IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)

An International Open Access, Peer-reviewed, Refereed Journal

A NOVEL SINGLE PHASE NINE-LEVEL TRANSFORMER-LESS PHOTOVOLTAIC (PV) INVERTER

[1]AZMEERA LAKSHMI TEJA, [2]MALIGA SAI KIRAN, [3]MOLUGU SHIVA SAI, [4]VELPULA NAGARAJU

Abstract

The main aim of the project is to design a nine-level inverter using solar panel as input DC voltage. In recent years, high-order multi-level inverters have attracted the attention of many scholars in low-voltage applications such as new energy power generation, microgrids, and motor drives, due to their advantages of high output power quality, low current harmonics, and low voltage stress of switching devices. To reduce the device number per unit level of the existing nine-level inverters, a topology of single-phase transformer less nine-level inverter was proposed. The proposed topology consists of only 10 switching devices and 4 capacitors. In this project, the main controlling component is PIC Microcontroller. PWM signals are sent to the 9-level inverter circuit

CHAPTER 1: INTRODUCTION

1.1 Introduction

In recent years, high-order multi-level inverters have attracted the attention of many scholars in lowvoltage applications such as new energy power generation, microgrids, and motor drives, due to their advantages of high output power quality, low current harmonics, and low voltage stress of switching devices. At present, multi-level inverter circuits mainly include neutral-point-clamped (NPC), flying capacitors (FC), cascaded H-bridge (CHB), stacked multicell converter (SMC) and other topologies. A nine-level active NPC (ANPC) inverter topology is proposed to expand the inverter capacity while reducing the filter size by interleaving and paralleling two five-level ANPC inverters. However, this topology requires 24 switching devices, and the circuit hardware cost is high. A new approach is developed in, which connects four flying capacitor H-bridges in series with one two-level half bridge, effectively reducing the number of switching devices in the nine-level topology to, but the flying capacitor voltage control of this topology is relatively complex. The nine-level inverter topology presented in uses a switched capacitor circuit combined with an H-bridge. This circuit only needs one voltage source, and fewer switching devices. Although the voltage stress of switching devices is relatively small, the energy of this circuit can only be transmitted in one direction. The stacked multiunit multi-level circuit is proposed in, which not only reduces the energy storage of the inverter, but also improves the voltage withstand capability of the circuit. The abovementioned multi-level topology is not suitable for low-voltage application, due to the large number of devices and complex control.

1.2 Literature Survey:

1. **Zhang et al** proposed solution for maintaining constant CMV. To generate three level in the output voltage eight switches are used in this configuration. Switching losses reduces in this topology but there are high conduction losses. If more than three level operation needed, extra number of switches is required.

2. **Ji et al** proposes one topology based on constant CMV with low switching losses. Two diodes and six switches are used in this topology. This method is less convenient to extend the number of levels in the voltage and it has high conduction losses.

3. **Islam and Mekhilef proposed** another topology to lower leakage current by retain constant CMV. Six switches are used for generation of three levels in the output voltage. Conduction losses and switching losses are more and this topology cannot be extended to more than three levels.

From the above-mentioned discussion, we conclude that we need transformer less inverter with minimum semiconductor switches to increase efficiency and economy. Along with extension of higher number of levels in output voltage, Switching and conduction losses is also minimum. This paper proposes one solution to minimize leakage current with less conduction and switching losses for transformer less grid connected PV inverter. Leakage current is minimized by avoiding high frequency transition in terminal voltage with proposed PWM technique. Ten switching devices are required for generation of nine levels in the inverter output voltage.

1.3 Thesis:

The thesis explains the implementation of "**A Novel Single-Phase Nine-Level Transformer-less Photovoltaic (PV) Inverter**" using PIC16F72 microcontroller. The organization of the thesis is explained here with:

Chapter 1 Presents introduction to the overall thesis and the overview of the project. In the project overview, a brief introduction of **A Novel Single-Phase nine-Level Transformer-less Photovoltaic (PV) Inverter** and its applications are discussed.

Chapter 2 Presents the topic embedded systems. It explains the about what is embedded systems, need for embedded systems, explanation of it along with its applications.

Chapter 3 Presents the hardware description. It deals with the block diagram of the project and explains the purpose of each block. In the same chapter the explanation of each module is considered.

Chapter 4 Presents the software description. It explains the implementation of the project using PIC C Compiler software.

Chapter 5 Presents the project description along with solar panel, nine level inverter interfacing to microcontroller.

Chapter 6: Advantages, Disadvantages And Applications

Chapter 7 Presents the results, conclusion and future scope of the project.

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.

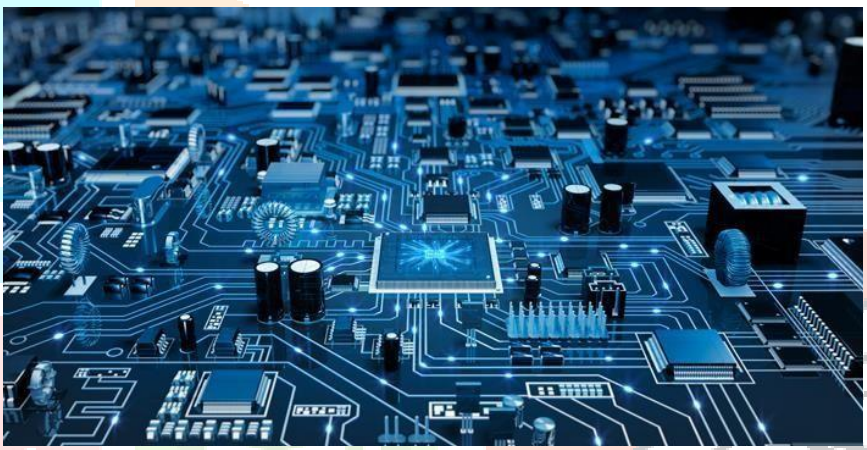


Figure 1. A modern example of embedded system

Labeled parts include microprocessor, RAM, flash memory. 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 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 were there are only 3 or 4 major ones. This means that the tools are more expensive. It also means that they're lowering 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.

2.1.2 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.

2.1.3 Real Time Issues:

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

2.2 Need For Embedded Systems:

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

2.2.1 Debugging:

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

- 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 backups 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.

2.3 Explanation of Embedded Systems:

2.3.1 Software Architecture:

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

A. 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.

B. 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.

C. 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.

D. 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. **E. 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 take 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 come 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:

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

Eg: Consider a TV remote control system, if the remote control takes a few milliseconds delay it will not cause damage either to the TV or to the remote control. These systems which will not cause damage when they are not operated at considerable time period those systems come under soft real-time embedded systems. **2.3.4 Network communication embedded systems:**

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

2.3.5 Different types of processing units:

The central processing unit (c.p.u) can be any one of the following microprocessors, 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.

2.4 APPLICATIONS OF EMBEDDED SYSTEMS:

A. Consumer applications:

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

B. Office automation:

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

C. 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. In critical industries where human presence is avoided there, we can use robots which are programmed to do a specific operation. **D. Computer networking:**

Embedded systems are used as bridges routers etc.

Bridge mode lets you connect two routers without the risk of performance issues. Bridge mode is the configuration that disables the NAT feature on the modem and allows a router to function as a DHCP server without an IP Address conflict. Connecting multiple routers can extend the Wi-Fi coverage in your office/home.

CHAPTER 3: SYSTEM DESIGN

3.1 Introduction: This is the block diagram of single phase 9-level inverter

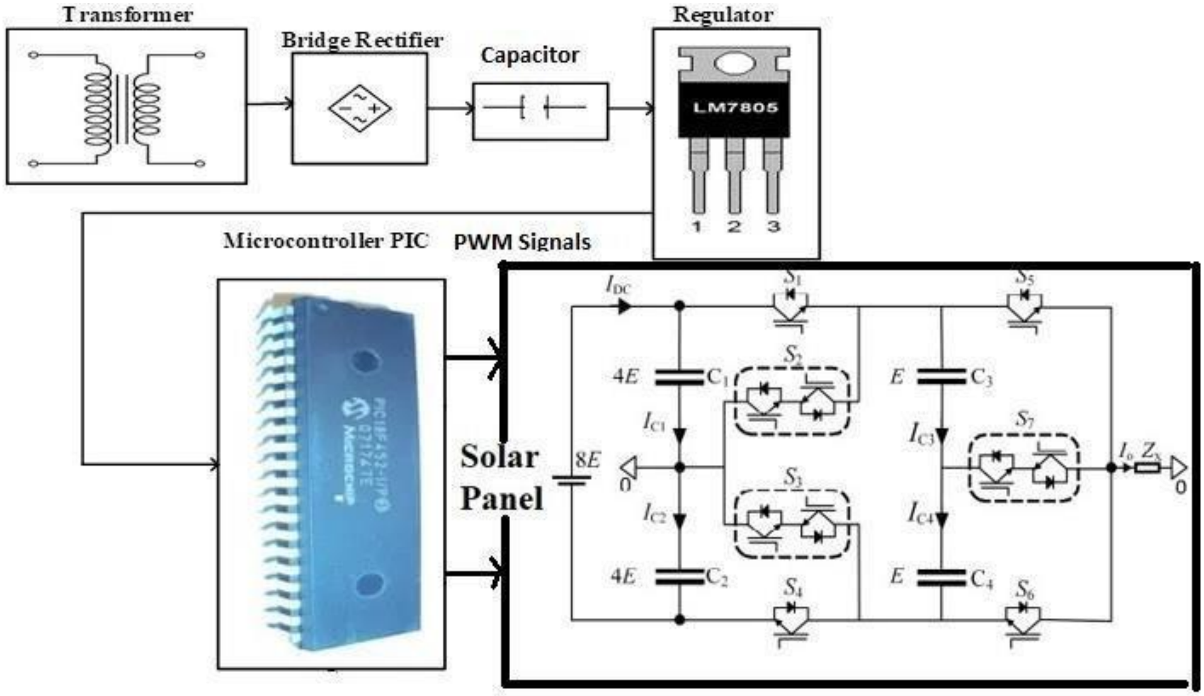


Figure2: Block diagram of A Novel Single-Phase Nine-Level Transformer-less Photovoltaic (PV) Inverter

3.1.1.The major building blocks of this project are:

1. PIC MICROCONTROLLER.
2. PHOTO VOLTAIC PANNEL
3. NINE LEVEL INVERTER
4. CAPACITOR
5. DIODES.
6. MOSFETS
7. PWM SIGNALS.

3.1.2 HARDWARE OF THE PROJECT

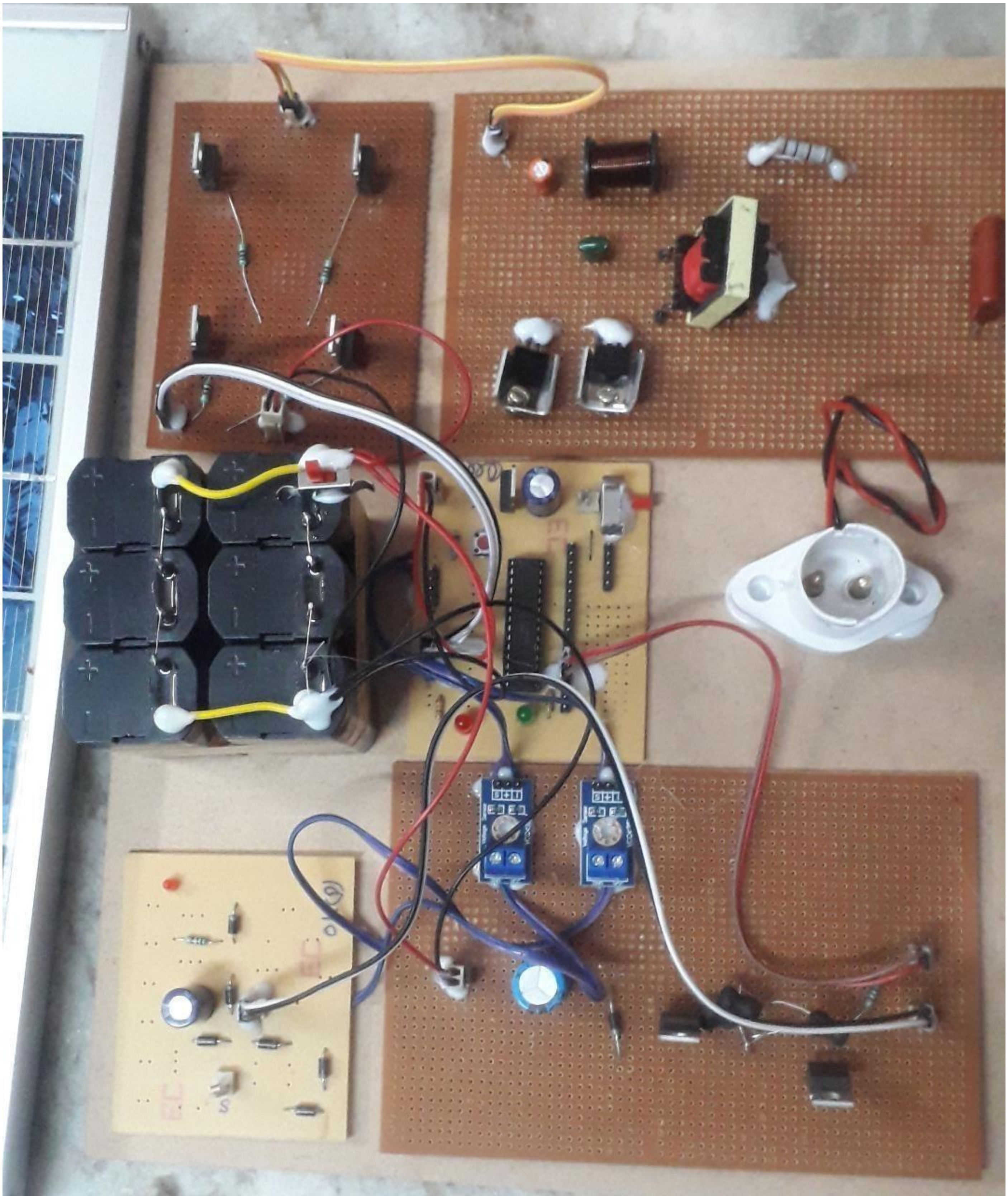


Figure 3 KIT OF THE PROJECT

3.2 Micro controller:

3.2.1 Introduction:

The PIC16F72 CMOS FLASH-based 8-bit microcontroller is upward compatible with PIC16C72/72A and PIC16F872devices. It features 200 ns instruction execution, self-programming, an ICD, 2 Comparators, 5 channels of 8-bit Analog-to-Digital (A/D) converter, 2 capture/compare/PWM functions, a synchronous serial port that can be configured as either 3-wire SPI or 2-wire I2C bus, a USART, and a Parallel Slave Port.

High-Performance RISC CPU

- High performance RISC CPU
- Only 35 single word instructions to learn
- All single cycle instructions except for program branches which are two-cycle
- Operating speed: DC - 20 MHz clock input DC - 200 ns instruction cycle
- 2K x 14 words of Program Memory 128 x 8 bytes of Data Memory (RAM)
- Pin out compatible to the PIC16C72/72A and PIC16F872
- Interrupt capability
- Eight level deep hardware stack
- Direct, Indirect and Relative Addressing modes

3.2.2 Peripheral Features

- Timer0: 8-bit timer/counter with 8-bit prescaler
- Timer1: 16-bit timer/counter with prescaler, can be incremented during SLEEP via external crystal/clock
- Timer2: 8-bit timer/counter with 8-bit period register, prescaler and postscaler
- Capture, Compare, PWM(CCP) module
- Capture is 16-bit, max resolution is 12.5 ns
- Compare is 16-bit, max resolution is 200 ns
- PWM max resolution is 10-bit
- 8-bit, 5-channel Analog-to-Digital converter
- Synchronous Serial Port (SSP) with SPI (Master mode) and I2C (Slave)
- Heat sink/Source Current: 25 mA

- Brown-out detection circuitry for Brown-out Reset (BOR)

3.2.3 CMOS Technology:

- Low power, high speed CMOS FLASH technology
- Fully static design
- Wide operating voltage range: 2.0V to 5.5V
- Industrial temperature range
- Low power consumption:

- < 0.6 mA typical @ 3V, 4 MHz

- 20 µA typical @ 3V, 32 kHz

- < 1 µA typical standby current

Following are the major blocks of PIC Microcontroller.

A. Program memeory :(FLASH)

It is used for storing a written program. Since memory made in FLASH technology can be programmed and cleared more than once, it makes this microcontroller suitable for device development. **B. EPROM :**

Data memory that needs to be saved when there is no supply. It is usually used for storing important data that must not be lost if power supply suddenly stops. For instance, one such data is an assigned temperature in temperature regulators. If during a loss of power supply this data was lost.

C. RAM- Data memory used by a program during its execution

- In RAM are stored all inter-results or temporary data during run-time.
- PORTS are physical connections between the microcontroller and the outside world. PIC16F72 has 22 I/O.

D. FREE-RUN TIMER is an 8-bit register inside a microcontroller that works independently of the program. On every fourth clock of the oscillator, it increments its value until it reaches the maximum (255), and then it starts counting over again from zero. As we know the exact timing between each two increments of the timer contents, timer can be used for measuring time which is very useful with some devices.

3.2.4 Crystal oscillator:

The crystal oscillator speed that can be connected to the PIC microcontroller range from DC to 20Mhz. Using the CCS C compiler normally 20Mhz oscillator will be used and the price is very cheap. The 20 MHz crystal oscillator should be connected with about 22pF capacitor. Please refer to my circuit schematic.

There are 5 input/output ports on PIC microcontroller namely port A, port B, port C, port D and port E. Each port has different function. Most of them can be used as I/O port.

3.2.5 Clock / instruction cycle

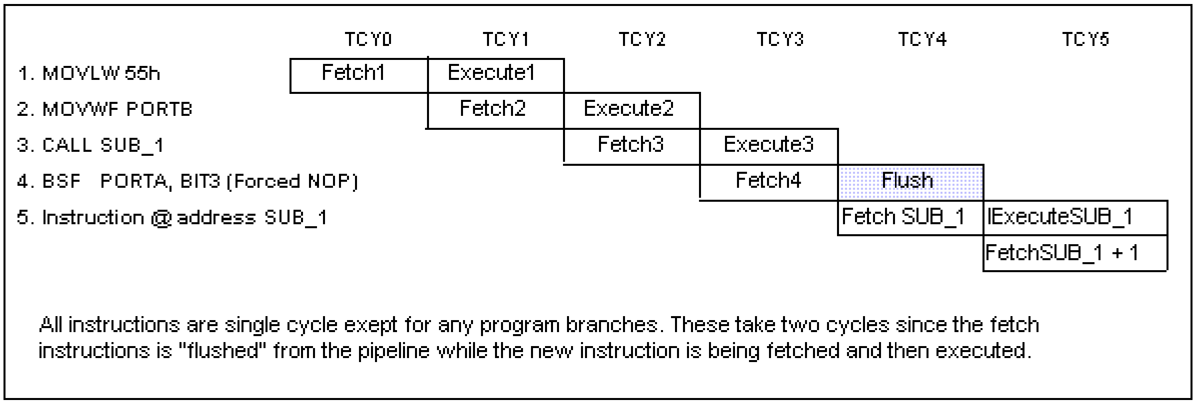
Clock is microcontroller's main starter, and is obtained from an external component called an "oscillator". If we want to compare a microcontroller with a time clock, our "clock" would then be a ticking sound we hear from the time clock. In that case, oscillator could be compared to a spring that is wound so time clock can run. Also, force used to wind the time clock can be compared to an electrical supply.

Clock from the oscillator enters a microcontroller via OSC1 pin where internal circuit of a microcontroller divides the clock into four even clocks Q1, Q2, Q3, and Q4 which do not overlap. These four clocks make up one instruction cycle (also called machine cycle) during which one instruction is executed.

Execution of instruction starts by calling an instruction that is next in string. Instruction is called from program memory on every Q1 and is written in instruction register on Q4. Decoding and execution of instruction are done between the next Q1 and Q4 cycles. On the following diagram we can see the relationship between instruction cycle and clock of the oscillator (OSC1) as well as that of internal clocks Q1-Q4. Program counter (PC) holds information about the address of the next instruction.

3.2.6 Pipelining

Instruction cycle consists of cycles Q1, Q2, Q3 and Q4. Cycles of calling and executing instructions are connected in such a way that in order to make a call, one instruction cycle is needed, and one more is needed for decoding and execution. However, due to pipelining, each instruction is effectively executed in one cycle. If instruction causes a change on program counter, and PC doesn't point to the following but to some other address (which can be the case with jumps or with calling subprograms), two cycles are needed for executing an instruction. This is so because instruction must be processed again, but this time from the right address. Cycle of calling begins with Q1 clock, by writing into instruction register (IR). Decoding and executing begins with Q2, Q3 and Q4 clocks.



Instruction Pipeline Flow

3.2.7 Pin description

IC16F72 has a total of 28 pins. It is most frequently found in a DIP28 type of case but can also be found in SMD case which is smaller from a DIP. DIP is an abbreviation for Dual In Package. SMD is an abbreviation for Surface Mount Devices suggesting that holes for pins to go through when mounting aren't necessary in soldering this type of a component.

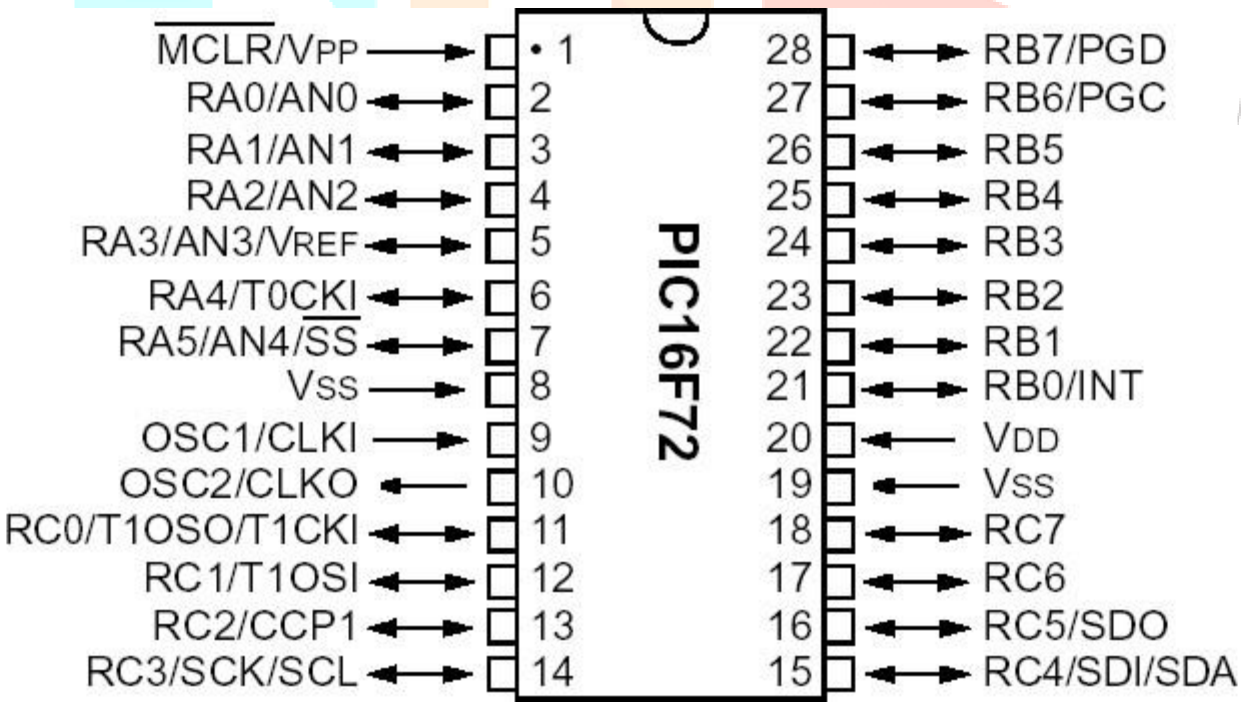


Figure 4: Pins on PIC16F72 microcontroller

There are 28 pins on PIC16F72. Most of them can be used as an IO pin. Others are already for specific functions. These are the pin functions.

1. MCLR – to reset the PIC
2. RA0 – port A pin 0
3. RA1 – port A pin 1

4. RA2 – port A pin 2
5. RA3 – port A pin 3
6. RA4 – port A pin 4
7. RA5 – port A pin 5
8. VSS – ground
9. OSC1 – connect to oscillator
10. OSC2 – connect to oscillator
11. RC0 – port C pin 0 VDD – power supply
12. RC1 – port C pin 1
13. RC2 – port C pin 2
14. RC3 – port C pin 3
15. RC4 - port C pin 4
16. RC5 - port C pin 5
17. RC6 - port C pin 6
18. RC7 - port C pin 7
19. VSS - ground
20. VDD – power supply
21. RB0 - port B pin 0
22. RB1 - port B pin 1
23. RB2 - port B pin 2
24. RB3 - port B pin 3
25. RB4 - port B pin 4
26. RB5 - port B pin 5
27. RB6 - port B pin 6
28. RB7 - port B pin 7

By utilizing all of this pin so many application can be done such as:

1. LCD – connect to Port B pin.
2. LED – connect to any pin declared as output.
3. Relay and Motor - connect to any pin declared as output.
4. External EEPROM – connect to I2C interface pin – RC3 and RC4 (SCL and SDA)
5. LDR, Potentiometer and sensor – connect to analogue input pin such as RA0.
6. GSM modem dial up modem – connect to RC6 and RC7 – the serial communication interface using RS232 protocol. For more detail function for each specific pin please refer to the device datasheet from Microchip.

3.2.8 Memory organization

PIC16F72 has two separate memory blocks, one for data and the other for program. EEPROM memory with GPR and SFR registers in RAM memory make up the data block, while FLASH memory makes up the program block.

3.2.9 Program memory

Program memory has been carried out in FLASH technology which makes it possible to program a microcontroller many times before it's installed into a device, and even after its installment if eventual changes in program or process parameters should occur. The size of program memory is 1024 locations with 14 bits width where locations zero and four are reserved for reset and interrupt vector.

3.2.10 Data memory

Data memory consists of EEPROM and RAM memories. EEPROM memory consists of 256 eight-bit locations whose contents are not lost during loosing of power supply. EEPROM is not directly addressable, but is accessed indirectly through EEADR and EEDATA registers. As EEPROM memory usually serves for storing important parameters (for example, of a given temperature in temperature regulators), there is a strict procedure for writing in EEPROM which must be followed in order to avoid accidental writing. RAM memory for data occupies space on a memory map from location 0x0C to 0x4F which comes to 68 locations. Locations of RAM memory is also called GPR registers which is an abbreviation for *General Purpose Registers*. GPR registers can be accessed regardless of which bank is selected at the moment.

3.2.11 Applications

Perfectly fits many uses, from automotive industries and controlling home appliances to industrial instruments, remote sensors, electrical door locks and safety devices. It is also ideal for smart cards as well as for battery supplied devices because of its low consumption.

EEPROM memory makes it easier to apply microcontrollers to devices where permanent storage of various parameters is needed (codes for transmitters, motor speed, receiver frequencies, etc.). Low cost, low consumption, easy handling and flexibility make PIC16F72 applicable even in areas where microcontrollers had not previously been considered (example: timer functions, interface replacement in larger systems, coprocessor applications, etc.).

3.3 REGULATED POWER SUPPLY:

3.3.1 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.

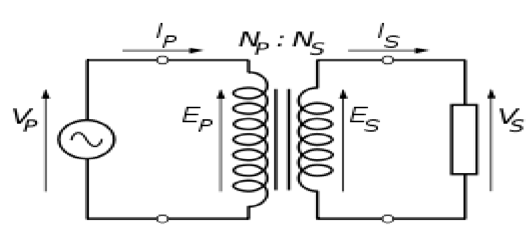
3.3.2 Transformers:

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: 8 shows step-down transformer.



$$\frac{V_P}{V_S} = \frac{I_S}{I_P} = \frac{N_P}{N_S}$$

Figure 5: 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.

3.3.2.1Step 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.

3.3.2.2 Step down transformer:

In case of step-down transformer, Primary winding induces more flux than the secondary winding, and secondary winding is having a smaller number of turns because of that it accepts a smaller number of fluxes, and releases less amount of voltage.

3.3.3 Block Diagram:

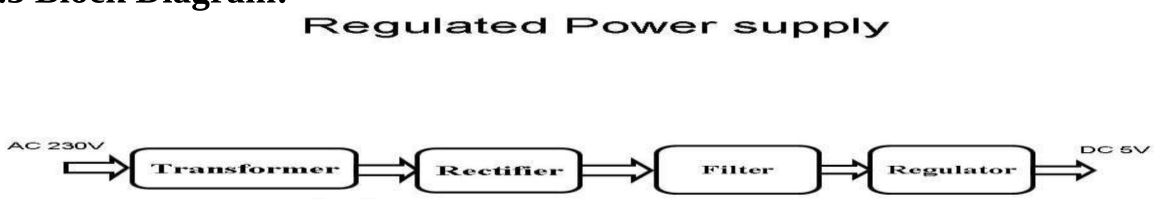


Figure 6: Regulated Power Supply

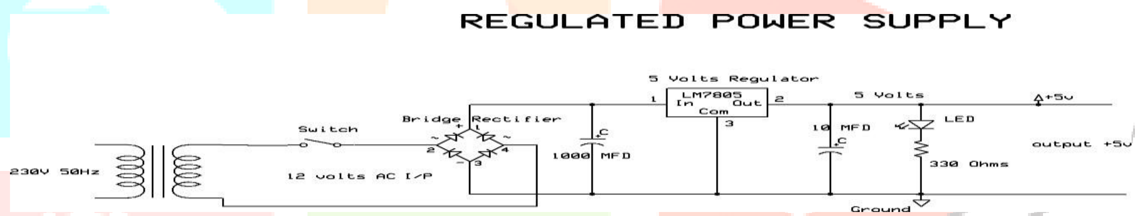


Figure 7: Circuit diagram of Regulated Power Supply with Led connection

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:

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

3.3.4 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: 9 shows Hi-Watt 9V battery

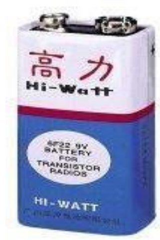


Figure 8: Hi-Watt 9V Battery

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 nickelcadmium 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: 10 shows pencil battery of 1.5V.

Figure 9: Pencil Battery of 1.5V

3.4 Rectification:

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

3.4.1 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.

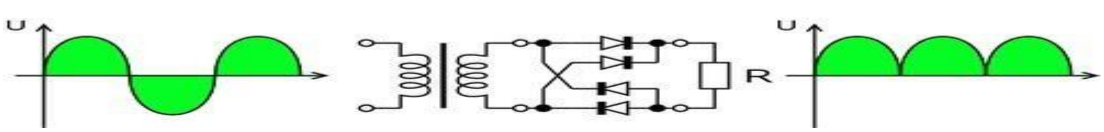
When only one diode is used to rectify AC (by blocking the negative or positive portion of the waveform), the difference between the term diode and the term rectifier is merely one of usage, i.e., the term rectifier describes a diode that is being used to convert AC to DC. Almost all rectifiers comprise 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.

3.4.2 Bridge full wave rectifier:

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

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

Figure 10: Bridge rectifier: a full-wave rectifier using 4 diodes

3.4.3 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. The picture of DB 107 is shown in fig: 3.3.8.

Figure 11: DB107

Features:

- Good for automation insertion
- Surge overload rating - 30 amperes peak
- Ideal for printed circuit board
- Reliable low cost construction utilizing molded
- Glass passivated device
- Polarity symbols molded on body
- Mounting position: Any **3.4.4 Filtration:**

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

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

3.5 CAPACITORS

3.5.1 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

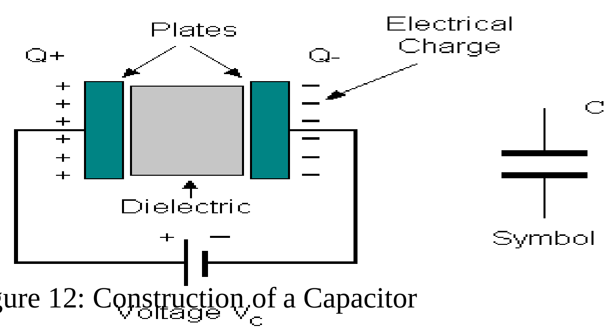


Figure 12: Construction of a Capacitor

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. At this point the capacitor is said to be fully charged and this is illustrated below. The construction of capacitor and an electrolytic capacitor are shown in figures 13 and 14 respectively.

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

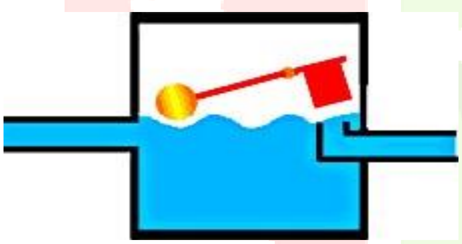
= 10^{-9} F Pico farad (pF) 1pF = 1/1,000,000,000,000 = 0.000000000001

= 10^{-12} F

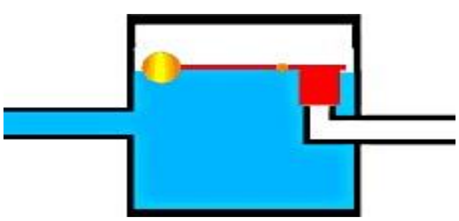
3.5.2 Operation of Capacitor:

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.



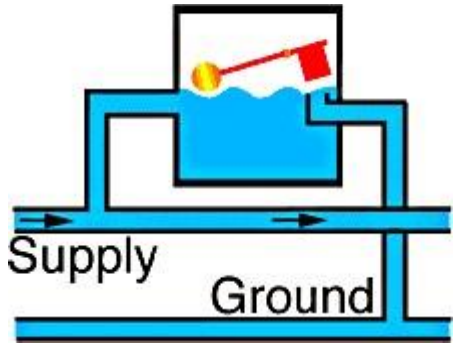
If the current flow is alternating between zero and a maximum, our "storage tank" capacitor will allow the current waves to pass through.



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.

3.6 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.

3.6.1 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 shows voltage regulator.

Figure 13: Voltage 29**Regulator**

3.7 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.

3.7.1 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).

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

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

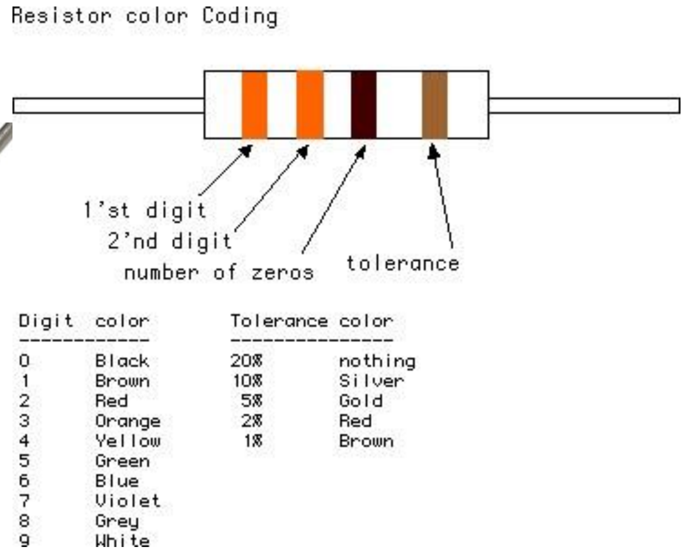
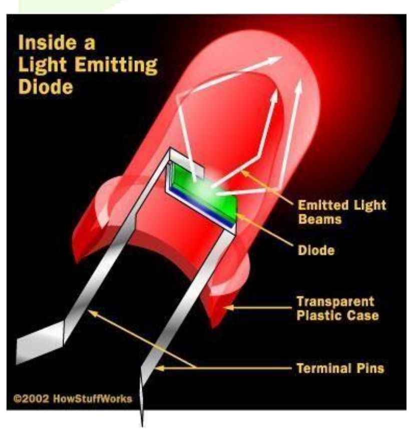


Fig 14: Resistor **Fig 15: Color Bands In Resistor**

3.8 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 in figures 3.4.1 and 3.4.2 respectively.



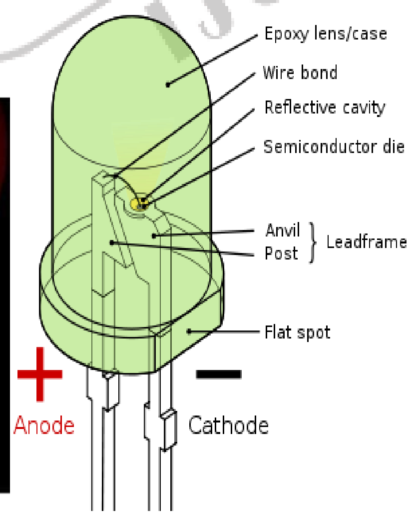


Fig 16: Inside a LED Fig 17: Parts of a LED

3.8.1 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: 3.4.3.

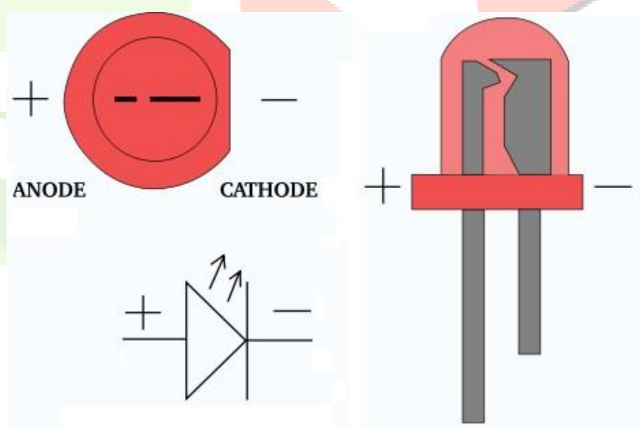


Figure 18: Electrical Symbol & Polarities of LED

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.

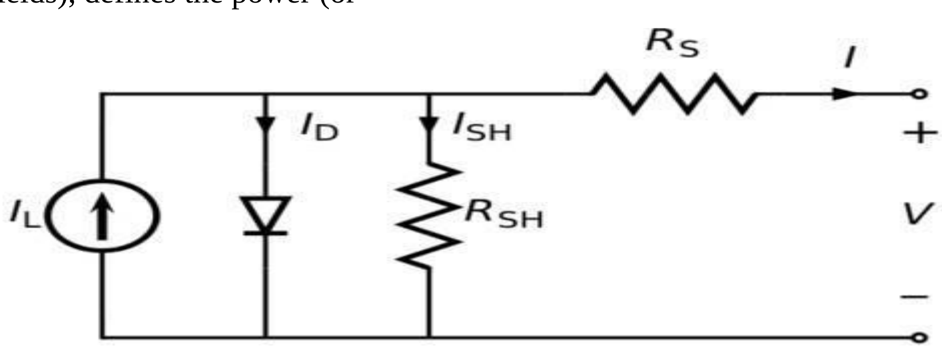
3.9 Solar panel

Photovoltaic Cells: Converting Photons to Electrons

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

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

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



wattage) that the solar cell can produce.

Equivalent circuit of a solar cell

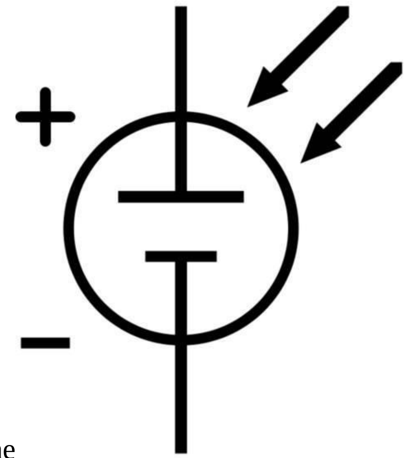


Figure 19: The Figureschematic18: Thesymbol equivalent of a solar circuit cell of a solar cell

1. Photons in sunlight hit the solar panel and are absorbed by semi conducting materials, such as silicon.

2. Electrons (negatively charged) are knocked loose from their atoms, allowing them to flow through the material to produce electricity. Due to the special composition of solar cells, only allow the electrons to move in a single direction. The complementary positive charges that are also created (like bubbles) are called holes and flow in the direction opposite of the electrons in a silicon solar panel.

3. An array of solar panels converts solar energy into a usable amount of direct current (DC) electricity.

3.9.1 Solar Panel Setup:

The use of batteries requires the installation of another component called a **charge controller**. Batteries last a lot longer if they aren't overcharged or drained too much. That's what a charge controller does. Once the batteries are fully charged, the charge controller doesn't let current from the PV modules continue to flow into them. Similarly, once the batteries have been drained to a certain predetermined level, controlled by measuring battery voltage, many charge controllers will not allow more current to be drained from the batteries until they have been recharged. The use of a charge controller is essential for long battery life.

The other problem besides energy storage is that the electricity generated by your solar panels, and extracted from your batteries if you choose to use them, is not in the form that's supplied by your utility or used by the electrical appliances in your house. The electricity generated by a solar system is direct current, so you'll need an **inverter** to convert it into alternating current. Most large inverters will allow you to automatically control how your system works. Some PV modules, called **AC modules**, actually have an inverter already built into each module, eliminating the need for a large, central inverter, and simplifying wiring issues.

Throw in the mounting hardware, wiring, junction boxes, grounding equipment, over current protection, DC and AC disconnects and other accessories, and you have yourself a system. You must follow electrical codes (there's a section in the National Electrical Code just for PV), and it's highly recommended that a licensed electrician who has experience with PV systems do the installation. Once installed, a PV system requires very little maintenance (especially if no batteries are used), and will provide electricity cleanly and quietly for 20 years or more.

3.9.2 Categories of Solar Panel:

A .POLYCRYSTALLINE MODULES

Polycrystalline (or multi crystalline) modules are composed of a number of different crystals, fused together to make a single cell (hence the term 'multi'). They have long been the most popular type of solar module, due to the lower cost in manufacturing the cells. Recently, the cost of monocrystalline has come down, making them more popular in the residential market.

As you can see in the image (left), the construction of these different crystals gives the solar panel a visible crystal grain, or a 'metal flake effect'. They are slightly cheaper to produce than Mono panels, but are also less efficient (anywhere from 0.5% to 2% less efficient depending on the manufacturer). This is because the crystal grain boundaries can trap electrons, which results in lower efficiency.

The BP Solar modules that EnviroGroup installs are approximately 13.5% efficient (meaning that if 100 Watts of potential solar energy strikes the panel, it will produce approximately 13.5 Watts of solar electricity).

These panels are very popular in Australia, and offer a good balance of value vs performance.

✓	✗
Cost effective to manufacture	Not as efficient as mono
Good efficiency	Has more silicon – high embodied energy
Commonly available – easy to replace	
Takes up small area on roof	

Table 1: Advantages and disadvantages of polycrystalline

B. MONOCRYSTALLINE MODULES

Monocrystalline, as the name suggests, is constructed using one single crystal, cut from ingots. This gives the solar panel a uniform appearance across the entire module. These large single crystals are exceedingly rare, and the process of 'recrystallising' the cell is more expensive to produce.

This technology is now the most widely available in Australia, with the cost of producing monocrystalline cells coming down every year. They are still more expensive than polycrystalline, but can be up to 2% more efficient. EnviroGroup uses SunOwe (14.5%) and Suntech (16.5%) monocrystalline solar modules for our installations.

Suntech have recently made some exciting developments in monocrystalline efficiency, with the patent pending Pluto technology. Unique texturing technology, with lower reflectivity, ensures more sunlight can be absorbed throughout the day even without direct solar radiation, and thinner metal lines on the top surface reduces

shading loss. Importantly, the process was developed at the University of New South Wales, and has achieved lab efficiency of 25%, and verified efficiency of approx 19%. These panels will be more expensive, but will offer far more solar electricity for less area of solar panel.

Table 2: Advantages and disadvantages of monocrystalline

✓	✗
Most efficient module available	More expensive to produce
Most popular technology on market	Has more silicon – high embodied energy
Commonly available – easy to replace	
Takes up small area on roof	

C. AMORPHOUS MODULES

Amorphous (or 'thin film') solar modules have recently become very popular in the Australian market. They offer better performance in higher temperatures, and have some benefits in shady locations. However, the benefits have been greatly exaggerated by some suppliers, and it is important to weigh that up against the negatives of thin film technology.

The manufacture of these panels is highly automated - silicon is sprayed onto the substrate as a gas (called 'vapour deposition'), which means that the silicon wafer is approx 1 micron thick (compared to approx 200 microns for mono and poly). This means that the panel uses less energy to produce therefore will pay itself back from an energy point of view in a shorter time. However, it also means that the panels are far less efficient than mono or poly (approx 5-6% efficient).

The electrical connections are etched by a laser. Etching these as long horizontal cells across the panel makes these less susceptible from being blocked by shade, but it's important to recognise that there will still be a significant drop-off in performance when the panel is shaded.

Thin-film panels are significantly less efficient than crystalline panels, and a greater number is required for the same output. On average, a thin film solar array will need 2.5 times more roof area than mono or poly. This is critical if you intend to increase the size of your system later, as you may take up all of your north-facing roof for a relatively small system.

One of the biggest selling points of thin film is the performance in hotter temperatures. Unfortunately, this has been misrepresented by some suppliers of thin film panels. As an example, if you

Table 3 :Advantages and Disadvantages of Amorphous Module

✓	✗
Partially shade tolerant	Poor efficiency (6%)
More effective in hotter climate	Takes up more space for same output
Uses less silicon – low embodied energy	New technology – less proven reliability
No aluminium frame – low embodied energy	Less popular – harder to replace

live in Melbourne, and you are shown a graph that indicates the performance of thin film panels in Alice Springs, it's obvious that those panels won't provide the same advantage in a cooler climate.

3.9.3 Advantages of Solar Power Generation

The greatest advantage of solar power generation is perhaps its minimal environmental impact. It requires no water for cooling of the system, thus creating no large heat imbalance. Also, no by-products are produced that are detrimental to the environment. Another advantage of solar power generation is that bulky mechanical generators are not needed. The process of electricity generation is quick and the arrays are available in a variety of sizes according to the specific use.

1. Solar energy is free of pollution.
2. The plant requires little maintenance or help after setup.
3. It is economical.
4. When it is connected to the grid, solar energy can overtake the highest cost electricity at peak demand and can also reduce grid loading, apart from getting rid of the need for local battery power in darkness.

3.9.4 Disadvantages:

1. It is available only by day and not when the sky is cloudy, thereby reducing the chances of it being totally reliable and requiring storage facilities.
2. It needs a backup power plant to be kept hot and to replace solar power stations as they stop producing energy.
3. Keeping backup plants hot includes an energy cost which includes coal burning.

4. Places located at high altitudes or those that are often cloudy are not targets for solar power use.
5. It can only be used to power transport vehicles by converting energy into another form of energy and recurring an energy penalty.
6. Solar cell technologies produce DC power which needs to be converted to AC power, incurring an energy penalty.

Solar energy can be used to generate electricity using photovoltaic solar cells and concentrated solar power, apart from other means. You can use solar power in the house for domestic use.

3.9.5 Applications of solar technology:

Average insulation showing land area (small black dots) required to replace the world primary energy supply with solar electricity. 18 TW is 568 Exajoule (EJ) per year. Insulation for most people is from 150 to 300 W/m² or 3.5 to 7.0 kWh/m²/day.

Solar energy refers primarily to the use of solar radiation for practical ends. However, all renewable energies, other than geothermal and tidal, derive their energy from the sun.

Solar technologies are broadly characterized as either passive or active depending on the way they capture, convert and distribute sunlight. Active solar techniques use photovoltaic panels, 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

Solar cells can also be applied to other electronics devices to make it self-power sustainable in the sun. There are solar cell phone chargers, solar bike light and solar camping lanterns that people can adopt for daily use.

Solar power plants can face high installation costs, although this has been decreasing due to the learning curve. Developing countries have started to build solar power plants, replacing other sources of energy generation.

3.10 Nine level inverters:

Figure Below shows the 12 working states of the proposed topology. The solid arrows in the figure represent the reference positive direction of the current on each path, and the dashed arrows represent the actual flow direction of the current. The detailed switch status analysis is as follows: (1) State P4 (Figure 2a): The switches S1 and S5 are turned on, the current flows from the positive terminal of the dc-link through the switches S1, S5 and the load, and then returns to the neutral point, the inverter output voltage VO = VDC/2. The current flowing through capacitors C3 and C4 is IC3 = IC4 = 0. (2) State P3 (Figure 2b): The switches S1 and S7 are turned on, the current starts from the positive end of the dc-link and returns to the neutral point after passing through S1, C3, S7 and the load, and the output voltage VO = 3VDC/8. The current through C3 is IO and the current through C4 is 0. (3) State P2P (Figure 2c): the switches S1 and S6 are turned on, the current starts from the positive terminal of the dc-link and returns to the neutral point through S1, C3, C4, S6 and the load. The output voltage VO = VDC/4, and the currents IC3 = IC4 = IO. (4) State P2N (Figure 2d): the switch S3 and S5 are turned on, the current starts from the neutral point and returns to the neutral point after passing through S3, C4, C3, S5 and the load. The output voltage VO = VDC/4, and the currents IC3 = IC4= −IO. (5) State P1 (Figure 2e): the switches S3 and S7 are turned on, the current starts from the neutral point and returns to the neutral point after passing through S3, C4, S7 and the load. The output voltage VO = VDC/8, while the currents IC3 = 0 and IC4 = −IO. (6) State OP (Figure 2f): The switches S2 and S5 are turned on, and the current starts from the neutral point and returns to the neutral point after passing through S2, S5 and the load. At this time, VO = 0, IC3 = IC4 = 0. (7) The state is ON (Figure 2g): the switches S3 and S6 are turned on, the current starts from the neutral point and then returns to the neutral point after passing through S3, S6 and the load, and the voltage VO = 0, and the currents IC3 = IC4 = 0. (8) State N1 (Figure 2h): The switches S2 and S7 are turned on, the current starts from the neutral point and returns to the neutral point after passing through S2, C3, S7 and the load. The output voltage VO = −VDC/8, and the currents IC3 = IO, IC4 = 0.

State N2P (Figure 2i): The switch tubes S2 and S6 are turned on, the current starts from the neutral point and returns to the neutral point after passing through S2, C3, C4, S6 and the load. The voltage VO = −VDC/4, and the currents IC3 = IC4 = IO. (10) State N2N (Figure 2j): The switches S4 and S5 are turned on, and the current starts from the negative end of the dc-link and returns to the neutral point through S4,

C4, C3, S5 and the load. The output voltage VO = −VDC/4, and the currents IC3 = IC4 = −IO. (11) State N3 (Figure 2k): the switches S4 and S7 are turned on, the current starts from the negative end of the dclink and then returns to the negative end of the dc-link through S4, C4, S7 and the load. The voltage VO = −3VDC/8, and the current IC4 = −IO. (12) State N4 (Figure 2l): The switches S4 and S6 are turned on, the current starts from the negative end of the dc-link and returns to the neutral point after passing through S4, S6 and the load. The voltage VO = −VDC/2, and the currents IC3 = IC4 = 0.

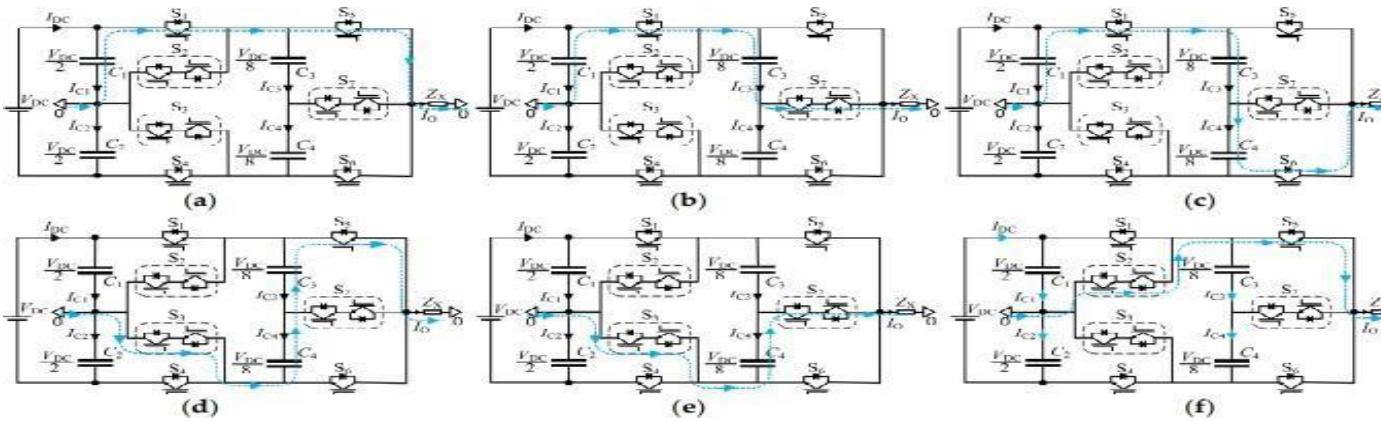


Figure 20: Working of nine level inverter in positive cycle

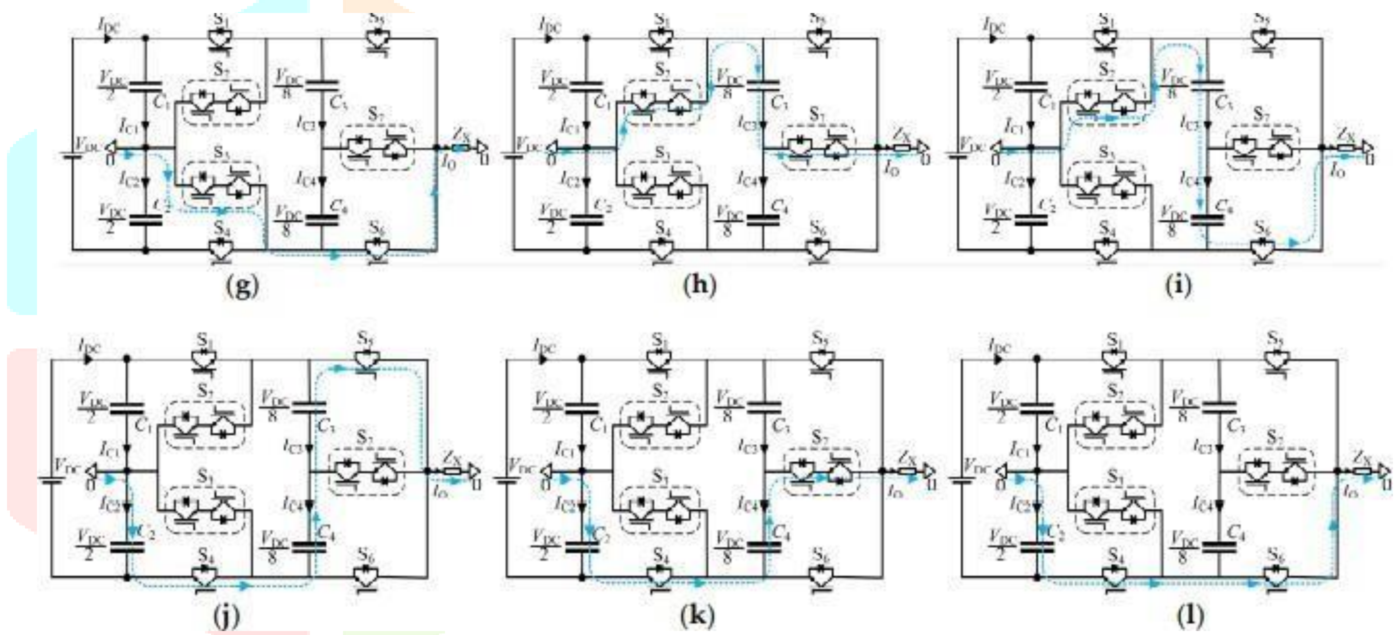


Figure 21: Working of nine level inverter in negative cycle

Table 4 :switching states of the proposed 9level converter

Table 1. Switching states of the proposed 9-level converter.

S_1–S_7	States	V_{C3}		V_{C4}		V_O
		$I_O > 0$	$I_O < 0$	$I_O > 0$	$I_O < 0$	
1000100	P4	-	-	-	-	4E
1000001	P3	↑	↓	-	-	3E
1000010	P2P	↑	↓	↑	↓	2E
0010100	P2N	↓	↑	↓	↑	2E
0010001	P1	-	-	↓	↑	E
0100100	OP	-	-	-	-	0
0010010	ON	-	-	-	-	0
0100001	N1	↑	↓	-	-	E
0100010	N2P	↑	↓	↑	↓	−2E
0001100	N2N	↓	↑	↓	↑	−2E
0001001	N3	-	-		↑	−3E
0001010	N4	-	-	-	-	−4E

Note: '↑' means capacitor charging; '↓' means capacitor discharge.

3.11 MOSFET

The **metal–oxide–semiconductor field-effect transistor** (**MOSFET**, **MOS-FET**, or **MOS FET**) is a transistor used for amplifying or switching electronic signals. Although the MOSFET is a fourterminal device with source (S), gate (G), drain (D), and body (B) terminals,[1] the body (or substrate) of the MOSFET often is connected to the source terminal, making it a three-terminal device like other fieldeffect transistors. When two terminals are connected to each other (short-circuited) only three terminals appear in electrical diagrams. The MOSFET is by far the most common transistor in both digital and analog circuits, though the bipolar junction transistor was at one time much more common.

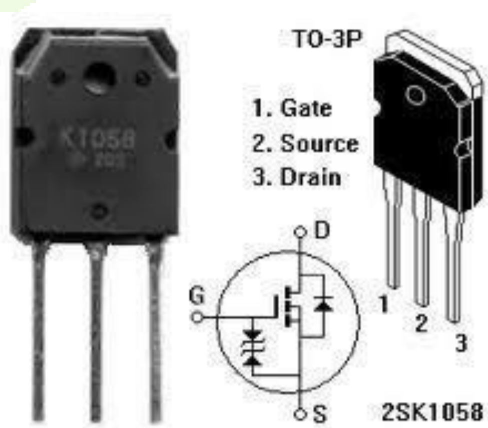


Figure 22: MOSFET (REGULATOR)

In enhancement mode MOSFETs, a voltage drop across the oxide induces a conducting channel between the source and drain contacts *via* the field effect. The term "enhancement mode" refers to the increase of conductivity with increase in oxide field that adds carriers to the channel, also referred to as the inversion layer. The channel can contain electrons (called an nMOSFET or nMOS), or holes (called a pMOSFET or pMOS), opposite in type to the substrate, so nMOS is made with a p-type substrate, and pMOS with an n-type substrate (see article on semiconductor devices). In the less common *depletion mode* MOSFET, described further later on, the channel consists of carriers in a surface impurity layer of opposite type to the substrate, and conductivity is decreased by application of a field that depletes carriers from this surface layer.[2]

The 'metal' in the name MOSFET is now often a misnomer because the previously metal gate material is now often a layer of polysilicon (polycrystalline silicon). Aluminium had been the gate material until the mid-1970s, when polysilicon became dominant, due to its capability to form self-aligned gates. Metallic gates are regaining popularity, since it is difficult to increase the speed of operation of transistors without metal gates.

Likewise, the 'oxide' in the name can be a misnomer, as different dielectric materials are used with the aim of obtaining strong channels with applied smaller voltages.

An insulated-gate field-effect transistor or **IGFET** is a related term almost synonymous with MOSFET. The term may be more inclusive, since many "MOSFETs" use a gate that is not metal, and a gate insulator that is not oxide. Another synonym is MISFET for metal–insulator–semiconductor FET.

A variety of symbols are used for the MOSFET. The basic design is generally a line for the channel with the source and drain leaving it at right angles and then bending back at right angles into the same direction as the channel. Sometimes three-line segments are used for enhancement mode and a solid line for depletion mode. Another line is drawn parallel to the channel for the gate.

The bulk connection, if shown, is shown connected to the back of the channel with an arrow indicating PMOS or NMOS. Arrows always point from P to N, so an NMOS (N-channel in P-well or Psubstrate) has the arrow pointing in (from the bulk to the channel). If the bulk is connected to the source (as is generally the case with discrete devices) it is sometimes angled to meet up with the source leaving the transistor. If the bulk is not shown (as is often the case in IC design as they are generally common bulk) an inversion symbol is sometimes used to indicate PMOS, alternatively an arrow on the source may be used in the same way as for bipolar transistors (out for nMOS, in for pMOS).

Comparison of enhancement-mode and depletion-mode MOSFET symbols, along with JFET symbols (drawn with source and drain ordered such that higher voltages appear higher on the page than lower voltages):

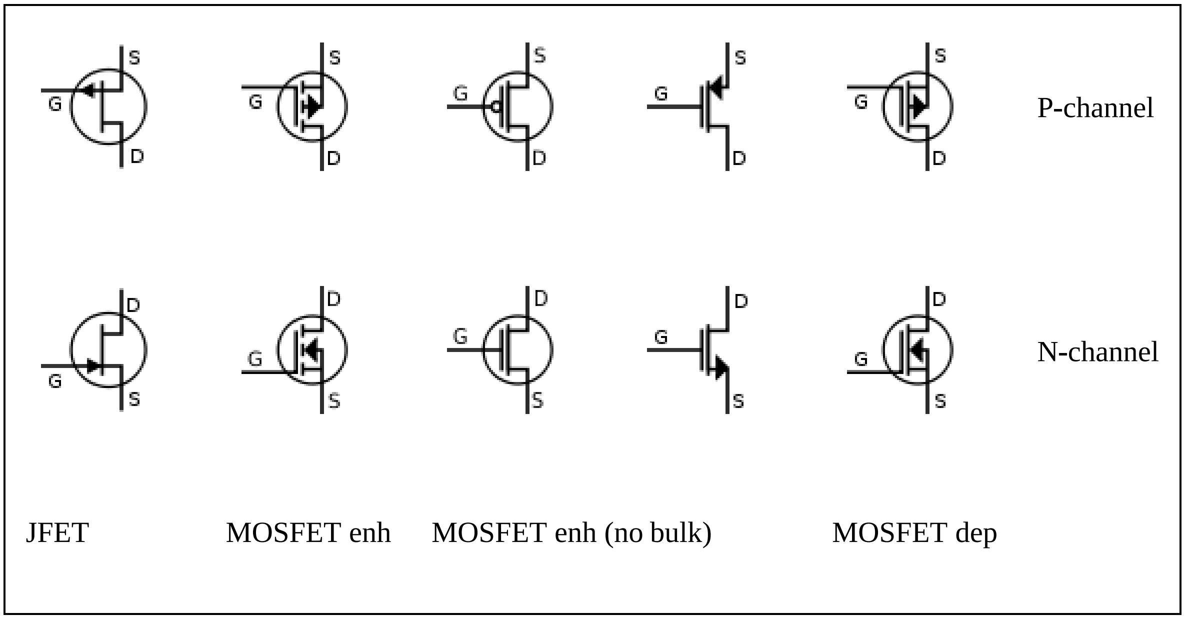
For the symbols in which the bulk, or body, terminal is shown, it is here shown internally connected to the source. This is a typical configuration, but by no means the only important configuration. In general, the MOSFET is a four-terminal device, and in integrated circuits many of the MOSFETs share a body connection, not necessarily connected to the source terminals of all the transistors.

3.11.1 Circuit symbols

A variety of symbols are used for the MOSFET. The basic design is generally a line for the channel with the source and drain leaving it at right angles and then bending back at right angles into the same direction as the channel. Sometimes three-line segments are used for enhancement mode and a solid line for depletion mode. Another line is drawn parallel to the channel for the gate.

The bulk connection, if shown, is shown connected to the back of the channel with an arrow indicating PMOS or NMOS. Arrows always point from P to N, so an NMOS (N-channel in P-well or Psubstrate) has the arrow pointing in (from the bulk to the channel). If the bulk is connected to the source (as is generally the case with discrete devices) it is sometimes angled to meet up with the source leaving the transistor. If the bulk is not shown (as is often the case in IC design as they are generally common bulk) an inversion symbol is sometimes used to indicate PMOS, alternatively an arrow on the source may be used in the same way as for bipolar transistors (out for nMOS, in for pMOS).

Comparison of enhancement-mode and depletion-mode MOSFET symbols, along with JFET symbols (drawn with source and drain ordered such that higher voltages appear higher on the page than lower voltages):



3.11.2 PIN DIAGRAM:

Figure 23: PIN DIAGRAM

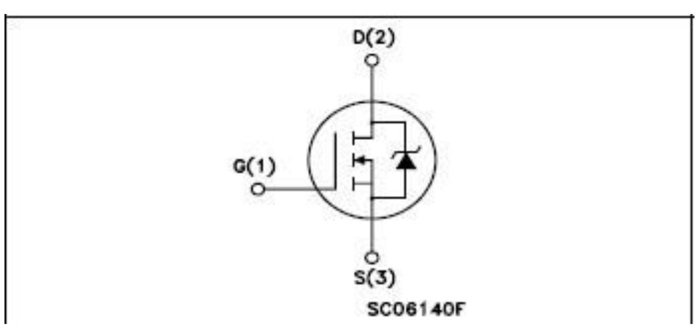


Figure 24: SCHEMATIC DIAGRAM

3.11.3 MOSFET operation

Metal–oxide–semiconductor structure

The traditional metal–oxide–semiconductor (MOS) structure is obtained by growing a layer of silicon dioxide (SiO_2) on top of a silicon substrate and depositing a layer of metal or polycrystalline silicon

(the latter is commonly used). As the silicon dioxide is a dielectric material, its structure is equivalent to a planar capacitor, with one of the electrodes replaced by a semiconductor. When a voltage is applied across a MOS structure, it modifies the distribution of charges in the semiconductor. If we consider a p-type semiconductor (with N_A the density of acceptors, p the density of holes; p = NA in neutral bulk), a positive voltage, V_{GB}, from gate to body (see figure) creates a depletion layer by forcing the positively charged holes away from the gate-insulator/semiconductor interface, leaving exposed a carrier-free region of immobile, negatively charged acceptor ions (see doping (semiconductor)).

If V_{GB} is high enough, a high concentration of negative charge carriers forms in an inversion layer located in a thin layer next to the interface between the semiconductor and the insulator. Unlike the MOSFET, where the inversion layer electrons are supplied rapidly from the source/drain electrodes, in the MOS capacitor they are produced much more slowly by thermal generation through carrier generation and recombination centers in the depletion region. Conventionally, the gate voltage at which the volume density of electrons in the inversion layer is the same as the volume density of holes in the body is called the threshold voltage. When the voltage between transistor gate and source (VGS) exceeds the threshold voltage (Vth), it is known as overdrive voltage.This structure with p-type body is the basis of the n-type MOSFET, which requires the addition of an n-type source and drain regions.

MOSFET structure and channel formation

Field effect (semiconductor)

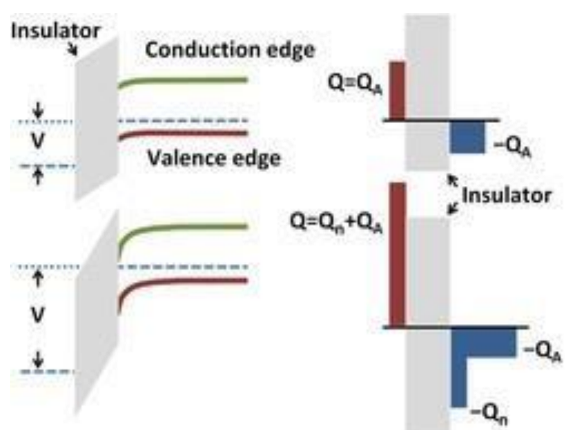


Figure 25: Channel formation

Channel formation in nMOS MOSFET: Top panels: An applied gate voltage bends bands, depleting holes from surface (left). The charge inducing the bending is balanced by a layer of negative acceptor-ion charge (right). Bottom panel: A larger applied voltage further depletes holes but conduction band lowers enough in energy to populate a conducting channel.

A metal–oxide–semiconductor field-effect transistor (MOSFET) is based on the modulation of charge concentration by a MOS capacitance between a body electrode and a gate electrode located above the body and insulated from all other device regions by a gate dielectric layer which in the case of a MOSFET is an oxide, such as silicon dioxide. If dielectrics other than an oxide such as silicon dioxide (often referred to as oxide) are employed the device may be referred to as a metal–insulator–semiconductor FET (MISFET). Compared to the MOS capacitor, the MOSFET includes two additional terminals (source and drain), each connected to individual highly doped regions that are separated by the body region. These regions can be either p or n type, but they must both be of the same type, and of opposite type to the body region. The source and drain (unlike the body) are highly doped as signified by a '+' sign after the type of doping.

If the MOSFET is an n-channel or nMOS FET, then the source and drain are 'n+' regions and the body is a 'p' region. If the MOSFET is a p-channel or pMOS FET, then the source and drain are 'p+' regions and the body is a 'n' region. The source is so named because it is the source of the charge carriers (electrons for n-channel, holes for p-channel) that flow through the channel; similarly, the drain is where the charge carriers leave the channel.

The occupancy of the energy bands in a semiconductor is set by the position of the Fermi level relative to the semiconductor energy-band edges. As described above, and shown in the figure, with sufficient gate voltage, the valence band edge is driven far from the Fermi level, and holes from the body are driven away from the gate.

At larger gate bias still, near the semiconductor surface the conduction band edge is brought close to the Fermi level, populating the surface with electrons in an inversion layer or n-channel at the interface between the p region and the oxide. This conducting channel extends between the source and the drain, and current is conducted through it when a voltage is applied between the two electrodes. Increasing the voltage on the gate leads to a higher electron density in the inversion layer and therefore increases the current flow between the source and drain.

For gate voltages below the threshold value, the channel is lightly populated, and only a very small sub threshold leakage current can flow between the source and the drain.

When a negative gate-source voltage (positive source-gate) is applied, it creates a p-channel at the surface of the n region, analogous to the n-channel case, but with opposite polarities of charges and voltages. When a voltage less negative than the threshold value (a negative voltage for p-channel) is applied between gate and source, the channel disappears and only a very small sub threshold current can flow between the source and the drain.

The device may comprise Silicon on Insulator (SOI) device in which a buried oxide (BOX) is formed below a thin semiconductor layer. If the channel region between the gate dielectric and a BOX region is very thin, the very thin channel region is referred to as an ultrathin channel (UTC) region with the source and drain regions formed on either side thereof in and/or above the thin semiconductor layer. Alternatively, the device may comprise a semiconductor on insulator (SEMOI) device in which semiconductors other than silicon are employed. Many alternative semiconductor materials may be employed.

When the source and drain regions are formed above the channel in whole or in part, they are referred to as raised source/drain (RSD) regions

Modes of operation

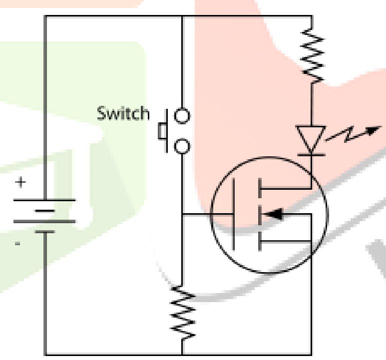


Figure 26: OPERATION MODES

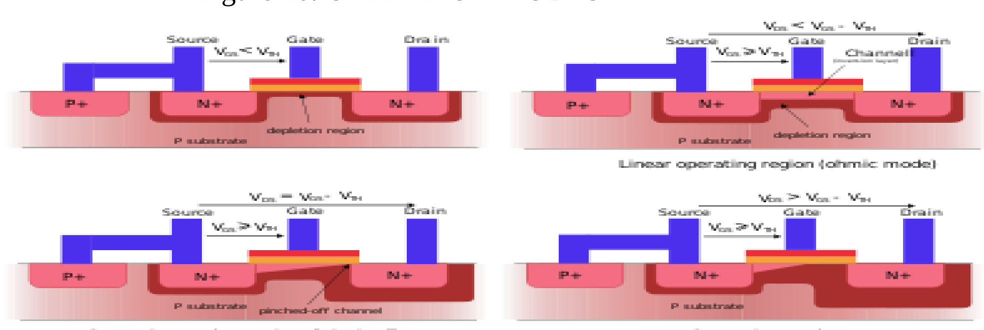


Figure 27: Working of N-channel mosfet

Example application of an N-Channel MOSFET When the switch is pushed the LED lights up Ohmic contact to body to ensure no body bias; top left:subthreshold, top right:Ohmic mode, bottom left: Active mode at onset of pinch-off, bottom right: Active mode well into pinch-off – channel length modulation evident

The operation of a MOSFET can be separated into three different modes, depending on the voltages at the terminals. In the following discussion, a simplified algebraic model is used.[5] Modern MOSFET characteristics are more complex than the algebraic model presented here.[6]

For an enhancement-mode, n-channel MOSFET, the three operational modes are:

Cutoff, sub threshold, or

weakinversion mode When

VGS< Vth:

Where V_{GS}gate-to-source is bias and $V_{th}$is the threshold voltage of the device.According to the basic threshold model, the transistor is turned off, and there is no conduction between drain and source. A more accurate model considers the effect of thermal energy on the Boltzmann distribution of electron energies which allow some of the more energetic electrons at the source to enter the channel and flow to the drain. This results in a sub threshold current that is an exponential function of gate–source voltage. While the current between drain and source should ideally be zero when the transistor is being used as a turnedoff switch, there is a weak-inversion current, sometimes called sub threshold leakage.

In weak inversion the current varies exponentially with V_{GS}as given approximately by:

$$I_D \approx I_{D0} e^{\frac{V_{GS}-V_{th}}{nV_T}},$$

Where I_{D0}= current at$V_{GS} = V_{th}$, the thermal voltage $V_T = kT/q$and the slope factor n is given by

$$n = 1 + C_D/C_{OX},$$

With C_D= capacitance of the depletion layer and C_{OX}= capacitance of the oxide layer. In a long-channel device, there is no drain voltage dependence of thecurrent once $V_{DS} \gg V_T$, but as channel length is reduced draininduced barrier lowering introduces drain voltage dependence that depends in a complex way upon the device geometry (for example, the channel doping, the junction doping and so on). Frequently, threshold voltage V_{th} for this mode is defined as the gate voltage at which a selected value of current I_{D0} occurs, for example, I_{D0} = 1 μA, which may not be the same V_{th}-value used in the equations for the following modes

Some micro power analog circuits are designed to take advantage of sub threshold conduction.[9][10][11] By working in the weak-inversion region, the MOSFETs in these circuits deliver the highest possible transconductance-tocurrent ratio, $g_m/I_D = 1/(nV_T)$

The sub threshold I–V curve depends exponentially upon threshold voltage, introducing a strong dependence on any manufacturing variation that affects threshold voltage; for example: variations in oxide thickness, junction depth, or body doping that change the degree of drain-induced barrier lowering. The resulting sensitivity to fabrication variations complicates optimization for leakage and performance.

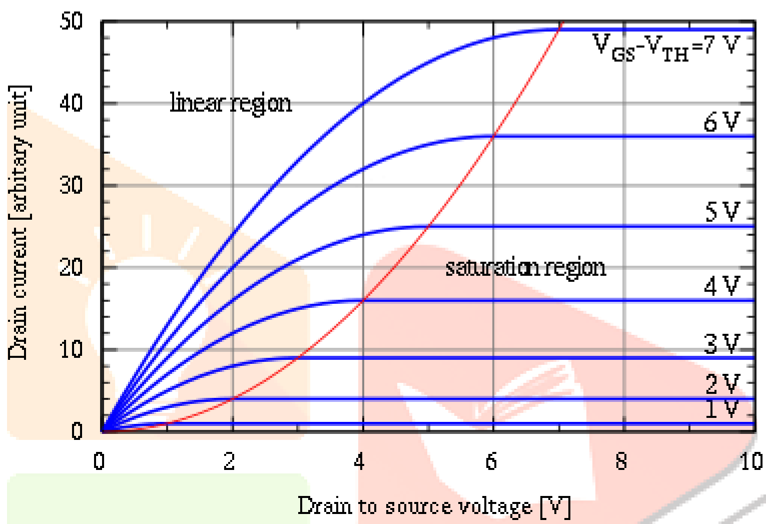


Figure 28: graph representation of N-channel mosfet

MOSFET drain current vs. drain-to-source voltage for several values of $V_{GS} - V_{th}$; the boundary between linear (Ohmic) and saturation (active) modes is indicated by the upward curving parabola.

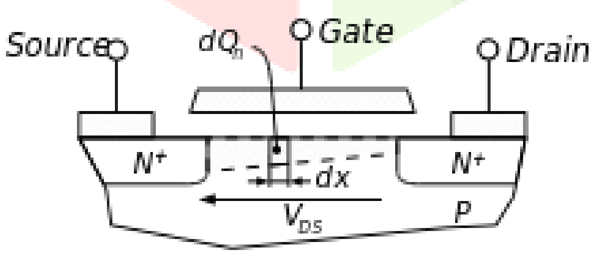


Figure 29: operation

Cross section of a MOSFET operating in the linear (Ohmic) region; strong inversion region present even near drain

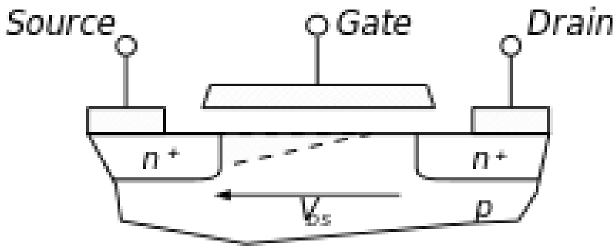


Figure 30: Working

Cross section of a MOSFET operating in the saturation (active) region; channel exhibits pinch-off near drain Triode mode or linear region (also known as the ohmic mode[15][16])When VGS> Vth and VDS<

(VGS – Vth) The transistor is turned on, and a channel has been created which allows current to flow between the drain and the source. The MOSFET operateslike a resistor, controlled by the gate voltage relative to both the source and drain voltages. The current from drain to source is modeled as:

$$I_D = \mu_n C_{ox} \frac{W}{L} \left((V_{GS} - V_{th}) V_{DS} - \frac{V_{DS}^2}{2} \right)$$

where μ_n is the charge-carrier effective mobility, W is the gate width, L is the gate length and C_{ox} is the gate oxide capacitance per unit area? The transition from the exponential subthreshold region to the triode region is not as sharp as the equations suggest.

3.11.4 FEATURES:

- Low voltage operation (2.7 V to 5.5 V)
- Calibrated directly in °C
- 10 mV/°C scale factor (20 mV/°C on TMP37)
- ±2°C accuracy over temperature (typ) ±0.5°C linearity (typ)
- Stable with large capacitive loads
- Specified −40°C to +125°C, operation to +150°C
- Less than 50 µA quiescent current
- Shutdown current 0.5 µA max
- Low self-heating

3.11.5 APPLICATIONS:

- Environmental control systems
- Thermal protection
- Industrial process control
- Fire alarms
- Power system monitors

3.12 PWM SIGNALS:

3.12.1 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 compared to the off periods, the higher the power supplied to the load is.

The PWM switching frequency has to be much faster than what would affect the load, which is to say the device that uses the power. Typically switching have to be done several times a minute in an electric stove, 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 of the time. Duty cycle is expressed 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 practically no current, and when it is on, there is almost no voltage drop across the switch. Power loss, being the product of voltage and current, is thus in both cases close to zero. PWM also works well with digital controls, which, because of their on/off nature, can easily set the needed 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.

3.12.2 Communication and control

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 keeping the signal digital, noise effects are minimized. Noise can only affect a digital signal if it is strong enough to change a logic-1 to a logic-0, or vice versa.

Increased noise immunity is yet another benefit of choosing PWM over analog control, and is the principal reason PWM is sometimes used for communication. Switching from an analog signal to PWM can increase the length of a communications channel dramatically. At the receiving end, a suitable RC (resistorcapacitor) 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, consider a PWM-controlled brake. To put it simply, a brake is a device that clamps down hard on something. In many brakes, the amount of clamping pressure (or stopping power) is controlled with an analog input signal. The more voltage or current that's applied to the brake, the more pressure the brake will exert.

The output of a PWM controller could be connected to a switch between the supply and the brake. To produce more stopping power, the software need only increase the duty cycle of the PWM output. If a specific amount of braking pressure is desired, measurements would need to be taken to determine the mathematical relationship between duty cycle and pressure. (And the resulting formulae or lookup tables would be tweaked for operating temperature, surface wear, and so on.)

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

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

3.12.3 PWM controllers

Many microcontrollers include on-chip PWM controllers. For example, Microchip's PIC16F72 includes two, each of which has a selectable on-time and period. 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 operation, the data sheet suggests the software should:

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

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

CHAPTER 4: SOFTWARE DESCRIPTION

This project is implemented using following software's:

- Express PCB – for designing circuit
- PIC C compiler - for compilation part

4.1 Express PCB:

Breadboards are great for prototyping equipment as it allows great flexibility to modify a design when needed; however, the final product of a project, ideally should have a neat PCB, few cables, and survive a shake test. Not only is a proper PCB neater but it is also more durable as there are no cables which can yank loose.

Express PCB is a software tool to design PCBs specifically for manufacture by the company Express PCB (no other PCB maker accepts Express PCB files). It is very easy to use, but it does have several limitations.

- It can be likened to more of a toy then a professional CAD program.
- It has a poor part library (which we can work around)
- It cannot import or export files in different formats
- It cannot be used to make prepare boards for DIY production

Express PCB has been used to design many PCBs (some layered and with surface-mount parts. Print out PCB patterns and use the toner transfer method with an Etch Resistant Pen to make boards. However, Express PCB does not have a nice print layout. Here is the procedure to design in Express PCB and clean up the patterns so they print nicely.

4.1.1 Preparing Express PCB for First Use:

Express PCB comes with a less then exciting list of parts. So before any project is started head over to Audio logic and grab the additional parts by morsel, ppl, and tangent, and extract them into your Express PCB directory. At this point start the program and get ready to setup the workspace to suit your style.

Click View -> Options. In this menu, setup the units for "mm" or "in" depending on how you think, and click "see through the top copper layer" at the bottom. The standard color scheme of red and green is generally used but it is not as pleasing as red and blue.

4.1.2 The Interface:

When a project is first started you will be greeted with a yellow outline. This yellow outline is the dimension of the PCB. Typically, after positioning of parts and traces, move them to their final position and then crop the PCB to the correct size. However, in designing a board with a certain size constraint, crop the PCB to the correct size before starting.

Fig: 4.1 show the toolbar in which each button has the following functions:

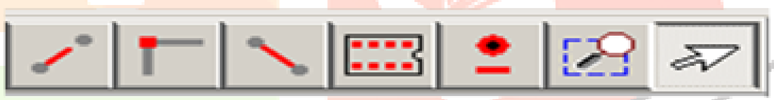


Figure 31: Tool bar necessary for the interface

- The select tool: It is fairly obvious what this does. It allows you to move and manipulate parts. When this tool is selected the top toolbar will show buttons to move traces to the top / bottom copper layer, and rotate buttons.
- The zoom to selection tool: does just that.
- The place pad: button allows you to place small soldier pads which are useful for board connections or if a part is not in the part library but the part dimensions are available. When this tool is selected the top toolbar will give you a large selection of round holes, square holes and surface mount pads.
- The place component: tool allows you to select a component from the top toolbar and then by clicking in the workspace places that component in the orientation chosen using the buttons next to the component list. The components can always be rotated afterwards with the select tool if the orientation is wrong.
- The place trace: tool allows you to place a solid trace on the board of varying thicknesses. The top toolbar allows you to select the top or bottom layer to place the trace on.

- The Insert Corner in trace: button does exactly what it says. When this tool is selected, clicking on a trace will insert a corner which can be moved to route around components and other traces.
- The remove a trace button is not very important since the delete key will achieve the same result.

4.1.3 Design Considerations:

Before starting a project there are several ways to design a PCB and one must be chosen to suit the project's needs When making a PCB you have the option of making a single sided board, or a doublesided board. Single sided boards are cheaper to produce and easier to etch, but much harder to design for large projects. If a lot of parts are being used in a small space it may be difficult to make a single sided board without jumpering over traces with a cable. While there's technically nothing wrong with this, it should be avoided if the signal travelling over the traces is sensitive (e.g., audio signals).

A double-sided board is more expensive to produce professionally, more difficult to etch on a DIY board, but makes the layout of components a lot smaller and easier. It should be noted that if a trace is running on the top layer, check with the components to make sure you can get to its pins with a soldering iron. Large capacitors, relays, and similar parts which don't have axial leads can NOT have traces on top unless boards are plated professionally.

Ground-plane or other special purposes for one side

When using a double-sided board, you must consider which traces should be on what side of the board. Generally, put power traces on the top of the board, jumping only to the bottom if a part cannot be soldiered onto the top plane (like a relay), and vice- versa.

Some projects like power supplies or amps can benefit from having a solid plane to use for ground. In power supplies this can reduce noise, and in amps it minimizes the distance between parts and their ground connections, and keeps the ground signal as simple as possible. However, care must be taken with stubborn chips such as the TPA6120 amplifier from TI. The TPA6120 datasheet specifies not to run a ground plane under the pins or signal traces of this chip as the capacitance generated could affect performance negatively.

4.2 PIC Compiler:

PIC compiler is software used where the machine language code is written and compiled. After compilation, the machine source code is converted into hex code which is to be dumped into the microcontroller for further processing. PIC compiler also supports C language code.

It's important that you know C language for microcontroller which is commonly known as Embedded C. As we are going to use PIC Compiler, hence we also call it PIC C. The PCB, PCM, and PCH are separate compilers. PCB is for 12-bit opcodes, PCM is for 14-bitopcodes, and PCH is for 16-bit opcode PIC microcontrollers. Due to many similarities, all three compilers are covered in this reference manual. Features and limitations that apply to only specific microcontrollers are indicated within. These compilers are specifically designed to meet the unique needs of the PIC microcontroller. This allows developers to quickly design applications software in a more readable, high-level language. When compared to a more traditional C compiler,

PCB, PCM, and PCH have some limitations. As an example of the limitations, function recursion is not allowed.

This is due to the fact that the PIC has no stack to push variables onto, and also because of the way the compilers optimize the code. The compilers can efficiently implement normal C constructs, input/output operations, and bit twiddling operations. All normal C data types are supported along with pointers to constant arrays, fixed point decimal, and arrays of bits.

PIC C is not much different from a normal C program. If you know assembly, writing a C program is not a crisis. In PIC, we will have a main function, in which all your application specific work will be defined. In case of embedded C, you do not have any operating system running in there. So, you have to make sure that your program or main file should never exit. This can be done with the help of simple while

(1) or for (; ;) loop as they are going to run infinitely.

We have to add header file for controller you are using, otherwise you will not be able to access registers related to peripherals.

#include <18F452.h> // header file for PIC 18F452//

4.2.1Proteus:

Proteus is software which accepts only hex files. Once the machine code is converted into hex code, that hex code has to be dumped into the microcontroller and this is done by the Proteus. Proteus is a programmer which itself contains a microcontroller in it other than the one which is to be programmed. This microcontroller has a program in it written in such a way that it accepts the hex file from the pic compiler and dumps this hex file into the microcontroller which is to be

programmed. As the Proteus programmer requires power supply to be operated, this power supply is given from the power supply circuit designed and connected to the microcontroller in proteus. The program which is to be dumped in to the microcontroller is edited in proteus
and is compiled and executed to check any errors and hence after the successful compilation of the program the program is dumped in to the microcontroller using a dumper.

4.3 Procedural steps for compilation, simulation and dumping:

4.3.1 Compilation and simulation steps:

For PIC microcontroller, PIC C compiler is used for compilation. The compilation steps are as follows:

- Open PIC C compiler.
- You will be prompted to choose a name for the new project, so create a separate folder where all the files of your project will be stored, choose a name and click save.
- Click Project**,** New, and something the box named 'Text1' is where your code should be written later.
- Now you have to click 'File, save as' and choose a file name for your source code ending with the letter '.c'. You can name as 'project.c' for example and click save. Then you have to add this file to your project work.

- You can then start to write the source code in the window titled 'project.c' then before testing your source code; you have to compile your source code, and correct eventual syntax errors.
- By clicking on compile option .hex file is generated automatically.
- This is how we compile a program for checking errors and hence the compiled program is saved in the file where we initiated the program.

After compilation, next step is simulation. Here first circuit is designed in Express PCB using Proteus 7 software and then simulation takes place followed by dumping. The simulation steps are as follows:

- Open Proteus 7 and click on IS1S6.
- Now it displays PCB where circuit is designed using microcontroller. To design circuit components are required. So, click on component option.

10. Now click on letter 'p', then under that select PIC16F876, other components related to the project and click OK. The PIC 18F452 will be called your "Target device", which is the final destination of your source code.

4.3.2 Dumping steps:

The steps involved in dumping the program edited in proteus 7 to microcontroller are shown below:

1. Initially before connecting the program dumper to the microcontroller kit the window is appeared as shown below.

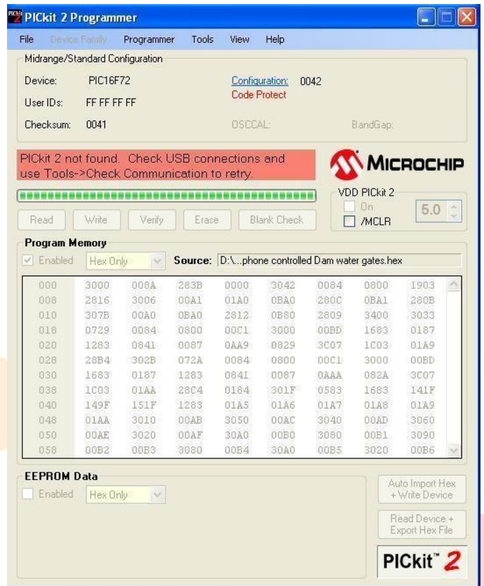


Figure 32: Picture of program dumper window

2. Select Tools option and click on Check Communication for establishing a connection as shown in below window

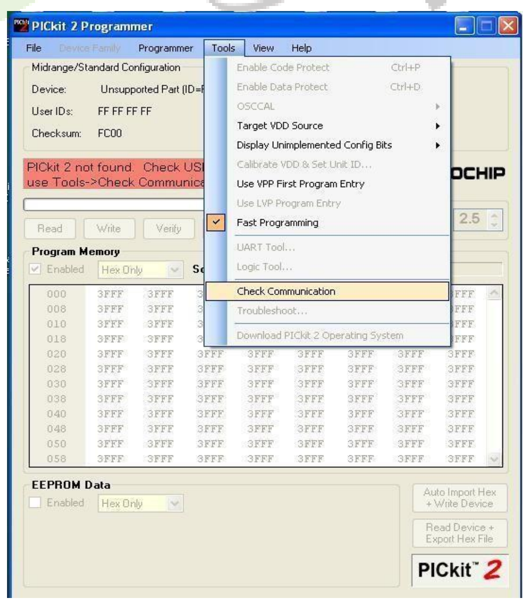


Figure 33: Picture of checking communications before dumping program into microcontroller

3. After connecting the dumper properly to the microcontroller kit the window is appeared as shown below.

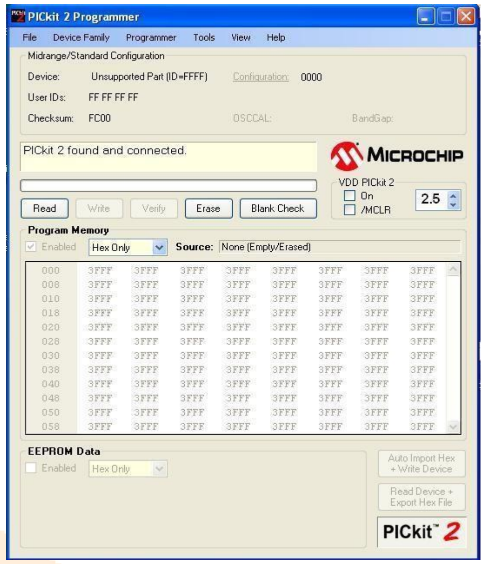


Figure 34: Picture after connecting the dumper to microcontroller

4. Again by selecting the Tools option and clicking on Check Communication the microcontroller gets recognized by the dumper and hence the window is as shown below.

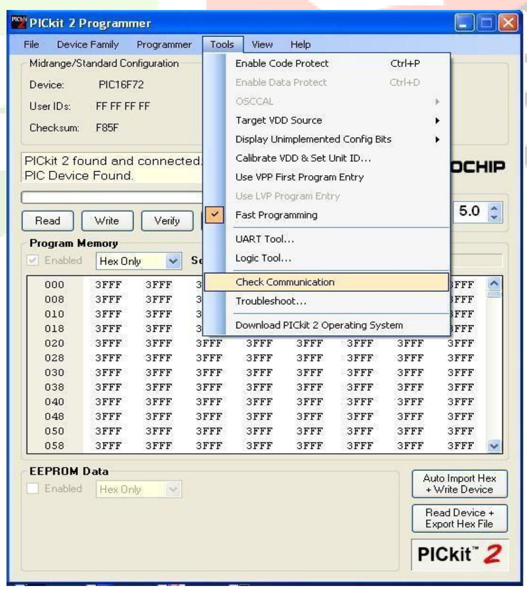


Figure 35: After damping

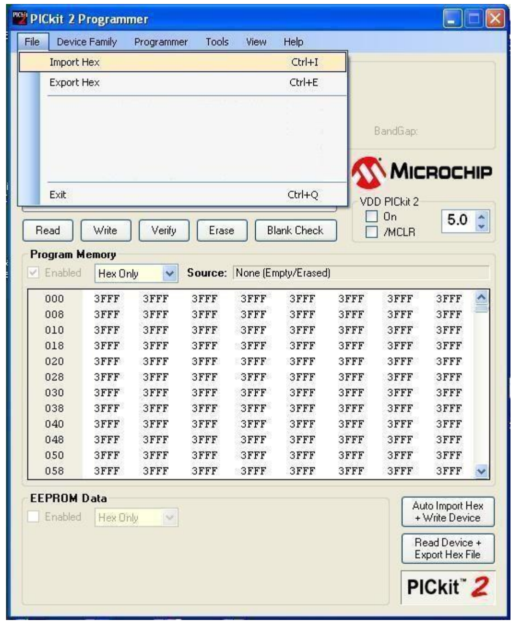


Figure 36: Picture of program importing into the microcontroller

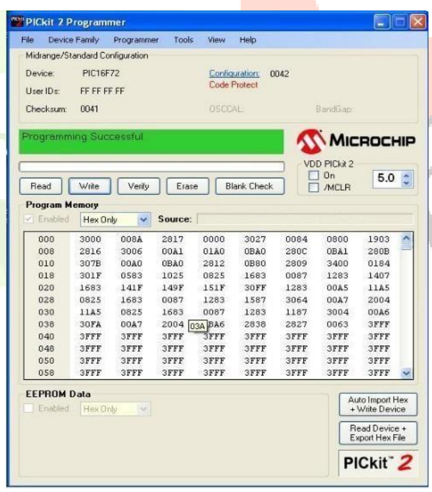


Figure 37: After successful dumping

5. After clicking on 'Import Hex' option we need to browse the location of our program and click the 'prog.hex' and click on 'open' for dumping the program into the microcontroller.

6. After the successful dumping of program, the window is as shown below.

CHAPTER 5: HARDWARE ASSEMBLE

In this chapter, schematic diagram and interfacing of PIC16F72 microcontroller with each module is considered.

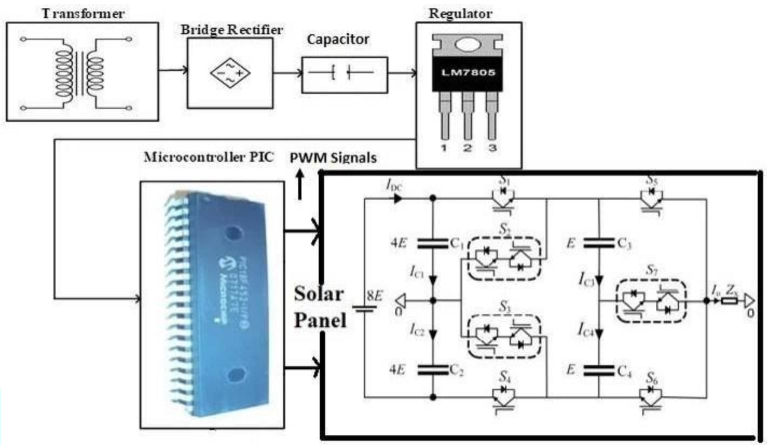


Figure 38: Schematic diagram of A Novel Single-Phase Nine-Level

Figure 1: Transformer-less

Photovoltaic

The above schematic diagram of A Novel Single-Phase Nine-Level Transformer-less Photovoltaic (PV) Inverter explains the interfacing section of each component with micro controller, Solar panel, nine level inverter. Crystal oscillator connected to 9th and 10th pins of micro controller and regulated power supply is also connected to micro controller and LEDs also connected to micro controller through resistors.

KIT ASSEMBLE:

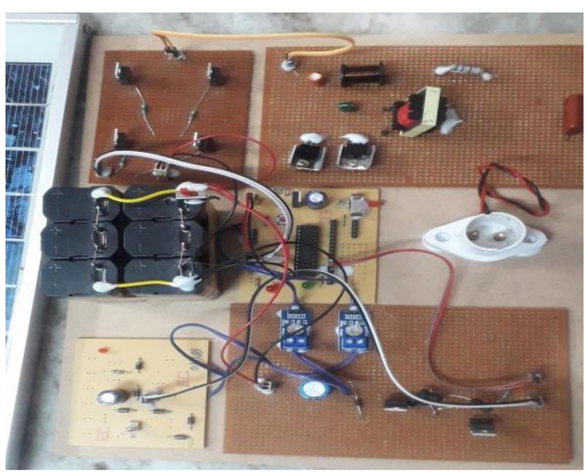


Figure 29 prototype

WORKING:

The main aim of the project is to design an inverter without using a transformer. In this project we are going to use MOSFET circuit in place of transformer .Which will convert DC voltage into pulsating AC voltage . These inverter can attain the maximum load of 50 watts. In these project we are having five circuits they

- Charging circuit
- Buck boost converter
- PIC Microcontroller
- Mosfet circuit (H-Bridge)
- Nine level inverter

Here we are take 12 v dc, which is taking from the solar panel as our input voltage for charging circuit . in these charging circuit consist of four diodes and one capacitor. Where acts as polarity corrector(if we connect the solar panel in reverse bias)and the capacitor is used for removing of ripples and sent to boost converter

The voltage from the charger circuit is given as input to the buck boost converter. This converter consist of two MOSFETS,,one inductor, diode and a capacitor. Actually, it is a Buck Boost Converter the main theme of these converter is to buck(decrease)voltage or boost (increase) voltage as per the requirement. It acts as boost converter when the voltage is less than 12.5v and above 8 volts.and it also act as buck converter when the voltage greater then 14 v .These operation is done by PIC microcontroller

Here we are going to use two voltage sensors, one is use for sense the input voltage of the solar panel and another is used to sense the output voltage of the converter circuit.it is closed loop buck boost converter. After that the output of the converter is given to batteries for charging the batteries

From batteries we are getting 12v Dc voltage and which is give as input to H-bridge circuit and which converts the 12v Dc into 12v,50 Hz pulsating Ac with the help of pic microcontroller. From the H-Bridge circuit we are only getting 12v ,but we need 230 v for the load we connected so the we are using nine level inverter

In these inverter circuit we are using to inductor coils and one capacitor so get 200v 50hz Ac output

From these project we are drawing **200v 50 hz AC** from just **12 v DC** input with the help of PIC microcntroller

CHAPTER 6: ADVANTAGES AND DISADVANTAGES

6.1 Advantages:

- High availability and huge number of applications

- Low initial cost when compared to other storage equipment's
- Large amount of power instantaneously produced when needed and its immunity to ripple currents
- Efficient and clean conversion of energy into electricity.
- Easy to operate.
- Low power consumption.
- Efficient design.

6.2 Disadvantages:

- This system requires periodic monitoring and maintenance.
- This system fails to work if the load is heavy.
- It requires more area for installation of panels .
- Maintains is required
- Low efficiency
- Depends on climatical conditions

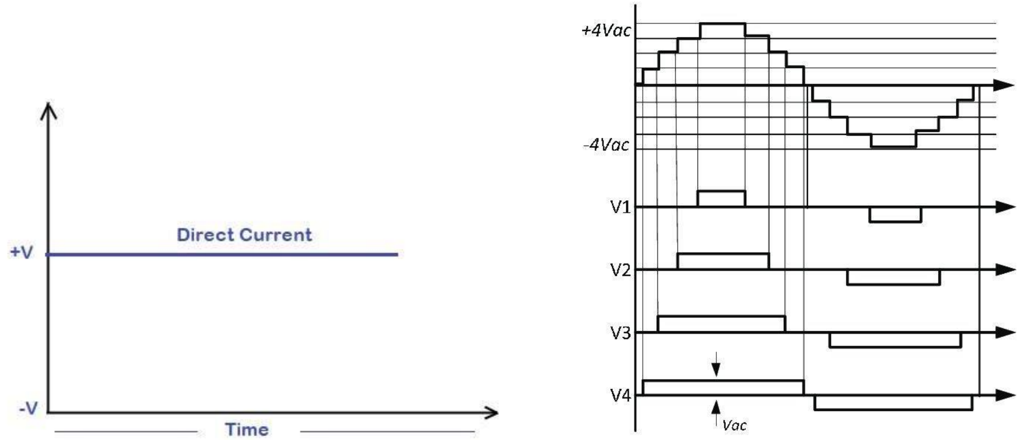
6.3 Applications:

- This system can be practically implemented in real time.
- Industries, Homes etc
- This system can be practically implemented in real time in Industrial applications, batteries, vehicles, mining.

CHAPTER 7: RESULTS

7.1 Result:

- The project "**A Novel Single-Phase Nine-Level Transformer-less Photovoltaic (PV) Inverter"** was designed a nine level common ground transformer less inverter with reduced output harmonic content for PV systems.
- In this to develop a multilevel inverter we are using MOSFETS, capacitors and diodes. The PWM duty cycle generated by microcontroller for switching the MOSFETs to reduce the harmonic



content.

Figure 40: DC signal is converting into ac signal

•

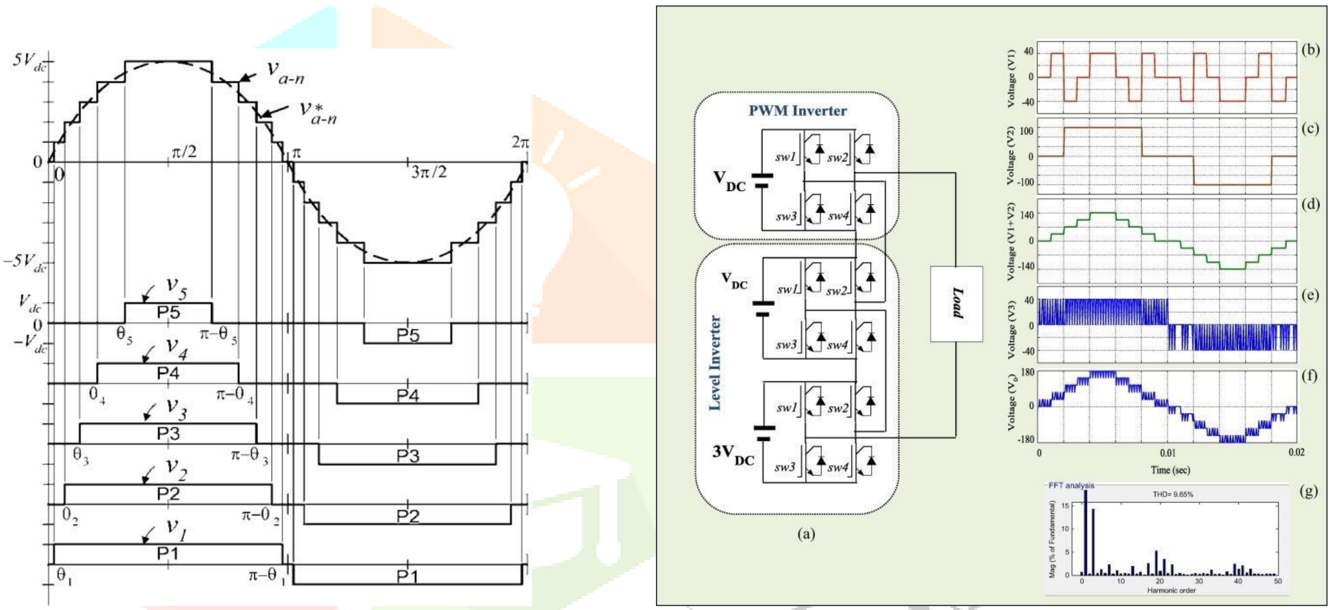


Figure 41: Switching frequency of mosfets

CHAPTER 8

8.1 CONCLUSION

- A photovoltaic power generation system with a nine-level inverter is introduced. The nine-level inverter can perform the functions of regulating the dc bus voltage, converting solar power to ac power with sinusoidal current and in phase with the utility voltage, balancing the two dc capacitor voltages, and hence overcome the main limitations of the conventional power electronic interface for photovoltaic power generation system. Main advantages of proposed nine level grid connected PV inverter are,

- Less switching power loss

- Reduced harmonic distortion
- Reduced EMI • Simplified control circuit
- Capacitor voltages can be easily balanced
- Better power efficiency
- Capacity of output filter can be reduced
- Cheaper, lighter and more compact

8.2 Future Scope:

- We can add MATLAB to this project for monitoring the voltage, current values of nine level inverter.
- We can add wireless technology to this project for sending the voltage, current values to the user mobile.

REFERENCES

[1] Wang, Y.Q.; Ku, R.H.; Zhou, C.L.; Wang, Z.; Wang, M.D. Hybrid T-type multilevel inverter and its modulation strategy. High Volt. Eng. 2020, 46, 3220–3228.

[2] Yu, H.Y.; Chen, B.; Yao, W.X.; Liu, Z.Y. Hybrid seven-level converter based on t-type converter and h-bridge cascaded under SPWM and SVM. IEEE Trans. Power Electron. 2018, 33, 689–702. [CrossRef]

[3] Zhang, Y.L.; Wang, Q.J.; Hu, C.G.; Zhou, Y.F. A novel low voltage seventeen-level converter and control strategy. Proc. CSEE 2020, 40, 1095–1105.

[4] Yousofi-Darmian, S.; Barakati, S.M. A new asymmetric multilevel inverter with reduced number of components. IEEEJ. Emerg. Sel. Top. Power Electron. 2020, 8, 4333–4342. [CrossRef]

[5] Hu, C.G.; Rui, T.; Ma, D.J.; Wang, Q.J.; Luo, F.L. SVM control strategy for neutral point voltage balance and switching loss reduction of three-level ANPC inverter. Proc. CSEE 2016, 36, 3598–3608

[6] Y. Nishida, S. Murakami, H. Toshi, H. Mizoguchi "Minimally privacy-Violative system for Locating Human by ultrasonic Radar Embedded on ceiling", in proceedings of 2004 IEEE International conference on systems, man and cybernetics (SMC '04), PP 1549-1554, October 2004.

[7] T. Hori, Y. Nishida, S. Murakami, H. Aizawa, H. Mizoguchi "Distributed Sensor Network for a Home for the Aged," in Proceedings of 2004 IEEE International Conference on System, Man Cybernetics (SMC '04), pp.1577-1582, October 2004.

[8] S. Murakami, Y. Nishida, T. Hori, H. Mizoguchi, Bg Detecting Human Head Location Using a Simply

Installed Ultrasonic Radar System, h in proceedings of the 22nd Annual Conference of the Robotics Society of, 1A23(1)-(2), September 2004.

[9] Rajasekar Gorthi, K.Giri Babu, Dr.S. Shiva Prasad: Simlink model for cost-effective analysis of hybride system :International journal of modern Enginnering Research(volume 4,issue:2, Feb 2014)

[10] Dr.Rajesh Thippraju,Suddala Janardhan,Rajasekhar Gorthi: PV arraybased BLDC motor drive water pump using solar technology:The international journal of analatical and experimental modal analysis(volume 1,issue:7,July 2020)