A MAJOR PROJECT

ON

WI-FI BASED ELECTRONICS APPLIANCES CONTROL AUTOMATION

SUBMITTED IN THE PRATIAL FUFILLMENT OF

REQUIRMENT FOR THE AWARD OF

THE DEGREE OF

BACHELOR OF TECHNOLOGY

in

ELECTRONICS AND COMMUNICATION ENGINEERING

By

SHIVANI YADAV (Enrolment no -1120434065)

SHUBHAM MISHRA (Enrolment no -1120434068)

SHIV SHANKAR YADAV(Enrolment no – 1120434063)

Under the supervision of
MR.ASHWANI KUMAR
ASSISTANT PROFESSOR
BBD University, Lucknow

School of Engineering
BABU BANARASI DAS UNIVERSITY
LUCKNOW

MAY, 2016

CERTIFICATE

It is certified that the work contained in this Project entitled **"Wi-Fi BASED ELECTRONIC APPLIANCES CONTROL AUTOMATION"** by SHIVANI YADAV (1120434065), SHUBHAM MISHRA (1120434068) SHIV SHANKAR YADAV (1120434063)for the award of **Bachelor of Technology** from Babu Banarasi Das University has been carried out under my supervision.

Signature
Mr. ASHWANI KUMAR
Asst. professor, E.C.E
Department of E.C.E
School of Engineering
BBD University
Lucknow (U.P)

Signature
Mrs. POONAM PATHAK
Head, E.C.E
Department of E.C.E
School of Engineering
BBD University
Lucknow (U.P)

ACKNOWLEDGEMENT

Whenever a module of work is completed successfully, a source of inspiration and guidance is always there for the student. I, hereby take the opportunity to thank those entire people who helped me in many different ways.

First and foremost, I am grateful to my thesis guide **ASST. PROFFESOR ASHWANI KUMAR** B.B.D. University, for showing faith in my capability and providing able guidance and his generosity and advice extended to me throughout my thesis.

Last, but not least I would like to thank all my faculties and my friends for helping me in all measure of life and for their kind cooperation and moral support.

SHIVANI YADAV

SHUBHAM MISHRA

SHIV SHANKAR YADAV

ABSTRACT

The main aim of the project is to control multiple electrical loads remotely over internet falling under the basic principles of Internet of Things-IOT. For this real-time scenario we use an Android app on any smart cell phone with user configurable front end (GUI).

The data sent from the cell phone upon touch commands are sent through allotted IP fed to it, to any nearby wireless modem which is then received by a Wi-Fi module interfaced to a microcontroller of 8051 series, under TCP IP via networked wireless modem environment.

Relays are then driven as per the command received at the controller end to handle electrical loads. The real time data is also seen at the sending end upon a LCD display interfaced to the microcontroller that displays the status of the loads too.

The power supply consists of a step down transformer 230/12V, which steps down the voltage to 12V AC. This is converted to DC using a Bridge rectifier and it is then regulated to +5V using a voltage regulator 7805 which is required for the operation of the microcontroller , 3.3 volt for the Wi-Fi unit and other components.

TABLE OF CONTENTS

Page No.

LIST OF FIGURES

LIST OF TABLES

CHAPTER 1 - INTRODUCTION

INTRODUCTION

The main aim of the project is to control multiple electrical loads remotely over internet falling under the basic principles of Internet of Things-IOT. For this real-time scenario we use an Android app on any smart cell phone with user configurable front end (GUI).

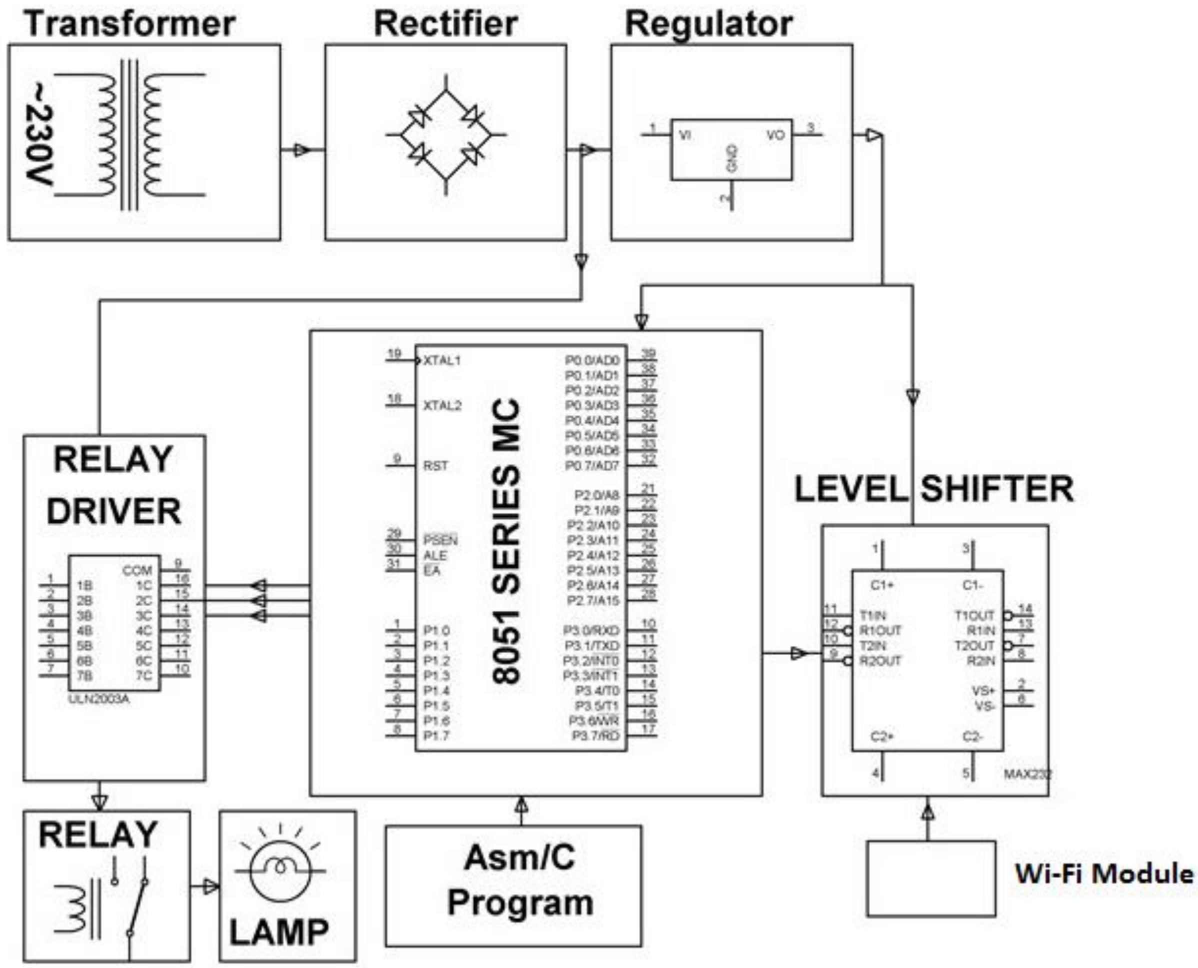
The data sent from the cell phone upon touch commands are sent through allotted IP fed to it, to any nearby wireless modem which is then received by a Wi-Fi module interfaced to a microcontroller of 8051 series, under TCP IP via networked wireless modem environment.

Relays are then driven as per the command received at the controller end to handle electrical loads. The real time data is also seen at the sending end upon a LCD display interfaced to the microcontroller that displays the status of the loads too.

The power supply consists of a step down transformer 230/12V, which steps down the voltage to 12V AC. This is converted to DC using a Bridge rectifier and it is then regulated to +5V using a voltage regulator 7805 which is required for the operation of the microcontroller , 3.3 volt for the Wi-Fi unit and other components.

CHAPTER 2 – BLOCK DIAGRAM

BLOCK DIAGRAM



Working:

- Microcontroller receives commands from any mobile device or computer. The characters of command are 1 2 3 4 5 0.
- The Wi- If module has been used here to set up a wireless link between microcontroller and Mobile device on 2.4 GHz.
- Wi-Fi works on Local Area Connection so we can have more than 1 device at the same instant connected with hardware.
- The TCP server created on wife module has an IP 192.168.4.1 which we need to set up in our App. The port number is 2525.
- Wi-Fi module number is ESP8266
- Wi-Fi Password is "esp82661.
- We have used BT136 Triad and MOC3021 based Solid State Relay (SSR) to control high voltage appliance.
- An 11.0592 MHz Crystal has been used with microcontroller to provide an operating frequency of 11.0592 MHz. This also helps in setting up baud rate of 9600 to communicate with wife module.
- 10uF capacitor and 10 K ohm resistance combination has been used as power On Reset circuit Helping in proper boot of microcontroller. A transformer 12 - 0 - 12 1.5 Ampere has been used. Centre tap transformer requires two diodes to make full wave rectifier so we have used 1N4007 diode. 7805 voltage regulator is providing 5 volt for microcontroller and LCD whereas LD33 regulator is giving 3.3 Volt for wi-fi module.
- A 16x2 LCD has been used in 4 Bit mode. 4 Bit mode requires only D4 D5 D6 D7 so we are discarding D0 D1 D1 D2 of LCD. Two LED are showing that number of devices can be increased.
- AT89s52 microcontroller is 8051 microcontroller.
- Kiel IDE with C51 Compiler has been used to make program for AT89s52.

CHAPTER 3 - COMPONENTS USED

- Microcontroller ATmega16
- Wi-Fi module
- Transformer

Personal Experiences:

- Time management
- Communication
- Accountability

COMPONENTS USED -

- Microcontroller
- Voltage Regulator
- Led
- Power Supply
- Relay
- Hardboard
- PCB
- Crystal Oscillator
- Diode
- Wi-Fi module
- Resistor
- LCD
- Capacitor

CHAPTER 4 - Microcontroller

4.1 Introduction

Microcontrollers, as the name suggests, are small controllers. They are like single chip computers that are often embedded into other systems to function as processing/controlling unit. For example, the remote control you are using probably has microcontrollers inside that do decoding and other controlling functions. They are also used in automobiles, washing machines, microwave ovens, toys ... etc, where automation is needed.

4.2 KEY FEATURES OF MICROCONTROLLERS:

- **HIGH INTEGRATION OF FUNCTIONALITY**

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.

- **FIELD PROGRAMMABILITY, FLEXIBILITY**

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.

- **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.

4.3 8051 MICROCONTROLER

8051 microcontroller has 128 bytes of RAM, 4K bytes of on-chip ROM, two timers, one serial port, and four ports (each 8-bits wide) all on a single chip. The 8051 is an 8-bit processor i.e. the CPU can work on only 8 bits of data at a time. The fixed amount of on-chip ROM, RAM, and number of I/O ports in microcontroller makes them ideal for many applications in which cost and space are critical.

The AT89C51 is a low-power, high-performance CMOS 8-bit microcomputer with 4K bytes of Flash programmable and erasable read only memory (PEROM). The on-chip Flash allows the program memory to be reprogrammed in-system or by a conventional nonvolatile memory programmer. By combining a versatile 8-bit CPU with Flash on a monolithic chip, the Atmel AT89C51 is a powerful microcomputer, which provides a highly flexible and cost-effective solution to many embedded control applications.

4.4 FEATURES:

• Compatible with MCS-51™ Products

• 4K Bytes of In-System Reprogrammable Flash Memory

• Fully Static Operation: 0 Hz to 24 MHz

• Three-level Program Memory Lock

• 128 x 8-bit Internal RAM

• 32 Programmable I/O Lines

• Two 16-bit Timer/Counter

• Six Interrupt Sources

• Programmable Serial Channel

• Low-power Idle and Power-down Modes

4.5 BLOCK DIAGRAM:

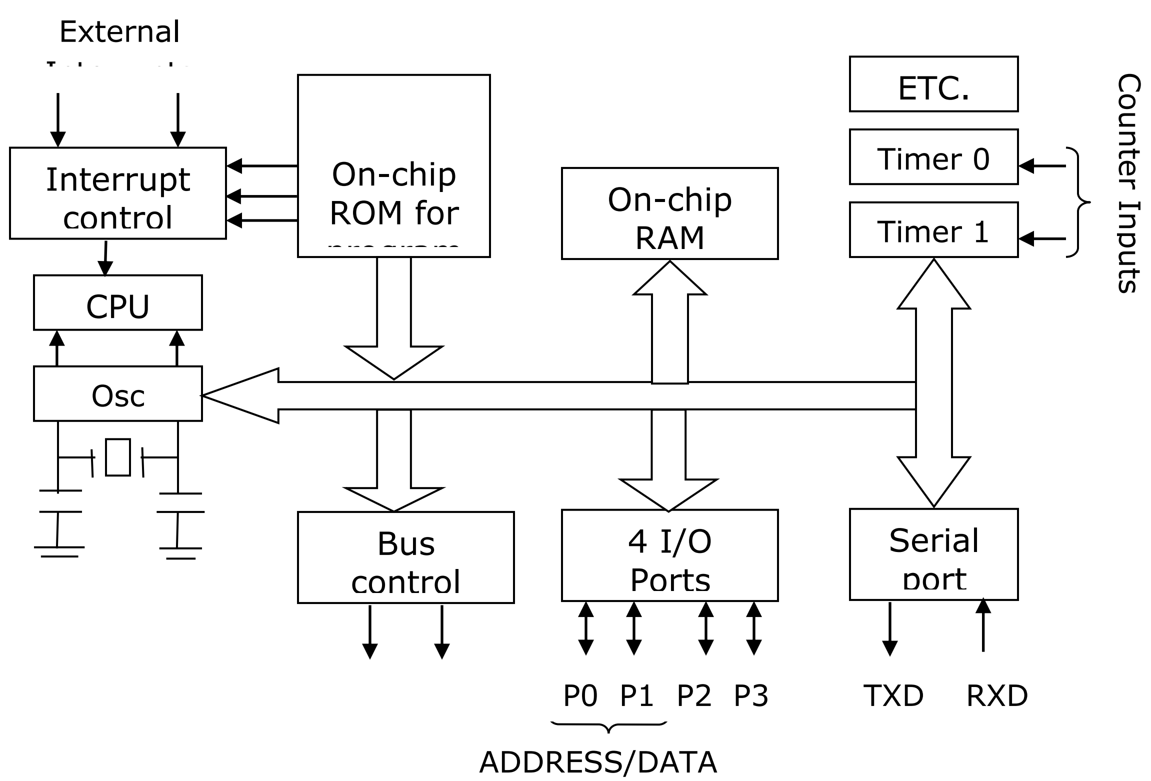


Fig.4.1- block diagram of 8051.

4.6 PIN CONFIGURATION:

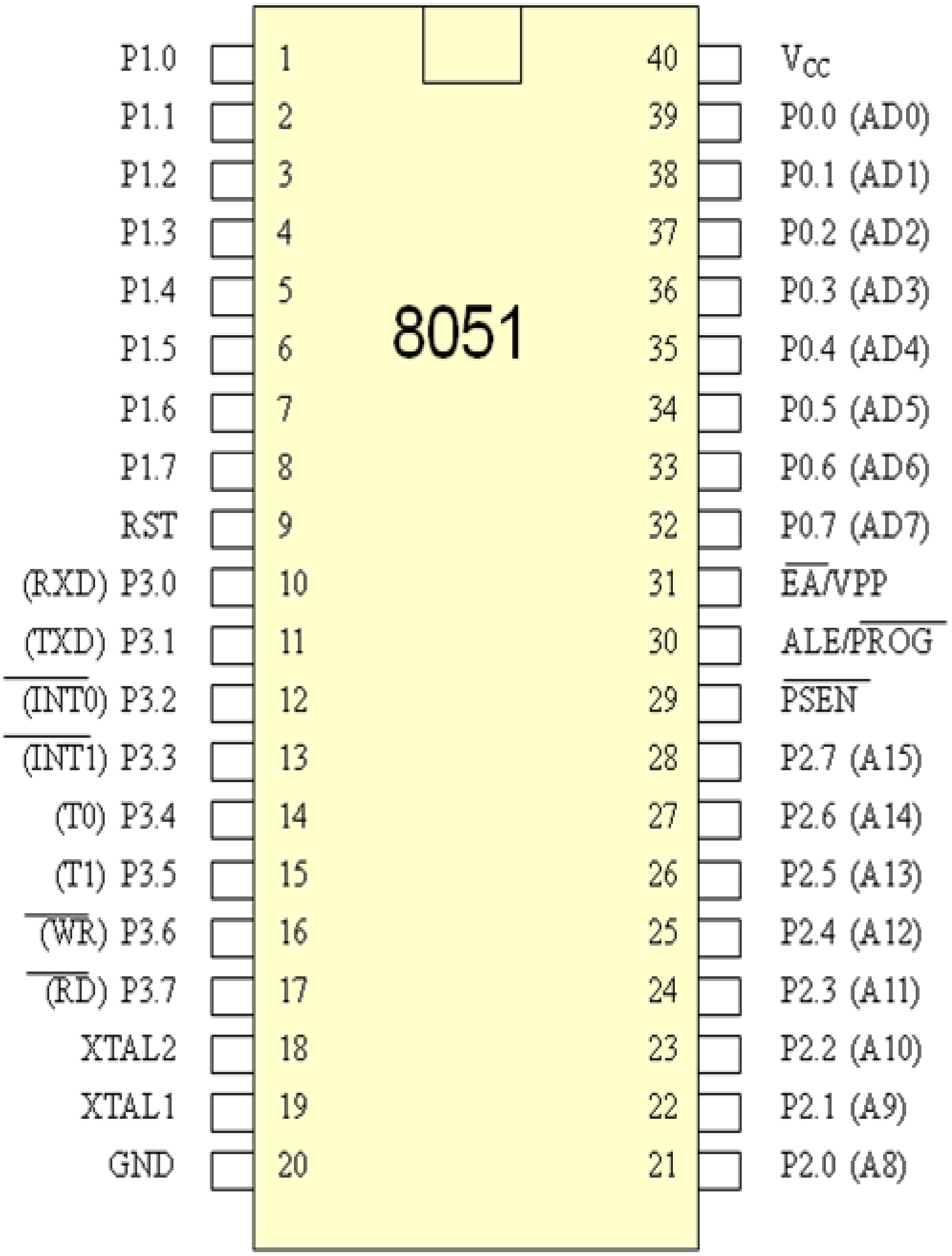


Fig 4.2 – pin out diagram of 8051.

4.7 Pin description

VCC - Supply voltage.

GND - Ground.

Port 0 - Port 0 is an 8-bit open-drain bi-directional I/O port. As an output port, each pin can sink eight TTL inputs. When 1s are written to port 0 pins, the pins can be used as high-impedance inputs.

Port 0 may also be configured to be the multiplexed low-order address/data bus during accesses to external program and data memory. In this mode P0 has internal pull-ups.

Port 0 also receives the code bytes during Flash programming, and outputs the code bytes during program verification. External pull-ups are required during program verification.

Port 1 - Port 1 is an 8-bit bi-directional I/O port with internal pull-ups.

The Port 1 output buffers can sink/source four TTL inputs. When 1s are written to 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 (IIL) because of the internal pull-ups. Port 1 also receives the low-order address bytes during Flash programming and verification.

Port 2 - Port 2 is an 8-bit bi-directional I/O port with internal pull-ups.

The Port 2 output buffers can sink/source four TTL inputs.

When 1s 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 (IIL) because of the internal pull-ups. Port 2 emits the high-order address byte during fetches from external program memory and during accesses to external data memory that uses 16-bit addresses (MOVX @ DPTR). In this application, it uses strong internal pull-ups when emitting 1s. During accesses to external data memory that uses 8-bit addresses (MOVX @ RI); Port 2 emits the contents of the P2 Special Function Register.

Port 2 also receives the high-order address bits and some control signals during Flash programming and verification.

Port 3 - Port 3 is an 8-bit bi-directional I/O port with internal pull-ups.

The Port 3 output buffers can sink/source four TTL inputs. When 1s are written to Port 3 pins they are pulled high by the internal pull-ups and can be used as inputs. As inputs, Port 3 pins that are externally being pulled low will source current (IIL) because of the pull-ups. Port 3 also serves the functions of various special features of the AT89C51 as listed below:

RST - Reset input. A high on this pin for two machine cycles while the oscillator is running resets the device.

ALE/PROG - Address Latch Enable output pulse for latching the low byte of the address during accesses to external memory. This pin is also the program pulse input (PROG) during Flash programming.

PORT PIN	**ALTERNATE FUNCTIONS**
P3.0	RXD (serial input port)
P3.1	TXD (serial output port)
P3.2	$\overline{\text{INT0}}$ (external interrupt 0)
P3.3	INT1 (external interrupt 1)
P3.4	T0 (timer 0 external input)
P3.5	T1 (timer 1 external input)
P3.6	WR (external data memory write strobe)
P3.7	RD (external data memory read strobe)

Table 1 - Port pin function

In normal operation ALE is emitted at a constant rate of 1/6 the oscillator frequency, and may be used for external timing or clocking purposes. Note, however, that one ALE pulse is skipped during each access to external Data Memory.

If desired, ALE operation can be disabled by setting bit 0 of SFR location 8EH. With the bit set, ALE is active only during a MOVX or MOVC instruction. Otherwise, the pin is

PSEN - Program Store Enable is the read strobe to external program memory. When the AT89C51 is executing code from external program memory, PSEN is activated twice each machine cycle, except that two PSEN activations are skipped during each access to external data memory.

EA/VPP - External Access Enable. EA must be strapped to GND in order to enable the device to fetch code from external program memory locations starting at 0000H up to FFFFH. Note, however, that if lock bit 1 is programmed, EA will be internally latched on reset.

EA should be strapped to VCC for internal program executions.

This pin also receives the 12-volt programming enable voltage (VPP) during Flash programming, for parts that require 12-volt VPP.

XTAL1 - Input to the inverting oscillator amplifier and input to the internal clock operating circuit.

XTAL2 - Output from the inverting oscillator amplifier.

4.8 THE 8051 REGISTERS:

The most widely used registers of the 8051 are A (accumulator), B, R0, R1, R2, R3, R4, R5, R6, R7, DPTR (data pointer), and PC (program counter). All of the above registers are 8-bits, except DPTR and the program counter. The 8 blocks of a register are shown below from the MSB (most significant bit) D7 to the LSB (least significant bit) D0.

D7	D6	D5	D4	D3	D2	D1	D0

Fig 4.3 – 8 blocks of register

4.9 PROGRAM COUNTER:

The program counter points to the address of the next instruction to be executed. As the CPU fetches the op-code from the program ROM, the program counter is incremented to point to the next instruction. The PC is 16 bits wide i.e. it can access program addresses 0000 to FFFFH, a total of 64K bytes of code.

4.10 PSW (PROGRAM STATUS WORD) REGISTER

The PSW contains status bits that reflect the current state of the CPU and is also called flag register. The PSW contains the Carry bit, the Auxiliary Carry bit, the two register bank select bits, the overflow flag bit, a parity bit, and two users' definable status flags.

CY	AC	F0	RS1	RS0	OV	---	P

Fig 4.4 – Carry flag of 8051 microcontroller.

CY PSW.7 Carry flag.

AC PSW.6 Auxiliary carry flag.

--- PSW.5 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 bit.

P PSW.0 Parity flag.

RS1	RS0	Register Bank	Address
0	0	0	00H – 07H
0	1	1	08H – 0FH
1	0	2	10H – 17H
1	1	3	18H – 1FH

Table 2 – Register and its particular address.

4.11 FLAGS

1. CY, THE CARRY FLAG

This flag is set whenever there is a carry out from the D7 bit. This flag bit is affected after an 8-bit addition or subtraction. It can also be set to

1 or 0 directly by an instruction such as “SETB C” and “CLR C” where “SETB C” stands for “set bit carry” and “CLR C” for “clear carry”.

2. AC, THE AUXILIARY CARRY FLAG

If there is a carry from D3 to D4 during an ADD or SUB operation, this bit is set; otherwise, it is cleared. This flag is used by instructions that perform BCD (binary coded decimal) arithmetic.

3. P, THE PARITY FLAG

The parity flag reflects the number of 1s in the A (accumulator) register only. If the A register contains an odd number of 1s, then P=1. Therefore, P=0 if A has an even number of 1s.

4. OV, THE OVERFLOW FLAG

This flag is set whenever the result of a signed number operation is too large, causing the high-order bit to overflow into the sign bit.

4.12 RAM MEMORY SPACE ALLOCATION IN THE 8051

There are 128 bytes of RAM in the 8051, which are assigned addresses 00 to 7FH. These 128 bytes are divided into three different groups:

1. A total of 32 bytes from locations 00 to 1H hex are set aside for register banks and the stack.
2. A total of 16 bytes from locations 20H to 2FH are set aside for bit-addressable read/write memory

.

3. A total of 80 bytes from locations 30H to 7FH are used for read and write storage, or what is normally called a scratch pad. These
80 locations of RAM are widely used for the purpose of storing data and parameters by 8051 programmers

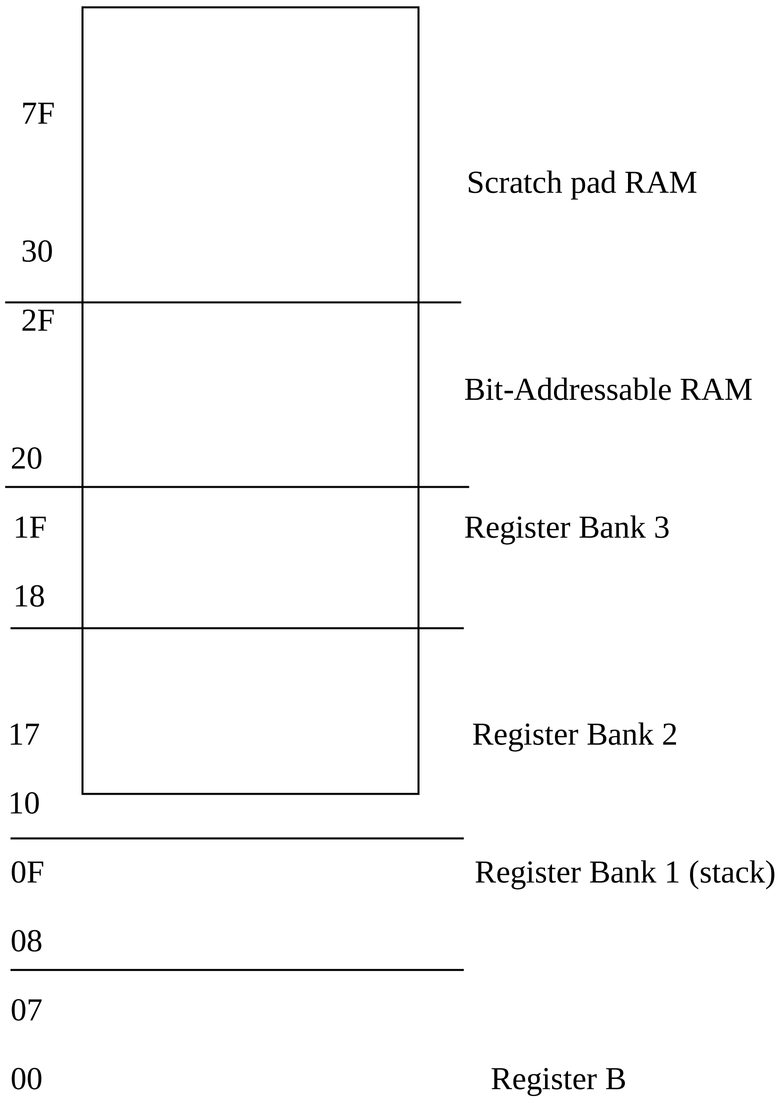


Fig 4.5 – space allocation of register in 8051.

4.13 REGISTER BANKS IN THE 8051

The 32 bytes of RAM which is set aside for the register banks and stack is divided into 4 banks of registers in which each bank has 8 registers, R0 – R7. RAM locations from 0 to 7 are set aside for bank 0 of R0 – R7

where R0 is RAM location 0, R1 is RAM location 1, R2 is location 2, and so on, until memory location 7 which belongs to R7 of bank 0. The second bank of registers R0 – R7 starts at RAM location 08 and goes to location 0FH.

The third bank of R0 – R7 starts at memory location 10H and goes to location 17H; and finally RAM locations 18H to 1FH are set aside for the fourth bank of R0 – R7. The following tables shows how the 32 bytes are allocated into 4 banks:

Bank 0		Bank 1		Bank 2		Bank 3	
R7	7	R7	7	R7	7	R7	7
R6	6	R6	6	R6	6	R6	6
R5	5	R5	5	R5	5	R5	5
R4	4	R4	4	R4	4	R4	4
R3	3	R3	3	R3	3	R3	3
R2	2	R2	2	R2	2	R2	2
R1	1	R1	1	R1	1	R1	1
R0	0	R0	0	R0	0	R0	0

Fig 4.6 – register bank of 8051.

CHAPTER 5 - Printed circuit board

A **printed circuit board** (**PCB**) mechanically supports and electrically connects electronic components using conductive tracks, pads and other features etched from copper sheets laminated onto a non-conductive substrate. PCBs can be single sided (one copper layer), double sided (two copper layers) or multi-layer. Conductors on different layers are connected with plated-through holes called vias. Advanced PCBs may contain components - capacitors, resistors or active devices - embedded in the substrate.

Printed circuit boards are used in all but the simplest electronic products. Alternatives to PCBs include wire wrap and point-to-point construction. PCBs require the additional design effort to lay out the circuit but manufacturing and assembly can be automated. Manufacturing circuits with PCBs is cheaper and faster than with other wiring methods as components are mounted and wired with one single part. Furthermore, operator wiring errors are eliminated.

When the board has only copper connections and no embedded components, it is more correctly called a printed wiring board (PWB) or etched wiring board. Although more accurate, the term printed wiring board has fallen into disuse. A PCB populated with electronic components is called a printed circuit assembly (PCA), printed circuit board assembly or PCB assembly (PCBA). The IPC preferred term for assembled boards is circuit card assembly (CCA), and for assembled backplanes it is backplane assemblies. The term PCB is used informally both for bare and assembled boards.

PCBs intended for extreme environments often have a conformal coating, which is applied by dipping or spraying after the components have been soldered. The coat prevents corrosion and leakage currents or shorting due to condensation. The earliest conformal coats were wax; modern conformal coats are usually dips of dilute solutions of silicone rubber, polyurethane, acrylic, or epoxy. Another technique for applying a conformal coating is for plastic to be sputtered onto the

Many assembled PCBs are static sensitive, and therefore must be placed in antistatic bags during transport. When handling these boards, the user must be grounded (earthed). Improper handling techniques might transmit an accumulated static charge through the board, damaging or destroying components. Even bare boards are sometimes static sensitive. Traces have become so fine that it's quite possible to blow an etch off the board (or change its characteristics) with a static charge. This is especially true on non-traditional PCBs such as MCMs and microwave PCBs.

PCBs intended for extreme environments often have a conformal coating, which is applied by dipping or spraying after the components have been soldered. The coat prevents corrosion and leakage currents or shorting due to condensation. The earliest conformal coats were wax; modern conformal coats are usually dips of dilute solutions of silicone rubber, polyurethane, acrylic, or epoxy. Another technique for applying a conformal coating is for plastic to be sputtered onto the PCB in a vacuum chamber.

Many assembled PCBs are static sensitive, and therefore must be placed in antistatic bags during transport. When handling these boards, the user must be grounded (earthed). Improper handling techniques might transmit an accumulated static charge through the board, damaging or destroying components. Even bare boards are sometimes static sensitive. Traces have become so fine that it's quite possible to blow an etch off the board (or change its characteristics) with a static charge. This is especially true on non-traditional PCBs such as MCMs and microwave PCBs.

Eventually processes were developed that would plate copper onto the walls of the drilled holes. That allowed circuits on both sides of the board to be connected electrically. Copper had replaced brass as the metal of choice because of its ability to carry electrical current, relatively low cost and ease of manufacturing. In 1956 the US Patent Office issued a patent for the "Process of Assembling Electrical Circuits" that was sought by a small group of scientists represented by the US Army. The patented process involved using a base material like melamine to which a layer of copper foil had been securely laminated. A drawing was made of the wiring pattern and then photographed onto a zinc plate. The plate was used to create a printing plate for an offset printing press. An acid resistant ink was printed onto the copper foil side of the board that was etched to remove the exposed copper leaving the "printed wire" behind. Other methods like using stencils, screening, hand printing and rubber stamping were also proposed to deposit the ink pattern. Holes were then punched in patterns using dies to match the position of the component wire leads or terminals. The leads were inserted through the non-plated holes in the laminate material and then the card was dipped or floated on a bath of molten solder. The solder would coat the traces as well as connecting the leads of the components to the traces.

They also used tinned eyelets, rivets and washers to attach various types of components to the board. Their patent even has a drawing showing two single sided boards stacked on top of each other with a standoff holding them apart. There are components on the top side of each board and one component shown with its leads extending through the top board into holes on the bottom board, connecting them together, a rough attempt at making the first multi-layer.

5.1 Design

A board designed in 1967; the sweeping curves in the traces are evidence of freehand design using self-adhesive tape.

Initially PCBs were designed manually by creating a photo mask on a clear Mylar sheet, usually at 2 or 4 times the true size. Starting from the schematic diagram the component pin pads were laid out on the Mylar and then traces were routed to connect the pads. Rub-on dry transfers of common component footprints increased efficiency. Traces were made with self-adhesive tape. Pre-printed non-reproducing grids on the Mylar assisted in layout. To fabricate the board the finished photo mask was photo lithographically reproduced on resist coated on the blank copper-clad boards.

Nowadays PCBs are designed with dedicated layout software, generally in the following steps:

1. Schematic capture through an electronic design automation (*EDA*) tool.
2. Card dimensions and template are decided based on required circuitry and case of the PCB.
3. The position of the components and heat sinks are determined.
4. Layer stack of the PCB is decided, with one to tens of layers depending on complexity. Ground and power planes are decided. A power plane is the counterpart to a ground plane and behaves as an AC signal ground while providing DC power to the circuits mounted on the PCB. Signal interconnections are traced on signal planes. Signal planes can be on the outer as well as inner layers. For optimal EMI performance high frequency signals are routed in internal layers between power or ground planes. Line impedance is determined using dielectric layer thickness, routing copper thickness and trace-width. Trace separation is also taken into account in case of differential signals. Micro strip, strip line or dual strip line can be used to route signals.
5. Components are placed. Thermal considerations and geometry are taken into account. Visa and lands are marked.
6. Signal traces are routed. Electronic design automation tools usually create clearances and connections in power and ground planes automatically.
7. Gerber files are generated for manufacturing.

5.2 Manufacturing

PCB manufacturing consists of many steps.

1. **PCB CAM**

Manufacturing starts from the PCB fabrication data generated by CAD. The Gerber or Exelon files in the fabrication data are never used directly on the manufacturing equipment but always read into the CAM (Computer Aided Manufacturing) software. CAM performs the following functions:

1. Input of the Gerber data
2. Verification of the data; optionally DFM
3. Compensation for deviations in the manufacturing processes (e.g. scaling to compensate for distortions during lamination)
4. Penalization
5. Output of the digital tools (copper patterns, solder resist image, legend image, drill files, automated optical inspection data, electrical test files,...)

2. **Penalization**

Penalization is a procedure whereby a number of PCBs are grouped for manufacturing onto a larger board - the panel. Usually a panel consists of a single design but sometimes multiple designs are mixed on a single panel. There are two types of panels: assembly panels - often called arrays - and bare board manufacturing panels. The assembler often mounts components on panels rather than single PCBs because this is efficient. The bare board manufactures always uses panels, not only for efficiency, but because of the requirements the plating process. Thus a manufacturing panel can consist of a grouping of individual PCBs or of arrays, depending on what must be delivered. The panel is eventually broken apart into individual PCBs; this is called depaneling. Separating the individual PCBs is frequently aided by drilling or routing perforations along the boundaries of the individual circuits, much like a sheet of postage stamps. Another method, which takes less space, is to cut V-shaped grooves across the full dimension of the panel. The individual PCBs can then be broken apart along this line of weakness. Today depaneling is often done by lasers which cut the board with no contact. Laser penalization reduces stress on the fragile circuits.

3. Copper patterning

The first step is to replicate the pattern in the fabricator's CAM system on a protective mask on the copper foil PCB layers. Subsequent etching removes the unwanted copper. (Alternatively, a conductive ink can be ink-jetted on a blank (non-conductive) board. This technique is also used in the manufacture of hybrid circuits.) The patterning method depend volume and resolution requirements.

1. **Silk screen printing** uses etch-resistant inks to create the protective mask.
2. **Photoengraving** uses a photo mask and developer to selectively remove a UV-sensitive photo resist coating and thus create a photo resist mask. Direct imaging techniques are sometimes used for high-resolution requirements. Experiments were made with thermal resist.
3. **PCB milling** uses a two or three-axis mechanical milling system to mill away the copper foil from the substrate. A PCB milling machine (referred to as a 'PCB Prototype') operates in a similar way to a plotter, receiving commands from the host software that control the position of the milling head in the x, y, and (if relevant) z axis.
4. **Laser resist ablation** Spray black paint onto copper clad laminate, place into CNC laser plotter. The laser raster-scans the PCB and ablates (vaporizes) the paint where no resist is wanted. (Note: laser copper ablation is rarely used and is considered experimental.

4. Patterning method by volume

The method chosen depends on the number of boards to be produced.

1. Large volume

- Silk screen printing– used for PCBs with bigger features
- Photoengraving–used when finer features are required.

2. Small volume

- Print onto transparent film and use as photo mask along with photo-sensitized boards. (i.e., pre-sensitized boards), then etch. (Alternatively, use a film photo plotter)
- Laser resists ablation.
- PCB milling.

5.5 Subtractive, additive and semi-additive processes

The two processing methods used to produce a double-sided PWB with plated through holes.

Subtractive methods remove copper from an entirely copper-coated board to leave only the desired copper pattern: In additive methods the pattern is electroplated onto a bare substrate using a complex process. The advantage of the additive method is that less material is needed and less waste is produced. In the full additive process the bare laminate is covered with a photosensitive film which is imaged (exposed to light through a mask and then developed which removes the unexposed film). The exposed areas are sensitized in a chemical bath, usually containing palladium and similar to that used for through hole plating which makes the exposed area capable of bonding metal ions. The laminate is then plated with copper in the sensitized areas. When the mask is stripped, the PCB is finished.

Semi-additive is the most common process: The unpatented board has a thin layer of copper already on it. A reverse mask is then applied. (Unlike a subtractive process mask, this mask exposes those parts of the substrate that will eventually become the traces.) Additional copper is then plated onto the board in the unmasked areas; copper may be plated to any desired weight. Tin-lead or other surface plating’s are then applied. The mask is stripped away and a brief etching step removes the now-exposed bare original copper laminate from the board, isolating the individual traces. Some single-sided boards which have plated-through holes are made in this way. General Electric made consumer radio sets in the late 1960s using additive boards.

The (semi-)additive process is commonly used for multi-layer boards as it facilitates the plating-through of the holes to produce conductive visa in the circuit board.

5.6 Chemical etching

Chemical etching is usually done with ammonium per sulfate or ferric chloride. For PTH (plated-through holes), additional steps of electro less deposition are done after the holes are drilled, then copper is electroplated to build up the thickness, the boards are screened, and plated with tin/lead. The tin/lead becomes the resist leaving the bare copper to be etched away.

The simplest method, used for small-scale production and often by hobbyists, is immersion etching, in which the board is submerged in etching solution such as ferric chloride. Compared with methods used for mass production, the etching time is long. Heat and agitation can be applied to the bath to speed the etching rate. In bubble etching, air is passed through the etchant bath to agitate the solution and speed up etching. Splash etching uses a motor-driven paddle to splash boards with etchant; the process has become commercially obsolete since it is not as fast as spray etching.

In spray etching, the etchant solution is distributed over the boards by nozzles, and recirculated by pumps. Adjustment of the nozzle pattern, flow rate, temperature, and etchant composition gives predictable control of etching rates and high production rates.

The developed PCB is etched with a 220 g/l solution of ammonium peroxydisulfate $(NH_4)_2S_2O_8$ a.k.a. ***ammonium persulfate***, 220 gram added to 1 liter of water and mix it until everything is dissolved. Theoretically it should be possible to etch slightly more than 60 grams of copper with 1 liter etching solution. Assume an 50% efficiency, about 30 grams of copper. With a thickness of 35 µm copper on your PCB this covers a copper area of about 1000 cm^2. Unfortunately the efficiency of the etching solution degrades, dissolved ammonium peroxydisulfate decomposes slowly. You better make just enough etching solution you need to etch. For an etching tray of about 20 x 25 cm a minimum practical amount is 200-250 ml solution. So you dissolve about 44 grams ammonium peroxydisulfate into 200 ml or 55 grams into 250 ml water.

Etching at ambient temperature might take over an hour, it is better to heat up the etching solvent to about 35-45 degrees Celcius. The etching solution heating up could be done in a magnetron, this takes about 40 to 60 seconds in a 850W magnetron depending on the initial temperature of the etching solution (hint: first try this with just water to determine the timer setting of the magnetron). The etching - rocking the etching tray - takes about 15-30 minutes at this temperature. If you have a heated, air-bubble circulated etching fluid tank available, this is probably the fastest way to etch. At higher temperatures the etching performance decreases. The etching process is an exothermic reaction, it generates heat. Take care, cool your etching tray when necessary! You should minimize the amount of copper to etch by creating copper area in your PCB layout as much as possible. When starting the etching process and little to etch it is difficult to keep the etching solution at 35-45 degrees Celsius. It helps to fill for example the kitchen sink with warm water and rock the etching tray in the filled kitchen sink.

When the ammonium peroxydisulfate is dissolved it is a clear liquid. After an etching procedure it gradually becomes blue and more deeper blue - the chemical reaction creates dissolved copper sulfate $CuSO_4$. Compared to other etching chemicals like hydrated iron (III) chloride $FeCl_3.6H_2O$ a.k.a. **ferric chloride** or the combination of hydrochloric acid HCL and hydrogen peroxide H_2O_2, using ammonium peroxydisulfate is a clean and safe method. Did you ever spilled dissolved iron chloride on your clothes or your assumed stainless steel kitchen sink? Do you really want to keep concentrated hydrochloric acid and hydrogen peroxide at home? So, without doubt ammonium peroxydisulfate is the best choice for etching at home. However, copper sulfate is a poisonous substance and should be treated as chemical waste.

As more copper is consumed from the boards, the etchant becomes saturated and less effective; different etchants have different capacities for copper, with some as high as 150 grams of copper per litre of solution. In commercial use, etchants can be regenerated to restore their activity, and the dissolved copper recovered and sold. Small-scale etching requires attention to disposal of used etchant, which is corrosive and toxic due to its metal content.

The etchant removes copper on all surfaces exposed by the resist. "Undercut" occurs when etchant attacks the thin edge of copper under the resist; this can reduce conductor widths and cause open-circuits. Careful control of etch time is required to prevent undercut. Where metallic plating is used as a resist, it can "overhang" which can cause short-circuits between adjacent traces when closely spaced. Overhang can be removed by wire-brushing the board after etching.

5.7 Inner layer automated optical inspection (AOI)

The inner layers are given a complete machine inspection before lamination because afterwards mistakes cannot be corrected. The automatic optical inspection system scans the board and compares it with the digital image generated from the original design data.

1. Lamination

Multi-layer printed circuit boards have trace layers inside the board. One way to make a 4-layer PCB is to use a two-sided copper-clad laminate, etch the circuitry on both sides, then laminate to the top and bottom of the copper foil. Lamination is done by placing the stack of materials in a press and applying pressure and heat for a period of time. This results in an inseparable one piece product. It is then drilled, plated, and etched again to get traces on top and bottom layers. Finally the PCB is covered with solder mask, marking legend, and a surface finish may be applied. Multi-layer PCBs allow for much higher component density.

2. Drilling

Holes through a PCB are typically drilled with small-diameter drill bits made of solid coated tungsten carbide. Coated tungsten carbide is recommended since many board materials are very abrasive and drilling must be high RPM and high feed to be cost effective. Drill bits must also remain sharp so as not to mar or tear the traces. Drilling with high-speed-steel is simply not feasible since the drill bits will dull quickly and thus tear the copper and ruin the boards.

The drilling is performed by automated drilling machines with placement controlled by a drill tape or drill file. These computer-generated files are also called numerically controlled drill (NCD) files or "Excellon files". The drill file describes the location and size of each drilled hole.

Holes may be made conductive, by electroplating or inserting metal eyelets (hollow), to electrically and thermally connect board layers. Some conductive holes are intended for the insertion of through-hole-component leads. Others, typically smaller and used to connect board layers, are called vias.

When very small vias are required, drilling with mechanical bits is costly because of high rates of wear and breakage.

In this case, the vias may be laser drilled—evaporated by lasers. Laser-drilled vias typically have an inferior surface finish inside the hole. These holes are called micro vias.

It is also possible with controlled-depth drilling, laser drilling, or by pre-drilling the individual sheets of the PCB before lamination, to produce holes that connect only some of the copper layers, rather than passing through the entire board.

5.8 Plating and coating

PCBs are plated with solder, tin, or gold over nickel as a resist for etching away the unneeded underlying copper.

After PCBs are etched and then rinsed with water, the solder mask is applied, and then any exposed copper is coated with solder, nickel/gold, or some other anti-corrosion coating.

Matte solder is usually fused to provide a better bonding surface or stripped to bare copper. Treatments, such as benzimidazolethiol, prevent surface oxidation of bare copper. The places to which components will be mounted are typically plated, because untreated bare copper oxidizes quickly, and therefore is not readily solder able. Traditionally, any exposed copper was coated with solder by hot air solder leveling (HASL). The HASL finish prevents oxidation from the underlying copper, thereby guaranteeing a solder able surface. This solder was a tin-lead alloy, however new solder compounds are now used to achieve compliance with the Rosh directive in the EU and US, which restricts the use of lead. One of these lead-free compounds is SN100CL, made up of 99.3% tin, 0.7% copper, 0.05% nickel, and a nominal of 60ppm germanium.

It is important to use solder compatible with both the PCB and the parts used. An example is Ball Grid Array (BGA) using tin-lead solder balls for connections losing their balls on bare copper traces or using lead-free solder paste.

5.9 Solder resists application

Areas that should not be soldered may be covered with solder resist (solder mask). One of the most common solder resists used today is called LPI (liquid photoimageable). A photo sensitive coating is applied to the surface of the PWB, then exposed to light through the solder mask image film, and finally developed where the unexposed areas are washed away. Dry film solder mask is similar to the dry film used to image the PWB for plating or etching. After being laminated to the PWB surface it is imaged and develops as LPI. Once common but no longer commonly used because of its low accuracy and resolution is to screen print epoxy ink. Solder resist also provides protection from the environment.

Legend printing

A legend is often printed on one or both sides of the PCB. It contains the component designators, switch settings, test points and other indications helpful in assembling, testing and servicing the circuit board.

There are three methods to print the legend.

1. Silk screen printing epoxy ink was the established method. It was so common that legend is often misnamed silk or silkscreen.
2. Liquid photo imaging is a more accurate method than screen printing.
3. Ink jet printing is new but increasingly used. Ink jet can print variable data such as a text or bar code with a serial number.

5.10 Bare-board test

Unpopulated boards may be subjected to a bare-board test where each circuit connection (as defined in a net list) is verified as correct on the finished board. For high-volume production, a bed of nails tester, a fixture or a rigid needle adapter is used to make contact with copper lands or holes on one or both sides of the board to facilitate testing. A computer will instruct the electrical test unit to apply a small voltage to each contact point on the bed-of-nails as required, and verify that such voltage appears at other appropriate contact points. A "short" on a board would be a connection where there should not be one; an "open" is between two points that should be connected but are not. For small- or medium-volume boards, flying probe and flying-grid testers use moving test heads to make contact with the copper/silver/gold/solder lands or holes to verify the electrical connectivity of the board under test. Another method for testing is industrial CT scanning, which can generate a 3D rendering of the board along with 2D image slices and can show details such as soldered paths and connections.

5.11 Assembly

After the printed circuit board (PCB) is completed, electronic components must be attached to form a functional printed circuit assembly, or PCA (sometimes called a "printed circuit board assembly" PCBA). In through-hole construction, component leads are inserted in holes. In surface-mount (SMT - surface mount technology) construction, the components are placed on pads or lands on the outer surfaces of the PCB. In both kinds of construction, component leads are electrically and mechanically fixed to the board with a molten metal solder.

There are a variety of soldering techniques used to attach components to a PCB. High volume production is usually done with SMT placement machine and bulk wave soldering or reflow ovens, but skilled technicians are able to solder very tiny parts (for instance 0201 packages which are 0.02 in. by 0.01 in.) by hand under a microscope, using tweezers and a fine tip soldering iron for small volume prototypes. Some parts may be extremely difficult to solder by hand, such as BGA packages.

Often, through-hole and surface-mount construction must be combined in a single assembly because some required components are available only in surface-mount packages, while others are available only in through-hole packages. Another reason to use both methods is that through-hole mounting can provide needed strength for components likely to endure physical stress, while components that are expected to go untouched will take up less space using surface-mount techniques. For further comparison, see the SMT page

5.12 Protection and packaging

PCBs intended for extreme environments often have a conformal coating, which is applied by dipping or spraying after the components have been soldered. The coat prevents corrosion and leakage currents or shorting due to condensation. The earliest conformal coats were wax; modern conformal coats are usually dips of dilute solutions of silicone rubber, polyurethane, acrylic, or epoxy. Another technique for applying a conformal coating is for plastic to be sputtered onto the PCB in a vacuum chamber. The chief disadvantage of conformal coatings is that servicing of the board is rendered extremely difficult.

Many assembled PCBs are static sensitive, and therefore must be placed in antistatic bags during transport. When handling these boards, the user must be grounded (earthed). Improper handling techniques might transmit an accumulated static charge through the board, damaging or destroying components. Even bare boards are sometimes static sensitive. Traces have become so fine that it's quite possible to blow an etch off the board (or change its characteristics) with a static charge. This is especially true on non-traditional PCBs such as MCMs and microwave PCBs.

CHAPTER 6 - Capacitor

A **capacitor** (originally known as a **condenser**) is a passive two-terminal electrical component used to store energy electro statically in an electric field. The forms of practical capacitors vary widely, but all contain at least two electrical conductors (plates) separated by a dielectric (i.e. insulator). The conductors can be thin films, foils or sintered beads of metal or conductive electrolyte, etc. The non-conducting dielectric acts to increase the capacitor's charge capacity. A dielectric can be glass, ceramic, plastic films, air, vacuum, paper, mica, oxide layer etc. Capacitors are widely used as parts of electrical circuits in many common electrical devices. Unlike a resistor, an ideal capacitor does not dissipate energy. Instead, a capacitor stores energy in the form of an electrostatic field between its plates.

When there is a potential difference across the conductors (e.g., when a capacitor is attached across a battery), an electric field develops across the dielectric, causing positive charge $+Q$ to collect on one plate and negative charge $-Q$ to collect on the other plate. If a battery has been attached to a capacitor for a sufficient amount of time, no current can flow through the capacitor. However, if a time-varying voltage is applied across the leads of the capacitor, a displacement current can flow.

An ideal capacitor is characterized by a single constant value for its capacitance. Capacitance is expressed as the ratio of the electric charge Q on each conductor to the potential difference V between them. The SI unit of capacitance is the farad (F), which is equal to one coulomb per volt (1 C/V). Typical capacitance values range from about 1 pF (10^{-12} F) to about 1 mF (10^{-3} F).

The capacitance is greater when there is a narrower separation between conductors and when the conductors have a larger surface area. In practice, the dielectric between the plates passes a small amount of leakage current and also has an electric field strength limit, known as the breakdown voltage. The conductors and leads introduce an undesired inductance and resistance.

Capacitors are widely used in electronic circuits for blocking direct current while allowing alternating current to pass. In analog filter networks, they smooth the output of power supplies. In resonant circuits they tune radios to particular frequencies. In electric power transmission systems, they stabilize voltage and power flow.

6.1 Theory of operation

Overview

A capacitor consists of two conductors separated by a non-conductive region. The non-conductive region is called the dielectric. In simpler terms, the dielectric is just an electrical insulator. Examples of dielectric media are glass, air, paper, vacuum, and even a semiconductor depletion region chemically identical to the conductors. A capacitor is assumed to be self-contained and isolated, with no net electric charge and no influence from any external electric field. The conductors thus hold equal and opposite charges on their facing surfaces, and the dielectric develops an electric field. In SI units, a capacitance of one farad means that one coulomb of charge on each conductor causes a voltage of one volt across the device.

An ideal capacitor is wholly characterized by a constant capacitance C, defined as the ratio of charge $\pm Q$ on each conductor to the voltage V between them:

Because the conductors (or plates) are close together, the opposite charges on the conductors attract one another due to their electric fields, allowing the capacitor to store more charge for a given voltage than if the conductors were separated, giving the capacitor a large capacitance.

6.2 Capacitor types

Practical capacitors are available commercially in many different forms. The type of internal dielectric, the structure of the plates and the device packaging all strongly affect the characteristics of the capacitor, and its applications.

Values available range from very low (microfarad range; while arbitrarily low values are in principle possible, stray (parasitic) capacitance in any circuit is the limiting factor) to about 5 kef super capacitors.

Above approximately 1 microfarad electrolytic capacitors are usually used because of their small size and low cost compared with other types, unless their relatively poor stability, life and polarized nature make them unsuitable. Very high capacity super capacitors use a porous carbon-based electrode material.

6.3 Dielectric materials

Capacitor materials. From left: multilayer ceramic, ceramic disc, multilayer polyester film, tubular ceramic, polystyrene, metalized polyester film, aluminum electrolytic. Major scale divisions are in centimeters.

Most types of capacitor include a dielectric spacer, which increases their capacitance. These dielectrics are most often insulators. However, low capacitance devices are available with a vacuum between their plates, which allows extremely high voltage operation and low losses. Variable capacitors with their plates open to the atmosphere were commonly used in radio tuning circuits. Later designs use polymer foil dielectric between the moving and stationary plates, with no significant air space between them.

In order to maximize the charge that a capacitor can hold the dielectric material needs to have as high a permittivity as possible, while also having as high a breakdown voltage as possible.

Several solid dielectrics are available, including paper, plastic, glass, mica and ceramic materials. Paper was used extensively in older devices and offers relatively high voltage performance. However, it is susceptible to water absorption, and has been largely replaced by plastic film capacitors. Plastics offer better stability and ageing performance, which makes them useful in timer circuits, although they may be limited to low operating temperatures and frequencies. Ceramic capacitors are generally small, cheap and useful for high frequency applications, although their capacitance varies strongly with voltage and they age poorly. They are broadly categorized as class 1 dielectrics, which have predictable variation of capacitance with temperature or class 2 dielectrics, which can operate at higher voltage.

6.4 Structure

Capacitor packages: SMD ceramic at top left; SMD tantalum at bottom left; through-hole tantalum at top right; through-hole electrolytic at bottom right. Major scale divisions are cm.

The arrangement of plates and dielectric has many variations depending on the desired ratings of the capacitor. For small values of capacitance (microfarads and less), ceramic disks use metallic coatings, with wire leads bonded to the coating. Larger values can be made by multiple stacks of plates and disks. Larger value capacitors usually use a metal foil or metal film layer deposited on the surface of a dielectric film to make the plates, and a dielectric film of impregnated paper or plastic – these are rolled up to save space. To reduce the series resistance and inductance for long plates, the plates and dielectric are staggered so that connection is made at the common edge of the rolled-up plates, not at the ends of the foil or metalized film strips that comprise the plates.

The assembly is encased to prevent moisture entering the dielectric – early radio equipment used a cardboard tube sealed with wax. Modern paper or film dielectric capacitors are dipped in a hard thermoplastic. Large capacitors for high-voltage use may have the roll form compressed to fit into a rectangular metal case, with bolted terminals and bushings for connections. The dielectric in larger capacitors is often impregnated with a liquid to improve its properties.

Capacitors may have their connecting leads arranged in many configurations, for example axially or radically. "Axial" means that the leads are on a common axis, typically the axis of the capacitor's cylindrical body – the leads extend from opposite ends. Radial leads might more accurately be referred to as tandem; they are rarely actually aligned along radii of the body's circle, so the term is inexact, although universal. The leads (until bent) are usually in planes parallel to that of the flat body of the capacitor, and extend in the same direction; they are often parallel as manufactured. Small, cheap discoid ceramic capacitors have existed since the 1930s, and remain in widespread use. Since the 1980s, surface mount packages for capacitors have been widely used. These packages are extremely small and lack connecting leads, allowing them to be soldered directly onto the surface of printed circuit boards. Surface mount components avoid undesirable high-frequency effects due to the leads and simplify automated assembly, although manual handling is made difficult due to their small size.

Mechanically controlled variable capacitors allow the plate spacing to be adjusted, for example by rotating or sliding a set of movable plates into alignment with a set of stationary plates. Low cost variable capacitors squeeze together alternating layers of aluminum and plastic with a screw. Electrical control of capacitance is achievable with varactors (or varicaps), which are reverse-biased semiconductor diodes whose depletion region width varies with applied voltage. They are used in phase-locked loops, amongst other applications.

6.5 Capacitor markings

Most capacitors have numbers printed on their bodies to indicate their electrical characteristics. Larger capacitors like electrolytic usually display the actual capacitance together with the unit (for example, **220 µF**). Smaller capacitors like ceramics, however, use a shorthand consisting of three numeric digits and a letter, where the digits indicate the capacitance in pF (calculated as $XY \times 10^{Z}$ for digits XYZ) and the letter indicates the tolerance (J, K or M for ±5%, ±10% and ±20% respectively).

Additionally, the capacitor may show its working voltage, temperature and other relevant characteristics.

For typographical reasons, some manufacturers print "MF" on capacitors to indicate microfarads (µF).

6.6 Applications

This mylar-film, oil-filled capacitor has very low inductance and low resistance, to provide the high-power (70 megawatt) and high speed (1.2 microseconds) discharge needed to operate a dye laser.

1. Energy storage

A capacitor can store electric energy when disconnected from its charging circuit, so it can be used like a temporary battery, or like other types of rechargeable energy storage system. Capacitors are commonly used in electronic devices to maintain power supply while batteries are being changed. (This prevents loss of information in volatile memory.)

Conventional capacitors provide less than 360 joules per kilogram of energy density, whereas a conventional alkaline battery has a density of 590 kJ/kg.

In car audio systems, large capacitors store energy for the amplifier to use on demand. Also for a flash tube a capacitor is used to hold the high voltage.

2. Pulsed power and weapons

Groups of large, specially constructed, low-inductance high-voltage capacitors (*capacitor banks*) are used to supply huge pulses of current for many pulsed power applications. These include electromagnetic forming, Marx generators, pulsed lasers (especially TEA lasers), pulse forming networks, radar, fusion research, and particle accelerators.

Large capacitor banks (reservoir) are used as energy sources for the exploding-bridge wire detonators or slapper detonators in nuclear weapons and other specialty weapons. Experimental work is under way using banks of capacitors as power sources for electromagnetic armor and electromagnetic rail guns and coil guns.

3. Power conditioning

Reservoir capacitors are used in power supplies where they smooth the output of a full or half wave rectifier. They can also be used in charge pump circuits as the energy storage element in the generation of higher voltages than the input voltage.

Capacitors are connected in parallel with the power circuits of most electronic devices and larger systems (such as factories) to shunt away and conceal current fluctuations from the primary power source to provide a "clean" power supply for signal or control circuits.

4. Power factor correction

In electric power distribution, capacitors are used for power factor correction. Such capacitors often come as three capacitors connected as a three phase load. Usually, the values of these capacitors are given not in farads but rather as a reactive power in volt-amperes reactive (vary). The purpose is to counteract inductive loading from devices like electric motors and transmission lines to make the load appear to be mostly resistive. Individual motor or lamp loads may have capacitors for power factor correction, or larger sets of capacitors (usually with automatic switching devices) may be installed at a load center within a building or in a large utility substation.

5. Suppression and coupling

Signal coupling

Because capacitors pass AC but block DC signals (when charged up to the applied dc voltage), they are often used to separate the AC and DC components of a signal. This method is known as AC coupling or "capacitive coupling". Here, a large value of capacitance, whose value need not be accurately controlled, but whose reactance is small at the signal frequency, is employed.

Decoupling

A decoupling capacitor is a capacitor used to protect one part of a circuit from the effect of another, for instance to suppress noise or transients. Noise caused by other circuit elements is shunted through the capacitor, reducing the effect they have on the rest of the circuit. It is most commonly used between the power supply and ground. An alternative name is bypass capacitor as it is used to bypass the power supply or other high impedance component of a circuit.

Decoupling capacitors need not always be discrete components. Capacitors used in these applications may be built in to a printed circuit board, between the various layers. These are often referred to as embedded capacitors. The layers in the board contributing to the capacitive properties also function as power and ground planes, and have a dielectric in between them, enabling them to operate as a parallel plate capacitor.

CHAPTER 7- Relay

7.1 Basics:

A relay is an electrical switch that uses an electromagnet to move the switch from the off to one position instead of a person moving the switch. It takes a relatively small amount of power to turn on a relay but the relay can control something that draws much more power. Ex: A relay is used to control the air conditioner in your home. The AC unit probably runs off of 220VAC at around 30A. That's 6600 Watts! The coil that controls the relay may only need a few watts to pull the contacts together.

This is the schematic representation of a relay. The contacts at the top are normally open (i.e. not connected). When current is passed through the coil it creates a magnetic field that pulls the switch closed (i.e. connects the top contacts). Usually a spring will pull the switch open again once the power is removed from the coil. A good diagram (without the return spring) is at:

7.2 Relay Selection:

Relays (and switches) come in different configurations. Single Pole Single Throw (SPST) is the simplest with only two contacts. Single Pole Double Throw (SPDT) has three contacts. The contacts are usually labelled Common (COM), Normally Open (NO), and Normally Closed (NC). The Normally Closed contact will be connected to the Common contact when no power is applied to the coil. The Normally Open contact will be open (i.e. not connected) when no power is applied to the coil. When the coil is energized the Common is connected to the Normally Open contact and the Normally Closed contact is left floating. The Double Pole versions are the same as the Single Pole version except there are two switches that open and close together.

Select a relay with contacts that can handle the voltage and current requirements of the load. Keep in mind that some loads (such as motors) draw much more current when first turned on than they do at steady state.

Select a relay with a coil voltage and current that you can control easily. Ex: If you want to turn on the AC unit with a 12VDC power supply get a 12VDC coil. Note: Coils will be rated for either AC or DC operation.

7.3 Practical Considerations:

Check the relay datasheet for the expected lifetime (i.e. # of times it can open and close before failure).

If the relay won't be used much (say to control the headlights on a car) a 20,000 cycle lifetime would last about 18 years if used three times a day. If the same relay was used to control a home AC unit which switches on and off much more often it would wear out in a few years. Some relays have lifetimes of over a million cycles.

CHAPTER 8 - Linear Power Supplies

In the last installment of the Power Supply Tutorial, we found that the most basic power supply was of a simple unregulated design. We also found that for all but the least demanding applications, the unregulated design is not able to maintain the output voltage close enough to the prescribed set point as the line voltage and load current changes. Thus, regulation methods have been developed to maintain the output voltage or current at a constant set point. The first type of regulated design was the linear regulator power supply.

The term "linear power supply" is typically thought of as a type of AC/DC system, providing a regulated output. The linear regulator is actually the part of the linear regulator power supply that performs the regulation.

8.1 Linear Regulator Theory

Linear regulators employ a pass element serving as a variable resistor which forms a voltage divider with the load.

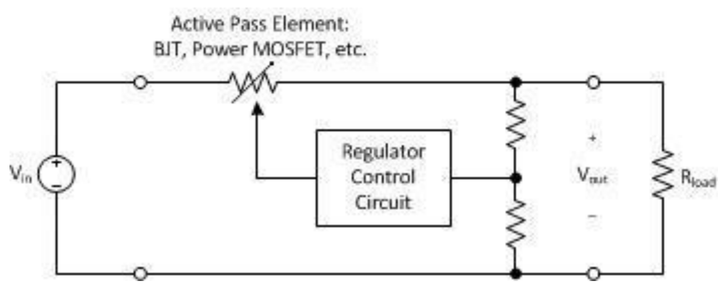


Fig 8.1 – linear regulator

The pass element functioning as a variable resistor can be semiconductor devices such as a bipolar junction transistor (BJT), power metal oxide semiconductor field effect transistor (MOSFET), insulated gate bipolar transistor (IGBT), or an electron tube such as a triode, tetrad, or pentode. Electron tubes would be used in highly specialized applications where there are no semiconductor devices suitable.

8.2 Power Output Capability

A linear regulator can be designed to regulate power outputs as small as a watt or less. Linear regulators used alone in this fashion are performing DC/DC conversion. Linear power supplies can be designed to provide AC/DC conversion up to tens of kilowatts or even more. In this case the linear regulator is coupled with additional circuitry providing rectification and filtering.

1. Noise and Ripple

Perhaps the most significant merit of linear power supplies is the cleanliness of the output voltage and the relative lack of electromagnetic emissions. The typical peak to peak output voltage ripple for a linear supply might be 1000x or 60dB less than the output DC level. So for a 5V output supply the typical peak to peak ripple voltage might be 5mV. A switching supply typically sees about a 100x or 40dB reduction. It is possible with careful design to achieve a 10,000x or 80dB reduction in a linear regulated power supply.

2. Transient Response

The response of linear power supplies to line and load transients are better their switching counterparts because the linear supply does not have a switching frequency to limit the bandwidth. In linear supplies, the regulation bandwidth is typically limited by parasitic device elements.

3. Weight and Size

The weight and size of the linear power supply is the major disadvantage. AC/DC conversion is done at low frequencies and therefore the transformer must be large to keep the core from saturating. This factor, along with efficiency to be discussed next, is the main reason why linear power supplies have limited use today. For example, a 500W linear power supply might weigh about 50 pounds and occupy a desktop. Whereas a 500W switching supply might weight less than 10 pounds and sits on a small part of the desktop.

8.3 Efficiency

Linear regulators are typically thought of a being extremely inefficient – but that is not always the case and they can sometimes be more efficient that a switching power supply!

On a first order basis, the efficiency of a linear regulator is very simple to determine. The efficiency is simply the output voltage divided by the input voltage. If determined effort is made to keep the difference between the pass element input voltage and the output voltage as small as possible, the efficiency can be very good.

This type of linear regulator is called a “low-dropout regulator”. For other cases where the operating point is not conducive to maintaining a low dropout, the linear regulator efficiency can suffer greatly.

As an example, if the input voltage in the figure above is 13.6 volts, and the regulator maintains an output voltage of 12 volts, for a voltage drop of 1.6 volts, the efficiency of the linear regulator is 12V/13.6V = 88.2%. The efficiency in this case is very good by most standards.

If the input voltage is 5 volts and the output voltage is 3.3 volts, for a voltage drop of 1.7 volts, the efficiency is 3.3V/5V = 66%. The efficiency in this case is not very good by most standards.

As a last example, if the input voltage is 5 volts and the output voltage is 1.8 volts, for a pass element voltage drop of 3.2 volts, the efficiency is 1.8V/5V = 36%. This efficiency in this case is very poor.

8.4 Summary

In this article we found that linear power supplies excel in producing outputs with very low noise and ripple, low electromagnetic emissions, and have excellent transient response. However, they are by nature large and heavy when compared to switching power supplies. Linear power supplies would be the type of choice when outputs with low ripple and noise content are of paramount concern, and where larger size and substantially greater weight can be tolerated.

Fig 8.2 -Switched-mode power supply

A switched-mode power supply (switching-mode power supply, SMPS, or switcher) is an electronic power supply that incorporates a switching regulator to convert electrical power efficiently. Like other power supplies, an SMPS transfers power from a source, like mains power, to a load, such as a personal computer, while converting voltage and current characteristics. Unlike a linear power supply, the pass transistor of a switching-mode supply continually switches between low-dissipation, full-on and full-off states, and spends very little time in the high dissipation transitions, which minimizes wasted energy. Ideally, a switched-mode power supply dissipates no power.

Voltage regulation is achieved by varying the ratio of on-to-off time. In contrast, a linear power supply regulates the output voltage by continually dissipating power in the pass transistor. This higher power conversion efficiency is an important advantage of a switched-mode power supply. Switched-mode power supplies may also be substantially smaller and lighter than a linear supply due to the smaller transformer size and weight.

Switching regulators are used as replacements for linear regulators when higher efficiency, smaller size or lighter weight is required. They are, however, more complicated; their switching currents can cause electrical noise problems if not carefully suppressed, and simple designs may have a poor power factor.

8.5 Explanation

A linear regulator provides the desired output voltage by dissipating excess power in ohmic losses (e.g., in a resistor or in the collector–emitter region of a pass transistor in its active mode). A linear regulator regulates either output voltage or current by dissipating the excess electric power in the form of heat, and hence its maximum power efficiency is voltage-out/voltage-in since the volt difference is wasted.

In contrast, a switched-mode power supply regulates either output voltage or current by switching ideal storage elements, like inductors and capacitors, into and out of different electrical configurations. Ideal switching elements (e.g., transistors operated outside of their active mode) have no resistance when "closed" and carry no current when "open", and so the converters can theoretically operate with 100% efficiency (i.e., all input power is delivered to the load; no power is wasted as dissipated heat).

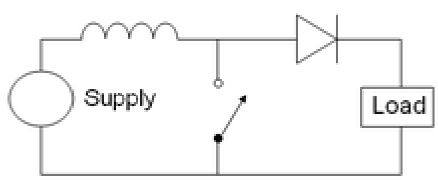


Fig 8.3 – basic structure

8.6 Advantages and disadvantages

The main advantage of the switching power supply is greater efficiency because the switching transistor dissipates little power when acting as a switch. Other advantages include smaller size and lighter weight from the elimination of heavy line-frequency transformers, and lower heat generation due to higher efficiency. Disadvantages include greater complexity, the generation of high-amplitude, high-frequency energy that the low-pass filter must block to avoid electromagnetic interference (EMI), a ripple voltage at the switching frequency and the harmonic frequencies thereof.

Very low cost SMPSs may couple electrical switching noise back onto the mains power line, causing interference with A/V equipment connected to the same phase. Non-power-factor-corrected SMPSs also cause harmonic distortion.

8.7 SMPS and linear power supply comparison

There are two main types of regulated power supplies available: SMPS and linear. The following table compares linear regulated and unregulated AC-to-DC supplies with switching regulators in general:

Theory of operation

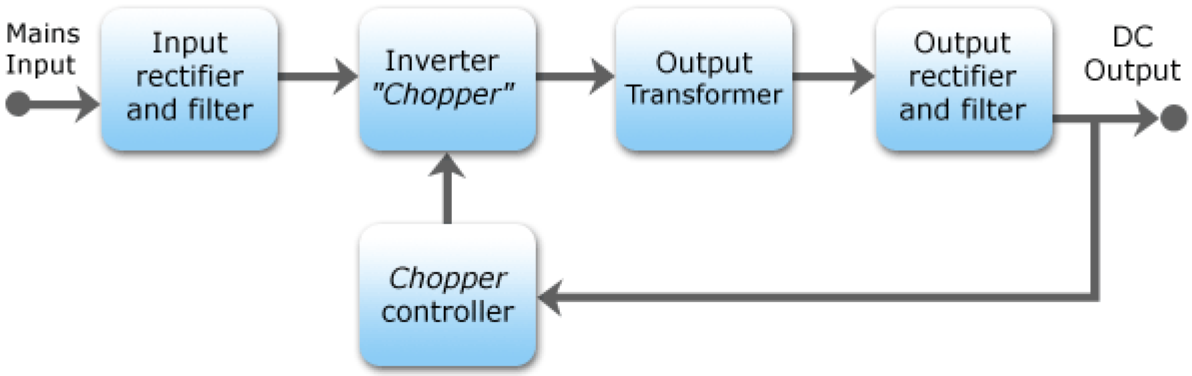


Fig 8.4-Block diagram of a mains operated AC/DC SMPS with output voltage regulation

1. Input rectifier stage

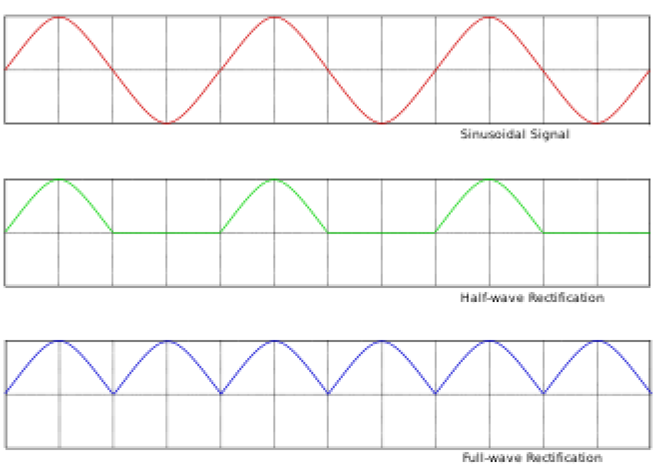


Fig 8.5-AC, half-wave and full-wave rectified signals.

If the SMPS has an (AC input), then the first stage is to convert the input to DC. This is called rectification. A SMPS with a DC input does not require this stage. In some power supplies (mostly computer ATX power supplies), the rectifier circuit can be configured as a voltage doublers by the addition of a switch operated either manually or automatically. This feature permits operation from power sources that are normally at 115 V or at 230 V. The rectifier produces an unregulated DC voltage which is then sent to a large filter capacitor. The current drawn from the mains supply by this rectifier circuit occurs in short pulses around the AC voltage peaks. These pulses have significant high frequency energy which reduces the power factor. To correct for this, many newer SMPS will use a special PFC circuit to make the input current follow the sinusoidal shape of the AC input voltage, correcting the power factor. Power supplies that use Active PFC usually are auto-ranging, supporting input voltages from ~100 VAC – 250 VAC, with no input voltage selector switch.

A SMPS designed for AC input can usually be run from a DC supply, because the DC would pass through the rectifier unchanged. If the power supply is designed for 115 VAC and has no voltage selector switch, the required DC voltage would be 163 VDC (115 × √2). This type of use may be harmful to the rectifier stage, however, as it will only use half of diodes in the rectifier for the full load. This could possibly result in overheating of these components, causing them to fail prematurely. On the other hand, if the power supply has a voltage selector switch for 115/230V (computer ATX power supplies typically are in this category), the selector switch would have to be put in the 230 V position, and the required voltage would be 325 VDC (230 × √2).

2. Voltage converter and output rectifier

If the output is required to be isolated from the input, as is usually the case in mains power supplies, the inverted AC is used to drive the primary winding of a high-frequency transformer. This converts the voltage up or down to the required output level on its secondary winding. The output transformer in the block diagram serves this purpose.

If a DC output is required, the AC output from the transformer is rectified. For output voltages above ten volts or so, ordinary silicon diodes are commonly used. For lower voltages, Schottky diodes are commonly used as the rectifier elements; they have the advantages of faster recovery times than silicon diodes (allowing low-loss operation at higher frequencies) and a lower voltage drop when conducting. For even lower output voltages, MOSFETs may be used as synchronous rectifiers; compared to Schottky diodes, these have even lower conducting state voltage drops.

The rectified output is then smoothed by a filter consisting of inductors and capacitors. For higher switching frequencies, components with lower capacitance and inductance are needed.

Simpler, non-isolated power supplies contain an inductor instead of a transformer. This type includes boost converters, buck converters, and the buck-boost converters. These belong to the simplest class of single input, single output converters which use one inductor and one active switch. The buck converter reduces the input voltage in direct proportion to the ratio of conductive time to the total switching period, called the duty cycle. For example an ideal buck converter with a 10 V input operating at a 50% duty cycle will produce an average output voltage of 5 V. A feedback control loop is employed to regulate the output voltage by varying the duty cycle to compensate for variations in input voltage. The output voltage of a boost converter is always greater than the input voltage and the buck-boost output voltage is inverted but can be greater than, equal to, or less than the magnitude of its input voltage.

CHAPTER 9 - Resistor

A **resistor** is a passive two-terminal electrical component that implements electrical resistance as a circuit element. Resistors act to reduce current flow, and, at the same time, act to lower voltage levels within circuits. In electronic circuits resistors are used to limit current flow, to adjust signal levels, bias active elements, terminate transmission lines among other uses. High-power resistors that can dissipate many watts of electrical power as heat may be used as part of motor controls, in power distribution systems, or as test loads for generators. Fixed resistors have resistances that only change slightly with temperature, time or operating voltage. Variable resistors can be used to adjust circuit elements (such as a volume control or a lamp dimmer), or as sensing devices for heat, light, humidity, force, or chemical activity.

Resistors are common elements of electrical networks and electronic circuits and are ubiquitous in electronic equipment. Practical resistors as discrete components can be composed of various compounds and forms. Resistors are also implemented within integrated circuits.

The electrical function of a resistor is specified by its resistance: common commercial resistors are manufactured over a range of more than nine orders of magnitude. The nominal value of the resistance will fall within a manufacturing tolerance.

9.1 Electronic symbols and notation

Two typical schematic diagram symbols are as follows;

(a) resistor, (b) rheostat (variable resistor), and (c) potentiometer

The notation to state a resistor's value in a circuit diagram varies, too. The European notation BS 1852 avoids using a decimal separator, and replaces the decimal separator with the SI prefix symbol for the particular value. For example, *8k2* in a circuit diagram indicates a resistor value of 8.2 kΩ. Additional zeros imply tighter tolerance, for example *15M0*. When the value can be expressed without the need for an SI prefix, an 'R' is used instead of the decimal separator. For example, *1R2* indicates 1.2 Ω, and *18R* indicates 18 Ω. The use of a SI prefix symbol or the letter 'R' circumvents the problem that decimal separators tend to 'disappear' when photocopying a printed circuit diagram

9.2 Theory of operation

The hydraulic analogy compares electric current flowing through circuits to water flowing through pipes. When a pipe (left) is filled with hair (right), it takes a larger pressure to achieve the same flow of water. Pushing electric current through a large resistance is like pushing water through a pipe clogged with hair: It requires a larger push (voltage drop) to drive the same flow (electric current).

9.3 Ohm's law

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

Ohm's law states that the voltage (V) across a resistor is proportional to the current (I), where the constant of proportionality is the resistance (R). For example, if a 300 ohm resistor is attached across the terminals of a 12 volt battery, then a current of 12 / 300 = 0.04 amperes flows through that resistor.

Practical resistors also have some inductance and capacitance which will also affect the relation between voltage and current in alternating current circuits.

The ohm (symbol: Ω) is the SI unit of electrical resistance, named after Georg Simon Ohm. An ohm is equivalent to a volt per ampere. Since resistors are specified and manufactured over a very large range of values, the derived units of milliohm ($1\ m\Omega = 10^{-3}\ \Omega$), kilohm ($1\ k\Omega = 10^{3}\ \Omega$), and megohm ($1\ M\Omega = 10^{6}\ \Omega$) are also in common usage.

9.4 Series and parallel resistors

The total resistance of resistors connected in series is the sum of their individual resistance values.

The total resistance of resistors connected in parallel is the reciprocal of the sum of the reciprocals of the individual resistors.

So, for example, a 10 ohm resistor connected in parallel with a 5 ohm resistor and a 15 ohm resistor will produce the inverse of 1/10+1/5+1/15 ohms of resistance, or 1/(.1+.2+.067)=2.725 ohms.

A resistor network that is a combination of parallel and series connections can be broken up into smaller parts that are either one or the other.

9.5 Power dissipation

At any instant of time, the power *P* (watts) consumed by a resistor of resistance *R* (ohms) is calculated as: where *V* (volts) is the voltage across the resistor and *I* (amps) is the current flowing through it. Using Ohm's law, the two other forms can be derived. This power is converted into heat which must be dissipated by the resistor's package before its temperature rises excessively.

Resistors are rated according to their maximum power dissipation. Most discrete resistors in solid-state electronic systems absorb much less than a watt of electrical power and require no attention to their power rating. Such resistors in their discrete form, including most of the packages detailed below, are typically rated as 1/10, 1/8, or 1/4 watt.

An aluminum-housed power resistor rated for 50 W when heat-sinked

Resistors required to dissipate substantial amounts of power, particularly used in power supplies, power conversion circuits, and power amplifiers, are generally referred to as power resistors; this designation is loosely applied to resistors with power ratings of 1 watt or greater. Power resistors are physically larger and may not use the preferred values, color codes, and external packages described below.

If the average power dissipated by a resistor is more than its power rating, damage to the resistor may occur, permanently altering its resistance; this is distinct from the reversible change in resistance due to its temperature coefficient when it warms. Excessive power dissipation may raise the temperature of the resistor to a point where it can burn the circuit board or adjacent components, or even cause a fire. There are flameproof resistors that fail (open circuit) before they overheat dangerously.

Since poor air circulation, high altitude, or high operating temperatures may occur, resistors may be specified with higher rated dissipation than will be experienced in service.

All resistors have a maximum voltage rating; this may limit the power dissipation for higher resistance values.

9.6 Non- ideal properties

Practical resistors have a series inductance and a small parallel capacitance; these specifications can be important in high-frequency applications. In a low-noise amplifier or pre-amp, the noise characteristics of a resistor may be an issue.

The temperature coefficient of the resistance may also be of concern in some precision applications.

The unwanted inductance, excess noise, and temperature coefficient are mainly dependent on the technology used in manufacturing the resistor. They are not normally specified individually for a particular family of resistors manufactured using a particular technology. A family of discrete resistors is also characterized according to its form factor, that is, the size of the device and the position of its leads (or terminals) which is relevant in the practical manufacturing of circuits using them.

Practical resistors are also specified as having a maximum power rating which must exceed the anticipated power dissipation of that resistor in a particular circuit: this is mainly of concern in power electronics applications. Resistors with higher power ratings are physically larger and may require heat sinks. In a high-voltage circuit, attention must sometimes be paid to the rated maximum working voltage of the resistor. While there is no minimum working voltage for a given resistor, failure to account for a resistor's maximum rating may cause the resistor to incinerate when current is run through it.

1. Fixed resistor

A single in line (SIL) resistor package with 8 individual, 47 ohm resistors. One end of each resistor is connected to a separate pin and the other ends are all connected together to the remaining (common) pin – pin 1, at the end identified by the white dot.

2. Lead arrangements

Resistors with wire leads for through-hole mounting

Through-hole components typically have "leads" (pronounced to rhyme with "reeds") leaving the body "axially," that is, on a line parallel with the part's longest axis. Others have leads coming off their body "radically" instead. Other components may be SMT (surface mount technology), while high power resistors may have one of their leads designed into the heat sink.

3. Carbon pile

A carbon pile resistor is made of a stack of carbon disks compressed between two metal contact plates. Adjusting the clamping pressure changes the resistance between the plates. These resistors are used when an adjustable load is required, for example in testing automotive batteries or radio transmitters. A carbon pile resistor can also be used as a speed control for small motors in household appliances (sewing machines, hand-held mixers) with ratings up to a few hundred watts. A carbon pile resistor can be incorporated in automatic voltage regulators for generators, where the carbon pile controls the field current to maintain relatively constant voltage. The principle is also applied in the carbon microphone.

4. Carbon film

A carbon film is deposited on an insulating substrate, and a helix is cut in it to create a long, narrow resistive path. Varying shapes, coupled with the resistivity of amorphous carbon (ranging from 500 to 800 μΩ m), can provide a wide range of resistance values. Compared to carbon composition they feature low noise, because of the precise distribution of the pure graphite without binding. Carbon film resistors feature a power rating range of 0.125 W to 5 W at 70 °C. Resistances available range from 1 ohm to 10 megohm. The carbon film resistor has an operating temperature range of −55 °C to 155 °C. It has 200 to 600 volts maximum working voltage range. Special carbon film resistors are used in applications requiring high pulse stability.

5. Printed carbon resistor

A carbon resistor printed directly onto the SMD pads on a PCB. Inside a 1989 vintage Psion II Organiser.Carbon composition resistors can be printed directly onto printed circuit board (PCB) substrates as part of the PCB manufacturing process. Although this technique is more common on hybrid PCB modules, it can also be used on standard fibreglass PCBs. Tolerances are typically quite large, and can be in the order of 30%. A typical application would be non-critical pull-up resistors.

9.7 Thick and thin film

Laser Trimmed Precision Thin Film Resistor Network from Fluke, used in the Keithley DMM7510 multimeter. Ceramic backed with glass hermetic seal cover.

Thick film resistors became popular during the 1970s, and most SMD (surface mount device) resistors today are of this type. The resistive element of thick films is 1000 times thicker than thin films, but the principal difference is how the film is applied to the cylinder (axial resistors) or the surface (SMD resistors).

Thin film resistors are made by sputtering (a method of vacuum deposition) the resistive material onto an insulating substrate. The film is then etched in a similar manner to the old (subtractive) process for making printed circuit boards; that is, the surface is coated with a photo-sensitive material, then covered by a pattern film, irradiated with ultraviolet light, and then the exposed photo-sensitive coating is developed, and underlying thin film is etched away.

The resistance of both thin and thick film resistors after manufacture is not highly accurate; they are usually trimmed to an accurate value by abrasive or laser trimming. Thin film resistors are usually specified with tolerances of 0.1, 0.2, 0.5, or 1%, and with temperature coefficients of 5 to 25 ppm/K. They also have much lower noise levels, on the level of 10–100 times less than thick film resistors.

Thick film resistors may use the same conductive ceramics, but they are mixed with sintered (powdered) glass and a carrier liquid so that the composite can be screen-printed. This composite of glass and conductive ceramic (cermet) material is then fused (baked) in an oven at about 850 °C.

Thick film resistors, when first manufactured, had tolerances of 5%, but standard tolerances have improved to 2% or 1% in the last few decades. Temperature coefficients of thick film resistors are high, typically ±200 or ±250 ppm/K; a 40 kelvin (70 °F) temperature change can change the resistance by 1%.

Thin film resistors are usually far more expensive than thick film resistors. For example, SMD thin film resistors, with 0.5% tolerances, and with 25 ppm/K temperature coefficients, when bought in full size reel quantities, are about twice the cost of 1%, 250 ppm/K thick film resistors.

9.8. Metal film

1. Metal oxide film

Metal-oxide film resistors are made of metal oxides such as tin oxide. This results in a higher operating temperature and greater stability/reliability than Metal film. They are used in applications with high endurance demands

2. Wire wound

Wirewound resistors are commonly made by winding a metal wire, usually nichrome, around a ceramic, plastic, or fiberglass core. The ends of the wire are soldered or welded to two caps or rings, attached to the ends of the core. The assembly is protected with a layer of paint, molded plastic, or an enamel coating baked at high temperature. These resistors are designed to withstand unusually high temperatures of up to 450 °C.

Wire leads in low power wire wound resistors are usually between 0.6 and 0.8 mm in diameter and tinned for ease of soldering. For higher power wire wound resistors, either a ceramic outer case or an aluminum outer case on top of an insulating layer is used – if the outer case is ceramic, such resistors are sometimes described as "cement" resistors, though they do not actually contain any traditional cement. The aluminum-cased types are designed to be attached to a heat sink to dissipate the heat; the rated power is dependent on being used with a suitable heat sink, e.g., a 50 W power rated resistor will overheat at a fraction of the power dissipation if not used with a heat sink. Large wire wound resistors may be rated for 1,000 watts or more.

3. Foil resistor

The primary resistance element of a foil resistor is a special alloy foils several micrometers thick. Since their introduction in the 1960s, foil resistors have had the best precision and stability of any resistor available. One of the important parameters influencing stability is the temperature coefficient of resistance (TCR). The TCR of foil resistors is extremely low, and has been further improved over the years. One range of ultra-precision foil resistors offers a TCR of 0.14 ppm/°C, tolerance ±0.005%, long-term stability (1 year) 25 ppm, (3 year) 50 ppm (further improved 5-fold by hermetic sealing), stability under load (2000 hours) 0.03%, thermal EMF 0.1 μV/°C, noise −42 dB, voltage coefficient 0.1 ppm/V, inductance 0.08 μH, capacitance 0.5 pF.

4. Ammeter shunts

An ammeter shunt is a special type of current-sensing resistor, having four terminals and a value in milliohms or even micro-ohms. Current-measuring instruments, by themselves, can usually accept only limited currents. To measure high currents, the current passes through the shunt across which the voltage drop is measured and interpreted as current. A typical shunt consists of two solid metal blocks, sometimes brass, mounted on an insulating base. Between the blocks, and soldered or brazed to them, are one or more strips of low temperature coefficient of resistance (TCR) manganin alloy. Large bolts threaded into the blocks make the current connections, while much smaller screws provide volt meter connections. Shunts are rated by full-scale current, and often have a voltage drop of 50 mV at rated current. Such meters are adapted to the shunt full current rating by using an appropriately marked dial face; no change need to be made to the other parts of the meter.

5. Grid resistor

In heavy-duty industrial high-current applications, a grid resistor is a large convection-cooled lattice of stamped metal alloy strips connected in rows between two electrodes. Such industrial grade resistors can be as large as a refrigerator; some designs can handle over 500 amperes of current, with a range of resistances extending lower than 0.04 ohms. They are used in applications such as dynamic braking and load banking for locomotives and trams, neutral grounding for industrial AC distribution, control loads for cranes and heavy equipment, load testing of generators and harmonic filtering for electric substations.

The term grid resistor is sometimes used to describe a resistor of any type connected to the control grid of a vacuum tube. This is not a resistor technology; it is an electronic circuit topology.

9.8 Variable resistors

1. Adjustable resistors

A resistor may have one or more fixed tapping points so that the resistance can be changed by moving the connecting wires to different terminals. Some wirewound power resistors have a tapping point that can slide along the resistance element, allowing a larger or smaller part of the resistance to be used.

Where continuous adjustment of the resistance value during operation of equipment is required, the sliding resistance tap can be connected to a knob accessible to an operator. Such a device is called a rheostat and has two terminals.

2. Potentiometers

A common element in electronic devices is a three-terminal resistor with a continuously adjustable tapping point controlled by rotation of a shaft or knob. These variable resistors are known as potentiometers when all three terminals are present, since they act as a continuously adjustable voltage divider. A common example is a volume control for a radio receiver.

Accurate, high-resolution panel-mounted potentiometers (or "pots") have resistance elements typically wire wound on a helical mandrel, although some include a conductive-plastic resistance coating over the wire to improve resolution. These typically offer ten turns of their shafts to cover their full range. They are usually set with dials that include a simple turns counter and a graduated dial. Electronic analog computers used them in quantity for setting coefficients, and delayed-sweep oscilloscopes of recent decades included one on their panels.

Resistor marking

COLOR	DIGIT	MULTIPLIER	TOLERANCE	TC
Silver		x 0.01 Ω	±10%	
Gold		x 0.1 Ω	±5%	
Black	0	x 1 Ω		
Brown	1	x 10 Ω	±1%	$\pm100*10^{-6}$/K
Red	2	x 100 Ω	±2%	$\pm50*10^{-6}$/K
Orange	3	x 1 kΩ		$\pm15*10^{-6}$/K
Yellow	4	x 10 kΩ		$\pm25*10^{-6}$/K
Green	5	x 100 kΩ	±0.5%	
Blue	6	x 1 MΩ	±0.25%	$\pm10*10^{-6}$/K
Violet	7	x 10 MΩ	±0.1%	$\pm5*10^{-6}$/K
Grey	8	x 100 MΩ		
White	9	x 1 GΩ		$\pm1*10^{-6}$/K

TABLE 4 – Resistor marking scheme.

CHAPTER 10 - Light-emitting diode

10.1 LED

Parts of an LED. Although not directly labeled, the flat bottom surfaces of the anvil and post embedded inside the epoxy act as anchors, to prevent the conductors from being forcefully pulled out from mechanical strain or vibration.

A bulb-shaped modern retrofit LED lamp with aluminum heat sink, a light diffusing dome and E27 screw base, using a built-in power supply working on mains voltage

A **light-emitting diode** (**LED**) is a two-lead semiconductor light source. It is a pn-junction diode, which emits light when activated. When a suitable voltage is applied to the leads, electrons are able to recombine with electron holes within the device, releasing energy in the form of photons.

This effect is called electroluminescence, and the color of the light (corresponding to the energy of the photon) is determined by the energy band gap of the semiconductor.

An LED is often small in area (less than 1 mm^2) and integrated optical components may be used to shape its radiation pattern.

Appearing as practical electronic components in 1962, the earliest LEDs emitted low-intensity infrared light. Infrared LEDs are still frequently used as transmitting elements in remote-control circuits, such as those in remote controls for a wide variety of consumer electronics. The first visible-light LEDs were also of low intensity, and limited to red. Modern LEDs are available across the visible, ultraviolet, and infrared wavelengths, with very high brightness.

Early LEDs were often used as indicator lamps for electronic devices, replacing small incandescent bulbs. They were soon packaged into numeric readouts in the form of seven-segment displays, and were commonly seen in digital clocks.

Recent developments in LEDs permit them to be used in environmental and task lighting. LEDs have many advantages over incandescent light sources including lower energy consumption, longer lifetime, improved physical robustness, smaller size, and faster switching. Light-emitting diodes are now used in applications as diverse as aviation lighting, automotive headlamps, advertising, general lighting, traffic signals, and camera flashes. However, LEDs powerful enough for room lighting are still relatively expensive, and require more precise current and heat management than compact fluorescent lamp sources of comparable output.

10.2 Technology

An LED will begin to emit light when more than 2 or 3 volts is applied to it. Some external system must control the current through the LED to prevent destruction by overheating.

Physics

The LED consists of a chip of semiconducting material 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 thus 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 usually recombine by a non-radioactive 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.

LED development began with infrared and red devices made with gallium arsenide. Advances in materials science have enabled making devices with ever-shorter wavelengths, emitting 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.

Most materials used for LED production have very high refractive indices. This means that much light will be reflected back into the material at the material/air surface interface. Thus, light extraction in LEDs is an important aspect of LED production, subject to much research and development.

10.3 Refractive index

Idealized example of light emission cones in a semiconductor, for a single point-source emission zone. The left illustration is for a fully translucent wafer, while the right illustration shows the half-cones formed when the bottom layer is fully opaque. The light is actually emitted equally in all directions from the point-source, so the areas between the cones shows the large amount of trapped light energy that is wasted as heat.

The light emission cones of a real LED wafer are far more complex than a single point-source light emission. The light emission zone is typically a two-dimensional plane between the wafers. Every atom across this plane has an individual set of emission cones. Drawing the billions of overlapping cones is impossible, so this is a simplified diagram showing the extents of all the emission cones combined. The larger side cones are clipped to show the interior features and reduce image complexity; they would extend to the opposite edges of the two-dimensional emission plane.

Bare uncoated semiconductors such as silicon exhibit a very high refractive index relative to open air, which prevents passage of photons arriving at sharp angles relative to the air-contacting surface of the semiconductor. This property affects both the light-emission efficiency of LEDs as well as the light-absorption efficiency of photovoltaic cells. The refractive index of silicon is 3.96 (590 nm), while air is 1.0002926.

In general, a flat-surface uncoated LED semiconductor chip will emit light only perpendicular to the semiconductor's surface, and a few degrees to the side, in a cone shape referred to as the light cone, cone of light, or the escape cone The maximum angle of incidence is referred to as the critical angle. When this angle is exceeded, photons no longer escape the semiconductor but are instead reflected internally inside the semiconductor crystal as if it were a mirror.

Internal reflections can escape through other crystalline faces, if the incidence angle is low enough and the crystal is sufficiently transparent to not re-absorb the photon emission. But for a simple square LED with 90-degree angled surfaces on all sides, the faces all act as equal angle mirrors. In this case most of the light can not escape and is lost as waste heat in the crystal.

A convoluted chip surface with angled facets similar to a jewel or fresnel lens can increase light output by allowing light to be emitted perpendicular to the chip surface while far to the sides of the photon emission point.

10.4 Transition coatings

After the doping of the wafer, it is cut apart into individual dies. Each die is commonly called a chip.

Many LED semiconductor chips are encapsulated or potted in clear or colored molded plastic shells. The plastic shell has three purposes:

1. Mounting the semiconductor chip in devices is easier to accomplish.
2. The tiny fragile electrical wiring is physically supported and protected from damage.
3. The plastic acts as a refractive intermediary between the relatively high-index semiconductor and low-index open air.

10.5 Efficiency droop

Efficiency droop is the decrease (up to 20%) in luminous efficacy of LEDs as the electrical current increases above tens of milliamps (mA).

This effect, first reported in 1999, was initially theorized to be related to elevated temperatures. Scientists proved the opposite to be true that, although the life of an LED would be shortened, the efficiency droop is less severe at elevated temperatures. The mechanism causing efficiency droop was identified in 2007 as Auger recombination, which was taken with mixed reaction. In 2013, a study conclusively identified Auger recombination as the cause of efficiency droop.

In addition to being less efficient, operating LEDs at higher electrical currents creates higher heat levels which compromise the lifetime of the LED. Because of this increased heating at higher currents, high-brightness LEDs have an industry standard of operating at only 350 mA, which is a compromise between light output, efficiency, and longevity.

10.6 Possible solutions

Instead of increasing current levels, luminance is usually increased by combining multiple LEDs in one bulb. Solving the problem of efficiency droop would mean that household LED light bulbs would need fewer LEDs, which would significantly reduce costs.

Researchers at the U.S. Naval Research Laboratory have found a way to lessen the efficiency droop. They found that the droop arises from non-radioactive Auger recombination of the injected carriers. They created quantum wells with a soft confinement potential to lessen the non-radioactive Auger processes.

Researchers at Taiwan National Central University and Epistar Corp are developing a way to lessen the efficiency droop by using ceramic aluminum nitride (AlN) substrates, which are more thermally conductive than the commercially used sapphire. The higher thermal conductivity reduces self-heating effects.

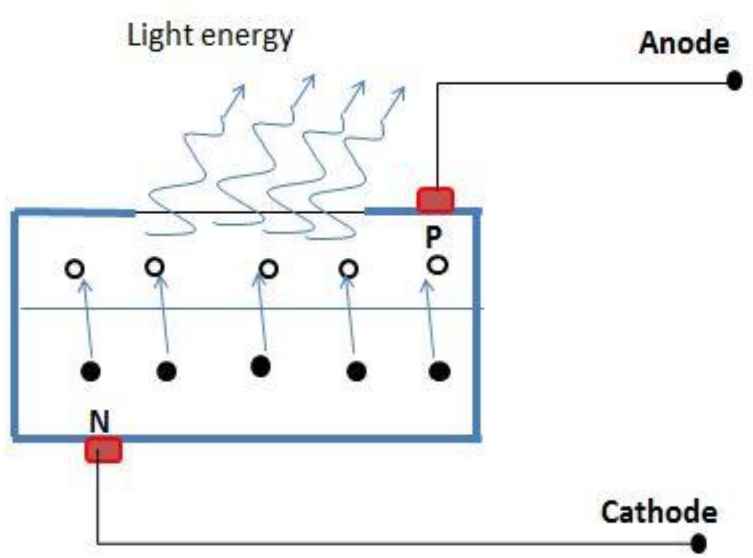


Fig 10.2 – basic structure of led

TYPES OF LED

LEDs are produced in a variety of shapes and sizes. The color of the plastic lens is often the same as the actual color of light emitted, but not always. For instance, purple plastic is often used for infrared LEDs, and most blue devices have colorless housings. Modern high-power LEDs such as those used for lighting and backlighting are generally found in surface-mount technology (SMT) packages (not shown).

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

1. Miniature

Photo of miniature surface mount LEDs in most common sizes. They can be much smaller than a traditional 5 mm lamp type LED which is shown on the upper left corner.
Very small (1.6x1.6x0.35 mm) red, green, and blue surface mount miniature LED package with gold wire bonding details.

These are mostly single-die LEDs used as indicators, and they come in various sizes from 2 mm to 8 mm, through-hole and surface mount packages. They usually do not use a separate heat sink. Typical current ratings ranges from around 1 mA to above 20 mA. The small size sets a natural upper boundary on power consumption due to heat caused by the high current density and need for a heat sink.

Common package shapes include round, with a domed or flat top, rectangular with a flat top (as used in bar-graph displays), and triangular or square with a flat top. The encapsulation may also be clear or tinted to improve contrast and viewing angle.

Researchers at the University of Washington have invented the thinnest LED. It is made of two-dimensional (2-D) flexible materials. It is 3 atoms thick, which is 10 to 20 times thinner than three-dimensional (3-D) LEDs and is also 10,000 times smaller than the thickness of a human hair. These 2-D LEDs are going to make it possible to create smaller, more energy-efficient lighting, optical communication and nano lasers.

There are three main categories of miniature single die LEDs:

- Low-current: typically rated for 2 mA at around 2 V (approximately 4 mW consumption).
- Standard: 20 mA LEDs (ranging from approximately 40 mW to 90 mW) at around:

1.9 to 2.1 V for red, orange and yellow,
3.0 to 3.4 V for green and blue,
2.9 to 4.2 V for violet, pink, purple and white.

- Ultra-high-output: 20 mA at approximately 2 V or 4–5 V, designed for viewing in direct sunlight.

5 V and 12 V LEDs are ordinary miniature LEDs that incorporate a suitable series resistor for direct connection to a 5 V or 12 V supply.

2. Mid-range

Medium-power LEDs are often through-hole-mounted and mostly utilized when an output of just tens of lumens are needed. They sometimes have the diode mounted to four leads (two cathode leads, two anode leads) for better heat conduction and carry an integrated lens. An example of this is the Superflux package, from Philips Lumileds. These LEDs are most commonly used in light panels, emergency lighting, and automotive tail-lights. Due to the larger amount of metal in the LED, they are able to handle higher currents (around 100 mA). The higher current allows for the higher light output required for tail-lights and emergency lighting.

3. High-power

High-power light-emitting diodes attached to an LED star base (Luxeon, Lumileds)
See also: Solid-state lighting, LED lamp and Thermal management of high-power LEDs

High-power LEDs (HPLEDs) or high-output LEDs (HO-LEDs) can be driven at currents from hundreds of mA to more than an ampere, compared with the tens of mA for other LEDs. Some can emit over a thousand lumens. LED power densities up to 300 W/cm^2 have been achieved. Since overheating is destructive, the HPLEDs must be mounted on a heat sink to allow for heat dissipation. If the heat from a HPLED is not removed, the device will fail in seconds. One HPLED can often replace an incandescent bulb in a flashlight, or be set in an array to form a powerful LED lamp.

Some well-known HPLEDs in this category are the Nichia 19 series, Lumileds Rebel Led, Osram Opto Semiconductors Golden Dragon, and Cree X-lamp. As of September 2009, some HPLEDs manufactured by Cree Inc. now exceed 105 lm/W (e.g. the XLamp XP-G LED chip emitting Cool White light) and are being sold in lamps intended to replace incandescent, halogen, and even fluorescent lights, as LEDs grow more cost competitive.

The impact of Haitz's law which describes the exponential rise in light output of LEDs over time can be readily seen in year over year increases in lumen output and efficiency. For example, the

4. AC driven LED

LEDs have been developed by Seoul Semiconductor that can operate on AC 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 efficacy of this type of HPLED is typically 40 lm/W. A large number of LED elements in series may be able to operate directly from line voltage. In 2009, Seoul Semiconductor released a high DC voltage LED, named as 'Acrich MJT', capable of being driven from AC power with a simple controlling circuit. The low-power dissipation of these LEDs affords them more flexibility than the original AC LED design.

Application-specific variations

Flashing

Used as attention seeking indicators without requiring external electronics. Flashing LEDs resemble standard LEDs but they contain an integrated multivibrator circuit that 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 one color, but more sophisticated devices can flash between multiple colors and even fade through a color sequence using RGB color mixing.

Bi-color LED

Two different LED emitters in one case. There are two types of these. One type consists of two dies connected to the same two leads antiparallel to each other. Current flow in one direction emits one color, and current in the opposite direction emits the other color. The other type consists of two dies with separate leads for both dies and another lead for common anode or cathode, so that they can be controlled independently.

Tri-color

Three different LED emitters in one case. Each emitter is connected to a separate lead so they can be controlled independently. A four-lead arrangement is typical with one common lead (anode or cathode) and an additional lead for each color.

RGB

Tri-color LEDs with red, green, and blue emitters, in general using a four-wire connection with one common lead (anode or cathode). These LEDs can have either common positive or common negative leads. Others however, have only two leads (positive and negative) and have a built in tiny electronic control unit.

Decorative multicolor

Incorporates several emitters of different colors supplied by only two lead-out wires. Colors are switched internally simply by varying the supply voltage. (In a cheap 'Melinera' garden lamp supplied by OWIM GmbH & Co KG in 2013 the LEDs are within a clear casting of 5mm diameter, 10mm long which encapsulates 3 LEDs which change between red, green and blue as the DC supply varies between about 2 volts and 3 volts).

Alphanumeric

Available in seven-segment, starburst and dot-matrix format. Seven-segment displays handle all numbers and a limited set of letters. Starburst displays can display all letters. Dot-matrix displays typically use 5x7 pixels per character. Seven-segment LED displays were in widespread use in the 1970s and 1980s, but rising use of liquid crystal displays, with their lower power needs and greater display flexibility, has reduced the popularity of numeric and alphanumeric LED displays.

Digital RGB

These are RGB LEDs that contain their own "smart" control electronics. In addition to power and ground, these provide connections for data in, data out, and sometimes a clock or strobe signal. These are connected in a daisy chain, with the data in of the first LED sourced by a microprocessor, which can control the brightness and color of each LED independently of the others. They are used where a combination of maximum control and minimum visible electronics are needed such as strings for Christmas and LED matrices, few even have refresh rates in the kHz range allowing for basic video applications.

10.7 Lifetime and failure

Solid-state devices such as LEDs are subject to very limited wear and tear if operated at low currents and at low temperatures. Many of the LEDs made in the 1970s and 1980s are still in service in the early 21st century. Typical lifetimes quoted are 25,000 to 100,000 hours, but heat and current settings can extend or shorten this time significantly.

The most common symptom of LED (and diode laser) failure is the gradual lowering of light output and loss of efficiency. Sudden failures, although rare, can also occur. Early red LEDs were notable for their short service life. With the development of high-power LEDs the devices are subjected to higher junction temperatures and higher current densities than traditional devices. This causes stress on the material and may cause early light-output degradation. To quantitatively classify useful lifetime in a standardized manner it has been suggested to use the terms L70 and L50, which is the time it will take a given LED to reach 70% and 50% light output respectively.

LED performance is temperature dependent. Most manufacturers' published ratings of LEDs are for an operating temperature of 25 °C (77 °F). LEDs used outdoors, such as traffic signals or in-pavement signal lights, and that are utilized in climates where the temperature within the light fixture gets very high, could result in low signal intensities or even failure.

LED light output rises at lower temperatures, leveling off, depending on type, at around −30 °C (−22 °F). Thus, LED technology may be a good replacement in uses such as supermarket freezer lighting and will last longer than other technologies. Because LEDs emit less heat than incandescent bulbs, they are an energy-efficient technology for uses such as in freezers and refrigerators. However, because they emit little heat, ice and snow may build up on the LED light fixture in colder climates. Similarly, this lack of waste heat generation has been observed to sometimes cause significant problems with street traffic signals and airport runway lighting in snow-prone areas. In response to this problem, some LED lighting systems have been designed with an added heating circuit at the expense of reduced overall electrical efficiency of the system; additionally, research has been done to develop heat sink technologies that will transfer heat produced within the junction to appropriate areas of the light fixture.

CHAPTER 11- Voltage Regulator

11.1 7805 Voltage Regulator

The **78xx** (sometimes **L78xx**, **LM78xx**, **MC78xx**...) is a family of self-contained fixed linear voltage regulator integrated circuits. The 78xx family is commonly used in electronic circuits requiring a regulated power supply due to their ease-of-use and low cost. For ICs within the family, the *xx* is replaced with two digits, indicating the output voltage (for example, the 7805 has a 5 volt output, while the 7812 produces 12 volts). The 78xx line are positive voltage regulators: they 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 positive and negative supply voltages in the same circuit.

78xx ICs have three terminals and are commonly found in the TO220 form factor, although smaller surface-mount and larger TO3 packages are available. These devices support an input voltage anywhere from a few volts over the intended output voltage, up to a maximum of 35 to 40 volts depending on the make, and typically provide 1 or 1.5 amperes of current (though smaller or larger packages may have a lower or higher current rating).

The LM7805, like most other regulators, is a three-pin IC.

Pin 1 (Input Pin): The Input pin is the pin that accepts the incoming DC voltage, which the voltage regulator will eventually regulate down to 5 volts.

Pin 2 (Ground): Ground pin establishes the ground for the regulator.

Pin 3 (Output Pin): The Output pin is the regulated 5 volts DC.

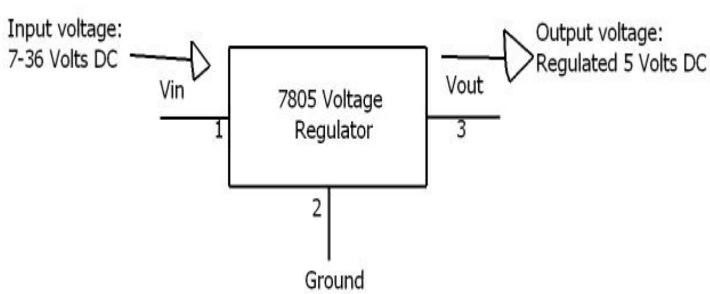


Fig 11.1: block diagram 7805

Pin configuration

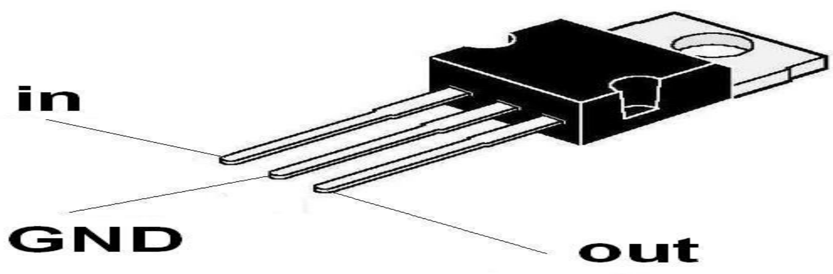


Fig 11.2 - voltage regulator 7805

If you hold the I.C. in your hand with the flat surface on the back side The 1st pin from the left is the input pin, 2nd or the middle pin is the common (COM) or ground (GND) & the 3rd pin is the output pin.

11.2 Advantages

- 78xx series ICs do not require additional components to provide a constant, regulated source of power, making them easy to use, as well as economical and efficient uses of space. Other voltage regulators may require additional components to set the output voltage level, or to assist in the regulation process. Some other designs (such as a switched-mode power supply) may need substantial engineering expertise to implement.
- 78xx series ICs have built-in protection against a circuit drawing too much current. They have protection against overheating and short-circuits, making them quite robust in most applications. In some cases, the current-limiting features of the 78xx devices can provide protection not only for the 78xx itself, but also for other parts of the circuit.

Disadvantages

- The input voltage must always be higher than the output voltage by some minimum amount (typically 2.5 volts). This can make these devices unsuitable for powering some devices from certain types of power sources (for example, powering a circuit that requires 5 volts using 6-volt batteries will not work using a 7805).
- As they are based on a linear regulator design, the input current required is always the same as the output current. As the input voltage must always be higher than the output voltage, this means that the total power (voltage multiplied by current) going into the 78xx will be more than the output power provided. The difference is dissipated as heat. This means both that for some applications an adequate heat sink must be provided, and also that a (often substantial) portion of the input power is wasted during the process, rendering them less efficient than some other types of power supplies. When the input voltage is significantly higher than the regulated output voltage (for example, powering a 7805 using a 24 volt power source), this inefficiency can be a significant issue.

CHAPTER 12 - LCD

12.1 Liquid crystal display

A liquid crystal display (LCD) is a thin, flat display device made up of any number of color or monochrome pixels arrayed in front of a light source or reflector. It is prized by engineers because it uses very small amounts of electric power, and is therefore suitable for use in battery-powered electronic devices.

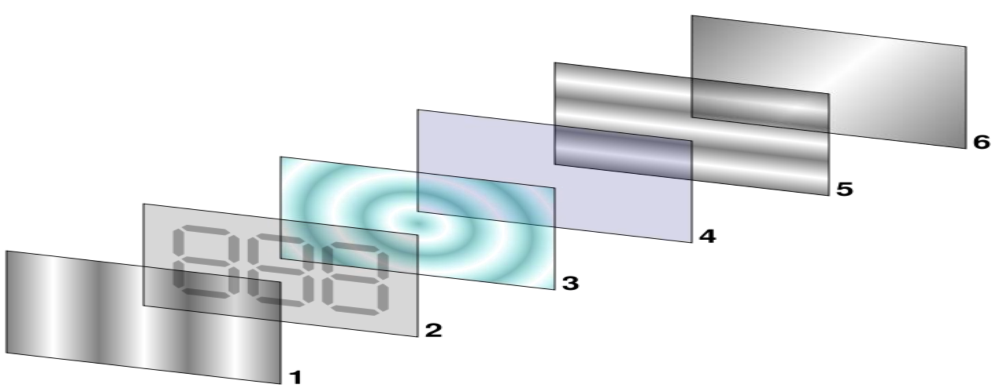


Fig 12.1 - LCD display inner structure.

Reflective twisted nematic liquid crystal display.

Vertical filter film to polarize the light as it enters.

Glass substrate with ITO electrodes. The shapes of these electrodes will determine the dark shapes that will appear when the LCD is turned on or off. Vertical ridges etched on the surface are smooth.

Twisted nematic liquid crystals.

Glass substrate with common electrode film (ITO) with horizontal ridges to line up with the horizontal filter.

Horizontal filter film to block/allow through light.

Reflective surface to send light back to viewer.

12.2 Overview

Each pixel of an LCD consists of a layer of liquid crystal molecules aligned between two transparent electrodes, and two polarizing filters, the axes of polarity of which are perpendicular to each other. With no liquid crystal between the polarizing filters, light passing through one filter would be blocked by the other.

The surfaces of the electrodes that are in contact with the liquid crystal material are treated so as to align the liquid crystal molecules in a particular direction. This treatment typically consists of a thin polymer layer that is unidirectionally rubbed using a cloth (the direction of the liquid crystal alignment is defined by the direction of rubbing).

Before applying an electric field, the orientation of the liquid crystal molecules is determined by the alignment at the surfaces. In a twisted nematic device (the most common liquid crystal device), the surface alignment directions at the two electrodes are perpendicular, and so the molecules arrange themselves in a helical structure, or twist. Because the liquid crystal material is birefringent (i.e. light of different polarizations travels at different speeds through the material), light passing through one polarizing filter is rotated by the liquid crystal helix as it passes through the liquid crystal layer, allowing it to pass through the second polarized filter. Half of the light is absorbed by the first polarizing filter, but otherwise the entire assembly is transparent.

When a voltage is applied across the electrodes, a torque acts to align the liquid crystal molecules parallel to the electric field, distorting the helical structure (this is resisted by elastic forces since the molecules are constrained at the surfaces).

This reduces the rotation of the polarization of the incident light, and the device appears gray. If the applied voltage is large enough, the liquid crystal molecules are completely untwisted and the polarization of the incident light is not rotated at all as it passes through the liquid crystal layer. This light will then be polarized perpendicular to the second filter, and thus be completely blocked and the pixel will appear black. By controlling the voltage applied across the liquid crystal layer in each pixel, light can be allowed to pass through in varying amounts, correspondingly illuminating the pixel.

With a twisted nematic liquid crystal device it is usual to operate the device between crossed polarizers, such that it appears bright with no applied voltage. With this setup, the dark voltage-on state is uniform. The device can be operated between parallel polarizers, in which case the bright and dark states are reversed (in this configuration, the dark state appears blotchy).

Both the liquid crystal material and the alignment layer material contain ionic compounds. If an electric field of one particular polarity is applied for a long period of time, this ionic material is attracted to the surfaces and degrades the device performance. This is avoided by applying either an alternating current, or by reversing the polarity of the electric field as the device is addressed (the response of the liquid crystal layer is identical).

12.3 Brief history

1904: Otto Lehmann publishes his work "Liquid Crystals"

1911: Charles Mauguin describes the structure and properties of liquid crystals.

1936: The Marconi Wireless Telegraph company patents the first practical application of the technology, "The Liquid Crystal Light Valve".

1962: The first major English language publication on the subject "Molecular Structure and Properties of Liquid Crystals", by Dr. **George W. Gray**.

Pioneering work on liquid crystals was undertaken in the late 1960s by the UK's Royal Radar Establishment at Malvern. The team at RRE supported ongoing work by George Gray and his team at the University of Hull who ultimately discovered the cyanobiphenyl liquid crystals (which had correct stability and temperature properties for application in LCDs).

The first operational LCD was based on the Dynamic Scattering Mode (DSM) and was introduced in 1968 by a group at RCA in the USA headed by George Heilmeier. Heilmeier founded Optel, which introduced a number of LCDs based on this technology.

In December 1970, the twisted nematic field effect in liquid crystals was filed for patent by M. Schadt and W. Helfrich, then working for the Central Research Laboratories of Hoffmann-LaRoche in Switzerland (Swiss patent No. 532 261). James Fergason at Kent State University filed an identical patent in the USA in February 1971. In 1971 the company of Fergason ILIXCO (now LXD Incorporated) produced the first LCDs based on the TN-effect, which soon superseded the poor-quality DSM types due improvements of lower operating voltages and lower power consumption.

In 1972, the first active-matrix liquid crystal display panel was produced in the United States by T. Peter Brody.

In 2005, Mary Lou Jepsen developed a new type of LCD display for the One Laptop Per Child project to reduce power consumption and manufacture cost of the Children's Machine. This display uses a plastic diffraction grating and lenses on the rear of the LCD to illuminate the colored sub pixels. This method absorbs very little light, allowing for a much brighter display with a lower powered backlight. Replacing the backlight with a white LED allows for reduced costs and increased durability as well as a wider color gamut.

12.4 Colour displays

In color LCDs each individual pixel is divided into three cells, or sub pixels, which are colored red, green, and blue, respectively, by additional filters (pigment filters, dye filters and metal oxide filters). Each sub pixel can be controlled independently to yield thousands or millions of possible colors for each pixel. Older CRT monitors employ a similar method.

Color components may be arrayed in various pixel geometries, depending on the monitor's usage. If software knows which type of geometry is being used in a given LCD, this can be used to increase the apparent resolution of the monitor through sub pixel rendering. This technique is especially useful for text anti-aliasing.

Fig 12.2 – LCD display.

12.5 Quality control

Some LCD panels have defective transistors, causing permanently lit or unlit pixels which are commonly referred to as stuck pixels or dead pixels respectively. Unlike integrated circuits, LCD panels with a few defective pixels are usually still usable. It is also economically prohibitive to discard a panel with just a few defective pixels because LCD panels are much larger than ICs. Manufacturers have different standards for determining a maximum acceptable number of defective pixels. The maximum acceptable number of defective pixels for LCD varies a lot (such as zero-tolerance policy and 11-dead-pixel policy from one brand to another, often a hot debate between manufacturers and customers. To regulate the acceptability of defects and to protect the end user, ISO released the ISO 13406-2 standard. However, not every LCD manufacturer conforms to the ISO standard and the ISO standard is quite often interpreted in different ways.

12.6 Drawbacks

LCD technology still has a few drawbacks in comparison to some other display technologies:

While CRTs are capable of displaying multiple video resolutions without introducing artifacts, LCD displays produce crisp images only in their "native resolution" and, sometimes, fractions of that native resolution. Attempting to run LCD display panels at non-native resolutions usually results in the panel scaling the image, which introduces blurriness.

LCD displays have a lower contrast ratio than that on a plasma display or CRT. This is due to their "light valve" nature: some light always leaks out and turns black into gray. In brightly lit rooms the contrast of LCD monitors can, however, exceed some CRT displays due to higher maximum brightness.

LCDs have longer response time than their plasma and CRT counterparts, older displays creating visible ghosting when images rapidly change; this drawback, however, is continually improving as the technology progresses and is hardly noticeable in current LCD displays with "overdrive" technology. Most newer LCDs have response times of around 8 ms.

In addition to the response times, some LCD panels have significant input lag, which makes them unsuitable for fast and time-precise mouse operations (CAD design, FPS gaming) as compared to CRTs

Overdrive technology on some panels can produce artifacts across regions of rapidly transitioning pixels (eg. video images) that looks like increased image noise or halos. This is a side effect of the pixels being driven past their intended brightness value (or rather the intended voltage necessary to produce this necessary brightness/colour) and then allowed to fall back to the target brightness in order to enhance response times.

CHAPTER 13 – Wi-Fi Module(ESP 8266)

13.1 ESP8266

Espressif Systems' Smart Connectivity Platform (ESCP) of high performance wireless SOCs, for mobile platform designers, provides unsurpassed ability to embed Wi-Fi capabilities within other systems, at the lowest cost with the greatest functionality.

ESP8266 offers a complete and self-contained Wi-Fi networking solution, allowing it to either host the application or to offload all Wi-Fi networking functions from another application processor.
When ESP8266 hosts the application, and when it is the only application processor in the device, it is able to boot up directly from an external flash. It has integrated cache to improve the performance of the system in such applications, and to minimize the memory requirements.
Alternately, serving as a Wi-Fi adapter, wireless internet access can be added to any microcontroller-based design with simple connectivity through UART interface or the CPU AHB bridge interface.
ESP8266 on-board processing and storage capabilities allow it to be integrated with the sensors and other application specific devices through its GPIOs with minimal development up-front and minimal loading during runtime. With its high degree of on-chip integration, which includes the antenna switch balun, power management converters, it requires minimal external circuitry, and the entire solution, including front-end module, is designed to occupy minimal PCB area.

Sophisticated system-level features include fast sleep/wake context switching for energy-efficient VoIP, adaptive radio biasing for low-power operation, advance signal processing, and spur cancellation and radio co-existence features for common cellular, Bluetooth, DDR, LVDS, LCD interference mitigation.

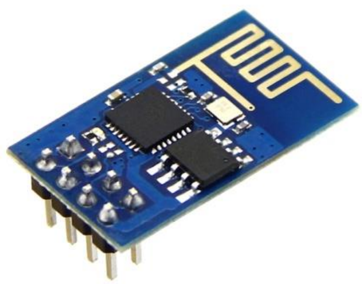


Fig 13.1 – wi-fi module (ESP8266)

13.2 Features

- 802.11 b/g/n protocol
- Wi-Fi Direct (P2P), soft-AP
- Integrated TCP/IP protocol stack
- Integrated TR switch, balun, LNA, power amplifier and matching network
- Integrated PLL, regulators, and power management units
- +19.5dBm output power in 802.11b mode
- Integrated temperature sensor
- Supports antenna diversity
- Power down leakage current of < 10uA
- Integrated low power 32-bit CPU could be used as application processor
- SDIO 2.0, SPI, UART
- STBC, 1×1 MIMO, 2×1 MIMO
- A-MPDU & A-MSDU aggregation & 0.4□s guard interval
- Wake up and transmit packets in < 2ms
- Standby power consumption of < 1.0mW (DTIM3)

ULTRA LOW POWER TECHNOLOGY

ESP8266 has been designed for mobile, wearable electronics and Internet of Things applications with the aim of achieving the lowest power consumption with a combination of several proprietary techniques. The power saving architecture operates in 3 modes: active mode, sleep mode and deep sleep mode.
By using advance power management techniques and logic to power-down functions not required and to control switching between sleep and active modes, ESP8266 consumes less than 12uA in sleep mode and less than 1.0mW (DTIM=3) or less than 0.5mW (DTIM=10) to stay connected to the access point.
When in sleep mode, only the calibrated real-time clock and watchdog remains active. The real-time clock can be programmed to wake up the ESP8266 at any required interval.
The ESP8266 can be programmed to wake up when a specified condition is detected. This minimal wake-up time feature of the ESP8266 can be utilized by mobile device SOCs, allowing them to remain in the low-power standby mode until Wi-Fi is needed.
In order to satisfy the power demand of mobile and wearable electronics, ESP8266 can be programmed to reduce the output power of the PA to fit various application profiles, by trading off range for power consumption.

CHAPTER 14 - MICROCONTROLLER(MOC302) , TRIAC & DIODE

14.1 MICROCONTROLLER(MOC 302)

1. DESCRIPTION

The MOC301XM and MOC302XM series are optically isolated triac driver devices. These devices contain a GaAs infrared
emitting diode and a light activated silicon bilateral switch, which functions like a triac. They are designed for interfacing between
electronic controls and power triacs to control resistive and inductive loads for 115/240 VAC operations.

2. FEATURES

• Excellent IFT stability—IR emitting diode has low degradation
• High isolation voltage—minimum 5300 VAC RMS
• Underwriters Laboratory (UL) recognized—File #E90700
• Peak blocking voltage
– 250V-MOC301XM
– 400V-MOC302XM

• VDE recognized (File #94766)
– Ordering option V (e.g. MOC3023VM)

3. APPLICATIONS

• Industrial controls
• Solenoid/valve controls
• Traffic lights
• Static AC power switch
• Vending machines
• Incandescent lamp dimmers
• Solid state relay
• Motor control

14.2 Triacs(BT 136 SERIES)

The TRIAC is a three terminal semiconductor device for controlling current. It gains its name from the term **Tri**ode for **A**lternating **C**urrent.

It is effectively a development of the SCR or thyristor, but unlike the thruster which is only able to conduct in one direction, the TRIAC is a bidirectional device.

The fact that the TRIAC can be used to control current switching on both halves of an alternating waveform allows much better power utilization. However the TRIAC is not always as convenient for some high power applications where its switching is more difficult.

5. TRIAC symbol

The circuit symbol recognizes the way in which the TRIAC operates. Seen from the outside it may be viewed as two back to back thyristors and this is what the circuit symbol indicates.

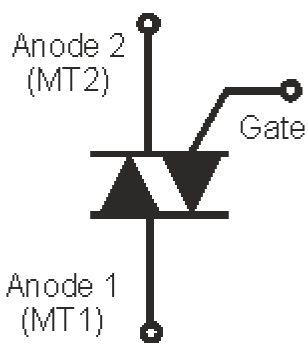


Fig 14.1 -TRIAC symbol for circuit diagrams

On the TRIAC symbol there are three terminals. These are the Gate and two other terminals are often referred to as an "Anode" or "Main Terminal". As the TRIAC has two of these they are labeled either Anode 1 and Anode 2 or Main Terminal, MT1 and MT2.

6. TRIAC basics

The TRIAC is a component that is effectively based on the thyristor. It provides AC switching for electrical systems. Like the thyristor, the TRIACs are used in many electrical switching applications. They find particular use for circuits in light dimmers, etc., where they enable both halves of the AC cycle to be used. This makes them more efficient in terms of the usage of the power available. While it is possible to use two thyristors back to back, this is not always cost effective for low cost and relatively low power applications.

It is possible to view the operation of a TRIAC in terms of two thyristors placed back to back.

14.3 DIODE

The diode is a p-n junction device. Diode is the component used to control the flow of the current in any one direction. The diode widely works in forward bias.

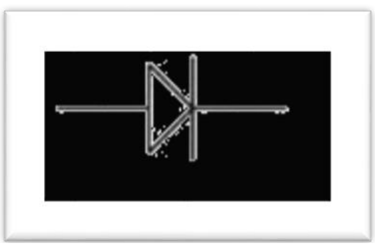


FIGURE 14.2 - SYMBOLIC REPRESENTATION OF DIODE

Diode when the current flows from the P to N direction. Then it is in forward bias. The Zener diode is used in reverse bias function i.e. N to P direction. Visually the identification of the diode`s terminal can be done by identifying he silver/black line. The silver/black line is the negative terminal (cathode) and the other terminal is the positive terminal (cathode).
If the connections are reversed, a very little current will flow. This is because under this condition, the p-type material will accept the electrons from the negative terminal of the battery and the N-type material will give up its free electrons to the battery, resulting in the state of electrical equilibrium since the N-type material has no more electrons. Thus there will be a small current to flow and the diode is called Reverse biased.
Thus the Diode allows direct current to pass only in one direction while blocking it in the other direction. Power diodes are used in concerting AC into DC. In this, current will flow freely during the first half cycle (forward biased) and practically not at all during the other half cycle (reverse biased). This makes the diode an effective rectifier, which convert ac into pulsating dc. Signal diodes are used in radio circuits for detection. Zener diodes are used in the circuit to control the voltage.

Some common diodes are:-

1. Zener diode.

2. Photo diode
.
3. Light Emitting diode.

APPLICATION

•Diodes: Rectification, free-wheeling, etc

•Zener diode: Voltage control, regulator etc.

•Tunnel diode: Control the current flow, snobbier circuit, etc.

CHAPTER 15- Transformer

15.1 Transformer

A **transformer** is an electrical device that transfers energy from one circuit to another by magnetic coupling with no moving parts. A transformer comprises two or more coupled windings, or a single tapped winding and, in most cases, a magnetic core to concentrate magnetic flux. A changing current in one winding creates a time-varying magnetic flux in the core, which induces a voltage in the other windings. Michael Faraday built the first transformer, although he used it only to demonstrate the principle of electromagnetic induction and did not foresee the use to which it would eventually be put.

Fig 15.1 -Three-phase pole-mounted step-down transformer.

15.2 Overview

The transformer is one of the simplest of electrical devices, yet transformer designs and materials continue to be improved. Transformers are essential for high voltage power transmission, which makes long distance transmission economically practical. This advantage was the principal factor in the selection of alternating current power transmission in the "War of Currents" in the late 1880s.

Audio frequency transformers (at the time called repeating coils) were used by the earliest experimenters in the development of the telephone. While some electronics applications of the transformer have been made obsolete by new technologies, transformers are still found in many electronic devices.

Transformers come in a range of sizes from a thumbnail-sized coupling transformer hidden inside a stage microphone to huge gigawatt units used to interconnect large portions of national power grids. All operate with the same basic principles and with many similarities in their parts.

Fig 15.2 -Single phase pole-mounted step-down transformer

Transformers alone cannot do the following:

Convert DC to AC or vice versa

Change the voltage or current of DC

Change the AC supply frequency.

However, transformers are components of the systems that perform all these functions

An analogy

The transformer may be considered as a simple two-wheel 'gearbox' for electrical voltage and current. The primary winding is analogous to the input shaft and the secondary winding to the output shaft. In this analogy, current is equivalent to shaft speed, voltage to shaft torque. In a gearbox, mechanical power (torque multiplied by speed) is constant (neglecting losses) and is equivalent to electrical power (voltage multiplied by current) which is also constant.

The gear ratio is equivalent to the transformer step-up or step-down ratio. A step-up transformer acts analogously to a reduction gear (in which mechanical power is transferred from a small, rapidly rotating gear to a large, slowly rotating gear): it trades current (speed) for voltage (torque), by transferring power from a primary coil to a secondary coil having more turns.

A step-down transformer acts analogously to a multiplier gear (in which mechanical power is transferred from a large gear to a small gear): it trades voltage (torque) for current (speed), by transferring power from a primary coil to a secondary coil having fewer turns.

15.3 Coupling by mutual induction

A simple transformer consists of two electrical conductors called the **primary winding** and the **secondary winding**. Energy is coupled between the windings by the time-varying magnetic flux that passes through (links) both primary and secondary windings. When the current in a coil is switched on or off or changed, a voltage is induced in a neighboring coil. The effect, called mutual inductance, is an example of electromagnetic induction

Simplified analysis

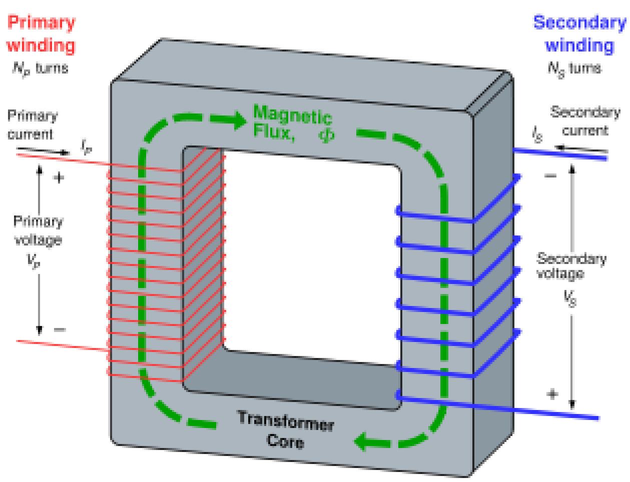


Fig 15.3 A practical step-down transformer showing magnetising flux in the core

If a time-varying voltage v_P is applied to the primary winding of N_P turns, a current will flow in it producing a magnetomotive force (MMF). Just as an electromotive force (EMF) drives current around an electric circuit, so MMF tries to drive magnetic flux through a magnetic circuit. The primary MMF produces a varying magnetic flux Φ_P in the core, and, with an open circuit secondary winding, induces a back electromotive force (EMF) in opposition to v_P. In accordance with Faraday's law of induction, the voltage induced across the primary winding is proportional to the rate of change of flux:

$$v_P = N_P \frac{d\Phi_P}{dt} \quad \text{and} \quad v_S = N_S \frac{d\Phi_S}{dt}$$

15.4 Analysis of the ideal transformer

This treats the windings as a pair of mutually coupled coils with both primary and secondary windings passing currents and with each coil linked with the same magnetic flux. In an *ideal* transformer the core requires no MMF. The primary and secondary MMFs, acting in opposite directions, are exactly balancing each other and hence, there is no overall resultant MMF acting on the core. There is, however, no need for any MMF acting on the core of an ideal transformer to create a magnetic flux. The flux in the core is unambiguously determined by the applied primary voltage in accordance with Faraday's law of induction, or rather by an integration of the aforesaid law.

In the ideal transformer at no load, i.e. with the secondary load removed, the voltage applied to the primary winding is opposed by an induced EMF in the winding equal to the applied voltage in accordance with Faraday's law of induction. No current will flow in the winding since no MMF is required by the core. One might also say that the inductance of the primary winding at no load is infinitely large.

Further on, the balance of the primary and secondary MMFs i.e. $N_P i_P = N_S i_S$, gives the ratio of the secondary and primary currents as:

$$\frac{i_P}{i_S} = \frac{N_S}{N_P}$$

That is, the ratio between the primary and secondary currents is the inverse of the ratio between the corresponding voltages.

15.5 DC voltages and currents

A DC voltage applied to a winding of an ideal transformer will cause a DC voltage to be induced in the other winding. This is because any voltage applied will create a changing flux. However, using a transformer with DC voltages would require the magnetic flux in the core (and current supplied by the DC voltage source) to increase without bound. If there is resistance in the winding, the final current and final flux will be limited by that. Once the flux stops changing, no voltage is induced in the other winding. If the core is made of anything other than air (e.g. iron) it will also saturate. Saturation will drastically reduce the amount of power that can be transferred, as well as causing the current to rise even more steeply. For these reasons it is very important to avoid having any DC component in the voltages being applied to a transformer. The amount of power being dissipated in the winding will be limited solely by the winding resistance.

15.6 The universal EMF equation

If the flux in the core is sinusoidal, the relationship for either winding between its number of turns, voltage, magnetic flux density and core cross-sectional area is given by the universal emf equation (from Faraday's law):

$$E = \frac{2\pi f N a B}{\sqrt{2}} = 4.44 f N a B$$

where

E is the sinusoidal rms or root mean square voltage of the winding,

f is the frequency in hertz,

N is the number of turns of wire on the winding,

A is the cross-sectional area of the core in square meters

B is the peak magnetic flux density in teslas,

Other consistent systems of units can be used with the appropriate conversions in the equation.

Practical considerations

15.7 Classifications

Transformers are adapted to numerous engineering applications and may be classified in many ways:

By power level (from fraction of a volt-ampere(VA) to over a thousand MVA),

By application (power supply, impedance matching, circuit isolation),

By frequency range (power, audio, radio frequency(RF))

By voltage class (a few volts to about 750 kilovolts)

By cooling type (air cooled, oil filled, fan cooled, water cooled, etc.)

By purpose (distribution, rectifier, arc furnace, amplifier output, etc.).

15.7 DC voltages and currents

A DC voltage applied to a winding of an ideal transformer will cause a DC voltage to be induced in the other winding. This is because any voltage applied will create a changing flux. However, using a transformer with DC voltages would require the magnetic flux in the core (and current supplied by the DC voltage source) to increase without bound. If there is resistance in the winding, the final current and final flux will be limited by that. Once the flux stops changing, no voltage is induced in the other winding. If the core is made of anything other than air (e.g. iron) it will also saturate. Saturation will drastically reduce the amount of power that can be transferred, as well as causing the current to rise even more steeply. For these reasons it is very important to avoid having any DC component in the voltages being applied to a transformer. The amount of power being dissipated in the winding will be limited solely by the winding resistance.

It is possible to draw DC current from a transformer, as a DC current merely represents a constant offset to the flux in the core. DC currents are caused by some non-linear loads (e.g. a half-wave rectifier). Most transformers are designed to be driven to near saturation without any DC current components, so having a DC current will make the transformer saturate more easily. Full-wave rectifiers do not have this issue, since the current they draw has no DC component.

The equation shows that the EMF of a transformer at a given flux density increases with frequency. By operating at higher frequencies, transformers can be physically more compact without reaching saturation, and a given core is able to transfer more power. However, other properties of the transformer, such as losses within the core and skin-effect, also increase with frequency. Generally, operation of a transformer at its designed voltage but at a higher frequency than intended will lead to reduced magnetizing (no load primary) current. At a frequency lower than the design value, with the rated voltage applied, the magnetizing current may increase to an excessive level.

Steel cores develop a larger hysteresis loss due to eddy currents as the operating frequency is increased. Ferrite or thinner steel laminations for the core are typically used for frequencies above 1 kHz. The thinner steel laminations serve to reduce the eddy currents. Some types of very thin steel laminations can operate at up to 10 kHz or higher. Ferrite is used in higher frequency applications, extending to the VHF band and beyond. Aircraft traditionally use 400 Hz power systems since the slight increase in thermal losses is more than offset by the reduction in core and winding weight. Military gear includes 400 Hz (and other frequencies) to supply power for radar or servomechanisms.

Fly back transformers are built using ferrite cores. They supply high voltage to the CRTs at the frequency of the horizontal oscillator. In the case of television sets, this is about 15.7 kHz. It may be as high as 75 - 120 kHz for high-resolution computer monitors.

Switching power supply transformers usually operate between 30-1000 kHz. The tiny cores found in wristwatch backlight power supplies produce audible sound (about 1 kHz).

Operation of a power transformer at other than its design frequency may require assessment of voltages, losses, and cooling to establish if safe operation is practical.

Operation at different frequencies

The equation shows that the EMF of a transformer at a given flux density increases with frequency. By operating at higher frequencies, transformers can be physically more compact without reaching saturation, and a given core is able to transfer more power. However, other properties of the transformer, such as losses within the core and skin-effect, also increase with frequency. Generally, operation of a transformer at its designed voltage but at a higher frequency than intended will lead to reduced magnetizing (no load primary) current. At a frequency lower than the design value, with the rated voltage applied, the magnetizing current may increase to an excessive level.

Steel cores develop a larger hysteresis loss due to eddy currents as the operating frequency is increased. Ferrite or thinner steel laminations for the core are typically used for frequencies above 1 kHz. The thinner steel laminations serve to reduce the eddy currents. Some types of very thin steel laminations can operate at up to 10 kHz or higher. Ferrite is used in higher frequency applications, extending to the VHF band and beyond. Aircraft traditionally use 400 Hz power systems since the slight increase in thermal losses is more than offset by the reduction in core and winding weight. Military gear includes 400 Hz (and other frequencies) to supply power for radar or servomechanisms.

Fly back transformers are built using ferrite cores. They supply high voltage to the CRTs at the frequency of the horizontal oscillator. In the case of television sets, this is about 15.7 kHz. It may be as high as 75 - 120 kHz for high-resolution computer monitors.

Switching power supply transformers usually operate between 30-1000 kHz. The tiny cores found in wristwatch backlight power supplies produce audible sound (about 1 kHz).

Operation of a power transformer at other than its design frequency may require assessment of voltages, losses, and cooling to establish if safe operation is practical. For example, transformers at hydroelectric generating stations may be equipped with over-excitation protection, so-called "volts per hertz" protection relays, to protect the transformer from overvoltage at higher-than-rated frequency which may occur if a generator loses its connected load.

Uses of transformers

1. For supplying power from an alternating current power grid to equipment which uses a different voltage.
2. Electric power transmission over long distances.
3. Large, specially constructed power transformers are used for electric arc furnaces used in steelmaking.
4. Rotating transformers are designed so that one winding turns while the other remains stationary. A common use was the video head system as used in VHS and Beta video tape players. These can pass power or radio signals from a stationary mounting to a rotating mechanism, or radar antenna.
5. Sliding transformers can pass power or signals from a stationary mounting to a moving part such as a machine tool head.
6. A transformer-like device is used for position measurement. See linear variable differential transformer.
7. Some rotary transformers are used to couple signals between two parts which rotate in relation to each other.
8. Other rotary transformers are precisely constructed in order to measure distances or angles. Usually they have a single primary and two or more secondaries, and electronic circuits measure the different amplitudes of the currents in the secondaries. See synchrony and resolver.
9. Small transformers are often used internally to couple different stages of radio receivers and audio amplifiers.
10. Transformers may be used as external accessories for impedance matching; for example to match a microphone to an amplifier.
11. Balanced-to-unbalanced conversion. A special type of transformer called a balun is used in radio and audio circuits to convert between balanced linecircuits and unbalanced transmission lines such as antenna down leads.

15.8 Circuit symbols

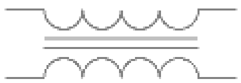
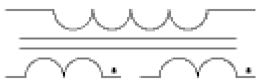
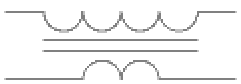
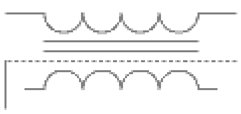
	Transformer with two windings and iron core.
	Transformer with three windings. The dots show the relative winding configuration of the windings.
	Step-down or step-up transformer. The symbol shows which winding has more turns, But does not usually show the exact ratio.
	Transformer with electrostatic screen, which prevents capacitive coupling between the windings.

Table 4 – Circuit symbol used in transformer

15.9 Losses

An ideal transformer would have no losses, and would therefore be 100% efficient. In practice, energy is dissipated due both to the resistance of the windings known as copper loss or I^2 R loss, and to magnetic effects primarily attributable to the core (known as *iron loss* measured in watts per pound). Transformers are, in general, highly efficient. Large power transformers (over 50 MVA) may attain efficiency as high as 99.75%. Small transformers, such as a plug-in "power brick" used to power small consumer electronics, may be less than 85% efficient.

Transformer losses arise from:

1. Winding resistance

Current flowing through the windings causes resistive heating of the conductors (I^2 R loss). At higher frequencies, skin effect and proximity effect create additional winding resistance and losses.

2. Eddy currents

Induced eddy currents circulate within the core, causing resistive heating. Silicon is added to the steel to help in controlling eddy currents. Adding silicon also has the advantage of stopping aging of the electrical steel that was a problem years ago.

3. Hysteresis losses

Each time the magnetic field is reversed, a small amount of energy is lost to hysteresis within the magnetic core. The amount of hysteresis is a function of the particular core material.

4. Magnetostriction

Magnetic flux in the core causes it to physically expand and contract slightly with the alternating magnetic field, an effect known as magnetostriction. This in turn causes losses due to frictional heating in susceptible ferromagnetic cores.

5. Mechanical losses

In addition to magnetostriction, the alternating magnetic field causes fluctuating electromagnetic forces between the primary and secondary windings. These incite vibrations within nearby metalwork, creating a familiar humming or buzzing noise, and consuming a small amount of power.

15.10 Operation at different frequencies

The equation shows that the EMF of a transformer at a given flux density increases with frequency. By operating at higher frequencies, transformers can be physically more compact without reaching saturation, and a given core is able to transfer more power. However, other properties of the transformer, such as losses within the core and skin-effect, also increase with frequency. Generally, operation of a transformer at its designed voltage but at a higher frequency than intended will lead to reduced magnetizing (no load primary) current. At a frequency lower than the design value, with the rated voltage applied, the magnetizing current may increase to an excessive level.

Steel cores develop a larger hysteresis loss due to eddy currents as the operating frequency is increased. Ferrite or thinner steel laminations for the core are typically used for frequencies above 1 kHz. The thinner steel laminations serve to reduce the eddy currents. Some types of very thin steel laminations can operate at up to 10 kHz or higher. Ferrite is used in higher frequency applications, extending to the VHF band and beyond.

Aircraft traditionally use 400 Hz power systems since the slight increase in thermal losses is more than offset by the reduction in core and winding weight. Military gear includes 400 Hz (and other frequencies) to supply power for radar or servomechanisms.

Fly back transformers are built using ferrite cores. They supply high voltage to the CRTs at the frequency of the horizontal oscillator. In the case of television sets, this is about 15.7 kHz. It may be as high as 75 - 120 kHz for high-resolution computer monitors.

Switching power supply transformers usually operate between 30-1000 kHz. The tiny cores found in wristwatch backlight power supplies produce audible sound (about 1 kHz).

Operation of a power transformer at other than its design frequency may require assessment of voltages, losses, and cooling to establish if safe operation is practical. For example, transformers at hydroelectric generating stations may be equipped with over-excitation protection, so-called "volts per hertz" protection relays, to protect the transformer from overvoltage at higher-than-rated frequency which may occur if a generator loses its connected load.

CHAPTER 16 - PROGRAM

16.1 Programming

- All the software developed for this project will be loaded into the memory of the microcontroller.
- The language must be supported by the compiler

  The compiler supports C and Assembly

Reasons for Selection C Programming Language:

- Vast amount of online resources
- Ease of development
- Team members have experience of coding in C.
- All the software developed for this project will be loaded into the memory of the microcontroller.
- The language must be supported by the compiler

  The compiler supports C and Assembly

Reasons for Selection C Programming Language:

- Vast amount of online resources
- Ease of development
- Team members have experience of coding in C.

16.2 Program Code

```
#include<regx51.h>

#include<delay.h>

#include<string.h>

#include<studio.h>

#define LCD_clear()LCD_command(0x01)        /* Clear display LCD */

#define LCD_origin()LCD_command(0x2)        /* Set to origin LCD */

#define LCD_row1() LCD_command(0x80)        /* Begin at Line 1 */

#define LCD_row2() LCD_command(0xC0)   /* Begin at Line 2 */

void LCD_enable();

void LCD_command(unsigned char command);

void LCD_putc(unsigned char ch);

void LCD_puts(unsigned char *lcd_string);

void LCD_init();

void sendc(unsigned char ch);

void sends(unsigned char *str);
```

```
void serial_init();

unsigned char arr[15],t,con[10];

unsigned char recvb();

void main()

{

LCD_init(); //initialize lcd

LCD_command(0x80); //select lcd line one

LCD_puts("   WiFi Based   ");

LCD_command(0xc0); //select lcd line two

LCD_puts("   Automation   ");

delay(1000);

LCD_command(0x80);

LCD_puts("Project Team    ");

LCD_command(0xc0);

LCD_puts("Shiv Shankar    ");

delay(1000);
```

```
LCD_command(0x80);

LCD_puts("Shubham Mishra  ");

LCD_command(0xc0);

LCD_puts("Shivani Yadav   ");

delay(1000);

LCD_command(0x80);

LCD_puts("E.C.E. Final Yr.");

LCD_command(0xc0);

LCD_puts("BBDU Lucknow    ");

delay(1000);

serial_init(); // initialize serial port to communicate with wifi module

sends("AT+CIPMUX=1\r");          // start TCP communication

sends("AT+CIPSERVER=1,2525\r");      //start TCP server at port 2525

LCD_command(0x80); //select lcd line one

LCD_puts("READY TO CONNECT");

LCD_command(0xc0);
```

```
LCD_puts("                ");
for(t=0;t<10;t++) // //receive response after connection with wifi device (mobile phone)
{
con[t]=recvb(); //receive response character and store in to array cont[]
}
LCD_command(0x01); //clear lcd
delay(1000);
LCD_command(0x80);
LCD_puts("D1  D2  D3  D4  ");
LCD_command(0xc0);
LCD_puts("OFF OFF OFF OFF ");
while(1) //infinite loop
{
arr[0]=recvb();        //receive character from wifi module and store in to array
if(arr[0]=='1')             // if received character is 1
{
```

```
P3_4=~P3_4; //toggle device one
}
else
if(arr[0]=='2')
{
P3_5=~P3_5;
}
else
if(arr[0]=='3')
{
P1_7=~P1_7;
}
else
if(arr[0]=='4')
{
P1_6=~P1_6;
```

```
}
else
if(arr[0]=='5')          //if received character is 5 switch on all
{
P3_4=1;P3_5=1;P1_7=1;P1_6=1;
}
else
if(arr[0]=='0')           // if received chracter is 0 switch off all
{
P3_4=0;P3_5=0;P1_7=0;P1_6=0;
}
LCD_command(0xc0);        //check status and print on lcd
if(P3_4==1)     // if device is on
LCD_puts("ON ");
else
LCD_puts("OFF");
```

```
LCD_command(0xc4);

if(P3_5==1)

LCD_puts("ON ");

else

LCD_puts("OFF");

LCD_command(0xc8);

if(P1_7==1)

LCD_puts("ON ");

else

LCD_puts("OFF");

LCD_command(0xcC);

if(P1_6==1)

LCD_puts("ON ");

else

LCD_puts("OFF");

}
}
```

CHAPTER 17-

17.1 Benefits:

1. To control multiple electronic load remotely over wi-fi using android application.

2. Multiple access of electronic appliances at a time.

17.2 Conclusions and Future Scope:

The goal of the paper was to design a system, which should be easy to implement and short ranged. The board is implemented through onboard wi-fi which has an inbuilt wi-fi and have a android system controlling it.

17.3 References:

1. Augarten, Stan (1983). The Most Widely Used Computer on a Chip: The TMS 1000. State of the Art: A Photographic History of the Integrated Circuit (New Haven and New York: Ticknor & Fields). ISBN 0-89919-195-9. Retrieved 2009-12-23.
2. "Oral History Panel on the Development and Promotion of the Intel 8048 Microcontroller" (PDF). Computer History Museum Oral History, 2008. p. 4. Retrieved 2011-06-28.
3. "Atmel's Self-Programming Flash Microcontrollers" (PDF). 2012-01-24. Retrieved 2008-10-25. by Odd Jostein Svendsli 2003
4. Jim Turley. "The Two Percent Solution" 2002.
5. Tom Cantrell "Microchip on the March". Circuit Cellar. 1998.
6. http://www.semico.com
7. Momentum Carries MCUs Into 2011 http://semico.com/content/momentum-carries-mcus-2011
8. "MCU Market on Migration Path to 32-bit and ARM-based Devices". April 25, 2013. It typically takes a global economic recession to upset the diverse MCU marketplace, and that's exactly what occurred in 2009, when the microcontroller business suffered its worst-ever annual sales decline of 22% to $11.1 billion.
9. Bill Giovino. "Zilog Buys Microcontroller Product Lines from Samsung". 2013.