. For rectification purpose we use a diode, a diode is a device that allows current to pass only in one direction i.e. when the anode of the diode is positive with respect to the cathode also called as forward biased condition & blocks current in the reversed biased condition.

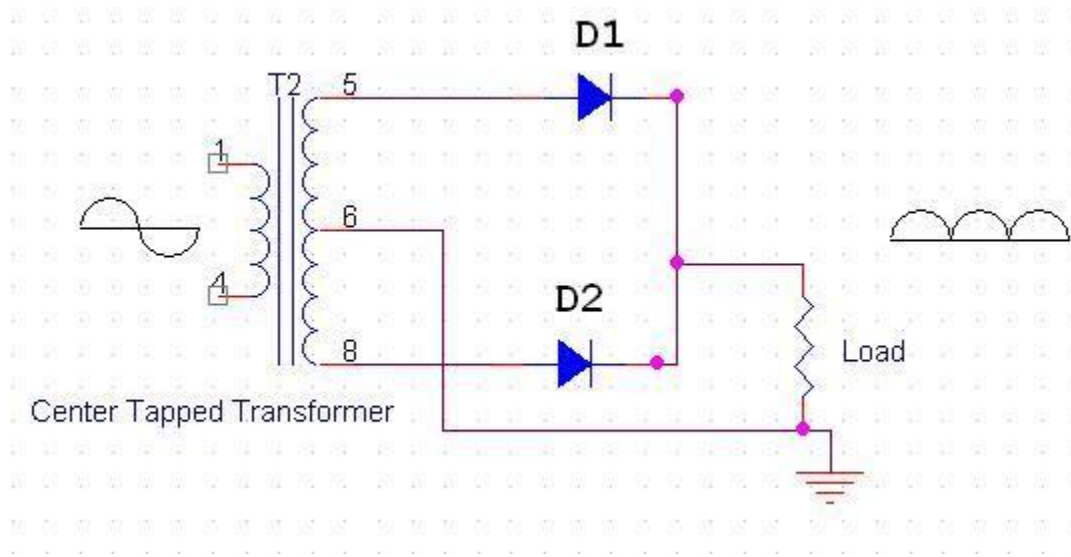
Rectifier can be classified as follows:

1) Half Wave rectifier.



This is the simplest type of rectifier as you can see in the diagram a half wave rectifier consists of only one diode. When an AC signal is applied to it during the positive half cycle the diode is forward biased & current flows through it. But during the negative half cycle diode is reverse biased & no current flows through it. Since only one half of the input reaches the output, it is very inefficient to be used in power supplies.

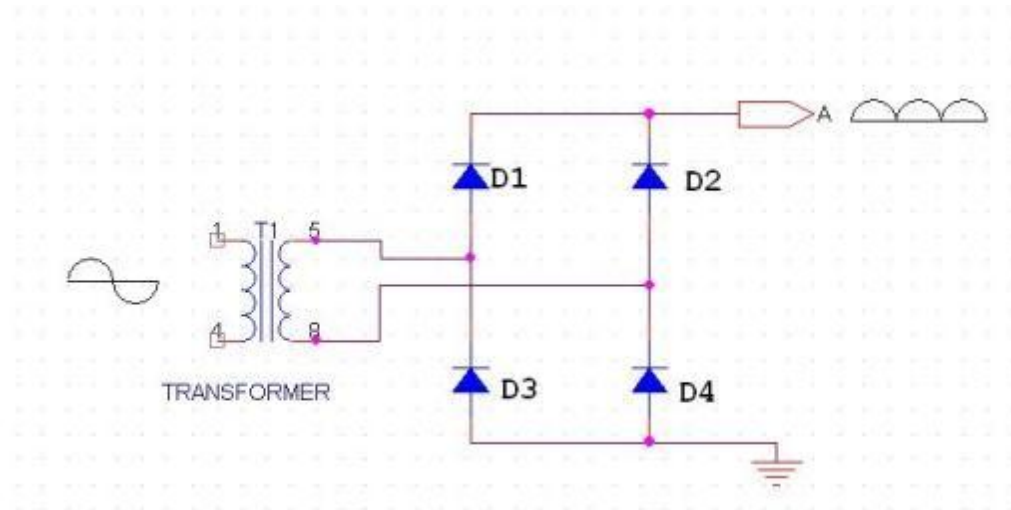
2) Full wave rectifier.



Half wave rectifier is quite simple but it is very inefficient, for greater efficiency we would like to use both the half cycles of the AC signal. This can be achieved by using a center tapped transformer i.e. we would have to double the size of secondary winding & provide connection to the center. So during the positive half cycle diode D1 conducts & D2 is in reverse biased condition. During the negative half cycle diode D2 conducts & D1 is reverse biased. Thus we get both the half cycles across the load.

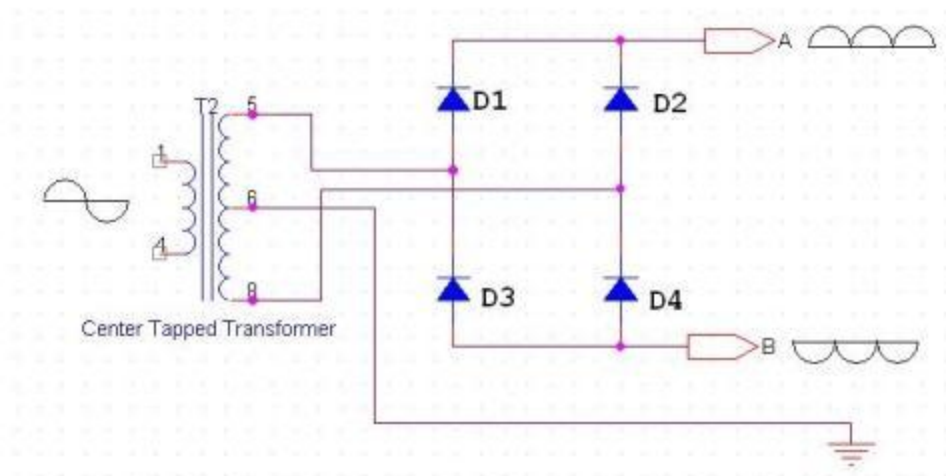
One of the disadvantages of Full Wave Rectifier design is the necessity of using a center tapped transformer, thus increasing the size & cost of the circuit. This can be avoided by using the Full Wave Bridge Rectifier.

3) BridgeRectifier.



As the name suggests it converts the full wave i.e. both the positive & the negative half cycle into DC thus it is much more efficient than Half Wave Rectifier & that too without using a center tapped transformer thus much more cost effective than Full Wave Rectifier.

Full Bridge Wave Rectifier consists of four diodes namely D1, D2, D3 and D4. During the positive half cycle diodes D1 & D4 conduct whereas in the negative half cycle diodes D2 & D3 conduct thus the diodes keep switching the transformer connections so we get positive half cycles in the output.

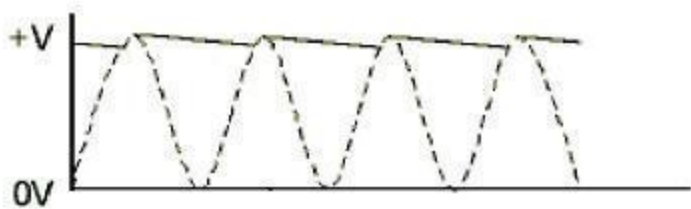
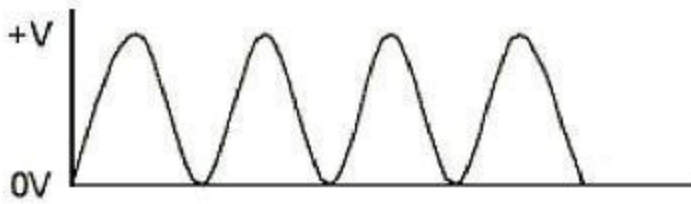


If we use a center tapped transformer for a bridge rectifier we can get both positive & negative half cycles which can thus be used for generating fixed positive & fixed negative voltages.

2.2.3 FILTER CAPACITOR

Even though half wave & full wave rectifier give DC output, none of them provides a constant output voltage. For this we require to smoothen the waveform received from the rectifier. This can be done by using a capacitor at the output of the rectifier this capacitor is also called as “FILTER CAPACITOR” or “SMOOTHING CAPACITOR” or “RESERVOIR CAPACITOR”. Even after using this capacitor a small amount of ripple will remain.

We place the Filter Capacitor at the output of the rectifier the capacitor will charge to the peak voltage during each half cycle then will discharge its stored energy slowly through the load while the rectified voltage drops to zero, thus trying to keep the voltage as constant as possible.



If we go on increasing the value of the filter capacitor then the Ripple will decrease. But then the costing will increase. The value of the Filter capacitor depends on the current consumed by the circuit, the frequency of the waveform & the accepted ripple.

$$C = \frac{V_r F}{I}$$

Where,

V_r = accepted ripple voltage. (should not be more than 10% of the voltage)

I = current consumed by the circuit in Amperes.

F = frequency of the waveform. A half wave rectifier has only one peak in one cycle so $F=25\text{hz}$

Whereas a full wave rectifier has Two peaks in one cycle so $F=100\text{hz}$.

2.2.4 VOLTAGE REGULATOR

A Voltage regulator is a device which converts varying input voltage into a constant regulated output voltage. Voltage regulator can be of two types

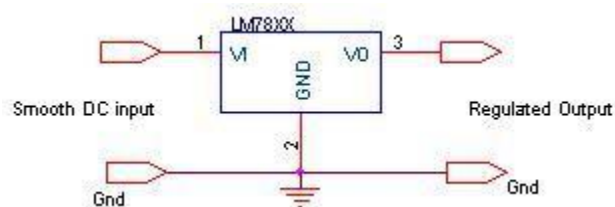
1) Linear Voltage Regulator

Also called as Resistive Voltage regulator because they dissipate the excessive voltage resistively as heat.

2) Switching Regulators.

They regulate the output voltage by switching the Current ON/OFF very rapidly. Since their output is either ON or OFF it dissipates very low power thus achieving higher efficiency as compared to linear voltage regulators. But they are more complex & generate high noise due to their switching action. For low level of output power switching regulators tend to be costly but for higher output wattage they are much cheaper than linear regulators.

The most commonly available Linear Positive Voltage Regulators are the 78XX series where the XX indicates the output voltage. And 79XX series is for Negative Voltage Regulators.



After filtering the rectifier output the signal is given to a voltage regulator. The maximum input voltage that can be applied at the input is 35V. Normally there is a 2-3 Volts drop across the regulator so the input voltage should be at least 2-3 Volts higher than the output voltage. If the input voltage gets below the V_{min} of the

regulator due to the ripple voltage or due to any other reason the voltage regulator will not be able to produce the correct regulated voltage.

Circuit diagram:

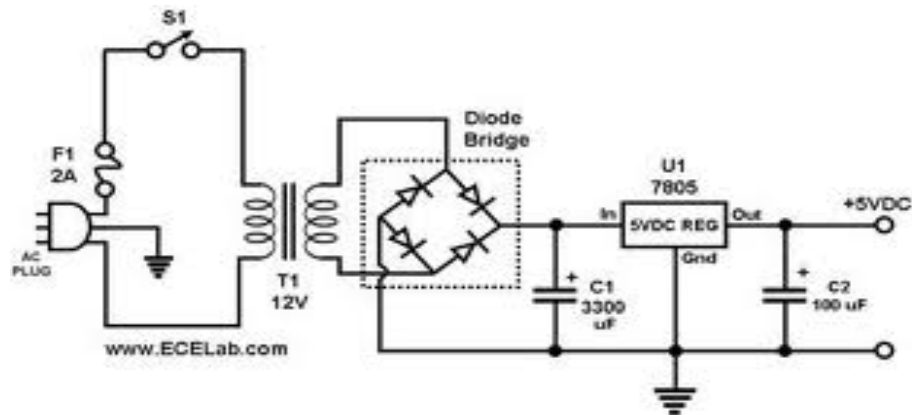


Fig 2.3. Circuit Diagram of power supply

IC 7805:

7805 is an integrated three-terminal positive fixed linear voltage regulator. It supports an input voltage of 10 volts to 35 volts and output voltage of 5 volts. It has a current rating of 1 amp although lower current models are available. Its output voltage is fixed at 5.0V. The 7805 also has a built-in current limiter as a safety feature. 7805 is manufactured by many companies, including National Semiconductors and Fairchild Semiconductors.

The 7805 will automatically reduce output current if it gets too hot. The last two digits represent the voltage; for instance, the 7812 is a 12-volt regulator. The 78xx series of regulators is designed to work in complement with the 79xx series of

negative voltage regulators in systems that provide both positive and negative regulated voltages, since the 78xx series can't regulate negative voltages in such a system.

The 7805 & 78 is one of the most common and well-known of the 78xx series regulators, as it's small component count and medium-power regulated 5V make it useful for powering TTL devices.

Table 2.1. Specifications of IC7805

SPECIFICATIONS	IC 7805
V_{out}	5V
$V_{ein} - V_{out}$ Difference	5V - 20V
Operation Ambient Temp	0 - 125°C
Output I_{max}	1A

NODEMCU

NodeMCU is an open source development board and firmware based in the widely used ESP8266 -12E Wi-Fi module. This is also an open source IOT platform. This module is programmed with the simple and powerful LUA programming language or Arduino IDE. With just a few lines of code it allows to establish a Wi-Fi connection and define input/output pins accordingly by turning the ESP8266 into a web server and a lot more. It is the Wi-Fi equivalent of Ethernet module. With its USB-TTL, the NodeMCU Development board supports directly flashing from USB port. It combines features of WIFI Access point and station + microcontroller. These features make the NodeMCU extremely powerful tool for Wi-Fi networking. It can be used as access point and/or station, host a webserver or connect to internet to fetch or upload data.

This is where NodeMCU comes handy that incorporates a built-in WiFi support, giving an easy pathway to design IoT applications as per your technical requirements.



Fig: NODE-MCU

INTRODUCTION TO NODEMCU

NodeMCU is an open-source firmware and development kit that plays a vital role in designing your own IoT product using a few Lua script lines.

Multiple GPIO pins on the board allow you to connect the board with other peripherals and are capable of generating PWM, I2C, SPI, and UART serial communications.

- The interface of the module is mainly divided into two parts including both Firmware and Hardware where former runs on the ESP8266 Wi-Fi SoC and later is based on the ESP-12 module.

The firmware is based on Lua – A scripting language that is easy to learn, giving a simple programming environment layered with a fast scripting language that connects you with a well-known developer community.

And open source firmware gives you the flexibility to edit, modify and rebuilt the existing module and keep changing the entire interface until you succeed in optimizing the module as per your requirements.

- USB to UART converter is added on the module that helps in converting USB data to UART data which mainly understands the language of serial communication.

Instead of the regular USB port, MicroUSB port is included in the module that connects it with the computer for dual purposes: programming and powering up the board.

- The board incorporates status LED that blinks and turns off immediately, giving you the current status of the module if it is running properly when connected with the computer.

The ability of module to establish a flawless WiFi connection between two channels makes it an ideal choice for incorporating it with other embedded devices like Raspberry Pi.

NODEMCU FEATURES

- Open-source
- Arduino-like hardware

- Status LED
- Micro-USB port
- Reset/Flash buttons
- Interactive and Programmable
- Low cost
- ESP8266 with inbuilt wifi
- USB to UART converter
- GPIO pins

NODEMCU PINOUT

NodeMCU comes with a number of GPIO Pins. Following figure shows the Pinout of the board.

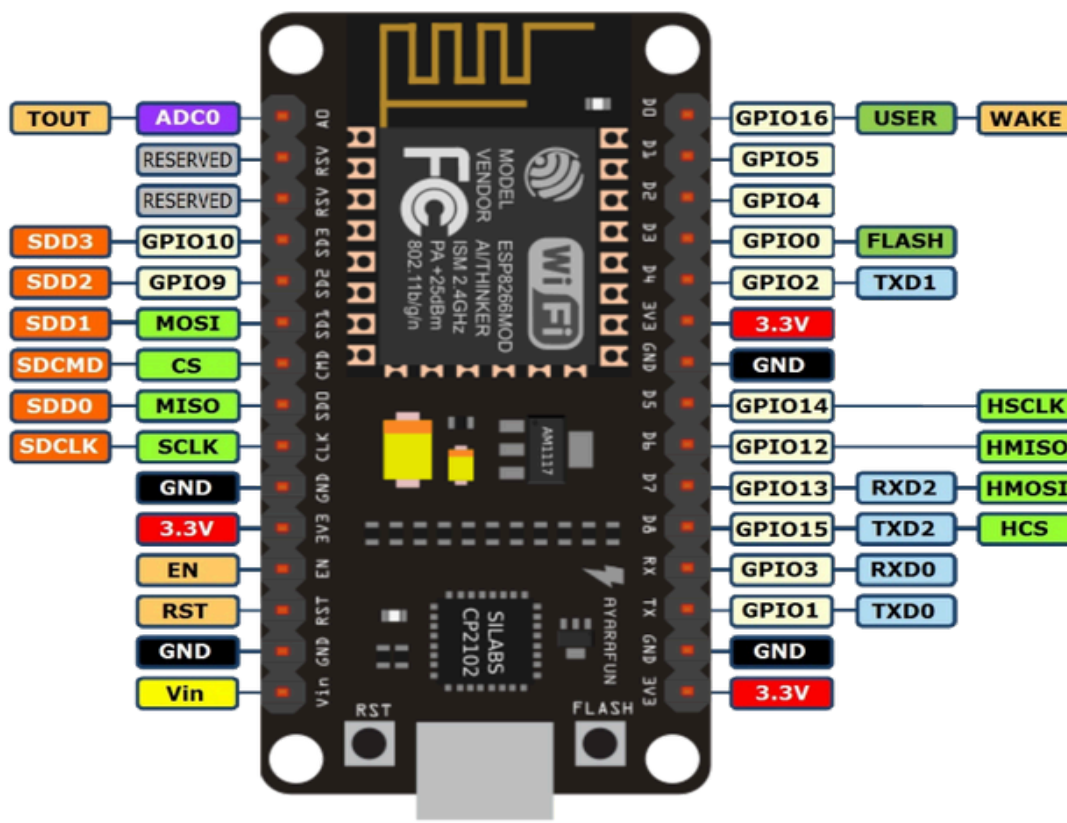


Fig. NODE-MCU PINOUT

There is a candid difference between Vin and VU where former is the regulated voltage that may stand somewhere between 7 to 12 V while later is the power voltage for USB that must be kept around 5 V.

- That must be kept around 5 V.

As mentioned above, a cable supporting micro USB port is used to connect the board. As you connect the board with a computer, LED will flash. You may need some drivers to be installed on your computer if it fails to detect the Node-MCU board.

Note: We use Arduino IDE software for programming this module. It is important to note that the pin configuration appearing on the board is different from the configuration we use to program the board on the software i.e. when we write code for targeting pin 16 on the Arduino IDE, it will actually help in laying out the communication with the D0 pin on the module.

Following figure shows the pin configuration to use in Arduino IDE.

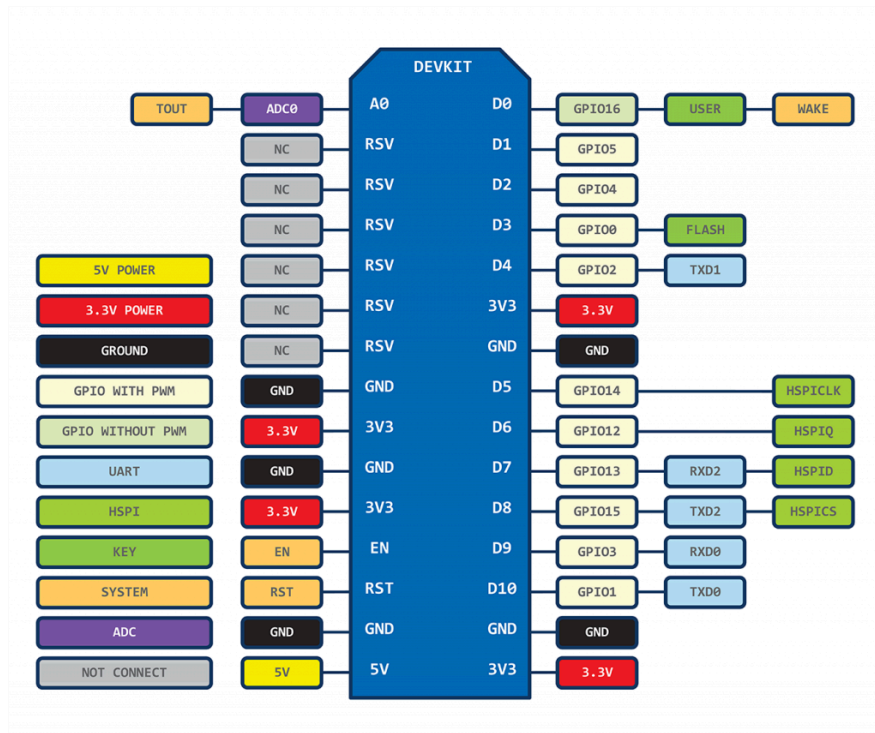


Fig. NODE-MCU configuration

Power Up Node-MCU

With reference to above image from the pin-out image above, there are five ground pins and three 3 pins on the board. The board can be powered up using the following three ways.

USB Power. It proves to an ideal choice for loading programs unless the project you aim to design requires separate interface i.e. disconnected from the computer.

Provide 3.3V. This is another great option to power up the module. If you have your own off-board regulator, you can generate an instant power source for your development kit.

Power Vin. This is a voltage regulator that comes with the ability to support up to 800 mA. It can handle somewhere between 7 to 12 V. You cannot power the devices operating at 3.3 V, as this regulator unable to generate as low as 3.3V.

ADVANTAGES

- Inexpensive module.
- Good on-board processing power to handle Sensors.
- More powerful processor than Arduino.

APPLICATIONS

- IoT Sensors and Controllers.
- Home Automation.
- Agricultural Robot.
- Sensor Networks.
- Industrial Wireless Control.
- Multiple DIY projects.

IR sensor

Infrared (IR) light is electromagnetic radiation with longer wavelengths than those of visible light, extending from the nominal red edge of the visible spectrum at 700 nanometres (nm) to 1 mm. This range of wavelengths corresponds to a frequency range of approximately 430 THz down to 300 GHz,^[1] and includes most of the thermal radiation emitted by objects near room temperature. Infrared light is emitted or absorbed by molecules when they change their rotational-vibrational movements. The existence of infrared radiation was first discovered in 1800 by astronomer William Herschel.

Much of the energy from the Sun arrives on Earth in the form of infrared radiation. Sunlight at zenith provides an irradiance of just over 1 kilowatt per square meter at sea level. Of this energy, 527 watts is infrared radiation, 445 watts is visible light, and 32 watts is ultraviolet radiation.^[2] The balance between absorbed and emitted infrared radiation has a critical effect on the Earth's climate.

Infrared light is used in industrial, scientific, and medical applications. Night-vision devices using infrared illumination allow people or animals to be observed without the observer being detected. In astronomy, imaging at infrared wavelengths allows observation of objects obscured by interstellar dust. Infrared imaging cameras are used to detect heat loss in insulated systems, to observe changing blood flow in the skin, and to detect overheating of electrical apparatus.

Light comparison^[3]

Name	Wavelength	<u>Frequency (Hz)</u>	<u>Photon Energy (eV)</u>
<u>Gamma ray</u>	less than 0.01 nm	more than 10 EHz	124 keV – 300+ GeV
<u>X-Ray</u>	0.01 nm to 10 nm	30 EHz – 30 PHz	124 eV to 124 keV
<u>Ultraviolet</u>	10 nm – 380 nm	30 PHz – 790 THz	3.3 eV to 124 eV
<u>Visible</u>	380 nm – 700 nm	790 THz – 430 THz	1.7 eV – 3.3 eV
<u>Infrared</u>	700 nm – 1 mm	430 THz – 300 GHz	1.24 <u>meV</u> – 1.7 eV
<u>Microwave</u>	1 mm – 1 meter	300 GHz – 300 MHz	1.24 <u>μeV</u> – 1.24 meV
<u>Radio</u>	1 mm – 100,000 km	<u>300 GHz</u> – <u>3 Hz</u>	12.4 <u>feV</u> – 1.24 meV

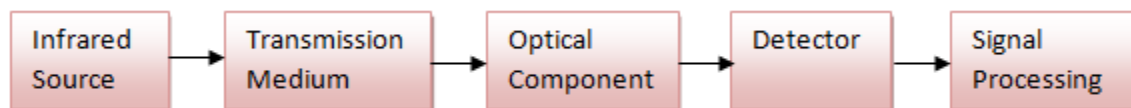
Infrared imaging is used extensively for military and civilian purposes. Military applications include target acquisition, surveillance, night vision, homing and tracking. Non-military uses include thermal efficiency analysis, environmental monitoring, industrial facility inspections, remote temperature sensing, short-ranged wireless communication, spectroscopy, and weather forecasting. Infrared astronomy uses sensor-equipped telescopes to penetrate dusty regions of space, such as molecular clouds; detect objects such as planets, and to view highly red-shifted objects from the early days of the universe.^[4]

Humans at normal body temperature radiate chiefly at wavelengths around 10 μm (micrometers), as shown by Wien's displacement law.

At the atomic level, infrared energy elicits vibrational modes in a molecule through a change in the dipole moment, making it a useful frequency range for study of these energy states for molecules of the proper symmetry. Infrared spectroscopy examines absorption and transmission of photons in the infrared energy range, based on their frequency and intensity.^[5]

ELEMENTS OF INFRARED DETECTION SYSTEM

A typical system for detecting infrared radiation is given in the following block diagram :



1. Infrared Source

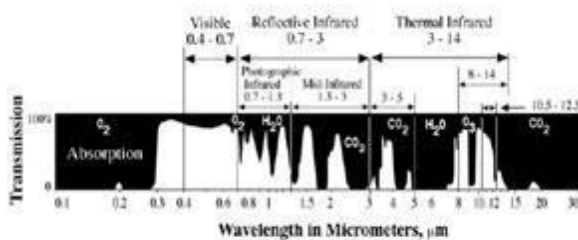
All objects above 0 K radiate infrared energy and hence are infrared sources. Infrared sources also include blackbody radiators, tungsten lamps, silicon carbide, and various others. For active IR sensors, infrared Lasers and LEDs of specific IR wavelengths are used as IR sources.

2. Transmission Medium

Three main types of transmission medium used for Infrared transmission are vacuum, the atmosphere, and optical fibers.

The transmission of IR – radiation is affected by presence of CO₂, water vapour and other elements in the atmosphere. Due to absorption by molecules of water carbon dioxide, ozone, etc. the atmosphere highly attenuates most IR wavelengths leaving some important IR windows in the electromagnetic spectrum; these are primarily utilized by thermal imaging/ remote sensing applications.

- Medium wave IR (MWIR:3-5 μm)
- Long wave IR (LWIR:8-14 μm)



Choice of IR band or a specific wavelength is dictated by the technical requirements of a specific application.

3. Optical Components.

Often optical components are required to converge or focus infrared radiations, to limit spectral response, etc. To converge / focus radiations, optical lenses made of quartz, CaF₂, Ge and Si, polyethylene Fresnel lenses, and mirrors made of Al, Au or a similar material are used. For limiting spectral responses, bandpass filters are used. Choppers are used to pass/ interrupt the IR beams.

4. Infrared detectors.

Various types of detectors are used in IR sensors. Important specifications of detectors are

- Photosensitivity or Responsivity

Responsivity is the Output Voltage/Current per watt of incident energy. Higher the better

- Noise Equivalent Power (NEP)

NEP represents detection ability of a detector and is the amount of incident light equal to intrinsic noise level of a detector

- Detectivity(D*: D-star)

D* is the photosensitivity per unit area of a detector. It is a measure of S/N ratio of a detector. D* is inversely proportional to NEP. Larger D* indicates better sensing element.

In addition, wavelength region or temperature to be measured, response time, cooling mechanism, active area, no of elements, package, linearity, stability, temperature characteristics, etc. are important parameters which need attention while selecting IR detectors.

5. Signal Processing

Since detector outputs are typically very small, preamplifiers with associated circuitry are used to further process the received signals.

Working:

IR sensors use infra red light to sense objects in front of them and gauge their distance. The commonly used Sharp IR sensors have two black circles which used for this process, an emitter and a detector (see image right).

A pulse of infra red light is emitted from the emitter and spreads out in a large arc. If no object is detected then the IR light continues forever and no reading is recorded. However, if an object is nearby then the IR light will be reflected and some of it will hit the detector. This forms a simple triangle between the object, emitter and detector. The detector is able to detect the angle that the IR light arrived back at and thus can determine the distance to the object. This is remarkably accurate and although interference from sunlight is still a problem, these sensors are capable of detecting dark objects in sunlight now.

Regions in the infrared

Objects generally emit infrared radiation across a spectrum of wavelengths, but sometimes only a limited region of the spectrum is of interest because sensors usually collect radiation only within a specific bandwidth. Therefore, the infrared band is often subdivided into smaller sections.

Division	Name	Abbreviation	Wavelength	Photon Energy	Characteristics
----------	------	--------------	------------	---------------	-----------------

Near-infrared NIR, IR-A DIN 0.75–1.4 μ m 0.9–1.7 eV

Defined by the water absorption, and commonly used in fiber optic telecommunication because of low attenuation losses in the SiO_2 glass (silica) medium. Image intensifiers are sensitive to this area of the spectrum. Examples include night vision devices such as night vision goggles.

Short-wavelength infrared SWIR, IR-B DIN 1.4–3 μ m 0.4–0.9 eV

Water absorption increases significantly at 1,450 nm. The 1,530 to 1,560 nm range is the dominant spectral region for long-distance telecommunications.

Mid-wavelength infrared
 MWIR, IR-C
 DIN; MidIR.^[2]
 Also called 3–8 μm 150–400 meV
 intermediate
 infrared (IIR)

Long-wavelength infrared
 LWIR, IR-C
 DIN 8–15 μm 80–150 meV

In guided missile technology the 3–5 μm portion of this band is the atmospheric window in which the homing heads of passive IR 'heat seeking' missiles are designed to work, homing on to the Infrared signature of the target aircraft, typically the jet engine exhaust plume

The "thermal imaging" region, in which sensors can obtain a completely passive image based on thermal emissions only and requiring no illumination such as the sun, moon or infrared illuminator.

Forward-looking infrared (FLIR) systems

use this area of the spectrum. This region is also called the "thermal infrared."

Far infrared	FIR	15 – 1,000 μm	1.2–80 meV	(see also far-infrared laser and far infrared).
--------------	-----	--------------------------------	------------	---

NIR and SWIR is sometimes called "reflected infrared" while MWIR and LWIR is sometimes referred to as "thermal infrared." Due to the nature of the blackbody radiation curves, typical 'hot' objects, such as exhaust pipes, often appear brighter in the MW compared to the same object viewed in the LW.

CIE division scheme:

The [International Commission on Illumination](#) (CIE) recommended the division of infrared radiation into the following three bands:^[8]

- IR-A: 700 nm–1400 nm (0.7 μm – 1.4 μm , 215 THz – 430 THz)
- IR-B: 1400 nm–3000 nm (1.4 μm – 3 μm , 100 THz – 215 THz)
- IR-C: 3000 nm–1 mm (3 μm – 1000 μm , 300 GHz – 100 THz)

ISO 20473 scheme:

[ISO 20473](#) specifies the following scheme

Designation	Abbreviation	Wavelength
-------------	--------------	------------

Near Infrared	NIR	0.78–3 μm
Mid Infrared	MIR	3–50 μm
Far Infrared	FIR	50–1000 μm

Sensor response division scheme

A third scheme divides up the band based on the response of various detectors:

Near infrared: from 0.7 to 1.0 μm (from the approximate end of the response of the human eye to that of silicon).

- Short-wave infrared: 1.0 to 3 μm (from the cut off of silicon to that of the MWIR atmospheric window. InGaAs covers to about 1.8 μm ; the less sensitive lead salts cover this region.
- Mid-wave infrared: 3 to 5 μm (defined by the atmospheric window and covered by Indium antimonide [InSb] and HgCdTe and partially by lead selenide [PbSe]).
- Long-wave infrared: 8 to 12 or 7 to 14 μm : the atmospheric window (Covered by HgCdTe and microbolometers).
- Very-long wave infrared (VLWIR): 12 to about 30 μm , covered by doped silicon.

These divisions are justified by the different human response to this radiation: near infrared is the region closest in wavelength to the radiation detectable by the human eye, mid and far infrared are progressively further from the visible spectrum. Other definitions follow different physical mechanisms

(emission peaks, vs. bands, water absorption) and the newest follow technical reasons (The common silicon detectors are sensitive to about 1,050 nm, while InGaAs' sensitivity starts around 950 nm and ends between 1,700 and 2,600 nm, depending on the specific configuration). Unfortunately, international standards for these specifications are not currently available.

The boundary between visible and infrared light is not precisely defined. The human eye is markedly less sensitive to light above 700 nm wavelength, so longer wavelengths make insignificant contributions to scenes illuminated by common light sources. But particularly intense light (e.g., from IR lasers, or from bright daylight with the visible light removed by colored gels) can be detected up to approximately 780 nm, and will be perceived as red light, although sources of up to 1050 nm can be seen as a dull red glow in intense sources. Using an opaque IR-passing photographic filter, it is possible to see the Wood effect of glowing foliage if all visible light leaks from around the filter are blocked, and the eye is given a moment to adjust to the extremely dim image.^[12] The onset of infrared is defined (according to different standards) at various values typically between 700 nm and 800 nm.

Telecommunication bands in the infrared

In optical communications, the part of the infrared spectrum that is used is divided into seven bands based on availability of light sources transmitting/absorbing materials (fibers) and detectors:

Band	Descriptor	Wavelength range
------	------------	------------------

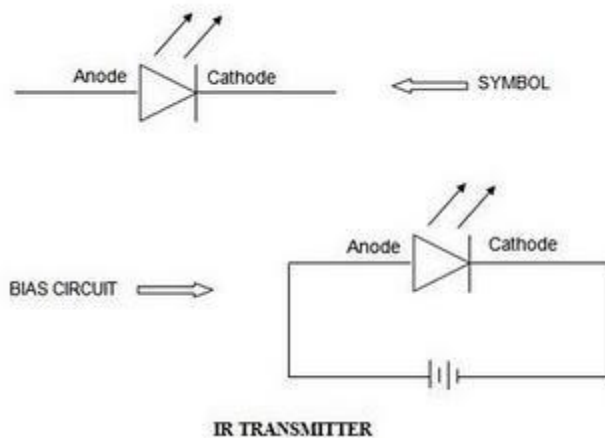
O band Original	1260–1360 nm
E band Extended	1360–1460 nm
S band Short wavelength	1460–1530 nm
C band Conventional	1530–1565 nm
L band Long wavelength	1565–1625 nm
U band Ultralong wavelength	1625–1675 nm

IR transmitter and receiver

Basics of IR transmitter and receiver transmitter and receiver are commonly used in engineering projects for remote control of objects. In particular, in Robotic system uses transmitter and receiver. Here i would like to describe the basics if IR transmitter and receiver

Basics of IR transmitter:

An electroluminescent IR LED is a product which requires care in use. IR LED's are fabricated from narrow band hetero structures with energy gap from 0.25 to 0.4 eV. Infra red transmitter emits IR rays in planar wave front manner. Even though infra red rays spread in all directions, it propagates along straight line in forward direction. IR rays have the characteristics of producing secondary wavelets when it collides with any obstacles in its path. This property of IR is used here.



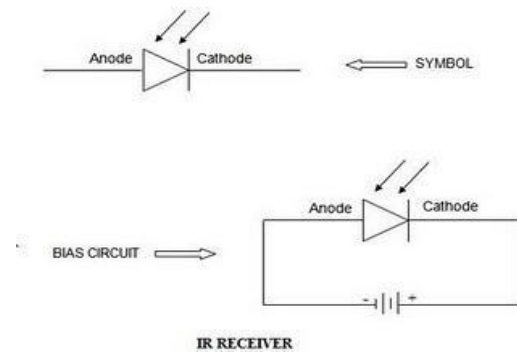
When IR rays get emitted from LED, it moves in the direction it is angled. When any obstacle interferes in the path, the IR rays get cut and it produces secondary wavelets which propagate mostly in return direction or in a direction opposite to that of the primary waves, which produces the net result like reflection of IR rays.

Basics of IR receiver:

Infrared photo receiver is a two terminal PN junction device, which operates in a reverse bias. It has a small transparent window, which allows light to strike the PN junction. A photodiode is a type of photo detector capable of converting light into either current or voltage, depending upon the mode of operation. Most photodiodes will look similar to a light emitting diode. They will have two leads, or wires, coming from the bottom. The shorter end of the two is the cathode, while the longer end is the anode.

A photodiode consists of PN junction or PIN structure. When a photon of sufficient energy strikes the diode, it excites an electron thereby creating a mobile electron and a positively charged electron hole. If the absorption occurs in the junction's depletion region, or one diffusion length away from it, these carriers are

swept from the junction by the built-in field of the depletion region. Thus holes move toward the anode, and electrons toward the cathode, and a photocurrent is produced.



Working of infrared communication:

Various types of infrared based applications are available in the market. The circuit for infrared based applications is designed along with the transmitter and receiver sections i.e. we can't use it for other application. But the infrared communication project which we have done here can be used in any application just by replacing the application at the place of infrared LED in the circuit diagram of infrared communication. By using this project we can design infrared based applications easily. The entire circuit consists of two sections named as

1. Transmitter section and
2. Receiver section

1. Transmitter section:

The transmitter section consists of a 555 timer IC functioning in astable mode. It is wired as shown in figure. The output from astable mode is fed to an IR

LED via resistor which limits its operating current. Infrared LED in the transmitter section emits IR radiation which is focused by a plastic lens (optics) in to a narrow beam.

2. Receiver section:

The receiver section consists of a silicon phototransistor to convert the infrared radiation to an electric current. It responds only to the rapidly pulsing signal created by the transmitter, and filters out slowly changing infrared radiation from ambient light. The receiver section comprises an infrared receiver module, and a led indicator. When the signals are interrupted, the IR Led goes off after a few seconds depending upon the value of RC combination.

We can increase the distance between the IR transmitter and receiver just by placing the lens between them. After connecting the IR transmitter and receiver circuit, we can get the output by applying 6V Power supply to the circuit. We can use this circuit with any application very simply. For example a buzzer circuit is placed at the output of IR circuit, when the signals are interrupted, the buzzer produces sound. Both the transmitter and receiver parts can be mounted on a single bread board or PCB. The infrared receiver must be placed behind the IR Led to avoid false indication due to infrared leakage. An object moving nearby actually reflects the IR rays emitted by the IR Led.

Photo Diodes:

A photodiode is a semiconductor diode that functions as a photo detector. Photodiodes are packaged with either a window or optical fiber connection, to let

in the light to the sensitive part of the device. They may also be used without a window to detect vacuum UV or X-rays.

A phototransistor is in essence nothing more than a bipolar transistor that is encased in a transparent case so that light can reach the base-collector junction. The phototransistor works like a photodiode, but with a much higher responsivity for light, because the electrons that are generated by photons in the base-collector junction are injected into the base, and this current is then amplified by the transistor operation.



Fig (3.13) Photodiode schematic symbol

Principle of operation:

A photodiode is a p-n junction or p-i-n structure. When a photon of sufficient energy strikes the diode, it excites an electron thereby creating a mobile electron and a positively charged electron hole. If the absorption occurs in the junction's depletion region, or one diffusion length away from it, these carriers are swept from the junction by the built-in field of the depletion region, producing a photocurrent.

Photodiodes can be used under either zero bias (photovoltaic mode) or reverse bias (photoconductive mode). In zero bias, light falling on the diode causes a

current across the device, leading to forward bias which in turn induces "dark current" in the opposite direction to the photocurrent. This is called the photovoltaic effect, and is the basis for solar cells in fact; a solar cell is just a large number of big photodiodes. Reverse bias induces only little current (known as saturation or back current) along its direction.

But a more important effect of reverse bias is widening of the depletion layer (therefore expanding the reaction volume) and strengthening the photocurrent. Circuits based on this effect are more sensitive to light than ones based on the photovoltaic effect and also tend to have lower capacitance, which improves the speed of their time response. On the other hand, the photovoltaic mode tends to exhibit less electronic noise.

Avalanche photodiodes have a similar structure, but they are operated with much higher reverse bias. This allows each photo-generated carrier to be multiplied by avalanche breakdown, resulting in internal gain within the photodiode, which increases the effective responsivity of the device.

Features:

Critical performance parameters of a photodiode include:

1. Responsivity:

The responsivity may also be expressed as quantum efficiency, or the ratio of the number of photo generated carriers to incident photons and thus a unit less quantity.

2. Dark current:

The dark current includes photocurrent generated by background radiation and the saturation current of the semiconductor junction. Dark current must be accounted for by calibration if a photodiode is used to make an accurate optical power measurement, and it is also a source of noise when a photodiode is used in an optical communication system.

3. Noise-equivalent power:

(NEP) The minimum input optical power to generate photocurrent, equal to the RMS noise current in a 1 hertz bandwidth. The related characteristic directivity (D) is the inverse of NEP, $1/NEP$. The NEP is roughly the minimum detectable input power of a photodiode.

Applications:

1. P-N photodiodes are used in similar applications to other photo detectors, such as photoconductors, charge-coupled devices, and photomultiplier tubes.
2. Photodiodes are used in consumer electronics devices such as compact disc players, smoke detectors, and the receivers for remote controls in VCRs and televisions.
3. PIN diodes are much faster and more sensitive than ordinary p-n junction diodes, and hence are often used for optical communications and in lighting regulation.

P-N vs. P-I-N Photodiodes:

1. Due to the intrinsic layer, a PIN photodiode must be reverse biased (V_r). The V_r increases the depletion region allowing a larger volume for electron-hole pair production, and reduces the capacitance thereby increasing the bandwidth.
2. The V_r also introduces noise current, which reduces the S/N ratio. Therefore, a reverse bias is recommended for higher bandwidth applications and/or applications where a wide dynamic range is required.
3. A PN photodiode is more suitable for lower light applications because it allows for unbiased operation.

Applications

Night vision

Infrared is used in night vision equipment when there is insufficient visible light to see.^[16] Night vision devices operate through a process involving the conversion of ambient light photons into electrons which are then amplified by a chemical and electrical process and then converted back into visible light.^[16] Infrared light sources can be used to augment the available ambient light for conversion by night vision devices, increasing in-the-dark visibility without actually using a visible light source.^[16]

The use of infrared light and night vision devices should not be confused with thermal imaging which creates images based on differences in surface temperature by detecting infrared radiation (heat) that emanates from objects and their surrounding environment.

Thermography

Infrared radiation can be used to remotely determine the temperature of objects (if the emissivity is known). This is termed thermography, or in the case of very hot objects in the NIR or visible it is termed pyrometry. Thermography (thermal imaging) is mainly used in military and industrial applications but the technology is reaching the public market in the form of infrared cameras on cars due to the massively reduced production costs.

Thermographic cameras detect radiation in the infrared range of the electromagnetic spectrum (roughly 900–14,000 nanometers or 0.9–14 μm) and produce images of that radiation. Since infrared radiation is emitted by all objects based on their temperatures, according to the black body radiation law, thermography makes it possible to "see" one's environment with or without visible illumination. The amount of radiation emitted by an object increases with temperature, therefore thermography allows one to see variations in temperature (hence the name).

Tracking

Infrared tracking, also known as infrared homing, refers to a passive missile guidance system which uses the emission from a target of electromagnetic radiation in the infrared part of the spectrum to track it. Missiles which use infrared seeking are often referred to as "heat-seekers", since infrared (IR) is just below the visible spectrum of light in frequency and is radiated strongly by hot bodies. Many objects such as people, vehicle engines, and aircraft generate and

retain heat, and as such, are especially visible in the infrared wavelengths of light compared to objects in the background

Heating

Infrared radiation can be used as a deliberate heating source. According to this [Mayo Clinic article](#) states that, "Several studies have looked at using infrared saunas in the treatment of chronic health problems, such as high blood pressure, congestive heart failure and rheumatoid arthritis, and found some evidence of benefit." For example it is used in [infrared saunas](#) to heat the occupants, and also to remove ice from the wings of aircraft ([de-icing](#)). [Far infrared](#) is also gaining popularity as a safe [heat therapy](#) method of natural health care and physiotherapy. Infrared can be used in cooking and heating food as it predominantly heats the opaque, absorbent objects, rather than the air around them.

Infrared heating is also becoming more popular in industrial manufacturing processes, e.g. curing of coatings, forming of plastics, annealing, plastic welding, and print drying. In these applications, infrared heaters replace convection ovens and contact heating. Infrared heaters produce heat that is a product of invisible light and they consist of three parts: infrared light bulbs, a heat exchanger and a fan that blows air onto the exchanger to disperse the heat.

Efficiency is achieved by matching the wavelength of the infrared heater to the absorption characteristics of the material.

Communications

IR data transmission is also employed in short-range communication among computer peripherals and personal digital assistants. These devices usually conform to standards published by IrDA, the Infrared Data Association. Remote controls and IrDA devices use infrared light-emitting diodes (LEDs) to emit infrared radiation which is focused by a plastic lens into a narrow beam.

The beam is modulated, i.e. switched on and off, to encode the data. The receiver uses a siliconphotodiode to convert the infrared radiation to an electric current. It responds only to the rapidly pulsing signal created by the transmitter, and filters out slowly changing infrared radiation from ambient light. Infrared communications are useful for indoor use in areas of high population density. IR does not penetrate walls and so does not interfere with other devices in adjoining rooms. Infrared is the most common way for remote controls to command appliances. Infrared remote control protocols like RC-5, SIRC, are used to communicate with infrared.

Free space optical communication using infrared lasers can be a relatively inexpensive way to install a communications link in an urban area operating at up to 4 gigabit/s, compared to the cost of burying fiber optic cable.

Infrared lasers are used to provide the light for optical fiber communications systems. Infrared light with a wavelength around 1,330 nm (least dispersion) or 1,550 nm (best transmission) are the best choices for standard silica fibers.

IR data transmission of encoded audio versions of printed signs is being researched as an aid for visually impaired people through the RIAS (Remote Infrared Audible Signage) project.

D.C. Motor:

A dc motor uses electrical energy to produce mechanical energy, very generally through the interaction of magnetic fields and current-containing conductors. The reverse process, producing electrical energy from mechanical energy, is carried out by an alternator, source or dynamo. Many types of electric motors can be run as sources, and vice versa. The input of a DC motor is current/voltage and its output is torque (speed).



Fig 3.19: DC Motor

The DC motor has two basic parts: the rotating part that is called the armature and the stable part that includes coils of wire called the field coils. The stationary part is also called up the stator. Figure shows a depict of a distinctive DC motor, Figure shows a picture of a DC armature, and Figure shows a picture of a

distinctive stator. From the picture you can see the armature is made of coils of wire wrapped around the core, and the core has an covered shaft that rotates on charges. You should also notice that the ends of each coil of wire on the armature are finished at one end of the armature. The outcome points are called the commutator, and this is where's brushes make electrical contact to bring electrical current from the stationary part to the rotating part of the machine.

Operation:

The DC motor you will find in modem industrial applications operates very similarly to the simple DC motor described earlier in this chapter. Figure 12-9 demonstrates an electrical diagram of a simple DC motor. comment that the DC voltage is applied directly to the field winding and the brushes. The armature and the area are both shown as a coil of wire. In afterward diagrams, a field resistor will be added in series with the field to control the motor speed. When voltage is applied to the motor, current begins to flow by the field coil from the negative terminal to the positive terminal. This sets up a inviolable magnetic field in the field winding. Current also begins to feed through the brushes into a commutator segment and then through an armature coil. The current goes forward to flow through the coil back to the brush that is attached to other end of the coil and returns to the DC power source. The current flow in the armature coil sets up a strong magnetic field in the armature.

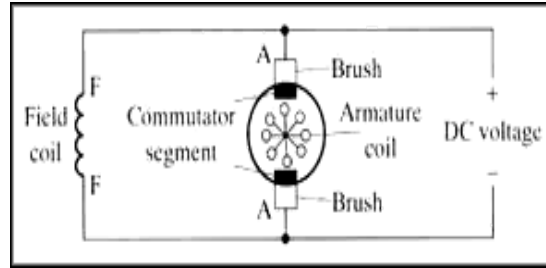


Fig 3.20: Simple electrical diagram of DC motor

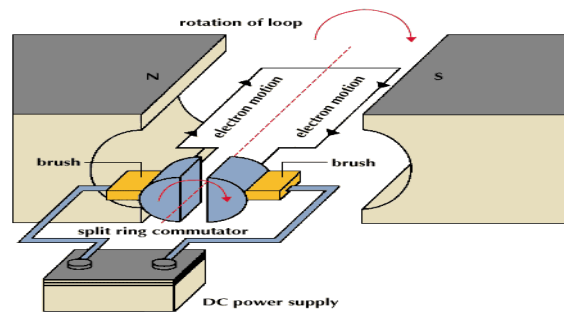


Fig 3.21: Operation of a DC Motor

The magnetic field in the armature and field coil causes the armature to begin to rotate. This occurs by the dissimilar magnetic poles attracting each other and the like magnetic poles grossing out each other. As the armature begins to rotate, the commutator sections will also begin to move beneath the brushes. As an individual commutator segment moves under the brush connected to positive voltage, it will become positive, and when it impresses under a brush connected to negative voltage it will turn negative. In this way, the commutator segments continually change polarity from positive to negative. Since the commutator segments are associated to the ends of the wires that make up the field winding in the armature, it induces the magnetic field in the armature to change polarity continually from north pole to south pole. The commutator sections and brushes are aligned in such a way that the switch in polarity of the armature coincides with

the location of the armature's magnetic field and the field winding's magnetic field. The switching accomplish is timed so that the armature will not lock up magnetically with the field. Rather the magnetic fields tend to build on each other and provide additional torque to keep the motor shaft rotating.

When the voltage is de-energized to the motor, the magnetic fields in that armature and the field winding will quickly diminish and the armature shaft's speed will begin to drop to zero. If voltage is enforced to the motor again, the magnetic fields will toughen and the armature will begin to rotate again .

Types of DC motors:

1. DC Shunt Motor,
2. DC Series Motor,
3. DC Long Shunt Motor (Compound)
4. DC Short Shunt Motor (Compound)

The rotational energy that you get from any motor is usually the battle between two magnetic fields going after each other. The DC motor has magnetic poles and an armature, to windward DC electricity is flowed, The Magnetic Poles are electromagnets, and when they are energized, they develop a strong magnetic field approximately them, and the armature which is given power with a commutator, invariably repels the poles, and therefore rotates.

1. The DC Shunt Motor:

In a 2 pole DC Motor, the armature will have two separate sets of winding, connected to a commutator at the end of the shaft that are in constant touch with carbon brushes. The brushes are motionless, and the commutator rotates and as

the portions of the commutator touching the respective positive or negative polarity brush will energize the respective part of the armature with the respective polarity. It is commonly arranged in such a way that the armature and the poles are always repelling.

The general idea of a DC Motor is, the stronger the Field Current, the stronger the magnetic field, and faster the rotation of the armature. When the armature revolves between the poles, the magnetic field of the poles induce power in the armature conductors, and some electricity is generated in the armature, which is called back emf, and it acts as a resistance for the armature. Generally an armature has resistance of less than 1 Ohm, and powering it with heavy voltages of Direct Current could result in immediate short circuits. This back emf helps us there. When an armature is loaded on a DC Shunt Motor, the speed naturally reduces, and therefore the back emf reduces, which allows more armatures current to flow. This results in more armature field, and therefore it results in torque.

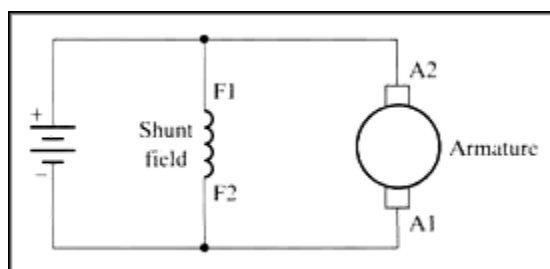


Fig: Diagram of DC shunt motor

When a DC Shunt Motor is overloaded, if the armature becomes too slow, the reduction of the back emf could cause the motor to burn due to heavy current flow thru the armature.

The poles and armature are excited separately, and parallel, therefore it is called a Shunt Motor.

2. The DC Series Motor:

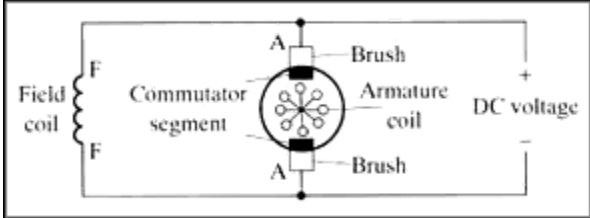


Fig: Diagram of DC series motor

A DC Series Motor has its field coil in series with the armature. hence any amount of power drawn by the armature will be passed through the field. As a result you cannot start a Series DC Motor without any load affiliated to it. It will either run uncontrollably in full speed, or it will block.

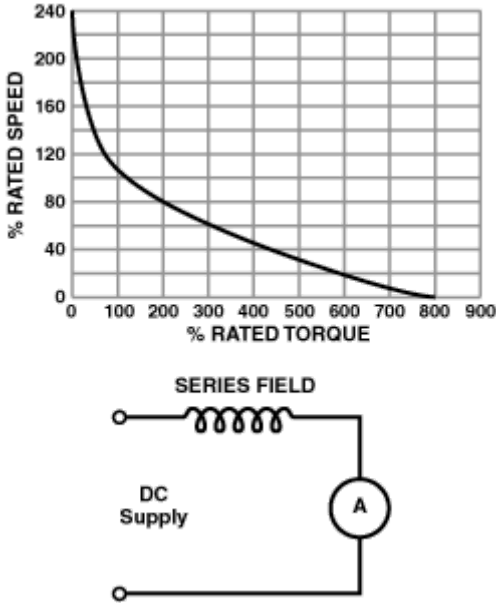


Fig: Diagram of DC series motor graph representation

When the load is increased then its efficiency increases with respect to the load employed. So these are on Electric Trains and elevators.

Specifications

- DC supply: 4 to 12V
- RPM: 300 at 12V
- Total length: 46mm
- Motor diameter: 36mm
- Motor length: 25mm
- Brush type: Precious metal
- Gear head diameter: 37mm
- Gear head length: 21mm
- Output shaft: Centred
- Shaft diameter: 6mm
- Shaft length: 22mm
- Gear assembly: Spur
- Motor weight: 105gms

We generally use 300 RPM Center Shaft Economy Series DC Motor which is high quality low cost DC geared motor. It has steel gears and pinions to assure longer life and better wear and tear places. The gears are fixed on hardened steel spindles polished to a mirror finish. The output shaft circumsolve in a plastic bushing. The whole assembly is crossed with a plastic ring. Gearbox is sealed off and lubricated with lithium grease and require no sustainment. The motor is screwed to the gear box from inside.

Although motor gives 300 RPM at 12V but motor runs smoothly from 4V to 12V and gives wide range of RPM, and torque. Tables below gives reasonably good idea of the motor's performance

in terms of RPM and no load current as a function of voltage and stall torque, stall current as a operate of voltage.

3. DC Compound Motor:

A compound of Series and Shunt excitation for the fields is done in a Compound DC Motor. This affords the best of both series and shunt motors. Improve torque as in a series motor, while the possible action to start the motor with no load.

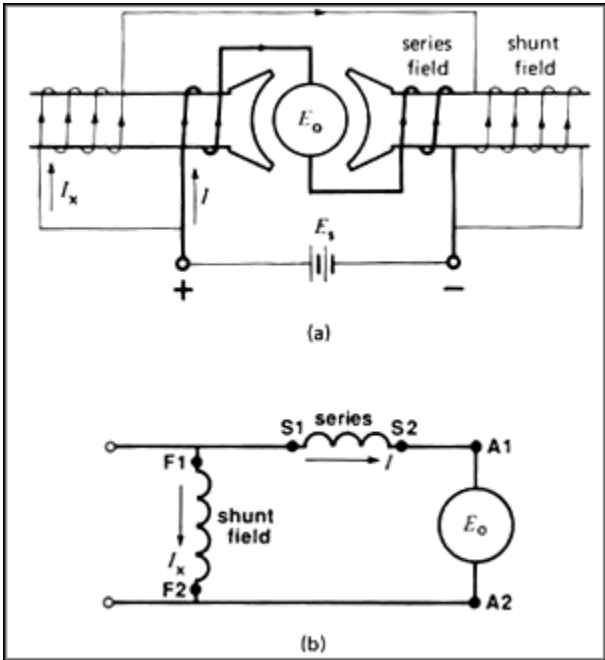


Fig: Diagram of DC compound motor

Above is the diagram of a long shunt motor, as in a short shunt, the shunt coil will be connected after the serial coil.

A Compound motor can be run as a shunt motor absent connecting the serial coil at all but not vice versa.

Applications

BLDC motors fulfill many functions originally performed by brushed DC motors, but cost and control complexity keeps BLDC motors from replacing brushed motors completely in the lowest-cost areas. However, DC motors have come to dominate many applications, especially devices such as computer hard drives and CD/DVD players. Small cooling fans in electronic instrumentation are powered exclusively by BLDC motors. They can be detected in cordless power tools where the increased efficiency of the motor leads to longer periods of use before the battery needs to be charged. Low speed, low power BLDC motors are expended in direct-drive turntables for "analog" audio discs.

Transport

High power BLDC motors are found in electric vehicles and hybrid vehicles. These motors are basically AC synchronous motors with permanent magnet rotors.

The Segway Scooter and Vectrix Maxi-Scooter expend BLDC technology.

A number of electric bicycles use BLDC motors that are sometimes built into the wheel hub itself, with the stator determined solidly to the axle and the magnets attached to and rotating withstand wheel. The bicycle wheel hub is the motor. This type of electric bicycle as well has a standard bicycle transmission on pedals, sprockets, and chain that can be pedaled along with, or absent, the use of the motor as need arises.

Heating and ventilation

There is a trend in the HVAC and refrigeration industries to use BLDC motors instead of various types of AC motors. The most significant conclusion to switch to a BLDC motor is the dramatic reduction in power required to operate them versus a typical AC motor.[8][9] While shaded-pole and permanent disconnected capacitor motors once dominated as the fan motor of choice, many fans are immediately run using a BLDC motor. Some fans use BLDC motors also in government to increase overall system efficiency.[10] In addition to the BLDC motor's higher efficiency, certain HVAC systems (especially those featuring variable-speed and/or load modulation) use BLDC motors because the built-in microprocessor allows for programmability, better assurance over airflow, and serial communication.

Industrial engineering

 This section requires expansion.

See Stepper motor, Servo motor.

Stepper motor

The stepper motor is used in microprocessor and micro controller-based and robotic equipment, as it takes less power and provides accurate movement of robotic arms. Semiconductor manufacturers include Infineon Technologies, Texas Instruments and Microchip. Infineon offers supposed LIN stepper motors used in applications such as instrumentation and gauges, CNC machining, multi-axis laying, printers and surveillance equipment.

Model engineering

BLDC motors are a popular motor choice for model aircraft including helicopters. Their prosperous power-to-weight ratios and large range of usable sizes, from under 5 gram to large motors rated at thousands of watts, have inspired the market for electric-powered model flight.

Their introduction has redefined performance in electric model aircraft and helicopters, moving virtually all brushed electric motors. They have also advocated a development of simple, lightweight electric model aircraft, rather than the premature internal combustion engines powering larger and greater models. The large power-to-weight ratio of modern batteries and brushless motors allows models to come up vertically, rather than climb gradually. The low noise and lack of mess compared to small glow fuel internal combustion engines that are used is another reason for their popularity.

Legal confinements for the use of combustion engine driven model aircraft in some countries have also supported the shift to high-power electric systems.

Their popularity has also risen in the Radio Controlled Car, cracked, and Truck scene, where sensor-type motors (with an extra six wires, connected to Hall effect sensors) allow the position of the rotor magnet to be detected. Brushless motors have been effectual in RC Car Racing in accordance to ROAR (the American governing body for RC Car Racing), since 2006. various RC Car Brushless motors, feature expendable and upgradable parts, such as sintered neodymium-iron-boron (rare earth magnets), ceramic bearings, and exchangeable motor timing assemblies. These motors as a result are rapidly rising to be the preferred motor type for electric on and off-road RC racers and recreational

drivers alike, for their low maintenance, high campaigning reliability and power efficiency (most Sensored motors have an efficiency rating of 80% or greater).

PULSE WIDTH MODULATION (PWM):

Pulse-width modulation (PWM), or pulse-duration modulation (PDM), is a commonly used technique for controlling power to inertial electrical devices, made practical by modern electronic power switches.

The average value of voltage (and current) fed to the load is controlled by turning the switch between supply and load on and off at a fast pace. The longer the switch is on equated to the off periods, the higher the power provided to the load is.

The PWM switching frequency has to be much faster than what would regard the load, which is to say the device that uses the power. generally switching have to be done several times a minute in an electric range, 120 Hz in a lamp dimmer, from few kilohertz (kHz) to tens of kHz for a motor drive and well into the tens or hundreds of kHz in audio amplifiers and computer power supplies.

The term duty cycle describes the proportion of 'on' time to the regular interval or 'period' of time; a low duty cycle corresponds to low power, because the power is off for most significant bit the time. Duty cycle is conveyed in percent, 100% being fully on.

The main advantage of PWM is that power loss in the switching devices is very low. When a switch is off there is much no current, and when it is on, there is nearly no voltage drop across the switch. Power loss, existence the product of

voltage and current, is thus in both examples close to zero. PWM also works well with digital assures, which, because of their on/off nature, can easily set the necessitated duty cycle. PWM has also been used in certain communication systems where its duty cycle has been used to convey information over a communications channel.

One of the advantages of PWM is that the signal remains digital all the way from the processor to the controlled system; no digital-to-analog conversion is necessary. By continuing the signal digital, noise effects are understated. Noise can only affect a digital signal if it is strong enough to change a logic-1 to a logic-0, or contrariwise.

Increased noise immunity is yet another benefit of choosing PWM over analog control, and is the principal conclude PWM is sometimes used for communication. Switching from each one analog signal to PWM can increase the length of a communication channel dramatically. At the receiving end, a suitable RC (resistor-capacitor) or LC (inductor-capacitor) network can remove the modulating high frequency square wave and return the signal to analog form.

PWM finds application in a variety of systems. As a concrete example, conceive a PWM-assured brake. To put it simply, a brake is a device that clamps down hard on something. In many brakes, the quantity of clamping enforced (or stopping power) is controlled with an analog input signal. The more voltage or current that's enforced to the brake, the more force the brake will exert.

The output of a PWM controller could be connected to a switch between the supply and the brake. To develop more stopping power, the software

necessitates only increase the duty cycle of the PWM output. If a particular amount of braking pressure is wanted, measurements would need to be taken to determine the mathematical relationship between duty cycle and pressure. (And the ensuing formulae or lookup tables would be tweaked for functioning temperature, surface wear, and so on.)

To set the pressure on the bracken to, say, 100 psi, the software would do a reverse lookup to determine the duty cycle that should produce that quantity of force. It would then set the PWM duty cycle to the new value and the brake would react accordingly. If a sensor is available in the system, the duty cycle can be tweaked, beneath closed-loop control, until the desired pressure is precisely achieved.

PWM is economical, space saving, and noise resistant. And it's now in your bag of deceptions. So use it.

PWM controllers

Many microcontrollers include on-chip PWM controllers. For example, Microchip's PIC16C67 admits two, each other which has a selectable on-time and period of time. The duty cycle is the ratio of the on-time to the period; the modulating frequency is the inverse of the period. To start PWM procedure, the data sheet suggests the software should:

- Set the period of time in the on-chip timer/counter that provides the modulating square wave
- Set the on-time in the PWM assure register
- Set the direction of the PWM output, which is one of the general-function I/O pins
- Start the timer

- Enable the PWM controller

Although particular PWM controllers do vary in their programmatic details, the basic idea is generally the same.

DC Motor Driver:

The L293 and L293D are quadruple high-current half-H drivers. The L293 is designed to allow for bidirectional drive currents of up to 1 A at voltages from 4.5 V to 36 V. The L293D is planned to provide bidirectional drive currents of up to 600-mA at voltages of 4.5 V to 36 V. Both devices are designed to drive inductive loads such as relays, solenoids, dc and bipolar maltreating motors, as well as other high-current/high up-voltage loads in positive-supply applications.

All inputs are TTL compatible. Each output is a complete totem-pole drive circuit, with a Darlington transistor drop and a pseudo-Darlington source. Drivers are changed in pairs, with drivers 1 and 2 enabled near 1,2EN and drivers 3 and 4 enabled by 3,4EN. When an enable input is high, the linked drivers are enabled and their outputs are active and in phase with their inputs.

When the enable input is low, those drivers are disabled and their outputs are off and in the high-impedance state. With the thoroughly data inputs, each pair of drivers forms a full-H (or bridge) reversible drive suitable for solenoid or motor applications. On the L293, international high-speed output clamp diodes should be used for inductive transient stifling. A VCC1 terminal, classify from VCC2, is provided for the logic inputs to minimize device power dissolution. The L293 and L293D are characterized for operation from 0°C to 70°C.

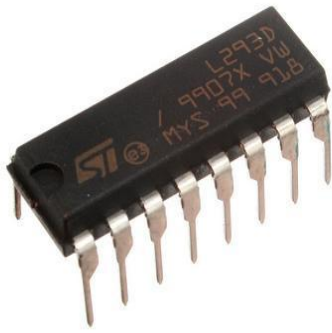


Fig 3.22: L293D IC

Pin Diagram of L293D motor driver:

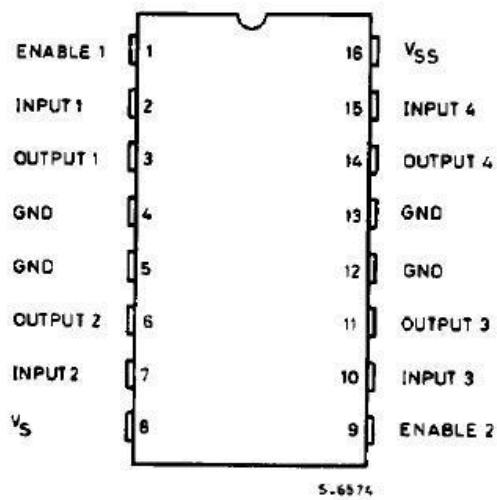


Fig 3.23: L293D pin diagram

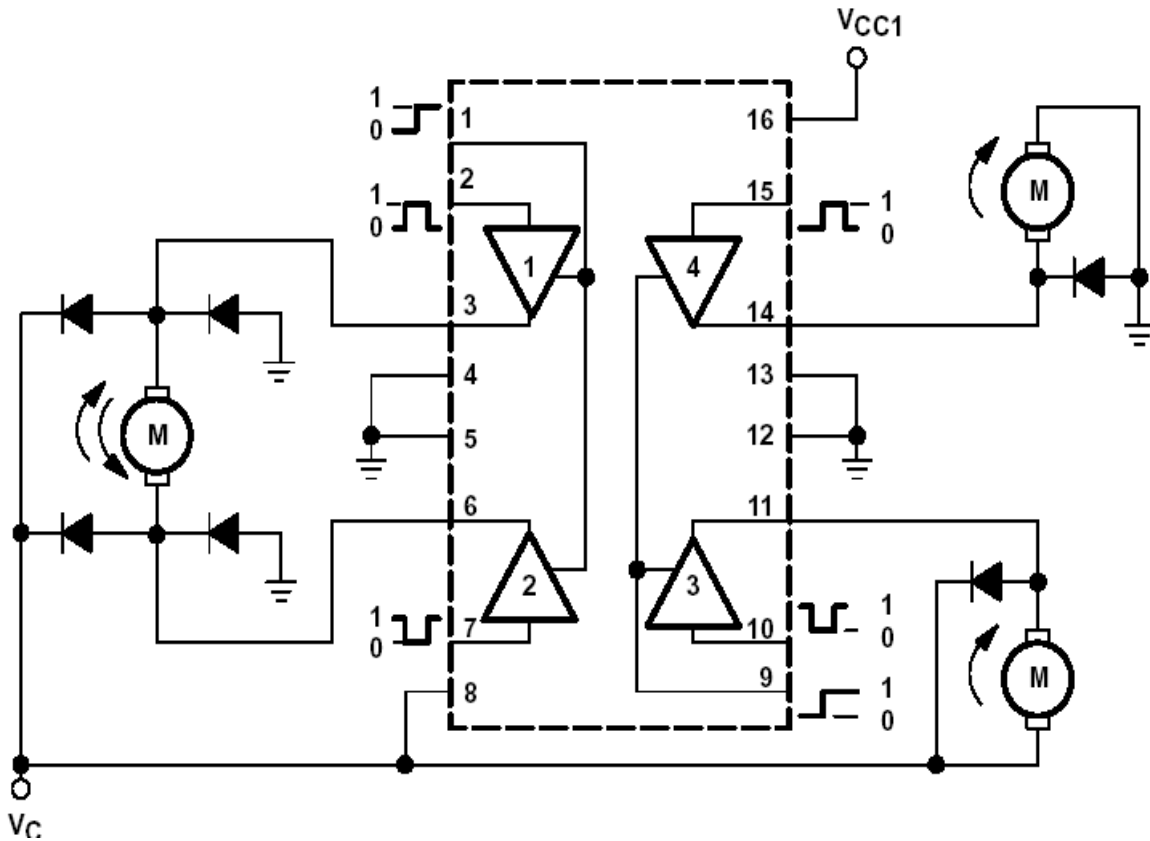


Fig 3.24: Internal structure of L293D.

Features of L293D:

- 600mA Output current capability per channel
- 1.2A Peak output current (non repetitive) per channel
- Enable facility
- Over temperature protection
- Logical "0" input voltage up to 1.5 v
- High noise immunity
- Internal clamp diodes

Applications of DC Motors:

1. Electric Train: A kind of DC motor called the DC Series Motor is used in Electric Trains. The DC Series Motors have the attribute to deliver more power when they are affluent more. So the more the people get on a train, the more herculean the train becomes.

2. Elevators: The best bidirectional motors are DC motors. They are expended in elevators. Compound DC Motors are used for this covering.

3. DC Fans, CD ROM Drives, and Hard Drives: All these things need motors, very miniature motors, with great exactness. AC motors can never conceive of any application in these places.

4. Starter Motors in Automobiles: An automobile battery supplies DC, so a DC motor is best fitted here. Also, you cannot start an engine with a small sized AC motor,

5. Electrical Machines Lab in Colleges.