CHAPTER – 1

INTRODUCTION

1.1 OVERVIEW OF THE PROJECT

Prepaid energy meter is an advantageous concept for the future. This advancing technology overheads the conventional digital meters at home. Its facilitates the exemption from electricity bills. Electricity coupons will be available at nearby shops.

Maximum units to be used is programmed. This data is given to IC 8051. 8051 is connected to digital energy meter. 8051 is programmed to decrement the maximum units as a response to the info from the digital energy meter. Buzzer is used to warn the user. When maximum use is made, relay will cut off and controller have to be reset.
CHAPTER 2
LITERATURE REVIEW

2.1 EMBEDDED SYSTEMS

Embedded system is a combination of hardware and software design to meet a specific need with performance in a given time frame. Embedded system is a subsystem which we can embed with a big system to enhance the functionality of the big system. For example printers and mouse can be considered as the embedded systems of the computer.

An embedded controller is a controller or computer that is embedded into some device for some purpose other than to provide general purpose computing.

Each day, our lives become more dependent on 'embedded systems', digital information technology that is embedded in our environment. This includes not only safety-critical applications such as automotive devices and controls, railways, aircraft, aerospace and medical devices, but also communications, 'mobile worlds' and 'e-worlds', the 'smart' home, clothes, factories etc. All of these have wide-ranging impacts on society, including security, privacy and modes of working and living. More than 98% of processors applied today are in embedded systems, and are no longer visible to the customer as 'computers' in the ordinary sense. New processors and methods of processing, sensors, actuators, communications and infrastructures are 'enablers' for this very pervasive computing.

They are in a sense ubiquitous, that is, almost invisible to the user and almost omnipresent. As such, they form the basis for a significant economic push. These applications are 'vision driven', as in the following examples:

- Automotive: Accident free driving
- Aerospace: A free, safe sky for all
- Medical Devices: Robotic surgeon
- Communications: Seamless connectivity
- e-Life: ubiquitous/pervasive computing
2.2 INTRODUCTION TO MICROCONTROLLERS

Microcontroller is a general purpose device meant to read data, to perform limited calculations on that data and to control its environment based on those calculations. The prime use of a microcontroller is to control the operation of a machine using a fixed program that is stored in ROM and that does not change over the lifetime of the system.

Microcontroller is a true computer on a chip. It incorporates all the features found in a microprocessor like CPU, ALU, PC, SP and registers. It also has additional features needed to make a complete computer like ROM, RAM, parallel input-output, serial input-output, counters and a clock circuit.

A microcontroller (often abbreviated MCU) is a single computer chip (integrated circuit) that executes a user program, normally for the purpose of controlling some device hence named as microcontroller.

The program is normally contained either in a second chip, called an EPROM, or within the same chip as the microcontroller itself. A microcontroller is normally found in devices such as microwave ovens, automobiles, keyboards, CD players, cell phones, VCRs, security systems, time & attendance clocks, etc.

Microcontroller-based systems are generally smaller, more reliable, and cheaper. They are ideal for the types of applications described above where cost and unit size are very important considerations. In such applications it is almost always desirable to produce circuits that require the smallest number of integrated circuits, that require the smallest amount of physical space, require the least amount of energy, and cost as little as possible.

Microcontrollers are hidden inside a surprising number of products these days. If your microwave oven has an LED or LCD screen and a keypad, it contains a microcontroller. All modern automobiles contain at least one microcontroller, and can have as many as six or seven. The engine is controlled by a microcontroller, as are the anti-lock brakes, the
cruise control and so on. Any device that has a remote control almost certainly contains a microcontroller: TVs, VCRs and high-end stereo systems all fall into this category. Digital cameras, cell phones, answering machines, laser printers, telephones (the ones with caller ID, 20-number memory, etc.), pagers, and refrigerators, dishwashers, washers and dryers (the ones with displays and keypads). Basically, any product or device that interacts with its user has a microcontroller buried inside.

### 2.2.1 FEATURES OF MICROCONTROLLERS

1. Perform a single set of functions.

2. Works in a time constrained environment.

3. Provides high-performance and reliability.

4. Mostly Embedded systems have low cost because they are mass produced in millions.

5. Some Embedded systems have mechanical moving parts like disk drives as they are less reliable as compared to solid state parts such as Flash memory.

6. High Integration of Functionality.

7. Microcontrollers sometimes are called single-chip computers because they have on-chip memory and I/O circuitry and other circuitries that enable them to function as small standalone computers without other supporting circuitry.

8. Field Programmability, Flexibility.

9. Microcontrollers often use EEPROM or EPROM as their storage device to allow field programmability so they are flexible to use. Once the program is tested to be correct then large quantities of microcontrollers can be programmed to be used in embedded systems.

10. Easy to Use: Assembly language is often used in microcontrollers and since they
usually follow RISC architecture, the instruction set is small. The development package of microcontrollers often includes an assembler, a simulator, a programmer to "burn" the chip and a demonstration board. Some packages include a high level language compiler such as a C compiler and more sophisticated libraries.

11. Eight bit CPU with registers A and B.

12. Sixteen bit program counter and data pointer.

13. Eight bit program status word.

14. Eight bit stack pointer.

15. Internal ROM of 4K.

16. Internal RAM of 128 bytes: Four register banks, each containing eight registers. Sixteen bytes, which may be addressed at bit level. Eighty bytes of general-purpose data memory.

17. Thirty two input/output pins arranged as four 8-bit ports: P0-P3.

18. Two 16-bit timer/counters: T0 and T1.

19. Full duplex serial data receiver/transmitter: SBUF.

20. Control register: TCON, TMOD, SCON, PCON, IP.

21. Two external and three internal interrupt sources.

22. Oscillator and clock circuits.
2.2.2 TYPES OF MICROCONTROLLERS

A micro controller can be of four types:-

1) 4 – Bit Micro controller.
2) 8 – Bit Micro controller
3) 16 – Bit Micro controller
4) 32 – Bit Micro controller

4 – BIT MICRO CONTROLLER:-

➤ They are the most popular micro controller in terms of production numbers
➤ They are economical.
➤ Applications: Appliances and toys.

8 – BIT MICRO CONTROLLER:-

➤ Represent a transition zone between dedicated, high-volume, 4-bit micro-controllers and the high performance 16 bit microcontrollers
➤ Application: simple appliance control, high-speed machine control, data collection

16 – BIT MICRO CONTROLLER:

➤ Provides faster response and more sophisticated calculation.
➤ Applications: They have their application mostly in Robotics.

32 – BIT MICRO CONTROLLER:

➤ In these micro controllers basically the emphasis is on the high speed computation features
➤ Application: These types have application in Robotics, Highly intelligent instrumentation system, telecommunication, automobiles etc.
2.2.3 BLOCK DIAGRAM OF MICROCONTROLERS

The figure below shows the block diagram of Microcontrollers:-

![Block Diagram of 8051]

**Fig 2.1 Block Diagram of 8051**

The block diagram of microcontroller basically explains:

1. **INTERRUPT CONTROL**: - The interrupt control basically handles the interrupts whether they should be handled or not. For the same purpose two registers of 8-bits are present i.e. IP and IE i.e. interrupt priority and interrupt enable.
2. **ON CHIP FLASH**: - Flash memory is present on the chip.
3. **ON CHIP RAM**: - RAM is also present on the chip.
4. **TIMERS**: - Timer control registers of 8 bits are also present on the chip. The counter input is given to the timers.
5 SERIAL PORTS: - the serial ports are also present on chip which allows the microcontroller to communicate serially.

6 I/O PORTS: - the I/O ports basically provides the input and output ports. These are present on the chip of microcontroller itself. They are of 8 bits. There is no requirement for providing the external interface. Basically there are 4 ports i.e. port 0, port 1, port 2 and port 3. PORT 0 provides both data and addresses along with I/O pins. PORT 1 provides only I/O pins. PORT 2 provides I/O pins and the remaining addresses. PORT 3 provides I/O pins and WR, RD, T0, T1, INT0, INT1, RXD, TXD

7 BUS CONTROL: - The control registers are present i.e. TCON, TMOD, SCON, PCON, IP, IE.

8 OSCILLATOR: -A particular frequency is provided i.e. 11.0592 MHz by a crystal oscillator.

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2.2.4 PIN DIAGRAM OF 8051

PIN DESCRIPTION

8051 is a 40 pin IC packed in DIP (Dual line packaging). This means that the pin performs the dual functions. Basically 8051 is a 40 pin IC but it performs 64 functions. This is due to the reason that 24 pins are multiplexed pins. So these pins perform dual functions and make it a total of 64 functions.

1. VCC: - PIN (40) - This pin is used to supply voltage to the micro controller. Generally +5V is provided to microcontroller.

2. GND: - PIN (20) - This pin is used for ground.
3. **RST**: - (PIN 9) It is a Reset Input. When this pin is given a high for the two continuous machine cycles while the oscillator is running, the device gets resets.
4. **ALE: - (PIN 30):** It is an Address latch enable. With the bit set the ALE is enabled during the MOVX or MOVC instruction.

5. **PSEN** : - (PIN 29): Program Store Enabled is the read strobe to external program memory. When the AT89C51 is executing code from external memory, This pin is activated during each machine cycle, except that two activation are skipped during each access to external data memory.

6. **PORT 0** :-( PINS 32-39 i.e. P0.0-P0.7) Port 0 is an 8 – bit bi-directional I/O port. When 1’s are written to the pins then port 0 acts as high impedance inputs. Port 0 may also be configured to be the multiplexed address/data bus (i.e. AD0-AD7) during accesses to external program and data memory.

7. **PORT 1:**- Port 1 is an 8 bit bi-directional I/O port with internal pull-ups. When 1’s are written to the port 1 pins they are pulled high by the internal pull-ups and can be used as inputs. As inputs, Port 1 pins that are externally being pulled low will source current because of internal pull-ups. Port 1 also receives the low order addresses bytes during Flash programming and verification.

8. **PORT 2:**- Port 2 is an 8 bit bi-directional I/O port with internal pull-ups. When 1’s are written to Port 2 pins they are pulled high by the internal pull ups and can be used as inputs. As inputs, Port 2 pins that are externally being pulled low will source current because of internal pull ups. Port 2 emits the high order addresses byte during fetches from external program memory and during accesses to external program memory, data memory that use 16bit addresses. In this application, this uses strong internal pull-ups when emitting 1’s.
PORT 3:

(PORT 10-17 i.e. P3.0-P3.7) Port 3 is an 8-bit bi-directional I/O port. So along with providing the I/O various other operations are also performed. In this each pin performs the different operations. They are explained as:

Table 2.1 Port Pins and Alternate Functions

<table>
<thead>
<tr>
<th>PORT PINS</th>
<th>ALTERNATE FUNCTIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>P3.0</td>
<td>RXD (serial input port)- This is used in serial communication at receiver’s side</td>
</tr>
<tr>
<td>P3.1</td>
<td>TXD (serial output port)- This is used in serial communication at transmitter’s side</td>
</tr>
<tr>
<td>P3.2</td>
<td>INT0 (external interrupt 0) - This pin is used for providing the interrupts.</td>
</tr>
<tr>
<td>P3.3</td>
<td>INT1 (external interrupt 1) - This pin is used for providing the interrupts.</td>
</tr>
<tr>
<td>P3.4</td>
<td>T0 (timer 0 external input) - This pin is used for providing the timers.</td>
</tr>
<tr>
<td>P3.5</td>
<td>T1 (timer 1 external input) - This pin is used for providing the timers.</td>
</tr>
<tr>
<td>P3.6</td>
<td>WR (external data memory write strobe) - This pin is used when we have to perform a write operation</td>
</tr>
<tr>
<td>P3.7</td>
<td>RD (external data memory read strobe) - This pin is used when we have to perform a write operation</td>
</tr>
</tbody>
</table>

10. **EA / VPP**: (PIN 31): - External access enabled. EA must be strapped to ground in order to enable the device to fetch code from external program memory location starting at 0000H to FFFFH. EA should be strapped to VCC for internal program execution. This pin also receives the 12 -Volt programming enabled voltage during Flash Programming, for parts that require 12-volt VPP. Where VPP is a peak to peak voltage.
11. XTAL1, XTAL 2 : (PINS 18-19): These pins are connected with a crystal oscillator which provides a frequency of 11.0592 MHz to a microcontroller. With an oscillator two capacitors are connected. The oscillator so formed by crystal, capacitors generates a pulse train at the frequency of crystal.

2.2.5 CRYSTAL OSCILLATOR’S CONNECTION

![Crystal Oscillator Connection Diagram](image)

Fig 2.3 Crystal Oscillator Connection

The heart of 8051 is a circuitry that generates the clock pulses by which all internal operations are synchronized. Pins XTAL1 and XTAL2 are provided for connecting a resonant network to form an oscillator. The crystal oscillator is the basic internal clock frequency of microcontroller. The typical maximum frequency is 16 MHz and the lowest is 1 MHz.

The oscillator so formed by the crystal and the two capacitors generates a pulse train at the frequency of crystal. The smallest interval of time to accomplish any simple instruction or a part of complex instruction is a MACHINE CYCLE. It is itself made up of 6 states. A state is a basic time interval for discrete operation such as fetching an opcode byte, decoding an opcode, executing an opcode or writing a data byte. Two oscillator pulses define each state. Program instructions may require 1, 2, 4 machine cycle to be executed depending upon the type of instruction. Instructions are fetched and
executed by the microcontroller automatically beginning with the instruction located at ROM memory address 0000h at the time the microcontroller is first reset. Generally we use a frequency of 11.0592 MHz.

2.2.6 MEMORY ORGANISATION

The diagram showing the organization of memory in a microcontroller is as follows:

The 8051 microcontroller actually includes a whole family of microcontrollers that have numbers ranging from 8031 to 8751 and are available in NMOS and CMOS constructions in a variety of package types. The 8051 has internal RAM and ROM. Memory for variable data can be altered as the program runs.
Fig 2.4 Memory Organization
INTERNAL RAM

The 128-byte internal RAM is organized into three distinct areas:

- Thirty-two bytes from address 00h to 1Fh that make up 32 working registers organized as four banks of eight registers each.
- A bit addressable area of 16 bytes occupies RAM byte addresses 20h to 2Fh forming a total of 128 addressable bits.
- A general purpose RAM area above the bit area, from 30h to 7Fh, addressable as bytes.

INTERNAL ROM

In 8051, data memory and program code memory are two different entities. Internal ROM occupies code addresses 0000h to 0FFFh. If program address exceeds 0FFFh then 8051 automatically fetches code from external program memory. Code bytes could also be fetched exclusively from external memory 0000h to FFFFh by connecting the EA pin to the ground.

MEMORY EXPANDING

In case the built-in amount of memory (either RAM or ROM) is not sufficient for the needs, there is always an option of adding two external 64KB memory chips. When added, they are addressed and accessed via I/O ports P2 and P3. From user's point of view it's all very simple, because if properly connected most of the job is carried out automatically by MCU. 8051 MCU has two separate read signals, RD BAR and PSEN BAR. The first one is active in case of reading byte from the external data memory (RAM), and the second one is active in case of reading byte from the external program memory (ROM). Both signals are active on low logical level. A typical scheme for such an expansion using separate chips for RAM, ROM is known as Harvard architecture.

Memory can also be mapped as a single block functioning as both data memory and program memory simultaneously (only one memory chip is used). This approach is
known as *Von Neumann architecture*. To be able to read the same block using RD BAR or PSEN BAR, these two signals were combined via logical AND. In this way, output of AND circuit is low if any of the two inputs is low. Using the Harvard architecture effectively doubles MCU memory, but that's not the only advantage offered by the method.

2.2.7 8051 REGISTERS

8051 Microcontrollers have 2 types of registers-

GENERAL PURPOSE REGISTERS

1) Registers (R0 – R7):- It is the set 8 auxiliary registers namely R0, R1...R7. There are 4 such banks in lower RAM.

2) Data Pointer (DPTR):- It is made of 16-bit register further composed pf two 8 – bit registers, namely DPH and DPL used to furnish memory addresses for internal and external code access and external data access.

3) Program Counter (PC):- It is a 16 – bit register and it hold the address of the next program instruction to be executed and automatically gets incremented after each instruction is fetched.
4) Stack Pointer (SP):- It is an 8 – bit register and is used to hold an internal RAM address called the Top of the Stack. As the data is pushed in the stack, firstly the pointer is incremented and then data is pushed and when the data is to be popped off then firstly the data is popped off and then stack pointer gets decremented.

2.2.8 SPECIAL PURPOSE REGISTERS

The 8051 operations that do not use the internal 128-byte Ram addresses from 00h to 7Fh are done by a group of specific internal register, each called a special function register (SFR).

<table>
<thead>
<tr>
<th>NAME</th>
<th>FUNCTION</th>
<th>INTERNAL RAM ADD.</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>ACCUMULATOR</td>
<td>0E0</td>
</tr>
<tr>
<td>B</td>
<td>ARITHMETIC</td>
<td>0F0</td>
</tr>
<tr>
<td>DPH</td>
<td>ADDRESSING EXTERNAL MEMORY</td>
<td>83</td>
</tr>
<tr>
<td>DPL</td>
<td>ADDRESSING EXTERNAL MEMORY</td>
<td>82</td>
</tr>
<tr>
<td>IE</td>
<td>INTERRUPT ENABLE CONTROL</td>
<td>0A8</td>
</tr>
<tr>
<td>IP</td>
<td>INTERRUPT PRIORITY</td>
<td>0B8</td>
</tr>
<tr>
<td>P0</td>
<td>INPUT/OUTPUT PORT LATCH</td>
<td>80</td>
</tr>
<tr>
<td>P1</td>
<td>INPUT/OUTPUT PORT LATCH</td>
<td>90</td>
</tr>
<tr>
<td>P2</td>
<td>INPUT/OUTPUT PORT LATCH</td>
<td>0A0</td>
</tr>
<tr>
<td>P3</td>
<td>INPUT/OUTPUT PORT LATCH</td>
<td>0B0</td>
</tr>
<tr>
<td>PCON</td>
<td>POWER CONTROL</td>
<td>87</td>
</tr>
<tr>
<td>PSW</td>
<td>PROGRAM STATUS WORD</td>
<td>0D0</td>
</tr>
<tr>
<td>SCON</td>
<td>SERIAL PORT CONTROL</td>
<td>98</td>
</tr>
<tr>
<td>SBUF</td>
<td>SERIAL PORT DATA BUFFER</td>
<td>99</td>
</tr>
<tr>
<td>SP</td>
<td>STACK POINTER</td>
<td>81</td>
</tr>
<tr>
<td>TMO</td>
<td>TIMER/COUNTER MODE CONTROL</td>
<td>99</td>
</tr>
<tr>
<td>TCON</td>
<td>TIMER/COUNTER MODE CONTROL</td>
<td>88</td>
</tr>
<tr>
<td>TL0</td>
<td>TIMER 0 LOW BYTE</td>
<td>8A</td>
</tr>
<tr>
<td>TH0</td>
<td>TIMER 0 HIGH BYTE</td>
<td>8C</td>
</tr>
<tr>
<td>TL1</td>
<td>TIMER 1 LOW BYTE</td>
<td>8B</td>
</tr>
<tr>
<td>TH1</td>
<td>TIMER 0 HIGH BYTE</td>
<td>8D</td>
</tr>
</tbody>
</table>
1) ACCUMULATOR: - It is an 8 – bit register and used as working register for the Arithmetic, Logical instructions. All the calculations are performed using this register. It can also be used as General purpose register. It is very necessary for some instructions. It is denoted by A.

2) B – REGISTER: - It also an 8 – bit register and can be used as General Purpose register. It is very necessary for the multiplication and division operations without it the operations are not accomplished.

3) PSW: PROGRAM STATUS WORD (bit Addressable):-

Table 2.3 PSW

<table>
<thead>
<tr>
<th>CY</th>
<th>AC</th>
<th>F0</th>
<th>RS1</th>
<th>RS0</th>
<th>OV</th>
<th>--------</th>
<th>P</th>
</tr>
</thead>
</table>

- CY PSW.7 carry flag
- AC PSW.6 auxiliary carry flag
- F0 PSW.5 flag 0 available to the user for general purpose.
- RS1 PSW.4 Register Bank selector bit 1.
- RS0 PSW.3 Register Bank selector bit 0.
- OV PSW.2 Overflow Flag
- --- PSW.1 User definable flag.
- P PSW.0 Parity Flag.

The following table shows the different combinations of RS0 and RS1: -

Table 2.4 Register Bank Select

<table>
<thead>
<tr>
<th>RS1</th>
<th>RS0</th>
<th>Register Bank</th>
<th>Address</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
<td>00h - 07h</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>1</td>
<td>08h - 0Fh</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>2</td>
<td>10h - 17h</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>3</td>
<td>18h - 1Fh</td>
</tr>
</tbody>
</table>

The above table shows that RS0 and RS1 are responsible for selecting the particular Register bank i.e. by using the different combinations of RS0 and RS1 the Register
Banks are selected.

4) TIMER MODE REGISTERS

<table>
<thead>
<tr>
<th>ATE</th>
<th>C/T</th>
<th>M1</th>
<th>M0</th>
<th>GATE</th>
<th>C/T</th>
<th>M1</th>
<th>M0</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**TIMER 1**

**TIMER 0**

Table 2.5 TMOD

**Modes** : -The Timer Counter function is selected by the control bits C/T in the Special function register TMOD. These two timers have four operating modes selected by the bit pairs (M1, M0) in TMOD.

**GATE** : - Gating control when set. Timer/Counter x is enabled only while INT pin is high and TRx control pin is set. When cleared, Timer x is enabled whenever TRx control bit is set.

**C/T**: - Timer or Counter selector : - When the Timer operation is to be performed then it gets reset and gets set for Counter operation.

5) TCON: TIMER CONTROL REGISTER

Table 2.6 TCON

<table>
<thead>
<tr>
<th>TF1</th>
<th>TR1</th>
<th>TF0</th>
<th>TR0</th>
<th>IE1</th>
<th>IT1</th>
<th>IE0</th>
<th>IT0</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**TF1, TF0:**- These are the Over flow flags for timer 1 and timer 0.

**TR1, TR0:**- It runs the control bits from Timer 1 and Timer 0. Set to run reset to hold.
IE1, IE0:- It is the Edge flag for the external interrupts 1 and 0. It is set by the interrupt edge and cleared when the interrupt is processed. These are not related to counter/timer operation.

IT1, IT0:- It is a type bit for external interrupts and gets set for falling edge interrupts and reset for 0 level interrupts. These are also not related to counter/timer operation.

6) SCON: SERIAL CONTROL REGISTER
This register is an 8-bit register and is used to control the various pins which are responsible for transmitting and receiving the data i.e. for the serial transmission.

7) SBUF: SERIAL BUFFER
The serial port is full duplex i.e. it can transmit and receive simultaneously. It can also receive buffer which means that it can begin receiving a second byte before the previously received byte has been read from the receive register. The serial port receive and transmit registers are both accessed by the Special Function Register SBUF i.e. SERIAL BUFFER. Writing to the SBUF register loads the transmit register, and reading. SBUF accesses a physically separate receive register.

8) IE : INTERRUPT ENABLED

<table>
<thead>
<tr>
<th>EA</th>
<th>-----</th>
<th>-----</th>
<th>ES</th>
<th>ET1</th>
<th>EX1</th>
<th>ET0</th>
<th>EX0</th>
</tr>
</thead>
</table>

EA : - Global Interrupt Register.
ES : - Serial interface
ET1 : - Timer 1
EX1 : - External interrupts 1
ET0 : - Timer 0
EX0 : - External interrupts 0

0 -- Disabled
1 – Enabled

Whenever the timer and external interrupt is to be enabled then EX1 and ET1 is used and
whenever the timer and external interrupt is to be disabled then EX0 and ET0 is used

9) IP : INTERRUPT PRIORITY REGISTER

Table 2.8 IP

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th>PS</th>
<th>PT1</th>
<th>PX1</th>
<th>PT0</th>
<th>PX0</th>
</tr>
</thead>
</table>
| PS : -Serial Interface
| PT1 : -Timer 1
| PX1 : -External Interrupt 1
| PT0 : -Timer 0
| PX0 : -External Interrupt 0

0- Low Priority
1- High Priority

The interrupt priority registers basically provides the priority to the interrupts that
which interrupt will be served first. Whenever the interrupt of low priority is
served then PT0 and PX0 are made high and when the interrupt of high priority is
served then PT1 and PX1 are made high

10) PCON: POWER CONTROL REGISTER

PCON is not bit addressable. It is also a special function register.
Table 2.9 PCON

PD (POWER DOWN OPERATION) : -
This power down operation performs the various operations which are as below:-
Setting PD bit stops the oscillator
Ram contents are saved
Exit via Reset
Some (newer) 8051 derivatives allow power down wake up via Interrupt

IDL (IDLE MODE OPERATION) :-
The idle mode operation also performs the various operations which are as below:-
Setting IDL Gates clocks off, leaves the oscillator running.
All registers and RAM contents are saved.

GF0 AND GF1 : - These are general purpose software flags. These can be set or reset according to the programmers wish.

SMOD (SERIAL BAUD RATE MODIFY BIT) : - It is set to 1 by the programmer to double the baud rate using the timer 1 for modes 1, 2, 3. It is cleared to 0 by program to use timer 1 baud rate.

2.2.9 APPLICATIONS OF MICROCONTROLLERS

1. Telecom: - Mobile phone systems (handsets and base stations), Modems,
Routers.

2. Automotive applications:- Braking systems, Traction control, Airbag release systems, Engine-management units, Steer-by-wire systems, Cruise control applications.

3. Domestic appliances:- Dishwashers, Televisions, Washing machines, Microwave ovens, Video recorders, Security systems, Garage door controllers, Calculators, Digital watches, VCRs, Digital cameras, Remote controls, Treadmills.


5. Aerospace applications:- Flight control systems, Engine controllers, Autopilots, Passenger in-flight entertainment systems.


7. Defence systems:- Radar systems, Fighter aircraft flight control systems, Radio systems, Missile guidance systems.

8. Office Automation:- Laser printers, Fax machines, Pagers, Cash registers, Gas pumps, Credit/Debit card readers, Thermostats, Grain analyzers.

2.3 DIODE

In electronics, a diode is a two-terminal device (thermionic diodes may also have one or two ancillary terminals for a heater).
Diodes have two active electrodes between which the signal of interest may flow, and most are used for their unidirectional electric current property. The varicap diode is used as an electrically adjustable capacitor.

The directionality of current flow most diodes exhibit is sometimes generically called the rectifying property. The most common function of a diode is to allow an electric current to pass in one direction (called the forward biased condition) and to block the current in the opposite direction (the reverse biased condition). Thus, the diode can be thought of as an electronic version of a check valve.

Real diodes do not display such a perfect on-off directionality but have a more complex non-linear electrical characteristic, which depends on the particular type of diode technology. Diodes also have many other functions in which they are not designed to operate in this on-off manner.
**Semiconductor diodes**

Most modern diodes are based on semiconductor p-n junctions. In a p-n diode, conventional current can flow from the p-type side (the anode) to the n-type side (the cathode), but cannot flow in the opposite direction. Another type of semiconductor diode, the Schottky diode, is formed from the contact between a metal and a semiconductor rather than by a p-n junction.

**Current–voltage characteristic**

A semiconductor diode's current–voltage characteristic, or I–V curve, is related to the transport of carriers through the so-called depletion layer or depletion region that exists at the p-n junction between differing semiconductors. When a p-n junction is first created, conduction band (mobile) electrons from the N-doped region diffuse into the P-doped region where there is a large population of holes (places for electrons in which no electron is present) with which the electrons "recombine". When a mobile electron recombines with a hole, both hole and electron vanish, leaving behind an immobile positively charged donor on the N-side and negatively charged acceptor on the P-side. The region around the p-n junction becomes depleted of charge carriers and thus behaves as an insulator.
However, the depletion width cannot grow without limit. For each electron-hole pair that recombines, a positively-charged dopant ion is left behind in the N-doped region, and a negatively charged dopant ion is left behind in the P-doped region. As recombination proceeds and more ions are created, an increasing electric field develops through the depletion zone which acts to slow and then finally stop recombination. At this point, there is a "built-in" potential across the depletion zone.

If an external voltage is placed across the diode with the same polarity as the built-in potential, the depletion zone continues to act as an insulator, preventing any significant electric current flow. This is the reverse bias phenomenon. However, if the polarity of the external voltage opposes the built-in potential, recombination can once again proceed, resulting in substantial electric current through the p-n junction. For silicon diodes, the built-in potential is approximately 0.6 V. Thus, if an external current is passed through the diode, about 0.6 V will be developed across the diode such that the P-doped region is positive with respect to the N-doped region and the diode is said to be "turned on" as it has a forward bias.

A diode’s I–V characteristic can be approximated by four regions of operation (see the figure at right).
At very large reverse bias, beyond the peak inverse voltage or PIV, a process called reverse breakdown occurs which causes a large increase in current that usually damages the device permanently. The avalanche diode is deliberately designed for use in the avalanche region. In the zener diode, the concept of PIV is not applicable. A zener diode contains a heavily doped p-n junction allowing electrons to tunnel from the valence band of the p-type material to the conduction band of the n-type material, such that the reverse voltage is "clamped" to a known value (called the zener voltage), and avalanche does not occur. Both devices, however, do have a limit to the maximum current and power in the clamped reverse voltage region. Also, following the end of forward conduction in any diode, there is reverse current for a short time. The device does not attain its full blocking capability until the reverse current ceases.

The second region, at reverse biases more positive than the PIV, has only a very small reverse saturation current. In the reverse bias region for a normal P-N rectifier diode, the current through the device is very low (in the µA range).

The third region is forward but small bias, where only a small forward current is conducted.

As the potential difference is increased above an arbitrarily defined "cut-in voltage" or "on-voltage" or "diode forward voltage drop (Vd)", the diode current becomes appreciable (the level of current considered "appreciable" and the value of cut-in voltage depends on the application), and the diode presents a very low resistance.

Types of semiconductor diode
There are several types of junction diodes, which either emphasize a different physical aspect of a diode often by geometric scaling, doping level, choosing the right electrodes, are just an application of a diode in a special circuit, or are really different devices like the Gunn and laser diode and the MOSFET:

![Diode Symbol](image)

**Fig. 2.7 Symbol of Diode**

Normal (p-n) diodes, which operate as described above, are usually made of doped silicon or, more rarely, germanium. Before the development of modern silicon power rectifier diodes, cuprous oxide and later selenium was used; its low efficiency gave it a much higher forward voltage drop (typically 1.4–1.7 V per “cell”, with multiple cells stacked to increase the peak inverse voltage rating in high voltage rectifiers), and required a large heat sink (often an extension of the diode’s metal substrate), much larger than a silicon diode of the same current ratings would require. The vast majority of all diodes are the p-n diodes found in CMOS integrated circuits, which include two diodes per pin and many other internal diodes.

**Avalanche diodes**

Diodes that conduct in the reverse direction when the reverse bias voltage exceeds the breakdown voltage. These are electrically very similar to Zener diodes, and are often mistakenly called Zener diodes, but break down by a different mechanism, the avalanche effect.

**Tunnel diodes**
These have a region of operation showing negative resistance caused by quantum tunneling, thus allowing amplification of signals and very simple bistable circuits. These diodes are also the type most resistant to nuclear radiation.

![Fig. 2.8 Symbol of Tunnel Diode](image)

**Gunn diodes**
These are similar to tunnel diodes in that they are made of materials such as GaAs or InP that exhibit a region of negative differential resistance. With appropriate biasing, dipole domains form and travel across the diode, allowing high frequency microwave oscillators to be built.

**Light-emitting diodes (LEDs)**
In a diode formed from a direct band-gap semiconductor, such as gallium arsenide, carriers that cross the junction emit photons when they recombine with the majority carrier on the other side. Depending on the material, wavelengths (or colors) from the infrared to the near ultraviolet may be produced.

![Fig. 2.9 Symbol of LED](image)

**Laser diodes**
When an LED-like structure is contained in a resonant cavity formed by polishing the parallel end faces, a laser can be formed. Laser diodes are commonly used in optical storage devices and for high speed optical communication.

**Photodiodes**
All semiconductors are subject to optical charge carrier generation. This is typically an undesired effect, so most semiconductors are packaged in light blocking material. Photodiodes are intended to sense light (photodetector), so they are packaged in materials that allow light to pass, and are usually PIN (the kind of diode most sensitive to light).

![Fig. 2.10 Symbol of Photo diode](image)

**Varactor diodes**

These are used as voltage-controlled capacitors. These are important in PLL (phase-locked loop) and FLL (frequency-locked loop) circuits, allowing tuning circuits, such as those in television receivers, to lock quickly, replacing older designs that took a long time to warm up and lock.

![Fig. 2.11 Symbol of Varactor diode](image)

**Zener diodes**

Diodes that can be made to conduct backwards. This effect, called Zener breakdown, occurs at a precisely defined voltage, allowing the diode to be used as a precision voltage reference. In practical voltage reference circuits Zener and switching diodes are connected in series and opposite directions to balance the temperature coefficient to near zero.
2.4 CAPACITOR

A capacitor is a passive electrical component that can store energy in the electric field between a pair of conductors (called "plates"). The process of storing energy in the capacitor is known as "charging", and involves electric charges of equal magnitude, but opposite polarity, building up on each plate. A capacitor's ability to store charge is measured by its capacitance, in units of farads.

Capacitors are often used in electric and electronic circuits as energy-storage devices. They can also be used to differentiate between high-frequency and low-frequency signals. This property makes them useful in electronic filters. Practical capacitors have series resistance, internal leakage of charge, series inductance and other non-ideal properties not found in a theoretical, ideal, capacitor.

2.4.1 THEORY OF OPERATION

A capacitor consists of two conductive electrodes, or plates, separated by a dielectric, which prevents charge from moving directly between the plates. Charge may however move from one plate to the other through an external circuit, such as a battery connected between the terminals.
Fig. 2.13 Dielectric is placed between two conducting plates, each of area \( A \) and with a separation of \( d \).

When any external connection is removed, the charge on the plates persists. The separated charges attract each other, and an electric field is present between the plates. The simplest practical capacitor consists of two wide, flat, parallel plates separated by a thin dielectric layer.

### 2.4.2 CAPACITANCE

A capacitor's ability to store charge is measured by its capacitance ‘\( C \)’, the ratio of the amount of charge stored on each plate to the voltage:

\[
q = Cv
\]

For an ideal parallel plate capacitor with a plate area ‘\( A \)’ and a plate separation ‘\( d \)’ :

\[
C' = \frac{\varepsilon A}{d}
\]

In SI units, a capacitor has a capacitance of one farad when one coulomb of charge stored on each plate causes a voltage difference of one volt between its plates. Since the farad is a very large unit, capacitance is usually expressed in microfarads (\( \mu F \)), nanofarads (nF), or picofarads (pF). In general, capacitance is greater in devices with large plate areas, separated by small distances. When a dielectric is present between two charged plates, its molecules become polarized and reduce the internal electric field and hence the voltage. This allows the capacitor to store more charge for a given voltage, so a dielectric
increases the capacitance of a capacitor, by an amount given by the dielectric constant, $\varepsilon$, of the material.

### 2.4.3 ELECTROLYTIC CAPACITORS

Electrolytic capacitors are the most popular type for values greater than about 1 microfarad. Electrolytic capacitors are constructed using a thin film of oxide on an aluminium foil. An electrolyte is used to make contact with the other plate. The two plates are wound around on one another and then placed into a can that is often aluminium.

![Fig.2.14 Electrolytic Capacitors](image)

Electrolytic capacitors are polarised, and care should be taken to ensure they are placed in circuit the correct way round. If they are connected incorrectly they can be damaged, and in some extreme instances they can explode.

Electrolytic capacitors have a wide tolerance. Typically the value of the component may be stated with a tolerance of -50% +100%. Despite this they are widely used in audio applications as coupling capacitors, and in smoothing applications for power supplies.

Electrolytic capacitors are available in both leaded and surface mount formats. The surface mount electrolytic capacitors are available in rectangular packages whereas the leaded versions are normally contained in a tubular aluminium can, each end being marked to show its polarity.
2.4.4 CERAMIC CAPACITOR

Ceramic capacitors are normally used for radio frequency and some audio applications. Ceramic capacitors range in value from figures as low as a few picofarads to around 0.1 microfarads. In view of their wide range and suitability for RF applications they are used for coupling and decoupling applications in particular. Here these ceramic capacitors are by far the most commonly used type being cheap and reliable and their loss factor is particularly low although this is dependent on the exact dielectric in use. Their stability and tolerance is not nearly as good as silver mica types, but their cost is much less. In view of their constructional properties, these capacitors are widely used both in leaded and surface mount formats.

There are a number of dielectrics that can be used with ceramic capacitors. For low values a dielectric designated "C0G" is normally used. This has the lowest dielectric constant but gives the highest stability and lowest loss. Where higher values are required in a given size, a dielectric with a higher dielectric constant must be used. Types with designations X7R and for higher values, Z5U are used, however their stability and loss are not as good as the capacitors made with C0G dielectric.

2.4.5 SILVER MICA CAPACITOR

Silver mica capacitors are not as widely used these days as they used to be. However these electronic components can still be obtained and are used where stability of value is of the utmost importance and where low loss is required. In view of this one of their major uses is within the tuned elements of circuits like oscillators, or within filters.

Values are normally in the range between a few picofarads up to two or possibly three thousand picofarads.
For this type of capacitor the silver electrodes are plated directly on to the mica dielectric. Again several layers are used to achieve the required capacitance. Wires for the connections are added and then the whole assembly is encapsulated.

### 2.4.6 TANTALUM CAPACITOR

Ordinary aluminium electrolytic capacitors are rather large for many uses. In applications where size is of importance tantalum capacitors may be used. These are much smaller than the aluminium electrolytic capacitors and instead of using a film of oxide on aluminium they use a film of oxide on tantalum. Tantalum capacitors do not normally have high working voltages, 35V is normally the maximum, and some even have values of only a volt or so.

Like electrolytic capacitors, tantalum capacitors are also polarised and they are very intolerant of being reverse biased, often exploding when placed under stress. However their small size makes them very attractive for many applications. They are available in both leaded and surface mount formats.

### 2.5 RESISTOR

A resistor is a two-terminal electronic component designed to oppose an electric current by producing a voltage drop between its terminals in proportion to the current, that is, in accordance with Ohm's law: $V = IR$. The resistance $R$ is equal to the voltage drop $V$ across the resistor divided by the current $I$ through the resistor.
Resistors are characterized primarily by their resistance and the power they can dissipate. Other characteristics include temperature coefficient, noise, and inductance. Practical resistors can be made of resistive wire, and various compounds and films, and they can be integrated into hybrid and printed circuits. Size, and position of leads are relevant to equipment designers; resistors must be physically large enough not to overheat when dissipating their power. Variable resistors, adjustable by changing the position of a tapping on the resistive element, and resistors with a movable tap ("potentiometers"), either adjustable by the user of equipment or contained within, are also used.

Resistors are used as part of electrical networks and electronic circuits.

There are special types of resistor whose resistance varies with various quantities, most of which have names, and articles, of their own: the resistance of thermistors varies greatly with temperature, whether external or due to dissipation, so they can be used for temperature or current sensing; metal oxide varistors drop to a very low resistance when a high voltage is applied, making them suitable for over-voltage protection; the resistance of a strain gauge varies with mechanical load; the resistance of photoresistors varies with illumination; the resistance of a Quantum Tunnelling Composite can vary by a factor of $10^{12}$ with mechanical pressure applied; and so on.
UNITs

The ohm (symbol: Ω) is the SI unit of electrical resistance, named after Georg Ohm. The most commonly used multiples and submultiples in electrical and electronic usage are the milliohm, ohm, kilohm, and megohm.

2.5.1 TYPES OF RESISTORS

Although resistors come in various forms we can divide them up into just two basic types:-

1. Fixed resistors
2. Variable resistors (or ‘potentiometers’)

A fixed resistor is a component with two wires which obeys Ohm's Law — i.e. it's a bit of material which behaves as we described in the last section. Electronic engineers and manufacturers have adopted some standards for resistors. These are intended to keep the cost down and make it easier for you to buy them from whichever supplier you like without having to redesign the equipment you want to put them in.
In an electrical circuit, some objects may need a lesser amount of current than the input value. In such cases, fixed resistors are used to reduce the flow of current. They are placed in such a way that a higher voltage must first pass through them before it flows further. The value of the resistance is fixed and does not change with change in the applied voltage or current flowing through it. The resistance value is measured in ohms and the value ranges from a few milliohms to about a giga-ohm.

Variable resistors consist of a resistance track with connections at both ends and a wiper which moves along the track as you turn the spindle. The track may be made from carbon, cermet (ceramic and metal mixture) or a coil of wire (for low resistances). The track is usually rotary but straight track versions, usually called sliders, are also available.

Variable resistors may be used as a rheostat with two connections (the wiper and just one end of the track) or as a potentiometer with all three connections in use. Miniature versions called presets are made for setting up circuits which will not require further adjustment.
Variable resistors are often called potentiometers in books and catalogues. They are specified by their maximum resistance, linear or logarithmic track, and their physical size. The standard spindle diameter is 6mm.

### 2.5.2 RESISTOR COLOR CODE

![4-band Resistor](image)

<table>
<thead>
<tr>
<th>Color</th>
<th>1st band value</th>
<th>2nd band value</th>
<th>Multiplier</th>
<th>Tolerances</th>
</tr>
</thead>
<tbody>
<tr>
<td>Black</td>
<td>0</td>
<td>0</td>
<td>× 1</td>
<td>± 1%</td>
</tr>
<tr>
<td>Brown</td>
<td>1</td>
<td>1</td>
<td>× 10</td>
<td>± 1%</td>
</tr>
<tr>
<td>Red</td>
<td>2</td>
<td>2</td>
<td>× 100</td>
<td>± 2%</td>
</tr>
<tr>
<td>Orange</td>
<td>3</td>
<td>3</td>
<td>× 1000</td>
<td>± 3%</td>
</tr>
<tr>
<td>Yellow</td>
<td>4</td>
<td>4</td>
<td>× 10,000</td>
<td>± 4%</td>
</tr>
<tr>
<td>Green</td>
<td>5</td>
<td>5</td>
<td>× 100,000</td>
<td>± 0.5%</td>
</tr>
<tr>
<td>Blue</td>
<td>6</td>
<td>6</td>
<td>× 1,000,000</td>
<td>± 0.25%</td>
</tr>
<tr>
<td>Violet</td>
<td>7</td>
<td>7</td>
<td>× 10,000,000</td>
<td>± 0.10%</td>
</tr>
<tr>
<td>Grey</td>
<td>8</td>
<td>8</td>
<td>× 100,000,000</td>
<td>± 0.05%</td>
</tr>
<tr>
<td>White</td>
<td>9</td>
<td>9</td>
<td>× 1,000,000,000</td>
<td>± 0.05%</td>
</tr>
<tr>
<td>Gold</td>
<td></td>
<td></td>
<td>× 0.1</td>
<td>± 5%</td>
</tr>
<tr>
<td>Silver</td>
<td></td>
<td></td>
<td>× 0.01</td>
<td>± 10%</td>
</tr>
<tr>
<td>No band</td>
<td></td>
<td></td>
<td></td>
<td>± 20%</td>
</tr>
</tbody>
</table>

*Fig. 2.21  4-Band Color Code of Resistor*

### 2.5.3 CALCULATING RESISTOR VALUES

The "left-hand" or the most significant coloured band is the band which is nearest to a connecting lead with the colour coded bands being read from left-to-right as follows;
Digit, Digit, Multiplier = Colour, Colour $\times 10^{\text{colour}}$ in Ohm's ($\Omega$'s)

For example, a Resistor has the following coloured markings;

Yellow Violet Red $= 4$ 7 2 $= 4 \times 7 \times 10^{-2} = 4700\Omega$ or 4k7.

The fourth band if used determines the percentage tolerance of the resistor and is given as;

Brown = 1%, Red = 2%, Gold = 5%, Silver = 10%

If resistor has no fourth tolerance band then the default tolerance would be at 20%.

It is sometimes easier to remember the resistor colour codes by using mnemonics, which is a saying that has a separate word to represent each of the Ten + Two colours in the code. However, these sayings are often crude but never the less effective and here are a few of the more "cleaner" versions:

Bad Booze Rots Our Young Guts But Vodka Goes Well

Bad Boys Ring Our Young Girls But Vicky Goes Without

Bad Boys Ring Our Young Girls But Vicky Gives Willingly -- Get Some Now
(This one is only slightly better because it includes the tolerance bands of Gold, Silver, and None).

2.6 LED (Light Emitting Diode)

A light-emitting-diode (LED) is a semiconductor diode that emits light when an electric current is applied in the forward direction of the device, as in the simple LED circuit. The effect is a form of electroluminescence where incoherent and narrow-spectrum light is emitted from the p-n junction.
LEDs are widely used as indicator lights on electronic devices and increasingly in higher power applications such as flashlights and area lighting. An LED is usually a small area (less than 1 mm²) light source, often with optics added to the chip to shape its radiation pattern and assist in reflection. The color of the emitted light depends on the composition and condition of the semiconducting material used, and can be infrared, visible, or ultraviolet. Besides lighting, interesting applications include using UV-LEDs for sterilization of water and disinfection of devices, and as a grow light to enhance photosynthesis in plants.

2.6.1 LED TECHNOLOGY

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

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

![Diagram of LED working原理](image)

**Fig. 2.23 Inner Working of LED**

LED development began with infrared and red devices made with gallium arsenide. Advances in materials science have made possible the production of devices with ever-shorter wavelengths, producing light in a variety of colors.

LEDs are usually built on an n-type substrate, with an electrode attached to the p-type layer deposited on its surface. P-type substrates, while less common, occur as well. Many commercial LEDs, especially GaN/InGaN, also use sapphire substrate.
Fig. 2.24 V-I diagram for a diode an LED will begin to emit light when the on-voltage is exceeded. Typical on voltages are 2-3 Volt

2.6.2 LIGHT EXTRACTION

The refractive index of most LED semiconductor materials is quite high, so in almost all cases the light from the LED is coupled into a much lower-index medium. The large index difference makes the reflection quite substantial (per the Fresnel coefficients). The produced light gets partially reflected back into the semiconductor, where it may be absorbed and turned into additional heat; this is usually one of the dominant causes of LED inefficiency. Often more than half of the emitted light is reflected back at the LED-package and package-air interfaces.

The reflection is most commonly reduced by using a dome-shaped (half-sphere) package with the diode in the center so that the outgoing light rays strike the surface perpendicularly, at which angle the reflection is minimized. Substrates that are transparent to the emitted wavelength, and backed by a reflective layer, increase the LED
efficiency. The refractive index of the package material should also match the index of the semiconductor, to minimize back-reflection. An anti-reflection coating may be added as well.

The package may be colored, but this is only for cosmetic reasons or to improve the contrast ratio; the color of the packaging does not substantially affect the color of the light emitted.

### 2.6.3 COLOR AND MATERIALS

Conventional LEDs are made from a variety of inorganic semiconductor materials, the following table shows the available colors with wavelength range, voltage drop and material:

<table>
<thead>
<tr>
<th>Color</th>
<th>Wavelength (nm)</th>
<th>Voltage (V)</th>
<th>Semi-conductor Material</th>
</tr>
</thead>
<tbody>
<tr>
<td>Infrared</td>
<td>$\lambda &gt; 760$</td>
<td>$\Delta V &lt; 1.9$</td>
<td>Gallium arsenide (GaAs)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Aluminium gallium arsenide (AlGaAs)</td>
</tr>
<tr>
<td>Red</td>
<td>$610 &lt; \lambda &lt; 760$</td>
<td>$1.63 &lt; \Delta V &lt; 2.03$</td>
<td>Aluminium gallium arsenide (AlGaAs) Gallium arsenide phosphide (GaAsP)</td>
</tr>
<tr>
<td>Orange</td>
<td>$590 &lt; \lambda &lt; 610$</td>
<td>$2.03 &lt; \Delta V &lt; 2.10$</td>
<td>Gallium arsenide phosphide (GaAsP) Aluminium gallium indium phosphide (AlGaInP)</td>
</tr>
<tr>
<td>Yellow</td>
<td>$570 &lt; \lambda &lt; 590$</td>
<td>$2.10 &lt; \Delta V &lt; 2.18$</td>
<td>Gallium arsenide phosphide (GaAsP) Gallium(III) phosphide (GaP)</td>
</tr>
<tr>
<td>Color</td>
<td>Wavelength Range</td>
<td>Voltage Range</td>
<td>Compound(s)</td>
</tr>
<tr>
<td>--------</td>
<td>------------------</td>
<td>---------------</td>
<td>-------------------------------------------------</td>
</tr>
<tr>
<td>Green</td>
<td>$500 &lt; \lambda &lt; 570$</td>
<td>$2.18 &lt; \Delta V &lt; 4.0$</td>
<td>Indium gallium nitride (InGaN) / Gallium(III) nitride (GaN)</td>
</tr>
<tr>
<td>Blue</td>
<td>$450 &lt; \lambda &lt; 500$</td>
<td>$2.48 &lt; \Delta V &lt; 3.7$</td>
<td>Zinc selenide (ZnSe) / Indium gallium nitride (InGaN)</td>
</tr>
<tr>
<td>Purple</td>
<td>multiple types</td>
<td>$2.48 &lt; \Delta V &lt; 3.7$</td>
<td>Dual blue/red LEDs, blue with red phosphor, or white with purple plastic</td>
</tr>
<tr>
<td>Violet</td>
<td>$400 &lt; \lambda &lt; 450$</td>
<td>$2.76 &lt; \Delta V &lt; 4.0$</td>
<td>Indium gallium nitride (InGaN)</td>
</tr>
<tr>
<td>Ultraviolet</td>
<td>$\lambda &lt; 400$</td>
<td>$3.1 &lt; \Delta V &lt; 4.4$</td>
<td>Diamond (C) / Aluminium nitride (AlN)</td>
</tr>
<tr>
<td>White</td>
<td>Broad spectrum</td>
<td>$\Delta V = 3.5$</td>
<td>Blue/UV diode with yellow phosphor</td>
</tr>
</tbody>
</table>

### 2.6.4 EFFICIENCY AND OPERATIONAL PARAMETERS

Typical indicator LEDs are designed to operate with no more than 30–60 milliwatts (mW) of electrical power. Around 1999, Philips Lumileds introduced power LEDs capable of continuous use at one watt (W). These LEDs used much larger semiconductor die sizes to handle the large power inputs. Also, the semiconductor dies were mounted onto metal slugs to allow for heat removal from the LED die.

One of the key advantages of LED-based lighting is its high efficiency, as measured by its light output per unit power input. White LEDs quickly matched and overtook the efficiency of standard incandescent lighting systems. In 2002, Lumileds made five-watt LEDs available with a luminous efficiency of 18–22 lumens per watt (lm/W). For comparison, a conventional 60–100 W incandescent lightbulb produces around 15 lm/W, and standard fluorescent lights produce up to 100 lm/W.

### 2.6.5 CONSIDERATIONS IN USE
Unlike incandescent light bulbs, which illuminate regardless of the electrical polarity, LEDs will only light with correct electrical polarity. When the voltage across the p-n junction is in the correct direction, a significant current flows and the device is said to be forward-biased. If the voltage is of the wrong polarity, the device is said to be reverse biased, very little current flows, and no light is emitted. LEDs can be operated on an alternating current voltage, but they will only light with positive voltage, causing the LED to turn on and off at the frequency of the AC supply.

Most LEDs have low reverse breakdown voltage ratings, so they will also be damaged by an applied reverse voltage above this threshold. If it is desired to drive the LED directly from an AC supply of more than the reverse breakdown voltage then it may be protected by placing a diode (or another LED) in inverse parallel.

2.6.6 TYPES OF LED’S

The main types of LEDs are miniature, high power devices and custom designs such as alphanumeric or multi-color.

1. Miniature LEDs
These are mostly single-die LEDs used as indicators, and they come in various-size packages:

1. Surface mount
2. 2 mm
3.3 mm (T1)
4. 5 mm (T1 3/4)
5. 10 mm
Other sizes are also available, but less common.

Common package shapes:
1. Round, dome top
2. Round, flat top
3. Rectangular, flat top (often seen in LED bar-graph displays)
4. Triangular or square, flat top

The encapsulation may also be clear or semi opaque to improve contrast and viewing angle.

There are three main categories of miniature single die LEDs:
1. Low current — typically rated for 2 mA at around 2 V (approximately 4 mW consumption).
2. Standard — 20 mA LEDs at around 2 V (approximately 40 mW) for red, orange, yellow & green, and 20 mA at 4–5 V (approximately 100 mW) for blue, violet and white.
3. Ultra-high output — 20 mA at approximately 2 V or 4–5 V, designed for viewing in direct sunlight.

2. Five- and twelve-volt LEDs
These are ordinary miniature LEDs that incorporate a suitable series resistor for direct connection to a 5 V or 12 V supply.
3. Flashing LEDs

Flashing LEDs are used as attention seeking indicators where it is desired to avoid the complexity of external electronics. Flashing LEDs resemble standard LEDs but they contain an integrated multivibrator circuit inside which causes the LED to flash with a typical period of one second. In diffused lens LEDs this is visible as a small black dot. Most flashing LEDs emit light of a single color, but more sophisticated devices can flash between multiple colors and even fade through a color sequence using RGB color mixing.

4. High power LEDs

High power LEDs (HPLED) can be driven at hundreds of mA (vs. tens of mA for other LEDs), some with more than one ampere of current, and give out large amounts of light. Since overheating is destructive, the HPLEDs must be highly efficient to minimize excess heat; furthermore, they are often mounted on a heat sink to allow for heat dissipation. If the heat from a HPLED is not removed, the device will burn out in seconds.

A single HPLED can often replace an incandescent bulb in a flashlight, or be set in an array to form a powerful LED lamp.

LEDs have been developed that can run directly from mains power without the need for a DC converter. For each half cycle part of the LED emits light and part is dark, and this is reversed during the next half cycle. The efficiency of HPLEDs is typically 40 lm/W[42]. As of November 2008 some HPLEDs manufactured by Cree, Inc exceed 95 lm/W [43] (e.g. the XLamp MC-E LED chip emitting Cool White light) and are being sold in lamps intended to replace incandescent, halogen, and even fluorescent style lights as LEDs become more cost competitive.

5. Multi-color LEDs
A “bi-color LED” is actually two different LEDs in one case. It consists of two dies connected to the same two leads but in opposite directions. Current flow in one direction produces one color, and current in the opposite direction produces the other color. Alternating the two colors with sufficient frequency causes the appearance of a blended third color. For example, a red/green LED operated in this fashion will color blend to produce a yellow appearance.

A “tri-color LED” is also two LEDs in one case, but the two LEDs are connected to separate leads so that the two LEDs can be controlled independently and lit simultaneously. A three-lead arrangement is typical with one common lead (anode or cathode).

RGB LEDs contain red, green and blue emitters, generally using a four-wire connection with one common lead (anode or cathode).

The Taiwanese LED manufacturer Everlight has introduced a 3 watt RGB package capable of driving each die at 1 watt.

6. Alphanumeric LEDs

LED displays are available in seven-segment and starburst format. Seven-segment displays handle all numbers and a limited set of letters. Starburst displays can display all letters.

Seven-segment LED displays were in widespread use in the 1970s and 1980s, but increasing use of liquid crystal displays, with their lower power consumption and greater display flexibility, has reduced the popularity of numeric and alphanumeric LED display.

2.6.7 ADVANTAGES OF USING LEDS

1. **Efficiency**: LEDs produce more light per watt than incandescent bulbs; this is useful in battery powered or energy-saving devices.[33]

2. **Color**: LEDs can emit light of an intended color without the use of color filters that traditional lighting methods require. This is more efficient and can lower initial costs.
3. **Size**: LEDs can be very small (>2 mm²) and are easily populated onto printed circuit boards.

4. **On/Off time**: LEDs light up very quickly. A typical red indicator LED will achieve full brightness in microseconds[34]. LEDs used in communications devices can have even faster response times.

5. **Cycling**: LEDs are ideal for use in applications that are subject to frequent on-off cycling, unlike fluorescent lamps that burn out more quickly when cycled frequently, or HID lamps that require a long time before restarting.

6. **Dimming**: LEDs can very easily be dimmed either by Pulse-width modulation or lowering the forward current.

7. **Cool light**: In contrast to most light sources, LEDs generate light and waste heat by different mechanisms – respectively radiation and conduction – so that suitably designed luminaires can produce a relatively cool light stream.

8. **Slow failure**: LEDs mostly fail by dimming over time, rather than the abrupt burn-out of incandescent bulbs.

9. **Lifetime**: LEDs can have a relatively long useful life. One report estimates 35,000 to 50,000 hours of useful life, though time to complete failure may be longer. Fluorescent tubes typically are rated at about 10,000 to 15,000 hours, depending partly on the conditions of use, and incandescent light bulbs at 1,000–2,000 hours.

10. **Shock resistance**: LEDs, being solid state components, are difficult to damage with external shock, unlike fluorescent and incandescent bulbs which are fragile.
11. **Focus**: The solid package of the LED can be designed to focus its light. Incandescent and fluorescent sources often require an external reflector to collect light and direct it in a usable manner.

12. **Toxicity**: LEDs do not contain mercury, unlike fluorescent lamps.

### 2.6.8 DISADVANTAGES OF USING LEDS

1. **High price**: LEDs are currently more expensive, price per lumen, on an initial capital cost basis, than most conventional lighting technologies. The additional expense partially stems from the relatively low lumen output and the drive circuitry and power supplies needed.

2. **Temperature dependence**: LED performance largely depends on the ambient temperature of the operating environment. Over-driving the LED in high ambient temperatures may result in overheating of the LED package, eventually leading to device failure.

3. **Voltage sensitivity**: LEDs must be supplied with the voltage above the threshold and a current below the rating. This can involve series resistors or current-regulated power supplies.

4. **Light quality**: Most white LEDs have spectra that differ significantly from a black body radiator like the sun or an incandescent light. The spike at 460 nm and dip at 500 nm can cause the color of objects to be perceived differently under LED illumination than sunlight or incandescent sources, due to metamerism,[38] red surfaces being rendered particularly badly by typical phosphor based LEDs white LEDs.

5. **Area light source**: LEDs do not approximate a “point source” of light, so cannot be used in applications needing a spherical light field. LEDs are not capable of providing
divergence below a few degrees. This is contrasted with lasers, which can produce beams with divergences of 0.2 degrees or less.

2.7 DIGITAL ENERGY METER

An electric meter or energy meter is a device that measures the amount of electrical energy consumed by a residence, business, or an electrically-powered device.

Electric meters are typically calibrated in billing units, the most common one being the kilowatt hour. Periodic readings of electric meters establishes billing cycles and energy used during a cycle.

In settings when energy savings during certain periods are desired, meters may measure demand, the maximum use of power in some interval. In some areas, the electric rates are higher during certain times of day, to encourage reduction in use. Also, in some areas meters have relays to turn off nonessential equipment.

The first accurate, recording electricity consumption meter was a DC meter by Dr Hermann Aron, who patented it in 1883. Hugo Hirst of the General Electric Company introduced it commercially into Great Britain from 1888. Meters had been used prior to this, but they measured the rate of power consumption at that particular moment. Aron's meter recorded the total energy used over time, and showed it on a series of clock dials.

The most common unit of measurement on the electricity meter is the kilowatt hour, which is equal to the amount of energy used by a load of one kilowatt over a period of one hour, or 3,600,000 joules. Some electricity companies use the SI megajoule instead.

Electricity meters operate by continuously measuring the instantaneous voltage (volts) and current (amperes) and finding the product of these to give instantaneous electrical power (watts) which is then integrated against time to give energy used (joules, kilowatt-hours etc). Meters for smaller services (such as small residential customers) can be
connected directly in-line between source and customer. For larger loads, more than about 200 amps of load, current transformers are used, so that the meter can be located other than in line with the service conductors. The meters fall into two basic categories, electromechanical and electronic.

2.7.1 ELECTROMECHANICAL METERS

The electromechanical induction meter operates by counting the revolutions of an aluminium disc which is made to rotate at a speed proportional to the power. The number of revolutions is thus proportional to the energy usage. It consumes a small amount of power, typically around 2 watts.

The metallic disc is acted upon by two coils. One coil is connected in such a way that it produces a magnetic flux in proportion to the voltage and the other produces a magnetic flux in proportion to the current. The field of the voltage coil is delayed by 90 degrees using a lag coil. This produces eddy currents in the disc and the effect is such that a force is exerted on the disc in proportion to the product of the instantaneous current and voltage. A permanent magnet exerts an opposing force proportional to the speed of rotation of the disc. The equilibrium between these two opposing forces results in the disc rotating at a speed proportional to the power being used. The disc drives a register mechanism which integrates the speed of the disc over time by counting revolutions, much like the odometer in a car, in order to render a measurement of the total energy used over a period of time.

The type of meter described above is used on a single-phase AC supply. Different phase configurations use additional voltage and current coils.
Three-phase electromechanical induction meter, metering 100 A 230/400 V supply. Horizontal aluminum rotor disc is visible in center of meter.

The aluminum disc is supported by a spindle which has a worm gear which drives the register. The register is a series of dials which record the amount of energy used. The dials may be of the cyclometer type, an odometer-like display that is easy to read where for each dial a single digit is shown through a window in the face of the meter, or of the pointer type where a pointer indicates each digit. With the dial pointer type, adjacent pointers generally rotate in opposite directions due to the gearing mechanism.

The amount of energy represented by one revolution of the disc is denoted by the symbol $K_h$ which is given in units of watt-hours per revolution. The value 7.2 is commonly seen. Using the value of $K_h$, one can determine their power consumption at any given time by timing the disc with a stopwatch. If the time in seconds taken by the disc to complete one revolution is $t$, then the power in watts is

$$P = \frac{3600 \cdot K_h}{t}$$

For example, if $K_h = 7.2$, as above, and one revolution took place in 14.4 seconds, the power is 1800 watts. This
method can be used to determine the power consumption of household devices by switching them on one by one.

Most domestic electricity meters must be read manually, whether by a representative of the power company or by the customer. Where the customer reads the meter, the reading may be supplied to the power company by telephone, post or over the internet. The electricity company will normally require a visit by a company representative at least annually in order to verify customer-supplied readings and to make a basic safety check of the meter.

In an induction type meter, creep is a phenomenon that can adversely affect accuracy, that occurs when the meter disc rotates continuously with potential applied and the load terminals open circuited. A test for error due to creep is called a creep test.

### 2.7.2 ELECTRONIC METERS

Electronic meters display the energy used on an LCD or LED display, and can also transmit readings to remote places. In addition to measuring energy used, electronic meters can also record other parameters of the load and supply such as maximum demand, power factor and reactive power used etc. They can also support time-of-day billing, for example, recording the amount of energy used during on-peak and off-peak hours.

### 2.8 IC 555

The 555 timer is an integrated circuit (chip) implementing a variety of timer and multivibrator applications. It was produced by Signetics Corporation in early 1970. The original name was the SE555/NE555 and was called "The IC Time Machine". The 555 gets its name from the three 5-KΩ resistors used in typical early implementations. It is widely used because of its ease to use, low price and reliability.
It is one of the most popular and versatile integrated circuits which can be used to build lots of different circuits. It includes 23 transistors, 2 diodes and 16 resistors on a silicon chip installed in an 8-pin mini dual-in-line package (DIP-8).

The 555 Timer is a monolithic timing circuit that can produce accurate and highly stable time delays or oscillations. The timer basically operates in one of the two modes—monostable (one-shot) multivibrator or as an astable (free-running) multivibrator. In the monostable mode, it can produce accurate time delays from microseconds to hours. In the astable mode, it can produce rectangular waves with a variable duty cycle. Frequently, the 555 is used in astable mode to generate a continuous series of pulses, but you can also use the 555 to make a one-shot or monostable circuit.

Applications of 555 timer in monostable mode include timers, missing pulse detection, bounce free switches, touch switches, frequency divider, capacitance measurement, pulse width modulation (PWM) etc.

In astable or free running mode, the 555 can operate as an oscillator. The uses include LED and lamp flashers, logic clocks, security alarms, pulse generation, tone generation, pulse position modulation, etc. In the bistable mode, the 555 can operate as a flip-flop and is used to make bounce-free latched switches, etc.

![Pin diagram of 555 Timer](image)

**Fig. 2.27 Pin diagram of 555 Timer**
Fig. 2.28 Block Diagram of 555 Timer

The connection of the pins is as follows:

<table>
<thead>
<tr>
<th>Nr.</th>
<th>Name</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>GND</td>
<td>Ground, low level (0 V)</td>
</tr>
<tr>
<td>2</td>
<td>TRIG</td>
<td>A short pulse high-to-low on the trigger starts the timer</td>
</tr>
<tr>
<td>3</td>
<td>OUT</td>
<td>During a timing interval, the output stays at $+V_{CC}$</td>
</tr>
<tr>
<td>4</td>
<td>RESET</td>
<td>A timing interval can be interrupted by applying a reset pulse to low (0 V)</td>
</tr>
<tr>
<td>5</td>
<td>CTRL</td>
<td>Control voltage allows access to the internal voltage divider (2/3 $V_{CC}$)</td>
</tr>
<tr>
<td>6</td>
<td>THR</td>
<td>The threshold at which the interval ends (it ends if the voltage at THR is at least 2/3 $V_{CC}$)</td>
</tr>
<tr>
<td>7</td>
<td>DIS</td>
<td>Connected to a capacitor whose discharge time will influence the timing interval</td>
</tr>
<tr>
<td>8</td>
<td>$V^+$, $V_{CC}$</td>
<td>The positive supply voltage which must be between 3 and 15 V</td>
</tr>
</tbody>
</table>

### 2.8.1 ASTABLE MULTIVIBRATOR

Figure shows 555 timer connected as an astable multivibrator. Pin 5 is bypassed to ground through a 0.01 $\mu$F capacitor. The power supply ($+V_{CC}$) is connected to common of pin 4 and pin 8 and pin 1 is grounded. If the output is high initially, capacitor C starts
charging towards through RA and RB. As soon as the voltage across the capacitor becomes equal to $V_{CC32}$, the upper comparator triggers the flip-flop, and the output becomes low. The capacitor now starts discharging through RB and transistor Q1. When the voltage across the capacitor becomes $V_{CC31}$, the output of the lower comparator triggers the flip-flop, and the output becomes high. The cycle then repeats. The output voltage and capacitor voltage waveforms are shown in Figure.

Fig. 2.29 Circuit diagram for Astable Multivibrator
2.8.2 MONOSTABLE MULTIVIBRATOR

A 555 timer connected for monostable operation is shown in Figure 2.30. The circuit has an external resistor and capacitor. The voltage across the capacitor is used for the threshold to pin 6. When the trigger arrives at pin 2, the circuit produces output pulse at pin 3.

Initially, if the output of the timer is low, that is, the circuit is in a stable state, transistor Q1 is on and the external capacitor C is shorted to ground. Upon application of a negative trigger pulse to pin 2, transistor Q1 is turned off, which releases the short circuit across the capacitor and as a result, the output becomes high. The capacitor now starts charging up towards through. When the voltage across the capacitor equals $\frac{1}{3}V_{cc}$, the output of comparator 1 switches from low to high, which in turn makes the output low via the output of the flip-flop. Also, the output of the flip-flop turns transistor Q1 on and hence the capacitor rapidly discharges through the transistor. The output of the monostable multivibrator remains low until a trigger pulse is again applied. The cycle then repeats. Figure shows the trigger input, output voltage, and capacitor voltage waveforms. As shown, the pulse width of the trigger input must be smaller than the expected pulse width of the output waveform. Moreover, the trigger pulse must be a
negative-going input signal with an amplitude larger than CCV31. The time for which the output remains high is given by

\[ T_p = 1.1 \, R_a \, C \]

where \( R_a \) is in ohms, \( C \) in farads and \( T_p \) in seconds. Once the circuit is triggered, the output will remain high for the time interval \( T_p \). It will not change even if an input trigger is applied during this time interval. In other words, the circuit is said to be non-retriggerable. However, the timing can be interrupted by the application of a negative signal at the reset input on pin 4. A voltage level going from CCV+ to ground at the reset input will cause the timer to immediately switch back to its stable state with the output low.

**Fig. 2.31 Monostable Multivibrator**

The trigger input may be driven by the output of astable multivibrator with high duty cycle. If the desired pulse width is of the order of seconds, the output can be seen using a
LED and the resistance value used will be of the order of MΩ. In this case the trigger can be supplied manually by grounding the trigger input for a fraction of a second.

![Input and output voltage waveforms](image)

**Fig. 2.32 Input and output voltage waveforms**

Supply voltage ($V_{CC}$) 4.5 to 15 V  
Supply current ($V_{CC} = +5$ V) 3 to 6 mA  
Supply current ($V_{CC} = +15$ V) 10 to 15 mA  
Output current (maximum) 200 mA  
Power dissipation 600 mW  
**Operating temperature** 0 to 70 °C

### 2.9 ULN 2804

Featuring continuous load current ratings to 500 mA for each of the drivers, ULN 2804 high voltage, high-current Darlington arrays are ideally suited for interfacing between low-level logic circuitry and multiple peripheral power loads. Typical power loads totaling over 260 W (350 mA x 8, 95 V) can be controlled at an appropriate duty cycle
depending on ambient temperature and number of drivers turned on simultaneously. Typical loads include relays, solenoids, stepping motors, magnetic print hammers, multiplexed LED and incandescent displays, and heaters.

These Darlington arrays are furnished in 18-pin dual in-line plastic packages or 18-lead small-outline plastic packages. All devices are pinned with outputs opposite inputs to facilitate ease of circuit board layout. Prefix ‘ULN’ devices are rated for operation over the temperature range of -20°C to +85°C.

Fig. 2.33 Pin Diagram of ULN 2804

FEATUERS

- TTL, DTL, PMOS, or CMOS Compatible Inputs
- Output Current to 500 mA
- Output Voltage to 95 V
• Transient-Protected Outputs
• Dual In-Line Package or Wide-Body Small-Outline Package

**RATINGS**

Output Voltage, VCE ULN 2804 ............... 50 V

Input Voltage, VIN .......................... 30 V

Continuous Output Current, IC .... 500 mA

Continuous Input Current, I IN ...... 25 mA

Power Dissipation, PD (one Darlington pair) .............. 1.0 W

Operating Temperature Range, TA Prefix ‘ULN’.............. -20°C to +85°C

Storage Temperature Range, TS.......................... -55°C to +150°C

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2.10 LCD DISPLAY

Liquid crystal displays (LCD) are widely used in recent years as compares to LEDs. This is due to the declining prices of LCD, the ability to display numbers, characters and graphics, incorporation of a refreshing controller into the LCD, their by relieving the CPU of the task of refreshing the LCD and also the ease of programming for characters and graphics. HD 44780 based LCDs are most commonly used.

![Fig. 2.34 A general purpose alphanumeric LCD, with two lines of 16 characters](image)

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2.10.1 LCD PIN DESCRIPTION
The LCD discussed in this section has the most common connector used for the Hitachi 44780 based LCD is 14 pins in a row and modes of operation and how to program and interface with microcontroller is described in this section.

![Fig. 2.35 LCD Display](image)

- **VCC, VSS, VEE**
  The voltage VCC and VSS provided by +5V and ground respectively while VEE is used for controlling LCD contrast. Variable voltage between Ground and Vcc is used to specify the contrast (or "darkness") of the characters on the LCD screen.

- **RS (register select)**
  There are two important registers inside the LCD. The RS pin is used for their selection as follows. If RS=0, the instruction command code register is selected, then allowing to user to send a command such as clear display, cursor at home etc.. If RS=1, the data register is selected, allowing the user to send data to be displayed on the LCD.

- **R/W (read/write)**
  The R/W (read/write) input allowing the user to write information from it. R/W=1, when it read and R/W=0, when it writing.

- **EN (enable)**
The enable pin is used by the LCD to latch information presented to its data pins. When data is supplied to data pins, a high power, a high-to-low pulse must be applied to this pin in order for the LCD to latch in the data presented at the data pins.

- **D0-D7 (data lines)**

The 8-bit data pins, D0-D7, are used to send information to the LCD or read the contents of the LCD’s internal registers. To displays the letters and numbers, we send ASCII codes for the letters A-Z, a-z, and numbers 0-9 to these pins while making RS =1. There are also command codes that can be sent to clear the display or force the cursor to the home position or blink the cursor. We also use RS =0 to check the busy flag bit to see if the LCD is ready to receive the information. The busy flag is D7 and can be read when R/W =1 and RS =0, as follows: if R/W =1 and RS =0, when D7 =1(busy flag =1), the LCD is busy taking care of internal operations and will not accept any information. When D7 =0, the LCD is ready to receive new information.

### 2.10.2 INTERFACING OF MICRO CONTROLLER WITH LCD DISPLAY

In most applications, the "R/W" line is grounded. This simplifies the application because when data is read back, the microcontroller I/O pins have to be alternated between input and output modes. In this case, "R/W" to ground and just wait the maximum amount of time for each instruction (4.1 msecs for clearing the display or moving the cursor/display to the "home position", 160 usecs for all other commands) and also the application software is simpler, it also frees up a microcontroller pin for other uses. Different LCD execute instructions at different rates and to avoid problems later on (such as if the LCD is changed to a slower unit). Before sending commands or data to the LCD module, the Module must be initialized. Once the initialization is complete, the LCD can be written to with data or instructions as required. Each character to display is written like the control bytes, except that the "RS" line is set. During initialization, by setting the "S/C" bit
during the "Move Cursor/Shift Display" command, after each character is sent to the LCD, the cursor built into the LCD will increment to the next position (either right or left). Normally, the "S/C" bit is set (equal to "1")

Fig 2.36 Interfacing of Microcontroller with LCD
2.11 BUZZER

A buzzer or beeper is a signalling device, usually electronic, typically used in automobiles, household appliances such as a microwave oven, or game shows.

![Fig. 2.37 Symbol of Buzzer](image)

It most commonly consists of a number of switches or sensors connected to a control unit that determines if and which button was pushed or a preset time has lapsed, and usually illuminates a light on the appropriate button or control panel, and sounds a warning in the form of a continuous or intermittent buzzing or beeping sound. Initially this device was based on an electromechanical system which was identical to an electric bell without the metal gong (which makes the ringing noise). Often these units were anchored to a wall or ceiling and used the ceiling or wall as a sounding board. Another implementation with some AC-connected devices was to implement a circuit to make the AC current into a noise loud enough to drive a loudspeaker and hook this circuit up to a cheap 8-ohm speaker. Nowadays, it is more popular to use a ceramic-based piezoelectric sounder like a Sonalert which makes a high-pitched tone. Usually these were hooked up to "driver" circuits which varied the pitch of the sound or pulsed the sound on and off.

In game shows it is also known as a "lockout system," because when one person signals ("buzzes in"), all others are locked out from signalling. Several game shows have large buzzer buttons which are identified as "plungers".

The word "buzzer" comes from the rasping noise that buzzers made when they were electromechanical devices, operated from stepped-down AC line voltage at 50 or 60 cycles. Other sounds commonly used to indicate that a button has been pressed are a ring or a beep.
2.12 OPTOCOUPLER

In electronics, an optocoupler is a device that uses a short optical transmission path to transfer a signal between elements of a circuit, typically a transmitter and a receiver, while keeping them electrically isolated — since the signal goes from an electrical signal to an optical signal back to an electrical signal, electrical contact along the path is broken.

The opto-isolator is simply a package that contains both an infrared LED and a photodetector such as silicon diode, transistor Darlington pair, or SCR. The wave-length response of each device is tailored to be as identical as possible to permit the highest measure of coupling possible.

![Schematic diagram of optocoupler](image)

Fig. 2.38 Schematic diagram of optocoupler

Schematic diagram of a very simple optocoupler with an LED and phototransistor. The dashed line represents the isolation barrier, over which no electrical contact can be permitted.

A common implementation involves a LED and a phototransistor, separated so that light may travel through a barrier but electrical current may not. When an electrical signal is applied to the input of the opto-isolator, its LED lights, its light sensor then activates, and a corresponding electrical signal is generated at the output. Unlike a transformer, the opto-isolator allows for DC coupling and generally provides significant protection from serious overvoltage conditions in one circuit affecting the other. If high transmission ratio is required Darlington photo transistor is used, however higher transmission ratio usually results in low noise immunity and higher delay.
With a photodiode as the detector, the output current is proportional to the amount of incident light supplied by the emitter. The diode can be used in a photovoltaic mode or a photoconductive mode. In photovoltaic mode, the diode acts like a current source in parallel with a forward-biased diode. The output current and voltage are dependent on the load impedance and light intensity. In photoconductive mode, the diode is connected to a supply voltage, and the magnitude of the current conducted is directly proportional to the intensity of light. This optocoupler type is significantly faster than one with photo transistor however transmission ratio is very low. Because of that it is common to integrate amplifier circuit in same package.

The optical path may be air or a dielectric waveguide. When high noise immunity is required optical conductive shield may be integrated into optical path. The transmitting and receiving elements of an optical isolator may be contained within a single compact module, for mounting, for example, on a circuit board; in this case, the module is often called an optocoupler.

For analog isolation, special "analog" optocoupler s are used. These devices have two independent, closely matched phototransistors, one of which is typically used to linearize the response using negative feedback.

![Fig. 2.39 Circuit with an opto-isolator](image)

A simple circuit with an opto-isolator. When switch $S_1$ is closed, LED $D_1$ lights, which triggers phototransistor $Q_1$, which pulls the output pin low. This circuit, thus, acts as a **NOT gate**.
Among other applications, opto-isolators can help cut down on ground loops, block voltage spikes, and provide electrical isolation.

- Most common application is for switched-mode power supplies. They utilise optocouplers for mains isolation. Because of noisy environment optocouplers with low transmission ratio are preferred.
- One of the requirements of the MIDI (Musical Instrument Digital Interface) standard is that input connections be opto-isolated.

They are used to isolate low-current control or signal circuitry from transients generated or transmitted by power supply and high-current control circuits. The latter are used within motor and machine control function blocks.

2.13 VOLTAGE REGULATOR (78XX)

The Voltage Regulator (78xx) (also sometimes known as LM78xx) series of devices is a family of self-contained fixed linear voltage regulator integrated circuits. The 78xx family is a very popular choice for many electronic circuits which require a regulated power supply, due to their ease of use and relative cheapness. When specifying individual ICs within this family, the xx is replaced with a two-digit number, which indicates the output voltage the particular device is designed to provide (for example, the 7805 has a 5 volt output, while the 7812 produces 12 volts). The 78xx line are positive voltage regulators, meaning that they are designed to produce a voltage that is positive relative to a common ground. There is a related line of 79xx devices which are complementary
negative voltage regulators. 78xx and 79xx ICs can be used in combination to provide both positive and negative supply voltages in the same circuit, if necessary.

78xx ICs have three terminals and are most commonly found in the TO220 form factor, although smaller surface-mount and larger TO3 packages are also available from some manufacturers. These devices typically support an input voltage which can be anywhere from a couple of volts over the intended output voltage, up to a maximum of 35 or 40 volts, and can typically provide up to around 1 or 1.5 amps of current (though smaller or larger packages may have a lower or higher current rating).

2.14 RELAY

A relay is an electrical switch that opens and closes under the control of another electrical circuit. In the original form, the switch is operated by an electromagnet to open or close one or many sets of contacts. It was invented by Joseph Henry in 1835. Because a relay is able to control an output circuit of higher power than the input circuit, it can be considered to be, in a broad sense, a form of an electrical amplifier.

2.14.1 BASIC DESIGN & OPERATION

A simple electromagnetic relay, such as the one taken from a car in the first picture, is an adaptation of an electromechanical solenoid. It consists of a coil of wire surrounding a soft iron core, an iron yoke, which provides a low reluctance path for magnetic flux, a moveable iron armature, and a set, or sets, of contacts; two in the relay pictured. The armature is hinged to the yoke and mechanically linked to a moving contact or contacts. It is held in place by a spring so that when the relay is de-energised there is an air gap in the magnetic circuit. In this condition, one of the two sets of contacts in the relay pictured is closed, and the other set is open. Other relays may have more or fewer sets of contacts
depending on their function. The relay in the picture also has a wire connecting the armature to the yoke. This ensures continuity of the circuit between the moving contacts on the armature, and the circuit track on the Printed Circuit Board (PCB) via the yoke, which is soldered to the PCB.

When an electric current is passed through the coil, the resulting magnetic field attracts the armature, and the consequent movement of the movable contact or contacts either makes or breaks a connection with a fixed contact. If the set of contacts was closed when the relay was de-energised, then the movement opens the contacts and breaks the connection, and vice versa if the contacts were open. When the current to the coil is switched off, the armature is returned by a force, approximately half as strong as the magnetic force, to its relaxed position. Usually this force is provided by a spring, but gravity is also used commonly in industrial motor starters. Most relays are manufactured to operate quickly. In a low voltage application, this is to reduce noise. In a high voltage or high current application, this is to reduce arcing.

If the coil is energized with DC, a diode is frequently installed across the coil, to dissipate the energy from the collapsing magnetic field at deactivation, which would otherwise generate a voltage spike dangerous to circuit components. Some automotive relays already include that diode inside the relay case. Alternatively a contact protection network, consisting of a capacitor and resistor in series, may absorb the surge. If the coil is designed to be energized with AC, a small copper ring can be crimped to the end of the solenoid. This "shading ring" creates a small out-of-phase current, which increases the minimum pull on the armature during the AC cycle.

2.14.2 SOLID STATE RELAY

A solid state relay (SSR) is a solid state electronic component that provides a similar function to an electromechanical relay but does not have any moving components,
increasing long-term reliability. With early SSR's, the tradeoff came from the fact that every transistor has a small voltage drop across it. This voltage drop limited the amount of current a given SSR could handle. As transistors improved, higher current SSR's, able to handle 100 to 1,200 amps, have become commercially available. Compared to electromagnetic relays, they may be falsely triggered by transients.

2.14.3 SOLID STATE CONTRACTOR RELAY

A solid state contactor is a very heavy-duty solid state relay, including the necessary heat sink, used for switching electric heaters, small electric motors and lighting loads; where frequent on/off cycles are required. There are no moving parts to wear out and there is no contact bounce due to vibration. They are activated by AC control signals or DC control signals from Programmable logic controller (PLCs), PCs, Transistor-transistor logic (TTL) sources, or other microprocessor controls.

2.14.4 APPLICATIONS

1. To control a high-voltage circuit with a low-voltage signal, as in some types of modems or audio amplifiers.
2. To control a high-current circuit with a low-current signal, as in the starter solenoid of an automobile.
3. To detect and isolate faults on transmission and distribution lines by opening and closing circuit breakers (protection relays).
4. To isolate the controlling circuit from the controlled circuit when the two are at different potentials.
5. To perform logic functions.
6. To perform time delay functions.
2.15 POWER SUPPLY

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

![Block Diagram of power supply](image)

**INTRODUCTION:**

The power supply supplies the required energy for both the microcontroller and the associated circuits. It is the most essential part of the circuit because to run its constituent IC’s circuit has to be provided with power. These IC’s can run on DC power. Hence the required D.C supply has to be generated. The main parts of a power supply unit and their function are as follows

**DESCRIPTION:**

Power supply is the main requirement of every project. The various parts of a power supply are explained below:

**Transformer:** The function of the transformer is to step down the voltage level from the available A.C.220V to the desired voltage. The 9-0-9 rating of the transformer upon the requirements of the IC’s in the circuit is used. The secondary has a center tapping which forms the neutral terminal.

**Bridge rectifier:** The function of the rectifier is to convert the alternating voltage signal into a unidirectional one. This function is provided by semiconductor diodes connected in bridge configuration. Diodes 1N4007 are used as rectifier.
Ripple Rejection: The output voltage of the rectifier is unidirectional but pulsating. A capacitor of 1000Pf is used for ripple rejection.

Regulation: To obtain a constant voltage specific IC’s are used as voltage regulator. Voltage regulator LM7805 is used. These IC’s have three terminals an input, an output and a ground terminal.
3.1 INTRODUCTION

3.1.1 BLOCK DIAGRAM: PREPAID ENERGY METER

![Fig. 3.1 Block Diagram of Prepaid Energy Meter]

3.1.2 COMPONENT DESCRIPTION

In this project, main components used are as follows:

- ATMEL 89C52 MICROCONTROLLER
- IC 555 TIMER
- DIGITAL ENERGY METER
- IC ULN 2804
- OPTOCOUPLER
3.1.3 CIRCUIT DIAGRAM OF PREPAID ENERGY METER

Fig. 3.2 Circuit Diagram of Prepaid Energy Meter

3.1.4 PCB LAYOUT OF PREPAID ENERGY METER
3.1.5 WORKING OF THIS SYSTEM
Prepaid energy meter is used to prepaid the ongoing supply of electricity to homes, offices etc. The word prepaid means "pay before use" one of the advantageous feature of this concept. First of all the LCD display the amount i.e 000 now when the card is swapped through the optocoupler to recharge (opto is a sensor) the recharged amount will be shown on a LCD and a build of 40 watt will get on. There are two opto for two cards and two cards of rs.10 and 15 is made.

555 timer is used to provide the basic needed timing or stable oscillations which is being used in monostable mode. Now after every 10 pulses 1rs will be deducted. There is switch on relay side on pressing the key the 100 watt bulb gets on and decrement gets faster.

555 also makes the microcontroller to sense the pulses adequately otherwise without 555 the microcontroller is not able to sense the rapid pulses given to it. Relay is used as a switch on output side by connecting the bulbs to it. For a relay to work ULN 2804 is used which is a relay driver because relay needs relatively large current. ULN 2804 IC is a current driver which gives relatively large current for driving relay.

Relay is an electromechanical switch which consists of a coil, spring and a set of electrical contacts made from metal. It allows one circuit to switch to a second circuit which can be completely separated from the first. Current flowing through the coil of the relay creates a magnetic field which attracts a lever and changes the switch contacts from OFF to ON positions. There is a generation of residue current voltage in reverse polarity across the coil while switching on/off to the coil current. This voltage may leads to serious effect on working operation of relay. For prevention, a protection diode across the relay must be connected.

3.2 FABRICATION PROCESS
3.2.1 PCB LAYOUT

A circuit layout is made considering following factors in mind:-

1. Position of components (properly spaced)
2. Inductive loops should be avoided.
3. The grounding system should be separated into ground conductors.
4. Undesirable coupling should be avoided.
5. Power supply tracks should be of adequate width to withstand a possible short circuit system.
6. Use of jumpers should be minimum or avoided as far as possible.

It should be easy to connect the board to test equipment.

Printed circuit board popularly known as PCB provides both physical, structure for mounting and holding electronic component as well as the electrical interconnection between components. A PCB consist of non-conducting substrate upon which a conductive pattern or circuit is formed. Copper is the most prevalent conductor. Although nickel, silver UN un-lead and gold may also be used as etch resists or top level metal. When the electronic component is an electronic assembly, also called a printed circuit assembly (PCA). This assembly is the basic building block for all large electronic system. From toys to toaster to telecommunications. The various processes involved in fabrication of the plate.

Considering these factors a layout is made. A mirror image of pattern is prepared and is carbon copied onto the copper clad laminate with the help of sharp pencil or ball pointed pen and position of holes must be marked carefully. Then with fine brush and enamel mark trace as copied earlier. Then board is dried for at least four to six hours before developing.

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I prepared a dotted background to fit components on Marked big blue spots repeats every 2.5mm thus corresponds standard stepping of most IC's and other single components.

Fig 3.4 Worksheet is prepared to be printed

Simply select and copy a desired hole and paste it on your PCB worksheet to set component connection points. Then copy and paste lines at proper thickness. Whole artwork is up to you. You may label important points of the circuit by a small font.
Remove color blue and it's ready to print ... It is not really necessary but preparing a component side layout of the PCB will help anyone to build it, even to you. Just flip the circuit horizontal (or vertical) then change the When completed, you may label it to be more informative.

We may found it very hard to cut the copper plated board since it is intended to be very strong. Cut the PCB drawing from the printed paper and place on the copper plated board then fix with adhesive tape. Mark the points to be drilled on the PCB with a thick needle or any other sharp object.
Remove the paper and draw the lines with a permanent waterproof marker. Please note that the final quality of etching depends on the ink used. You should try different brands or types of markers on a small piece before to find the best one. It does not matter if it is black or blue etc. but if you leave the painted plate for over a few minutes the ink becomes too dry and it flakes in the FeCl₃. So freshly paint and etch your PCBs.
The easy to find chemical which eats away the copper is FeCl₃. Here in Turkey it is sold both in solid and dissolved states but I recommend the solid one. Prepare a solution which looks very dark. Also hot solution works faster but it is not necessary if you have enough time. Attach a thread to the plate by a piece of adhesive tape then immerse it in the FeCl₃.
3.2.2 DEVELOPING OF PCB (ETCHING)

In this all excessive copper is removed from the copper clad laminate, and only pattern is left behind. Developing is done in a solution of heated tap water and ferric chloride (FeCl₃). To 100 ml of tap water around 30 to 40 gms. of FeCl₃ is added. A few drops of HCl may be added to speed up the process. The board with its copper side facing upward should be placed in a flat-bottomed plastic tray and the aqueous solution of FeCl₃ poured. The etching process would take 40 to 60 minutes to complete depending upon the size of the PCB. Then board is washed under the running water and dried. The printed pattern should be clearly visible otherwise allow it to stand in the solution for some more time. The paint should be removed with the help of alcohol or petrol.

After a few minutes (it may took more if your plate's copper layer is thick) the copper part of the plate which is not painted will be dissolved. When it is visible through the edges of the painted regions pay attention to the rest of the process. Move the plate in the solution to help it dissolve easier. When all unwanted copper parts are dissolved quickly take it out the solution and rinse with plenty of tap water. This is really important that FeCl₃ residue left on the PCB will make it rusty by the time. Be careful: do not split FeCl₃ on any part of your home. It eats much of the metals and leaves ugly stains surfaces.

Fig 3.8.1
After drying the rinsed PCB, remove painting with a solvent (such as acetone or thinner). Now it is ready to drill. Use proper hole diameters for your components to be soldered on. The one on the picture is a 1mm drill. You will also find the help of initial marking here as a guidance to the drill tip.

3.2.3 DRILLING

For drilling the plate one can use high tensile steel bit of diameter 1mm and following points should be kept in mind: For IC’s Always use IC bases, as direct soldering of IC may damage them. The drilling of holes is in such a manner so as to correspond to IC bases exactly so that no one faces any problem in inserting the pins of the bases. For other components, the holes are exactly placed so that components fix exactly in the holes without any bending or stretching of leads of components. For drilling of holes for fixing
PCB in chassis always ensure that no copper line passes near the holes. After drilling the proper sized holes (or sometimes slots as needed) start soldering the components on. For convenience first solder the small parts close to the board surface then the others last especially the fragile ones. I do not include soldering techniques here since there are many pages on web about it.

For drilling the plate one can use high tensile steel bit of diameter 1 mm and following points should be kept in mind:-

FOR IC’S:-
1. Always use IC bases, as direct soldering of IC may damage them.
2. The drilling of holes is in such manner so as to correspond to IC bases exact that no faces any problem in measuring the pins of the bases.

FOR OTHER COMPONENTS :-
1. The holes are exactly placed so that component fix exactly in the holes without any bending or stretching of leads of component.
2. For drilling of holes for fixing PCB in chassis always ensure that no copper line passes near the holes.

Fig 3.9 Drilling

3.2.4 SOLDERING
It is a process of joining two or more metal at a temperature below their melting point using filler metal (solder) having melting point below 450 degree celsius. Clean the two surfaces to be soldered thoroughly so that surfaces are free from all dust particles, Grease, oil, chemical etc. Preparation of component lead is done the component lead is done. The component lead may rusted during storage. It will be difficult to solder such leaded components thus leads of such components or wires need to be tinned. Apply small amount of flux on the surface to be soldered. Select an iron bit of correct size and temperature, clean the tip of soldering iron on the sponge select correct gauge of solder ensure the eutectic combination.

Apply the soldering iron to the joint from one side heat up the surface to the soldered. Apply solder directly on to the component not the tip of soldering iron. The join should give the shiny bead like appearance, if not , apply little more flux and reheat the joint. Now, extra lengths of component leads may be cut off with the help of suitable cutter.

All the components according to the component assembly diagram are mounted in the appropriate holes.

Soldering is a process of joining two or more metals at a temperature below their melting point using filler metal (solder) having melting point below 450 degree Celsius. Heat is applied to the metal parts, and the alloy metal is pressed against the joint, melts, and is drawn into the joint by capillary action and around the materials to be joined by wetting action. After the metal cools, the resulting joints are not as strong as the base metal, but have an adequate strength, electrical conductivity, and water tightness for many uses. Soldering is an ancient technique that has been used practically as long as humans have been making articles out of metal. Soldering can be done in number of ways, including passing parts over a bulk container of melted solder (wave soldering), using an infrared lamp, or by using a point source such as an electric soldering iron, a brazing torch, or a hot-air soldering tool. Flux is usually used to assist in the joining process. Flux can be manufactured as part of solder in single or multi-core solder in which case it is contained inside a hollow tube or multiple tubes that are contained inside the strand of solder. Flux
can also be applied separately from the solder, often in the form of paste. In some fluxes soldering, a forming gas tat is a reducing atmosphere rich in hydrogen can also serve much the same purpose as traditional flux, and provide the benefits of traditional flux in re-flow ovens through which electronic parts placed on a circuit board on a pad of solder cream are transported for a specific period of time. One application of soldering is making connections between electronic parts and printed circuit boards. Another is in plumbing. Joints in sheet metal objects such as cans for food, roof flashing, and drain gutters were also traditionally soldered. Jewelry and small mechanical parts are often assembled by soldering. Soldering can also be used to repair technique to patch a leak in a container or looking vessels. Soldering is distinct from welding in that the base materials to be joined are not melted, though the base metal is dissolved somewhat into the liquid solder – this dissolution process results in the soldered joints mechanical and electrical strengths. Brazing is similar to soldering but uses higher melting temperature alloys, based on copper, as the filter metal. Hard soldering or silver soldering (performed with high temperature solder containing up to 40% silver) is also a form of brazing, and involves solders with melting points above 450 C.

3.2.5 DESOLDERING & RESOLDERING

Due to the dissolution of the base metals into the solder, solder should never be reused. Once the solders capacity to dissolve base metal has been achieved, the solder will not properly bond with the base metal and a cold solder joint with a hard and brittle crystalline appearance will usually be the result. It is in good practice to remove solder from a joint prior to resoldering – desoldering wicks or vacuum desoldering equipment can be used. Desoldeing wicks contains plenty of flux that will lift the contamination from the copper trace and any device leads that are present. This will leave a bright, shiny, clean joint to be resoldered. The lower melting point of solder means it can be melted away from the base metal, leaving it mostly intact though the outer layer will be
‘tinned’ with solder. Flux will remain which can easily be removed by abrasive or chemical processes. This tinned layer will allow solder to flow into a new joint, as well as making the solder flow very quickly and easily.

3.2.6 SOLDERING DEFECTS

Soldering defects are solder joints that are not soldered correctly. These defects may arise when solder temperature is too low. When the base metals are too cold, the solder will not flow and will ‘ball up’, without creating the metallurgical bond. An incorrect solder type (for example, electronics solder for mechanical joints or vice versa) will lead to a weak point. An incorrect or missing flux can corrode the metals in the joint. Without flux the joint may not be clean. A dirty or contaminated joints leads to a weak bond. A lack of solder on a joint will make the joint fail. An excess of solder can create a ‘solder bridge’ which is a short circuit. Movement of metals being soldered before the solder has cooled will make the solder appear grainy and may cause a weakened joint.

Soldering defects in electronics can lead to short circuit, high resistance in joints, intermittent connections, components overheating and damage circuit boards. Flux left around integrated circuits leads will lead to inter-lead leakage. It is a big issue on surface mount components and causes improper device operation as moisture absorption rises. In mechanical joints, defects lead to joint failure and corrosion.
4.1 CONCLUSION & FUTURE SCOPE

In the present time of 21st century we have no space for errors or faults either in any technical system or in general applications. We studied PREPAID ENERGY METER and 8051-IDE software in this project which is also the main feature of this project.
Prepaid energy meter is an advantageous concept for the future. Its facilitates the exemption from electricity bills. Electricity coupons will be available at nearby shops. The word prepaid means "pay before use" one of the advantageous feature of this concept.

Prepaid energy meter is used to prepaid the ongoing supply of electricity to homes, offices etc.

CHAPTER – 5

RESULT

The project has been successfully completed and is in proper working condition. Prepaid energy meter is used to prepaid the ongoing supply of electricity to homes, offices etc. We will get rid of the monthly electricity bills as recharge coupons will be available at nearby shops. It is an advantageous concept for the future.