PROJECT REPORT

Submitted by:

AIM

DESIGN AND DEVELOPMENT OF A ELECTRONIC CONTROL OF STEAM TURBINE

INTRODUCTION

TITLE OF THE PROJECT:-

“Conceptual designs development & demonstrations of a ELECTRONIC CONTROL OF STEAM TURBINE”

OBJECTIVES:-

- To Design a electronic and mechanical assembly of a steam turbine.
- Develop new ideas to electronic implement this mechanical assembly purposely.
- To study the circuitry and different types of components & turbine, microcontroller (89c51), relay, LCD display in the mechanical projects.

Words to Know

Condenser: An instrument for cooling air or gases.

Cylinder: The chamber of an engine in which the piston moves.

Piston: A sliding piece that is moved by or moves against fluid pressure within a cylindrical vessel or chamber.

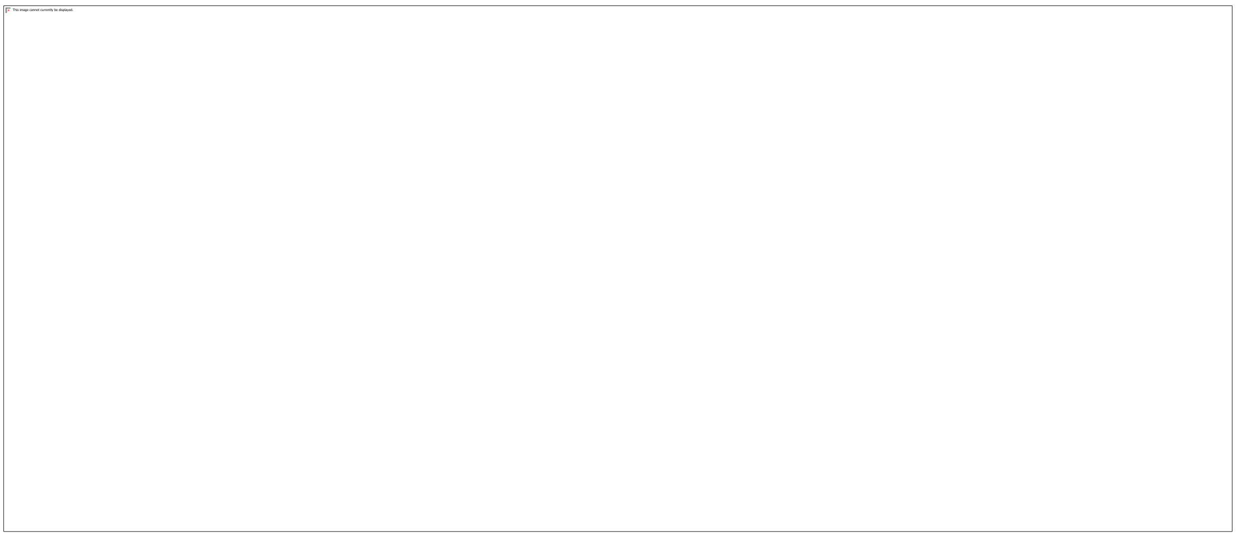
Turbine: An engine that moves in a circular motion when force, such as moving water, is applied to its series of baffles (thin plates or screens) radiating from a central shaft.

It is a speed control for a 25hp steam engine. I already have safety featured built into the mechanical design. This speed control will operate a 4 amp 12 volt linear actuator which will operate the steam valve adjusting steam volume into the cylinder. The circuit needs to be 12 volt. I need an RPM controlling rheostat and a rheostat also for a sensitivity/delay control so the valve isn't moving too much for every little change. RPM of the engine will be around 150 + or - 10% is good. A magnet can be placed on the flywheel and a magnetic pickup sensor can be used unless you have a better way.

Description: steam engine with electromagnetic inlet and release valves equipped with electronic control through unit interlocked to any regulation system.

Advantages: variation of the parameters during operation aimed at achieving the minimum wear of the components and optimise performance.

A steam engine (1) is described, including at least a cylinder (2) equipped with piston (3), at least one steam inlet valve (20) in said cylinder (2) and at least a release valve (21) of the steam from said cylinder(2). Said inlet (20) and release (21) valves are equipped with electromagnetic control



DESCRIPTION

This invention consists of a steam engine with inlet and release valves equipped with electromagnetic control. The scope of this invention is to conceive a steam engine equipped with valves, such to confer longer durability to the engine thanks to the lower wear of the components and optimise performance at various operating conditions. According to the invention, said scope is attained by a steam engine consisting of at least a cylinder equipped with piston, at least one steam inlet valve in said cylinder and at least a release valve of the steam from said cylinder, characterised by the fact that said inlet and release valves are equipped with electromagnetic control by means of an electronic circuit. The characteristics of this invention will be pointed out by the following detailed description of one form of construction, shown in the enclosed drawing as example only and not limitedly to, in which:
figure 1 shows a longitudinal section of a steam engine with closed release valves and open inlet valve, with piston near the upper dead point of the cylinder; figure 2 shows a longitudinal section of a steam engine with closed release valves and inlet valve, with downward piston; figure 3 shows a longitudinal section of a steam engine with open release valves and closed inlet valve, with piston near the lower dead point of the cylinder;
figure 4 shows the diagram of the section of the engine shaft;
figure 5 shows a lateral view of the engine shaft;
figure 6 shows the valves' control electronic circuit;
figure 7 shows schematically, a power generation system with linear generator Figures 1-3 show an example of steam engine 1 including an inlet chamber 9, a cylinder 2 and a sliding piston 3 inside said cylinder 2, including in turn a shaft 4 and a hammering end 6 in non-magnetic steel.

GOVERNING SYSTEM: OVERVIEW

INTRODUCTION

Governing system is an important control system in the power plant as it regulates the turbine speed, power and participates in the grid frequency regulation. For starting, loading governing system is the main operator interface. Steady state and dynamic performance of the power system depends on the power plant response capabilities in which governing system plays a key role. With the development of electro- hydraulic governors, processing capabilities have been enhanced but several adjustable parameters have been provided. A thorough understanding of the governing process is necessary for such adjustment.
In this paper an overview of the steam turbine governing system is given. The role of governing system in frequency control is also discussed.

BASIC GOVERNING SCHEME

Need for governing system

The load on a turbine generating unit does not remain constant and can vary as per consumer requirement. The mismatch between load and generation results in the speed (or frequency) variation. When the load varies, the generation also has to vary to match it to keep the speed constant. This job is done by the governing system. Speed which is an indicator of the generation – load mismatch is used to increase or decrease the generation.

Basic scheme

Governing system controls the steam flow to the turbine in response to the control signals like speed error, power error. It can also be configured to respond to pressure error. It is a closed loop control system in which control action goes on till the power mismatch is reduced to zero.

As shown in the basic scheme given in Fig. 1, the inlet steam flow is controlled by the control valve or the governor valve. It is a regulating valve. The stop valve shown in the figure ahead of control valve is used for protection. It is either closed or open. In emergencies steam flow is stopped by closing this valve by the protective devices.

The governing process can be functionally expressed in the form of signal flow block diagram shown in Fig.2. The electronic part output is a voltage or current signal and is converted into a hydraulic pressure or a piston position signal by the electro- hydraulic converter (EHC). Some designs use high pressure servo valves. The control valves are finally operated by hydraulic control valve servo motors.

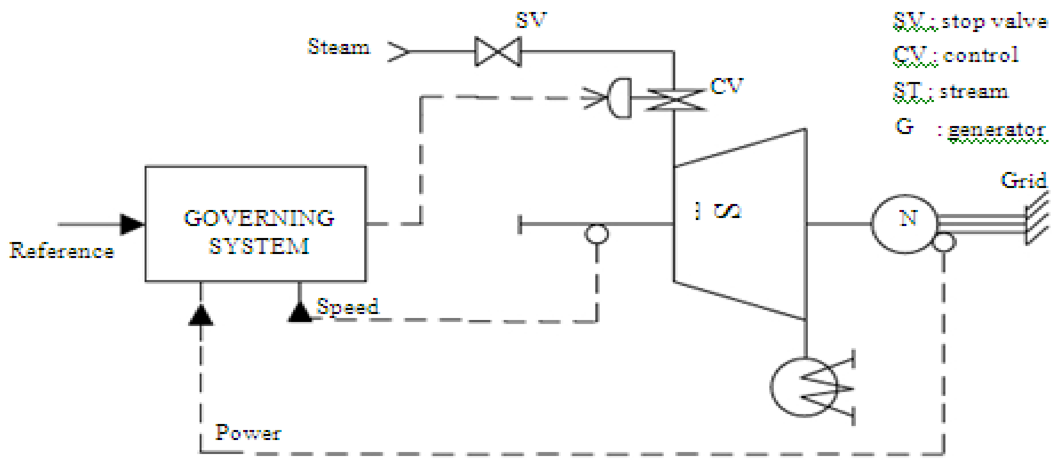


Fig. 1 STEAM TURBINE GOVERNING SCHEME

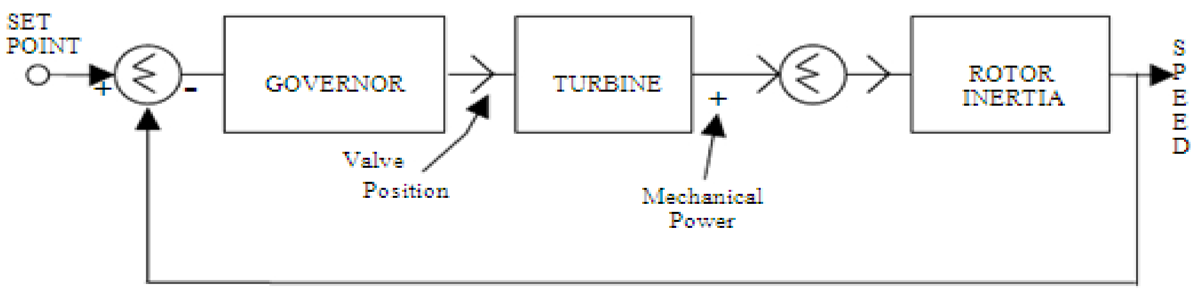


Fig 2 GOVERNING SYSTEM FUNCTIONAL BLOCK DIAGRAM

The steam flow through the control valve is proportional to the valve opening in the operating range. So when valve position changes, turbine steam flow changes and turbine power output also changes proportionally. Thus governing system changes the turbine mechanical power output.

In no load unsynchronized condition, all the power is used to accelerate the rotor only (after meeting rotational losses) and hence the speed changes. The rate of speed change is governed by the inertia of the entire rotor system. In the grid connected condition, only power pumped into the system changes when governing system changes the valve opening.

When the turbine generator unit is being started, governing system controls the speed precisely by regulating the steam flow. Once the unit is synchronized to the power system grid, same control system is used to load the machine. As the connected system has very large inertia (‘infinite bus’), one machine cannot change the frequency of the grid. But it can participate in the power system frequency regulation as part of a group of generators that are used for automatic load frequency control. (ALFC).

As shown in the block diagram, the valve opening changes either by changing the reference setting or by the change in speed (or frequency). This is called **primary regulation**. The reference setting can also be changed remotely by power system load frequency control. This is called **secondary regulation**. Only some generating units in a power system may be used for secondary regulation.

ELECTRO HYDRAULIC GOVERNING SYSTEM

Basically the controls can be described as i) speed control when the machine is not connected to the grid or in isolation and ii) load control when the machine is connected to the grid. The governing system has three functional parts: i) sensing part ii) processing part and iii) amplification. These functions are realized using a set of electronic, hydraulic and mechanical elements, in the electro-hydraulic governor (EHG), as shown in Fig. 3.

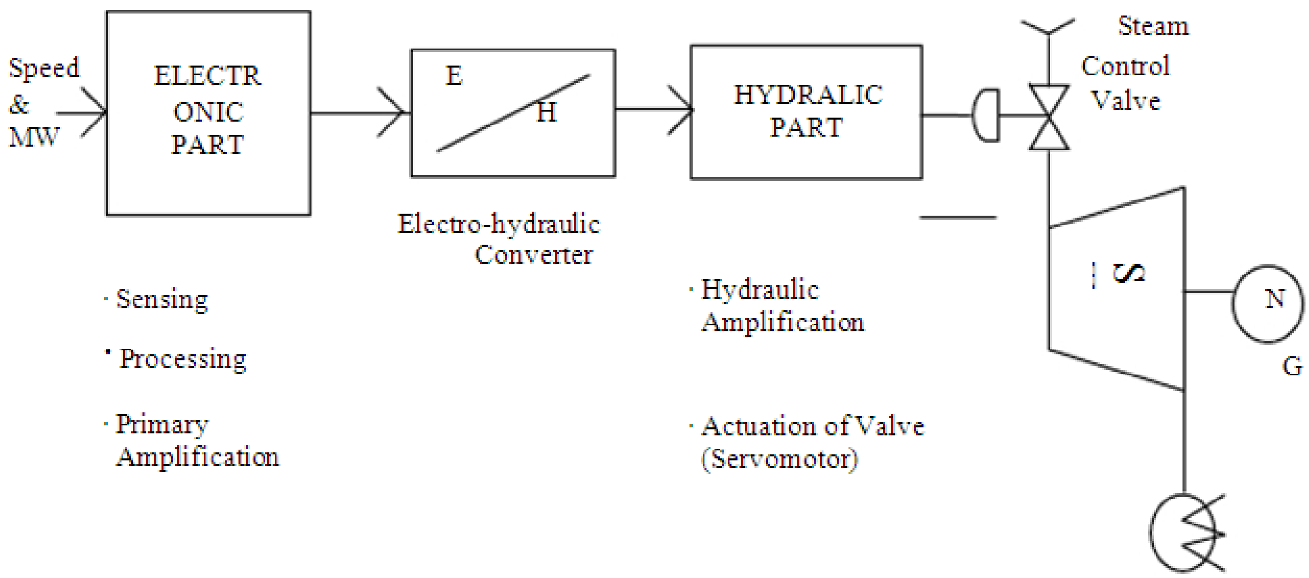


Fig 3 ELECTRO – HYDRAULIC GOVERNOR SCHEME

Earlier, only mechanical-hydraulic elements were employed in mechanical-hydraulic governor (MHG). With the developments in electronics technology, the microprocessor- based and digital signal processor (DSP) based governors are being offered by various manufacturers.

Sensing: to sense speed and power (or MW). The well known fly ball governor is amechanical speed sensor which converts speed signal in to a mechanical movement signal.

Nowadays electronic sensors using Hall Effect principle and/or hydraulic sensor (a special pump whose output pressure varies with pump speed linearly) is used for speed measurement.

Processing: to evolve the desired valve opening command signal: proportional (P) or proportional integral (PI) or proportional integral derivative (PID) or a combination of these. In digital governors the processing is done using software blocks.

Amplification is necessary to obtain sufficient power to operate the steam control valve (where forces due to steam pressure also act)

Speed controller and load controller

In the era of mechanical- hydraulic governors (MHG), the control action is mainly proportional. That is valve opening command is just proportional to the speed error. In the isolated operation where speed control is active and in the inter connected operation where power output or MW only is controlled same control action is present. In the electronic governors it has become easier to realize complex control logic. Separate control actions are incorporated for speed control and load control, as shown in Fig. 4.

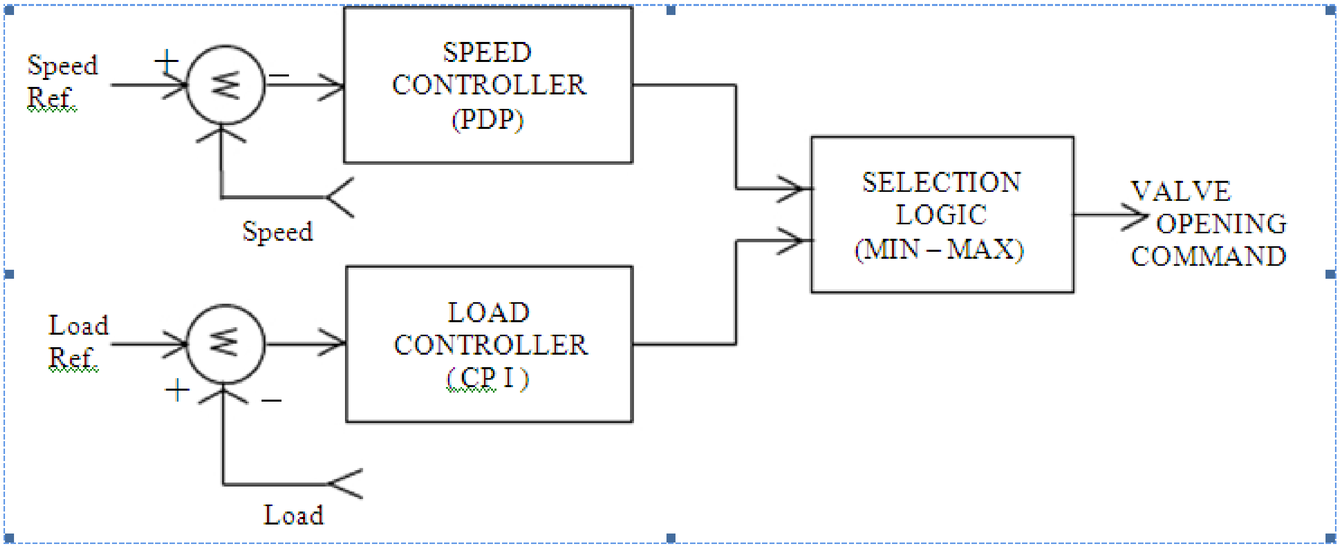


Fig 4 SPEED CONTROLLER AND LOAD CONTROLLER IN EHG

Speed control loop demands additional capability to dampen the speed oscillations. This is obtained using so called proportional derivative (PD) controller. In this the valve opening command is proportional to the rate of change (or derivative) of the error also. This can improve the dynamic response considerably.

Load control loop deals only with MW error, which is obtained using a MW- transducer and is mainly a proportional integral (PI) controller. This loop is active when the steam turbine generator is connected to the grid.
There is a selection logic which decides which control loop should prevail.

Mechanical hydraulic governor as backup
As mentioned earlier mechanical hydraulic governor comprising hydraulic speed sensor, primary amplification devices (called follow up pistons) are provided as backup to the electro hydraulic governor (EHG) in BHEL – KWU sets.

The EHG system and MHG system will be continuously generating command signals for the governor valve opening. Normally both will have the same value. There is a 'minimum logic' provided hydraulically (called hydraulic minimum). According to this whichever calls for lesser valve opening will prevail. In this way in case there is a failure in electronic part mechanical governing system will take over. The turbine can be run with MHG alone.

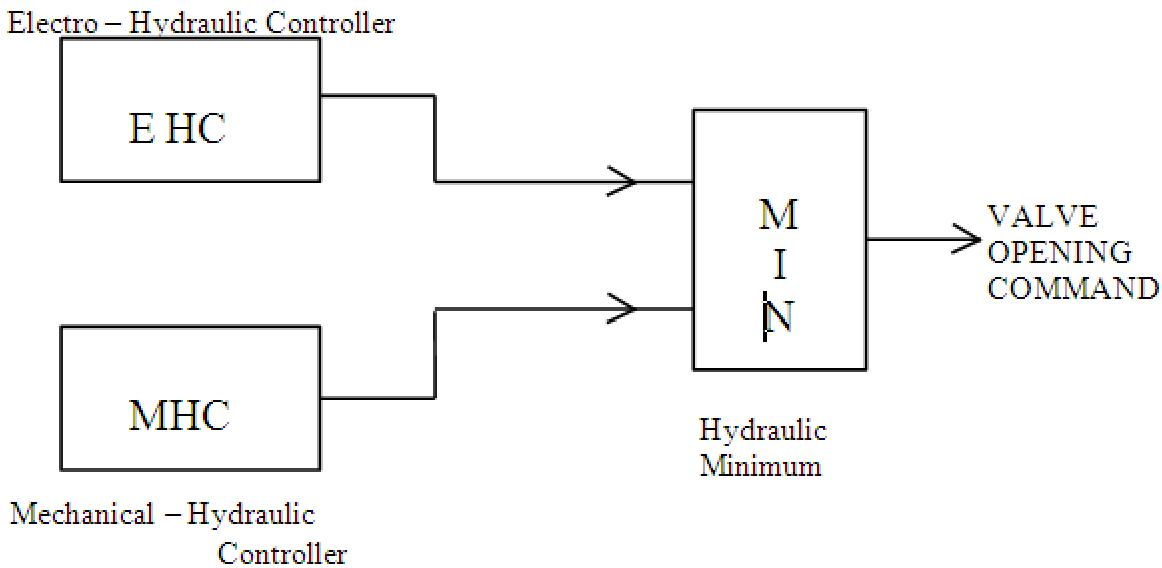


Fig 5 MECHANICAL HYDRAULIC GOVERNOR AS BACKUP

It may be noted that MHGs are functioning reliably in several power stations in India for more than thirty years.

PERFORMANCE ASPECTS

Regulation or droop characteristic

Whenever there is a mismatch in power, speed changes. As seen earlier, the governing system senses this speed change and adjusts valve opening which in turn changes power output. This action stops once the power mismatch is made zero. But the speed error remains. What should be the change in power output for a change in speed is decided by the 'regulation'. If 4 % change in speed causes 100 % change in power output, then the regulation is said to be 4 % (or in per unit 0.04).

The regulation can be expressed in the form of power – frequency characteristic as shown in Fig. 6. At 100 % load the generation is also 100 %, frequency (or speed) is also 100%. When load reduces frequency increases, as generation remains the same. When load reduces by 50 %, frequency increases by 2 %, in the characteristic shown. When load reduces by 100 %, frequency increases by 4 %. In other words 4 % rise in frequency should reduce power generation by 100 %. This 4 % is called 'droop' of 4 %. The characteristic is of 'drooping' type. Droop or regulation is an important parameter in the frequency regulation. In thermal power plants droop value is generally 4 % or 5 %.

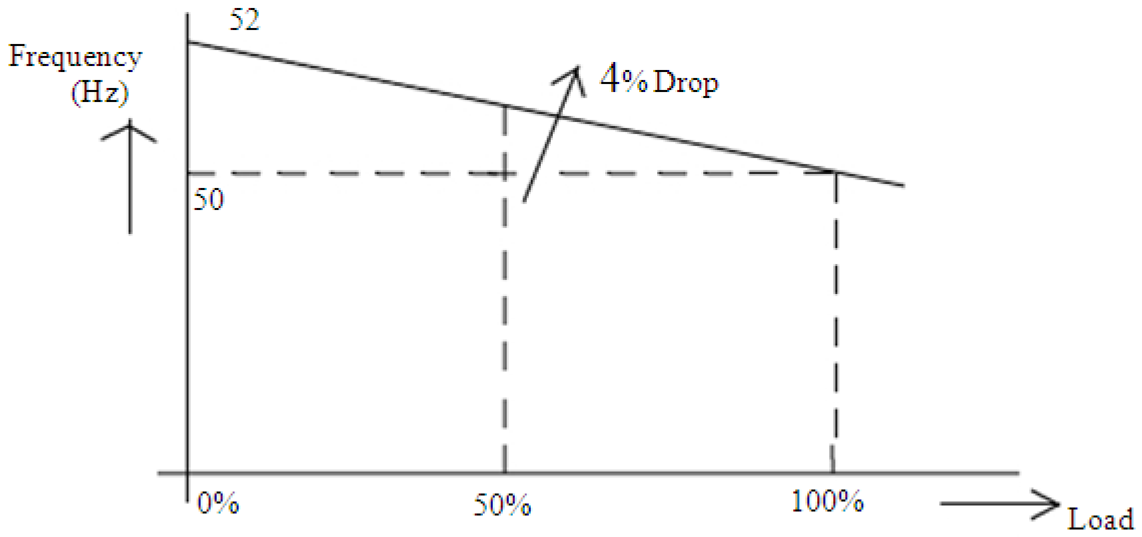


Fig 6 REGULATION OR DROOP CHARACTERSTIC

In terms of control system steady state gain it is expressed as inverse of droop: gain of 25 in per unit corresponds to 4 % (or 0.04 p.u) droop.

Transient performance

The governing system, as noted earlier is a closed loop control system. Stability is an important parameter in any feedback control system. Stability and speed of response depend on the signal modifications done by various blocks in the loop. The closed loop gain depends on the individual block gains and the adjustable gains provided in the speed controller and load controller. The gain at the steady state and during the transient is important in deciding the performance. If the gain is not proper there can be hunting in the system as shown in Fig. 7. Various parameters like speed, power, valve opening will be oscillating continuously and may ultimately result in the trip of the turbine.

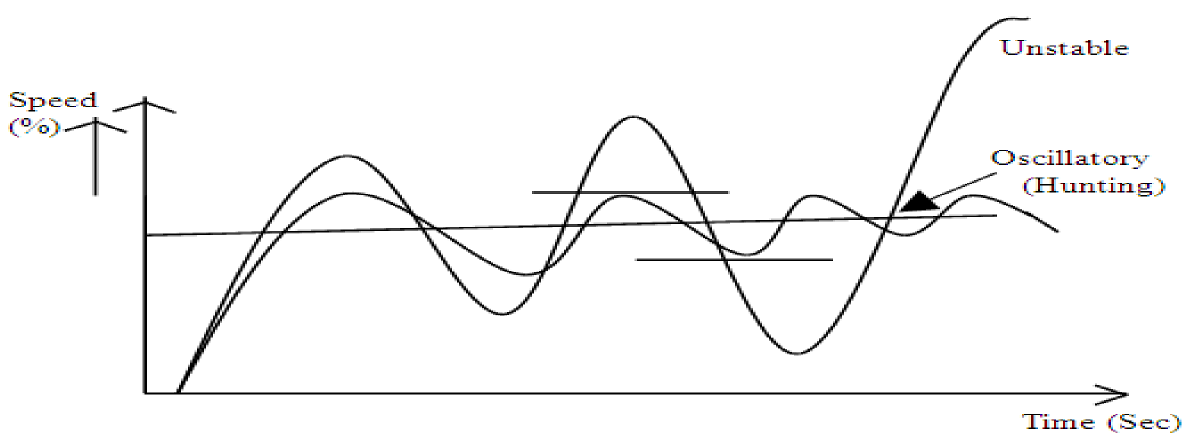


Fig 7 TYPICAL SPEED HUNTING TRANSIENT

Lift- flow characteristic
An important characteristic that decides the loop gain is the valve lift versus flow characteristic. Due to the nature of design, this characteristic is nonlinear. Though linearization is done either in the forward path or reverse path using mechanical cam, the gain introduced is different at low openings. The effective closed loop gain is less resulting in less damping capability at low loads.

Transient speed rise
Governing system maintains the turbine speed as set by the reference. When there are disturbances, the response should be quick otherwise speed may continue to deviate. Transient speed rise (TSR) is one important criterion that is used to judge the response capability of the governing system. Load throw off or load rejection is a major disturbance. When the TG unit is running at full load, if the circuit breaker opens, load is cut off. The full load steam flow causes the rotor to accelerate. The steam inflow is to be cutoff as soon as possible. It cannot be done instantaneously as the hydro mechanical elements take certain time to respond. Speed shoots up and then falls gradually due to the closure of control valve, as shown in Fig. 8. The peak value of speed is called transient speed rise (TSR).

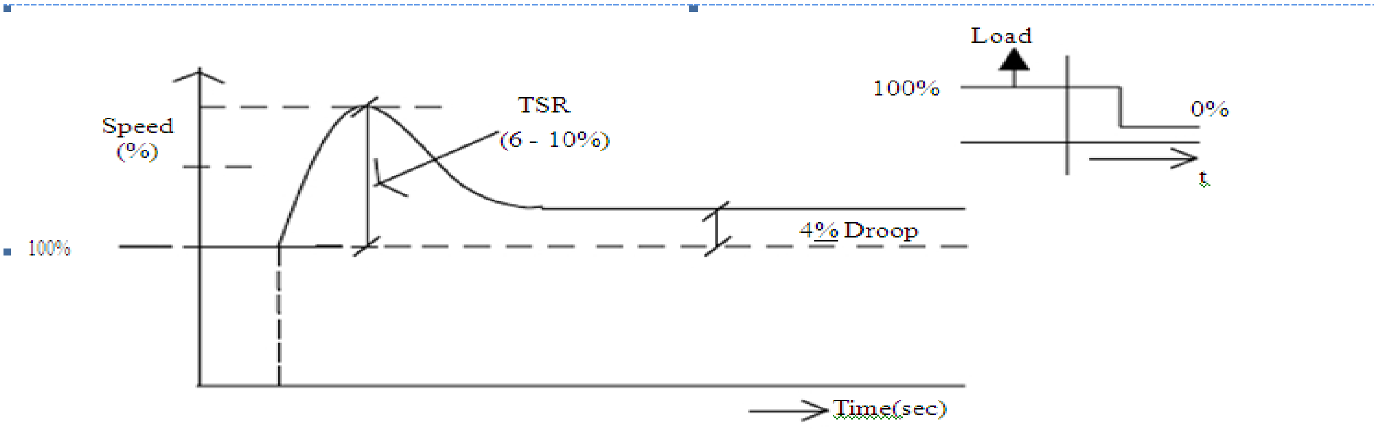


Fig 8 LOAD REJECTION RESPONSE SHOWING TRANSIENT SPEED RISE (TSR)

Even when the control valves are closed steam remaining in the steam volumes of reheater piping, turbine cylinders ('entrained steam') continue to do the work and increase the speed for few seconds.

There is an **emergency governor** provided to stop the turbine if the speed crosses its setting, usually 112 %. The standards specify that the TSR value should be less than the emergency governor setting. That means when there is a full load throw-off, governing system should act fast so that turbine does not trip.

There are other devices provided in the governing system which help in minimizing transient speed rise like load shedding relay (LSR) which cause feed forward action to close governing valves before speed variation is sensed by the speed transducer.

I P turbine control loop

In large steam turbines steam after re heater enters intermediate pressure (IP) turbine through another set of stop valves (called interceptor valves) and control valves, as shown in Fig. 9.

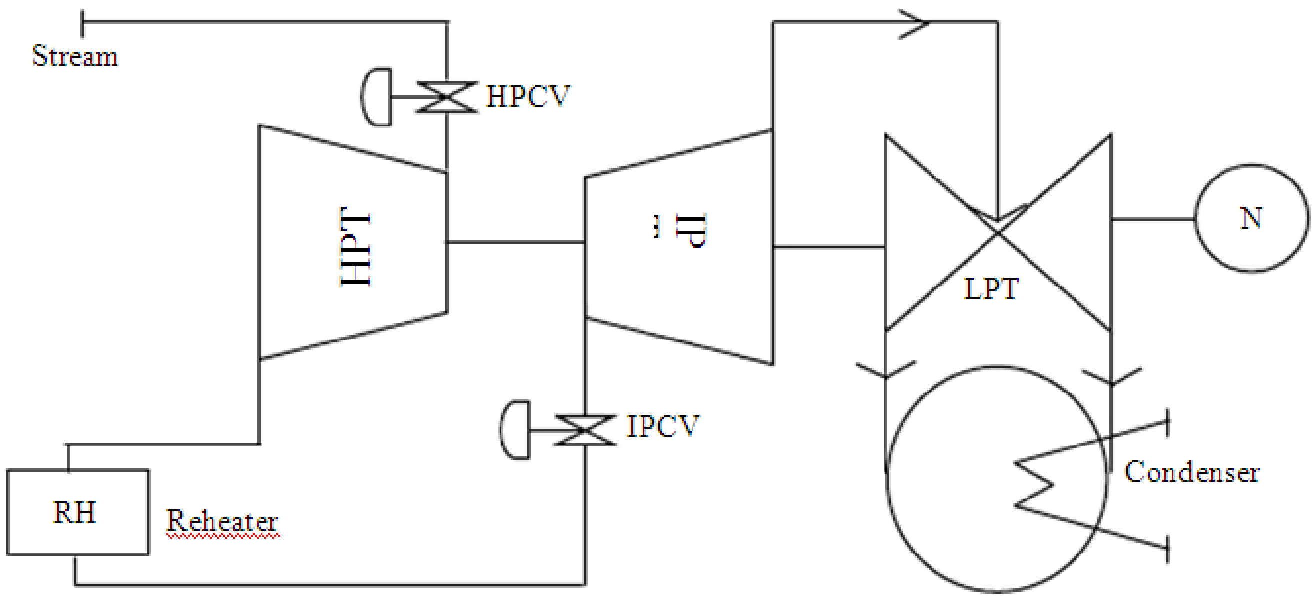


Fig 9 STREAM TURBINE SCHEME WITH HP AND LP PARTS

Normally small load variations are met by regulating steam admission in HP turbine only. But HP turbine generates only about 30 % of the total power output (IP turbine about 45 % and LP turbine the rest). So when large changes in generation is to be brought, IP control valves are also regulated through separate sets of electro-hydraulic elements, as shown in Fig. 10 below.In fact IP control action significantly reduces the transient speed rise.

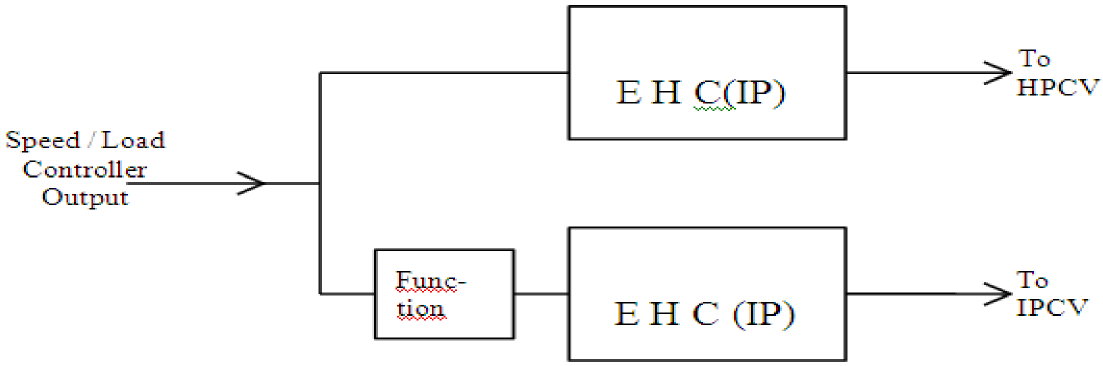


Fig.10 IP TURBINE CONTROLS

Governor insensitivity or dead band

The governing system action depends on speed sensing. There is a minimum value of speed which cannot be picked by the sensing mechanism and hence may remain uncorrected. This minimum value is called governor insensitivity or dead band. The characteristic is shown in Fig. 11.

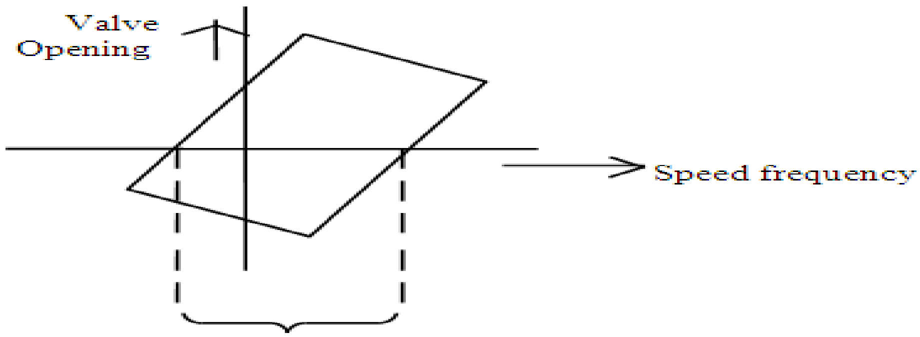


Fig 11 DEAD BAND CHARACTERISTIC

Sometimes due to wear and tear dead band increases over a period of time. This is detrimental to the frequency regulation. In control system analysis, it is well known that dead band or hysteresis in a closed loop causes instability or limit cycle oscillations. Governor hunting may occur. At the same time, governor should not react for very small changes in frequency, so dead band is introduced intentionally in the electronic governor which is an adjustable feature.

FREE GOVERNOR MODE OF OPERATION

When frequency changes in the grid every TG unit reacts and adjusts its generation as dictated by power frequency or droop characteristic. For instance when frequency falls by 0.1 %, generation has to be increased by 20 % with droop of 5 %. In Indian situation most of the generating units operate at their peak values and no additional generation is possible. With the result many units do not increase their generation and load shedding is resorted to. In some cases, due to various operational reasons generating companies do not like to their machines to respond, even though spare capacity is available. The governing is bypassed. If most of the generating stations in a grid do not respond naturally, there is a danger of grid becoming unstable also.

In the recently approved Grid code it has been made mandatory for each generator to be provided with capability to allow up to 105 % MCR(maximum continuous rating capacity)generation whenever situation demands. This is called Free Governor Mode of operation(FGMO). It has been reported that after introduction of FGMO, frequency profile has improved considerably.

INTERFACE WITH OTHER SYSTEMS

Turbine automation package

The governing system is part of comprehensive turbine automation package called Electronic Automation system for steam turbines (EAST). The governing system gets commands from automatic turbine run up system (ATRS) and automatic synchronizer during the starting and synchronization phase. The rate of rise of speed (and load) is decided by turbine stress evaluator (TSE) package.

The process of regulation by governing system causes disturbances in steam pressure, drum level, steam temperature, furnace draft etc., So the boiler control systems are also involved in the governing process.

Unit Coordinated Control system

The Unit coordinated control system (UCC) or unit demand control system (UDC) is used in the recent DDCs of power plants. When a command is given for increasing or decreasing power generation, UCC generates command signals for boiler as well as turbine based on various considerations like boiler storage time constant, boiler thermal stresses, availability of auxiliaries etc., The governing system thus interfaces with the UCC. It is also referred to as coordinated master control system (CMC) in some power plants. In the BHEL/ABB UDC, the command to change boiler generation and turbine power are simultaneously given. But the governing system actually receives the command after a time delay equivalent to the time taken by the boiler to increase its generation. This is shown by the steam flow coordinator block in Fig. 12.

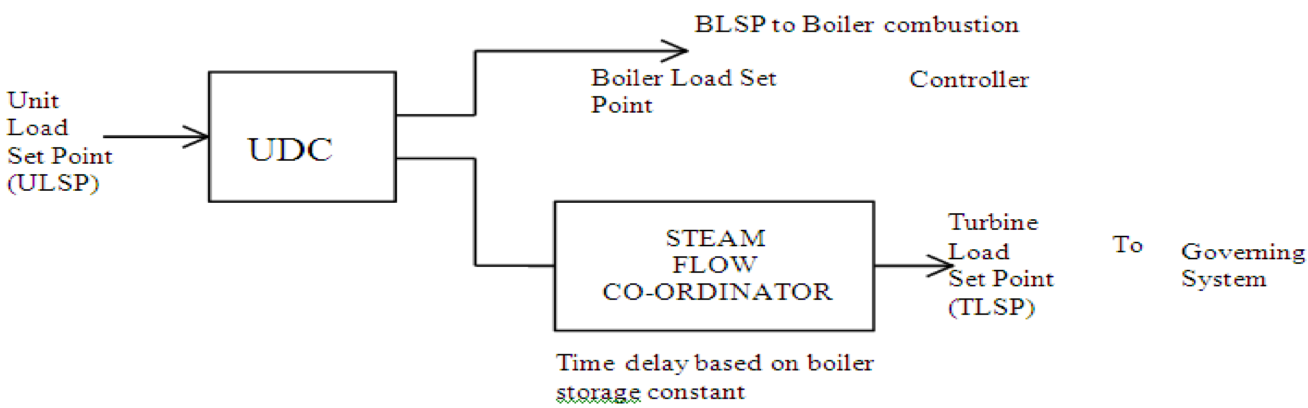


Fig 12 UNIT DEMAND CONTROL SYSTEM INTERFACE WITH GOVERNING SYSTEM

Automatic Load frequency Control system

The responsibility of maintaining grid frequency is given to Automatic Load Frequency Control (ALFC) system or automatic generation control (AGC) system. Whenever there is a mismatch between generation and load in a grid or an area of a power system (such as Regional electricity Board in India), the grid frequency varies and ALFC gives commands to adjust the generation through the governing systems, as shown in Fig. 13. Due to the absence of thermal rate limits hydro units are preferred. But the generations of many large thermal units are also increased/ decreased. The governing system must respond quickly for such requests. The load controller of electro hydraulic turbine control system has provision for such interfacing.

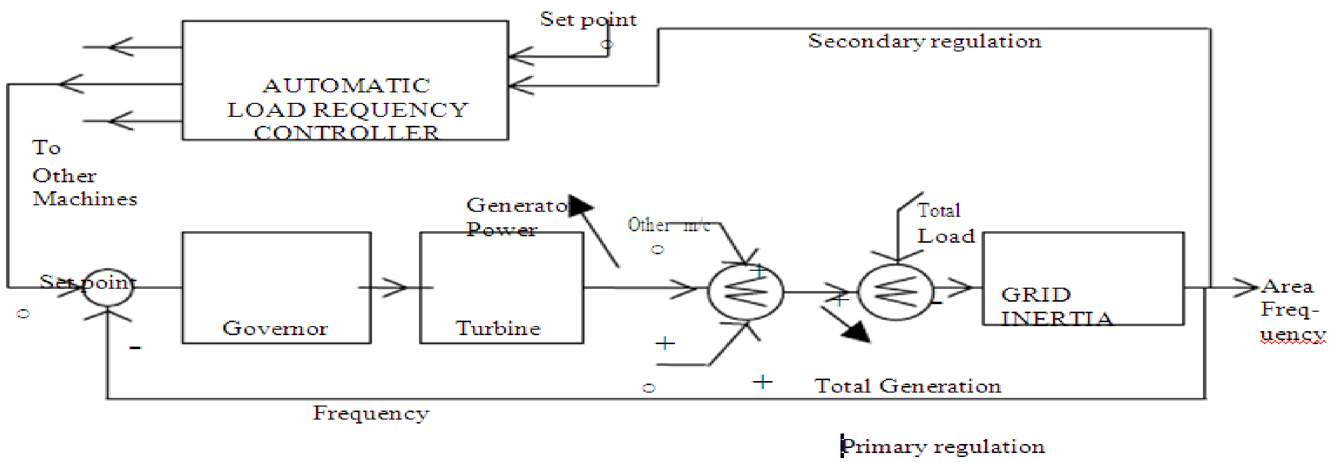
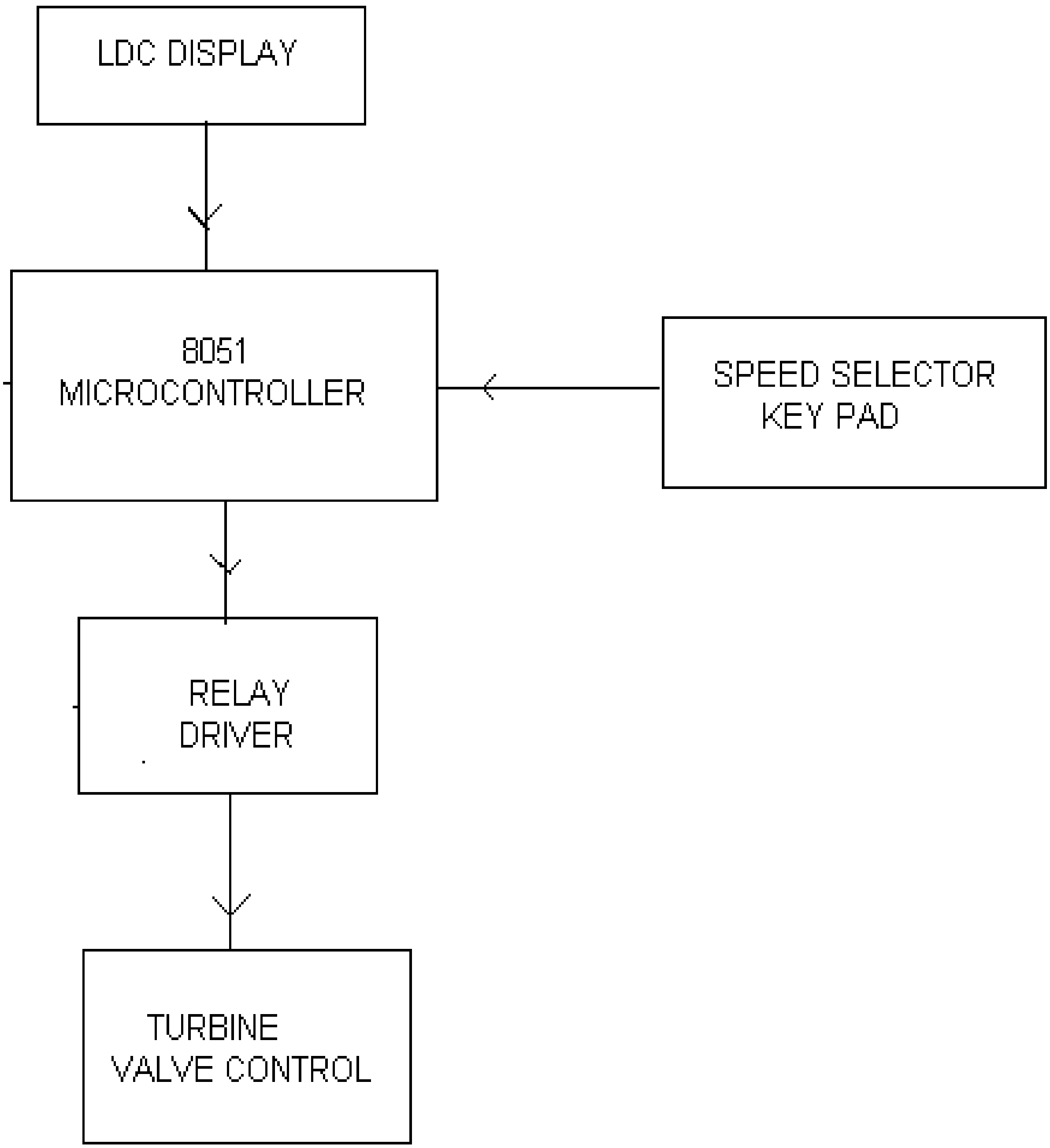


Fig 13 AUTOMATIC LOAD RFEQUENCY CONTROL SYSTEM

CONCLUSIONS

The governing system plays an important role in the start up, synchronization and loading of a steam turbine generating unit. It has to ensure stable and secure operation. With the developments in technology, digital governors are increasingly being used. In this paper a process overview of the governing system is given. Though BHEL/KWU design is main lydealt with, the concepts are applicable to the governing systems of other manufacturers also.



CIRCUIT BLOCK DIAGRAM

CIRCUIT DESCRIPTION

POWER SUPPLY

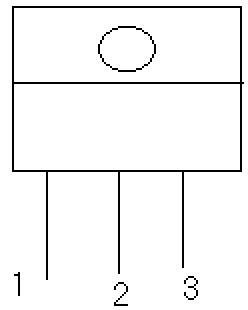
NEED OF POWER SUPPLY:-

Perhaps all of you are aware that a power supply is a primary requirement for the test bench of a home experimenter's mini lab. A battery eliminator can eliminate or replace the batteries of solid-state electronic equipment and 220V A.C. mains instead of the batteries or dry cells thus can operate the equipment. Nowadays, the sued of commercial battery eliminator or power supply unit have become increasingly popular as power source for household appliances like transceiver, record player, clock etc.

Summary of power supply circuit features:-

- **Brief description of operation:** gives out well regulated +5V output, output current capability of 500mA.
- **Circuit protection:** Built –in overheating protection shuts down output when regulator IC gets too hot.
- **Circuit complexity:** simple and easy to build.
- **Circuit performance:** Stable +5V output voltage, reliable Operation.
- **Availability of components:** Easy to get, uses only common basic components.
- **Design testing:** Based on datasheet example circuit, I have used this circuit successfully as part of other electronics projects.
- **Applications:** part of electronics devices, small laboratory power supply.
- **Power supply voltage:** unregulated 8-18V-power supply.
- **Power supply current:** needed output current 500 mA.

- **Components cost:** Few rupees for the electronic components plus the cost of input transformer.



Pin Diagram of 7805 Regulator IC

Pin 1: Unregulated voltage input
Pin 2: Ground
Pin3: Regulated voltage output

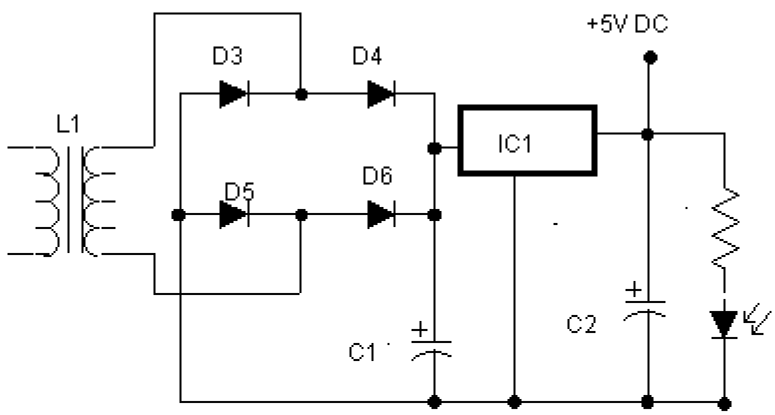
Component list

1. 7805 regulator IC
2. 9V DC Battery.
3. 1000uf., 10uf. Capacitor, at least 25V voltage rating.
4. 0-9 Step down transformer

DESCRITION OF POWER SUPPLY

This circuit is a small + 5 volts power supply Which is useful when experimenting with digital electronics. Small inexpensive battery with variable output voltage are available, but usually their voltage regulation is very poor, which makes them not very usable for digital circuit experimenter unless a better regulation can be achieved in some way. The following circuit is the answer to the problem.

This circuit can give +5V output at about 500mA current. The circuit has overload and terminal protection.



CIRCUIT DIAGRAM OF POWER SUPPLY

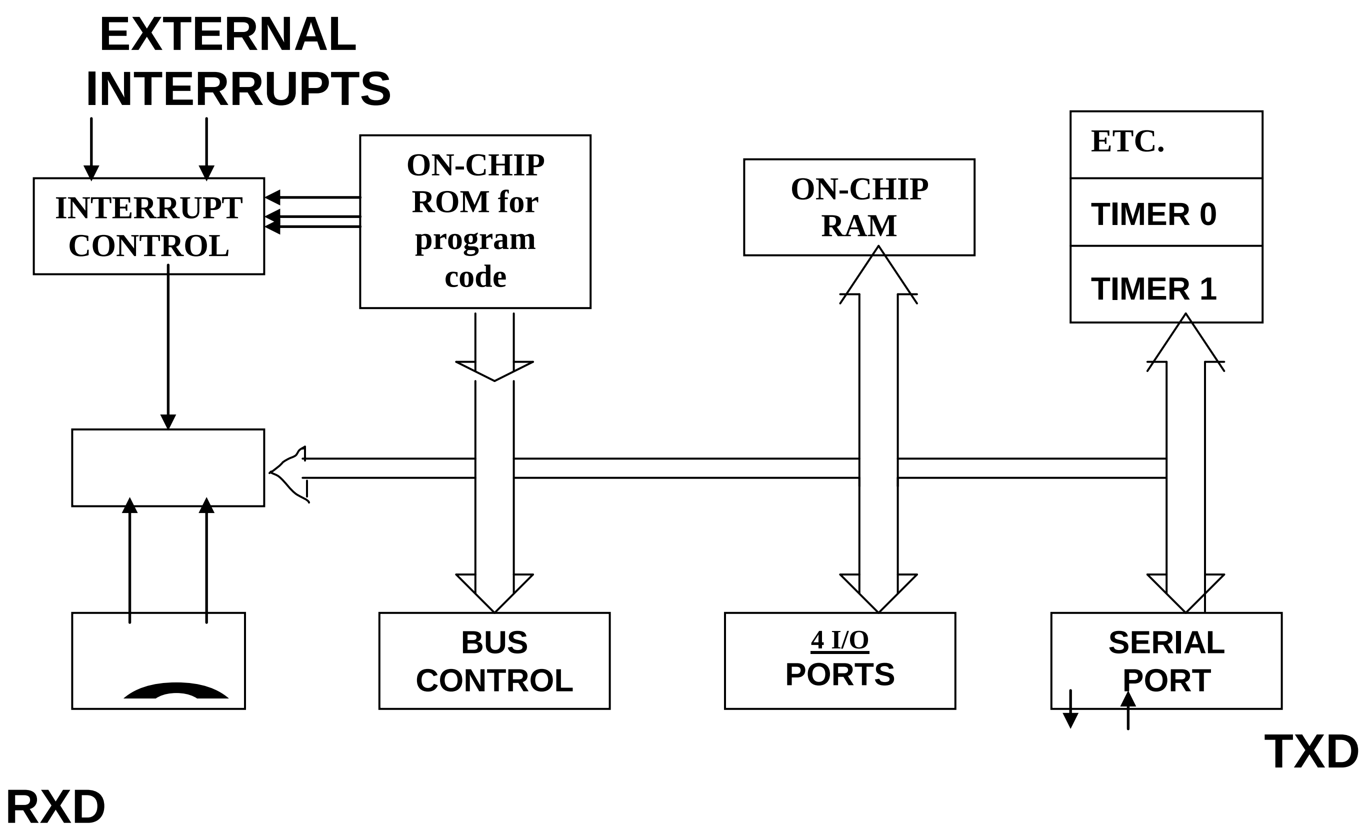
The above circuit utilizes the voltage regulator IC 7805 for the constant power supply. The capacitors must have enough high voltage rating to safely handle the input voltage feed to circuit. The circuit is very easy to build for example into a piece of Zero board.

THE MICROCONTROLER:

In our day to day life the role of micro-controllers has been immense. They are used in a variety of applications ranging from home appliances, FAX machines, Video games, Camera, Exercise equipment, Cellular phones musical Instruments to Computers, engine control, aeronautics, security systems and the list goes on.

MICROCONTROLLERS VERSUS MICROPROCESSORS

What is the difference between a microprocessor and microcontroller? The microprocessors (such as 8086,80286,68000 etc.) contain no RAM, no ROM and no I/O ports on the chip itself. For this reason they are referred as general- purpose microprocessors. A system designer using general- purpose microprocessor must add external RAM, ROM, I/O ports and timers to make them functional. Although the addition of external RAM, ROM, and I/O ports make the system bulkier and much more expensive, they have the advantage of versatility such that the designer can decide on the amount of RAM, ROM and I/o ports needed to fit the task at hand. This is the not the case with microcontrollers. A microcontroller has a CPU (a microprocessor) in addition to the fixed amount of RAM, ROM, I/O ports, and timer are all embedded together on the chip: therefore, the designer cannot add any external memory, I/O, or timer to it. The fixed amount of on chip RAM, ROM, and number of I/O ports in microcontrollers make them ideal for many applications in which cost and space are critical. In many applications, for example a TV remote control, there is no need for the computing power of a 486 or even a 8086 microprocessor. In many applications, the space it takes, the power it consumes, and the price per unit are much more critical considerations than the computing power. These applications most often require some I/O operations to read signals and turn on and off certain bits. It is interesting to know that some microcontrollers manufactures have gone as far as integrating an ADC and other peripherals into the microcontrollers.



MICROCONTROLLER BLOCK DIAGRAM

MICROCONTROLLERS FOR EMBEDDED SYSTEMS

In the literature discussing microprocessors, we often see a term embedded system. Microprocessors and microcontrollers are widely used in embedded system products. An embedded product uses a microprocessor (or microcontroller) to do one task and one task only. A printer is an example of embedded system since the processor inside it performs one task only: namely, get data and print it. Contrasting this with a IBM PC which can be used for a number of applications such as word processor, print server, network server, video game player, or internet terminal. Software for a variety of applications can be loaded and run. Of course the reason a PC can perform myriad tasks is that it has RAM memory and an operating system that loads the application software into RAM and lets the CPU run it. In an embedded system, there is only one application software that is burned into ROM. An PC contains or is connected to various embedded products such as the keyboard, printer, modem, disk controller, sound card, CD-ROM driver, mouse and so on. Each one of these peripherals has a microcontroller inside it that performs only one task. For example, inside every mouse there is a microcontroller to perform the task of finding the mouse position and sending it to the PC.

Although microcontrollers are the preferred choice for many embedded systems, there are times that a microcontroller is inadequate for the task. For this reason, in many years the manufacturers for general-purpose microprocessors have targeted their microprocessor for the high end of the embedded market.

INTRODUCTION TO 8051

In 1981, Intel Corporation introduced an 8-bit microcontroller called the 8051. This microcontroller had 128 bytes of RAM, 4K bytes of on-chip ROM, two timers, one serial port, and four ports (8-bit) all on a single chip. The 8051 is an 8-bit processor, meaning the CPU can work on only 8- bit pieces to be processed by the CPU. The 8051 has a total of four I/O ports, each 8- bit wide. Although 8051 can have a maximum of 64K bytes of on-chip ROM, many manufacturers put only 4K bytes on the chip.

The 8051 became widely popular after Intel allowed other manufacturers to make any flavor of the 8051 they please with the condition that they remain code compatible with the 8051. This has led to many versions of the 8051 with different speeds and amount of on-chip ROM marketed by more than half a dozen manufacturers. It is important to know that although there are different flavors of the 8051, they are all compatible with the original 8051 as far as the instructions are concerned. This means that if you write your program for one, it will run on any one of them regardless of the manufacturer. The major 8051 manufacturers are Intel, Atmel, Dallas Semiconductors, Philips Corporation, Infineon.

AT89C51 FROM ATMEL CORPORATION

This popular 8051 chip has on-chip ROM in the form of flash memory. This is ideal for fast development since flash memory can be erased in seconds compared to twenty minutes or more needed for the earlier versions of the 8051. To use the AT89C51 to develop a microcontroller-based system requires a ROM burner that supports flash memory: However, a ROM eraser is not needed. Notice that in flash memory you must erase the entire contents of ROM in order to program it again. The PROM burner does this erasing of flash itself and this is why a separate burner is not needed. To eliminate the need for a PROM burner Atmel is working on a version of the AT89C51 that can be programmed by the serial COM port of the PC.

FEATURES OF AT89C51

- 4K on-chip ROM
- 128 bytes internal RAM (8-bit)
- 32 I/O pins
- Two 16-bit timers
- Six Interrupts
- Serial programming facility
- 40 pin Dual-in-line Package

PIN DESCRIPTION

The 89C51 have a total of 40 pins that are dedicated for various functions such as I/O, RD, WR, address and interrupts. Out of 40 pins, a total of 32 pins are set aside for the four ports P0, P1, P2, and P3, where each port takes 8 pins. The rest of the pins are designated as Vcc, GND, XTAL1, XTAL, RST, EA, and PSEN. All these pins except PSEN and ALE are used by all members of the 8051 and 8031 families. In other words, they must be connected in order for the system to work, regardless of whether the microcontroller is of the 8051 or the 8031 family. The other two pins, PSEN and ALE are used mainly in 8031 based systems.

Vcc

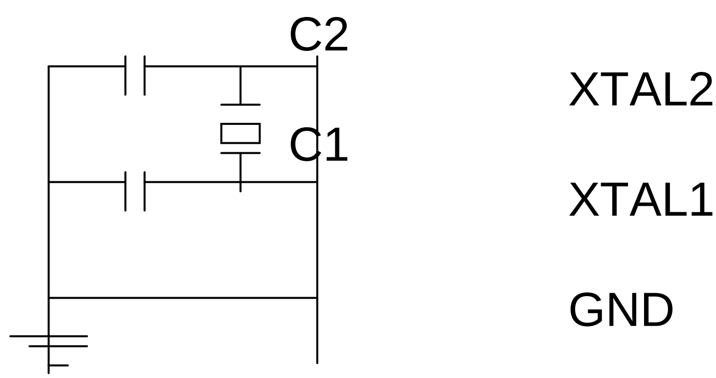
Pin 40 provides supply voltage to the chip. The voltage source is +5 V.

GND

Pin 20 is the ground.

XTAL1 and XTAL2

The 8051 have an on-chip oscillator but requires external clock to run it. Most often a quartz crystal oscillator is connected to input XTAL1 (pin 19) and XTAL2 (pin 18). The quartz crystal oscillator connected to XTAL1 and XTAL2 also needs two capacitors of 30 pF value. One side of each capacitor is connected to the ground.



It must be noted that there are various speeds of the 8051 family. Speed refers to the maximum oscillator frequency connected to the XTAL. For example, a 12 MHz chip must be connected to a crystal with 12 MHz frequency or less. Likewise, a 20 MHz microcontroller requires a crystal frequency of no more than 20 MHz. When the 8051 is connected to a crystal oscillator and is powered up, we can observe the frequency on the XTAL2 pin using oscilloscope.

RST

Pin 9 is the reset pin. It is an input and is active high (normally low). Upon applying a high pulse to this pin, the microcontroller will reset and terminate all activities. This is often referred to as a power –on reset. Activating a power-on reset will cause all values in the registers to be lost. Notice that the value of Program Counter is 0000 upon reset, forcing the CPU to fetch the first code from ROM memory location 0000. This means that we must place the first line of source code in ROM location 0000 that is where the CPU wakes up and expects to find the first instruction. In order to RESET input to be effective, it must have a minimum duration of 2 machine cycles. In other words, the high pulse must be high for a minimum of 2 machine cycles before it is allowed to go low.

EA

All the 8051 family members come with on-chip ROM to store programs. In such cases, the EA pin is connected to the Vcc. For family members such as 8031 and 8032 in which there is no on-chip ROM, code is stored on an external ROM and is fetched by the 8031/32. Therefore for the 8031 the EA pin must be connected to ground to indicate that the code is stored externally. EA, which stands for "external access," is pin number 31 in the DIP packages. It is input pin and must be connected to either Vcc or GND. In other words, it cannot be left unconnected.

PSEN

This is an output pin. PSEN stands for "program store enable." It is the read strobe to external program memory. When the microcontroller is executing from external memory, PSEN is activated twice each machine cycle.

ALE

ALE (Address latch enable) is an output pin and is active high. When connecting a microcontroller to external memory, potr 0 provides both address and data. In other words the microcontroller multiplexes address and data through port 0 to save pins. The ALE pin is used for de-multiplexing the address and data by connecting to the G pin of the 74LS373 chip.

I/O port pins and their functions

The four ports P0, P1, P2, and P3 each use 8 pins, making them 8-bit ports. All the ports upon RESET are configured as output, ready to be used as output ports. To use any of these as input port, it must be programmed.

Port 0

Port 0 occupies a total of 8 pins (pins 32 to 39). It can be used for input or output. To use the pins of port 0 as both input and output ports, each pin must be connected externally to a 10K-ohm pull-up resistor. This is due to fact that port 0 is an open drain, unlike P1, P2 and P3. With external pull-up resistors connected upon reset, port 0 is configured as output port. In order to make port 0 an input, the port must be programmed by writing 1 to all the bits of it. Port 0 is also designated as AD0-AD7, allowing it to be used for both data and address. When connecting a microcontroller to an external memory, port 0 provides both address and data. The microcontroller multiplexes address and data through port 0 to save pins. ALE indicates if P0 has address or data. When ALE=0, it provides data D0-D7, but when ALE=1 it has address A0-A7. Therefore, ALE is used for de-multiplexing address and data with the help of latch 74LS373.

Port 1

Port 1 occupies a total of 8 pins (pins 1 to 8). It can be used as input or output. In contrast to port 0, this port does not require pull-up resistors since it has already pull-up resistors internally. Upon reset, port 1 is configures as an output port. Similar to port 0, port 1 can be used as an input port by writing 1 to all its bits.

Port 2

Port 2 occupies a total of 8 pins (pins 21 to 28). It can be used as input or output. Just like P1, port 2 does not need any pull-up resistors since it has pull-up resistors internally. Upon reset port 2 is configured as output port. To make port 2 input, it must be programmed as such by writing 1s to it.

Port 3

Port 3 occupies a total of 8 pins (pins 10 to 17). It can be used as input or output. P3 does not need any pull-up resistors, the same as P1 and P2 did not. Although port 3 is configured as output port upon reset, this is not the way it is most commonly used. Port 3 has an additional function of providing some extremely important signals such as interrupts. Some of the alternate functions of P3 are listed below:

P3.0	RXD (Serial input)
P3.1	TXD (Serial output)
P3.2	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 memory write strobe)
P3.7	RD (External memory read strobe)

INSIDE THE 89C51

Registers

In the CPU, registers are used to store information temporarily. That information could be a byte of data to be processed, or an address pointing to the data to be fetched. In the 8051 there us only one data type: 8 bits. With an 8- bit data type, any data larger than 8 bits has to be broken into 8-bit chunks before it is processed.

A
B
R0
R1
R2
R3
R4
R5

DPH	DPL

Program Counter

(b) Some 8051 16-bit registers

(a) Some 8051 8-bit registers

The most commonly 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 the above registers are 8-bit registers except DPTR and the program counter. The accumulator A is used for all arithmetic and logic instructions.

Program Counter and Data Pointer

The program counter is a 16- bit register and it points to the address of the next instruction to be executed. As the CPU fetches op-code from the program ROM, the program counter is incremented to point to the next instruction. Since the PC is 16 bit wide, it can access program addresses 0000 to FFFFH, a total of 64K bytes of code. However, not all the members of the 8051 have the entire 64K bytes of on-chip ROM installed.

The DPTR register is made up of two 8-bit registers, DPH and DPL, which are used to furnish memory addresses for internal and external data access. The DPTR is under the control of program instructions and can be specified by its name, DPTR. DPTR does not have a single internal address, DPH and DPL are assigned an address each.

Flag bits and the PSW Register

Like any other microprocessor, the 8051 have a flag register to indicate arithmetic conditions such as the carry bit. The flag register in the 8051 is called the program status word (PSW) register.

The program status word (PSW) register is an 8-bit register. It is also referred as the flag register. Although the PSW register is 8-bit wide, only 6 bits of it are used by the microcontroller. The two unused bits are user definable flags. Four of the flags are conditional flags, meaning they indicate some conditions that resulted after an instruction was executed. These four are CY (carry), AC (auxiliary carry), P (parity), and OV (overflow). The bits of the PSW register are shown below:

CY	AC	F0	RS1	RS0	OV	--	P

CY	PSW.7	Carry flag
AC	PSW.6	Auxiliary carry flag
--	PSW.5	Available to the user for general purpose
RS1	PSW.6	Register bank selector bit 1
RS0	PSW.3	Register bank selector bit 0
OV	PSW.2	Overflow flag
F0	PSW.1	User definable bit
P	PSW.0	Parity flag

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.

AC, the auxiliary carry flag

If there is carry from D3 to D4 during an ADD or SUB operation, this bit is set: otherwise cleared. This flag is used by instructions that perform BCD arithmetic.

P, the parity flag

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

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. In general the carry flags is used to detect errors in unsigned arithmetic operations.

MEMORY SPACE ALLOCATION

1. Internal ROM

The 89C51 has a 4K bytes of on-chip ROM. This 4K bytes ROM memory has memory addresses of 0000 to 0FFFh. Program addresses higher than 0FFFh, which exceed the internal ROM capacity will cause the microcontroller to automatically fetch code bytes from external memory. Code bytes can also be fetched exclusively from an external memory, addresses 0000h to FFFFh, by connecting the external access pin to ground. The program counter doesn't care where the code is: the circuit designer decides whether the code is found totally in internal ROM, totally in external ROM or in a combination of internal and external ROM.

2. Internal RAM

The 1289 bytes of RAM inside the 8051 are assigned addresses 00 to 7Fh. These 128 bytes can be divided into three different groups as follows:

1. A total of 32 bytes from locations 00 to 1Fh 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 and instructions.
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.

Countdown timers can be con strutted using discrete digital Ics deluding up/down counters and /or 555 timers. If you wish to incorporate various facilities like setting the count, start, stop, reset and display facilities, these circuits would require too many Ics.

Here is a simple design based on 40- amel AT89C51 microcontroller that performs count- down operation for up to LCD displays showing the actual time left. During the activity period, a relay is latched and a flashing led indicates countdown timing’s progress.

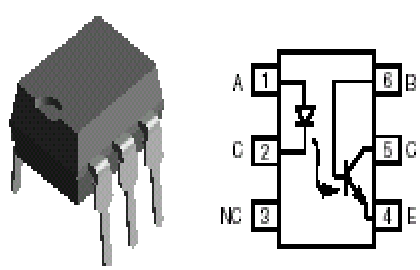
Four tactile, push-to-on switches are used to start /stop and to set the initial value for countdown operation. The timing value can also be changed while the counting is still in progress. Auto-repeat key logic also works, i.e., if you hold up or down key continuously, the timing as shown on L displays changes at a faster rate. The program code in hex is only 800 bytes long, while AT89C2051 microcontroller can take up to 2kb of code. This program can be ‘burnt’ into the chip using any universal progammer suitable for Atmel AT 89C2051 chip.

OPTOCOUPLER (MCT-2E)

The MCT2XXX series opt isolators consist of a gallium arsenate infrared emitting diode driving a silicon phototransistor in a 6-pin dual in-line package. There is no electrical connection between the two, just a beam of light. The light emitter is nearly always an LED. The light sensitive device may be a photodiode, phototransistor, or more esoteric devices such as thyristors, triacs etc. To carry a signal across the isolation barrier, optocouplers are operated in linear mode.

Pin Description of MCT2E

Fig shows the six-pin IC package for an optocoupler and the electronic diagram of its pin outline. The IC package may also be called an IC or a chip. It is important to note that each type of optocoupler may use different pin assignments [37].



Pin	Function
1	Anode

2	Cathode
3	NC
4	Emitter
5	Collector
6	Base

MCT-2E Pins

Detectors and Emitters

For carrying a linear signal across isolation barrier there are two types of optocouplers. Both types use an infrared light emitting diode (LED) to generate and send a light signal across an isolation barrier. The difference is in the detection method. Some optocouplers use a phototransistor detector while others use a photodiode detector which drives the base of a transistor.

The phototransistor detector uses the transistors collector base junction to detect the light signal. This necessitates that the base area be relatively large compared to a standard transistor. The result is a large collector to base capacitance which slows the collector rise time and limits the effective frequency response of the device. In addition the amplified photocurrent flows in the collector base junction and modulates the response of the transistor to the photons. This cause the transistor to behave in a non-linear manner. Typical phototransistor gains range from 100 to 1000.

The photodiode/transistor detector combination on the other hand uses a diode to detect the photons and convert them to a current to drive the transistor base. The transistor no longer has a large base area. The response of this pair is not affected by amplified photocurrent and the photodiode capacitance does not impair speed.

Optocoupler Operation

Optocouplers are good devices for conveying analog information across a power supply isolation barrier, they operate over a wide temperature range and are often safety agency approved they do, however, have many unique operating considerations.

Optocouplers are current input and current output devices. The input LED is excited by changes in drive current and maintains a relatively constant forward voltage. The output is a current which is proportional to the input current. The output current can easily be converted to a voltage through a pull-up or load resistor [38].

Applications

- AC mains detection
- Reed relay driving
- Switch mode power supply feedback
- Telephone ring detection
- Logic ground isolation
- Logic coupling with high frequency noise rejection.

LCD

The LCD acts as the output interface for communication with the microcontroller. Frequently, an AT89C51 program must interact with the outside world using input and output devices that communicate directly with human beings.

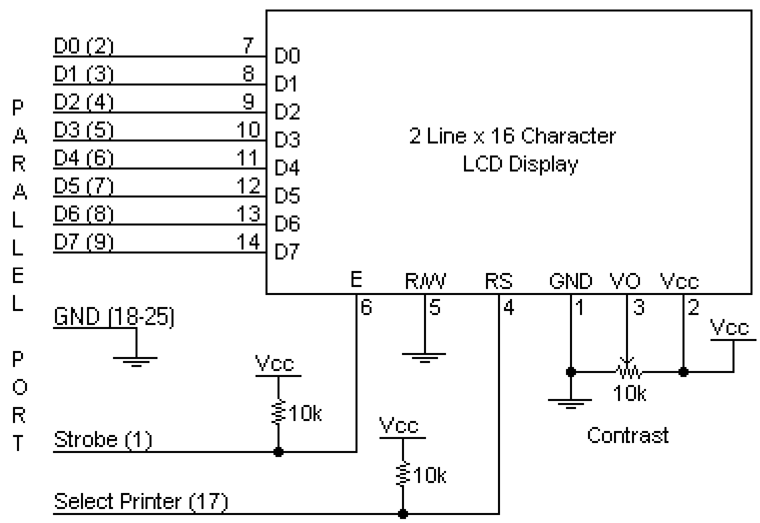
Some of the most common LCDs connected to the AT89C51 are 16X2 and 20x2 type. This means 16 characters per line by 2 lines and 20 characters per line by 2 lines, respectively. Here we have used a 16X2 display, which means there are two rows with a capacity of displaying 16 characters each.

Since an 8-bit data bus is used with this microcontroller, the LCDwill require a total of eleven data lines: 3 control lines plus 8 lines for the data bus. These three control lines are EN, RS and RW. The EN line is ‘Enable.’ To send data to the LCD, your program should make sure the EN line is low (0) and then set the other two control lines and put data on the data bus. When the other lines are completely ready, bring EN high (1) and wait for the minimal duration of time (this varies from LCD to LCD) required by the LCD as per the manufacturer’s specifications and end by bringing it low (0) again.

The RS line is the ‘Register Select’ line. When RS is low (0), the data is to be treated as a command or special instruction (such as clear screen and position cursor). When RS is high (1), the data being sent is text data, which should be displayed on the screen. For example, to display a character on the screen, you should set RS high. The RW line is the ‘Read/Write’ control line. When RW is low (0) , the information of the data bus is being written to the LCD. When RW is high (1), the program is effectively querying (or reading) the LCD.

These control lines are the vital nerves of a connection between an LCD and the microcontroller chip.

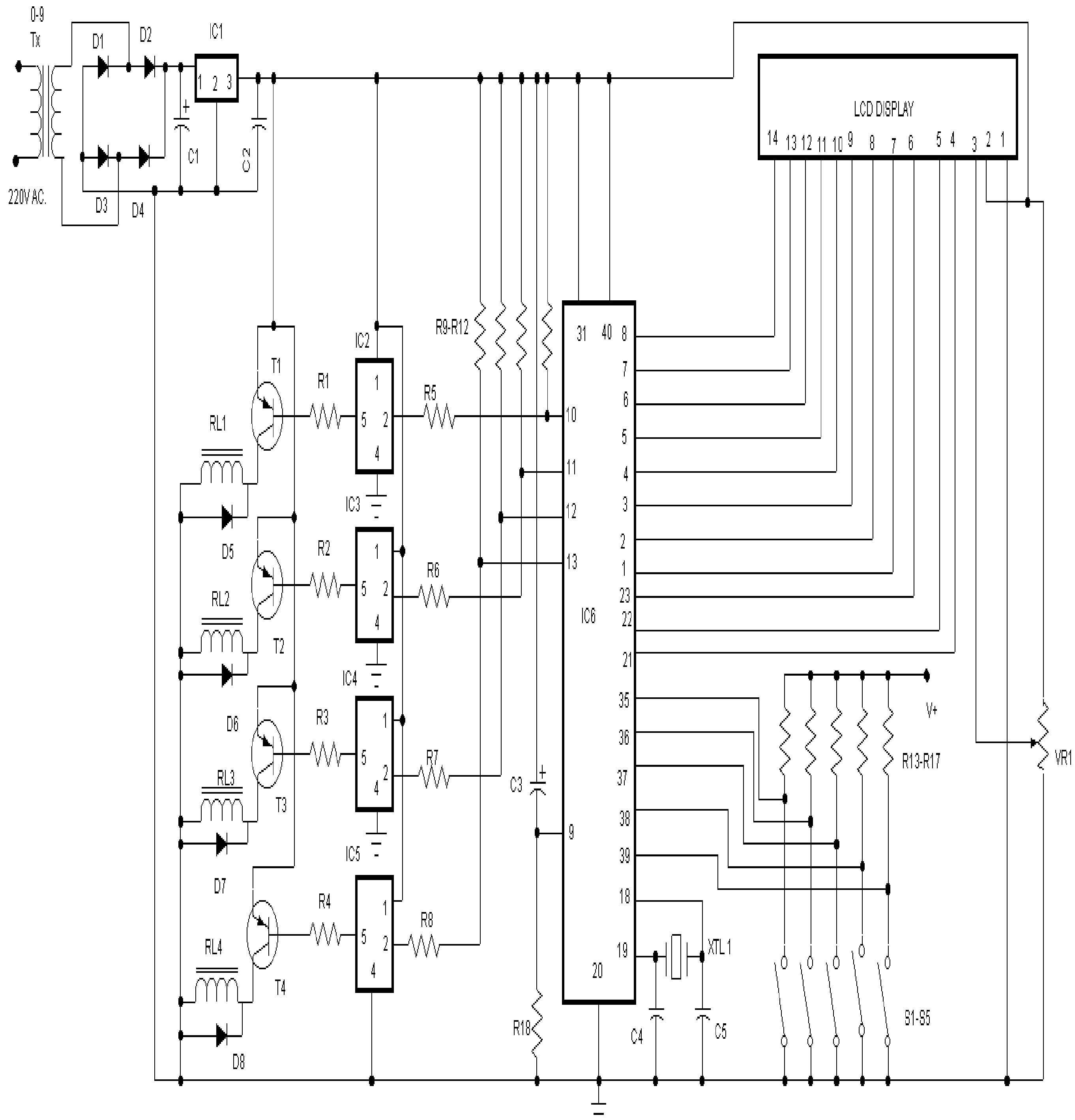
LCD PIN DESCRIPTION



Relay driver circuit:

To carry out the switching of any device we commonly use the relays. Since the output of the MCT2E opto-coupler is normally -5V or it is the voltage of logic low state. So we cannot use this output to run the device. Therefore here we use relays, which can handle a high voltage of 230V or more, and a high current in the rate of 10Amps to energize the electromagnetic coil of the relays +5V is sufficient. Here we use the transistors to energize the relay coil. The output of the opto-coupler is applied to the base of the transistor T5 via a resister. When the base voltage of the transistor is above 0.7V the emitter-base (EB) junction of the transistor forward biased as a result transistor goes to saturation region it is nothing but the switching ON the transistor. This intern switches on the relay. By this the device is a switch ON. When the output of opto-coupler goes high the base voltage drops below 0.7V as a result the device also switches OFF.

CIRCUIT DIAGRAM



USED COMPONENTS

SEMICONDUCTORS

(1) IC-1 ………….. 7805 (Regulator)
(2) IC2-IC5............. MCT2E (Opto-Coupler)
(3) IC-6..................... 89C51 (Micro-controller)
(4) D1-D2 ....IN 4007
(5) LED .... Light Eammiting Diode
(6) T1-T4…………..(PNP)
(7) XTL…………….Crystal 11.0592 Mhz.
(8) LCD

RESISTOR

(1) R1-R8…….........1K OHm.
(2) R9-R17…........... 10K OHm.
(4) VR1 ……............... 1K OHm.

CAPACITOR

(1) C1............. 1000uf.
(2) C2............. 100 uf.
(3) C3………..10 uf.
(4) C4,C5 …… 33 PF

MISCELLANEOUS

(1) RL1 ………………. RELAY 6V \100 0Hm.
(2) S1 ……………………… PUSH -TO- ON
(3) 9-0-9 …………………….STEP DWON TRANSFORMER.
(4) DC MOTOR …………………. 6v DC.

Conclusion

The monopolistic power distribution market in Asia is gradually transforming into a competitive marketplace. Differentiation in service is going to be the key competitive factor to improve market share in the deregulated power markets. Prepaid meters with their advantages over conventional ones are likely to help power distributors to differentiate and offer value-added services to consumers. Encourgaing consumers to opt for prepaid meters on a voluntary basis and offering tariff or non-tariff incentives to those consumers who prepay their power charges, would help the utilities to implement this sytem.

RESISTORS

The jobs done by resistors include directing and controlling current, making changing current produce changing voltage (as in a voltage amplifier) and obtaining variable voltages from fixed ones (as in a potential divider). There are two main types of resistor-those with fixed values and those that are variable.

Fixed Resistance   Variable Resistance

When choosing a resistor there are three factors which have to be considered, apart from the stated value.

(i) THE TOLERANCE. Exact values cannot be guaranteed by mass-production methods but this is not a great disadvantage because in most electronic circuits the values of resistors are not critical. The tolerance tells us the minimum and maximum values a resistor might have, e.g. one with a stated (called nominal) value of 100Ω and a tolerance of ±10% could have any value between 90Ω and 110Ω

(ii) THE POWER RATING. If the rate which a resistor changes electrical energy into heat exceeds its power rating, it will overheat and be damaged or destroyed. For most electronic circuit 0.25 Watt or 0.5 Watt power ratings are adequate. The greater the physical size of a resistor the greater is its rating.

(iii) THE STABILITY. This is the ability of a component to keep the same value as it ‘ages’ despite changes of temperature and other physical conditions. In some circuits this is an important factor.

RESISTOR MARKINGS

The value and tolerance of a fixed resistor is marked on it using codes. The resistor has four colored bands painted on it towards one end. The first three from the end give the value and the fourth the tolerance. Sometimes it is not clear which is the first band but deciding where to start should not be difficult if you remember that the fourth band (which is not always present) will be either gold or silver, these being colours not used for the first band.

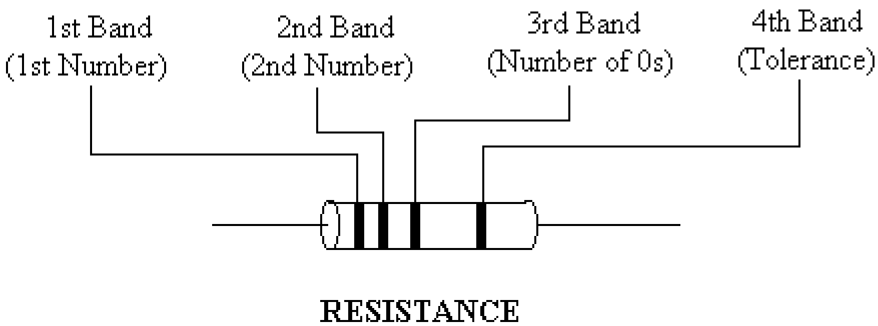
The first band gives the first number, the second band gives the second number and the third band tells how many naught (0) come after the first two numbers.

VALUE CODE

NUMBER	COLOUR
0	Black
1	Brown
2	Red
3	Orange
4	Yellow
5	Green
6	Blue
7	Violet
8	Gray
9	White

TOLERANCE CODE

PERCENTAGE	COLOUR
+-5%	Gold
+-10%	Silver
+-20%	no colour in 4th band



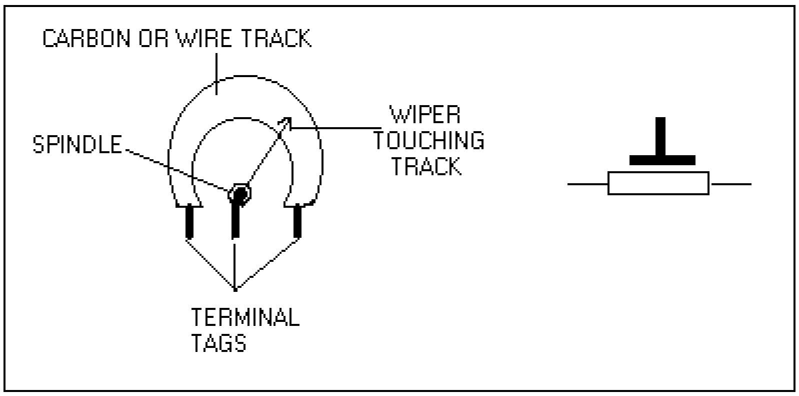
VARIABLE RESISTORS

Description. Variable resistors used as volume and other controls in radio and TV set are usually called 'pots' (short for potential divider- see below). They consist of an incomplete circular track of either a fixed carbon resistor for high values and low power (up to 2W) or of a fixed wire-wound resistor for high powers. Connections to each end of the track are bought out to two terminal tags. A wiper makes contact with the track and is connected to a third terminal tag, between the other two. Rotation of the spindle moves the wiper over the track and changes the resistance between the center tag and the ones. 'Slide' type variable resistors have a straight track.

In a linear track equal changes of resistance occur when the spindle is rotated through equal angles. In a log track, the change of resistance at one end of the track is less than at the other for equal angular rotations.

Maximum values range from a few ohms to several mega ohms, common values are 10k Ohm, 50k Ohm., 100k Ohm., 500k ohm. and 1M Ohm.

Some circuits use small preset types, the symbol and form of which are shown in figs. These are adjusted with a screwdriver when necessary and have tracks of carbon or ceramic (ceramic and metal oxide).



CAPACITOR

A capacitor stores electric charge. It does not allow direct current to flow through it and it behaves as if alternating current does flow through. In its simplest form it consists of two parallel metal plates separated by an insulator called the dielectric. The symbols for fixed and variable capacitors are given in fig. Polarized types must be connected so that conventional current enters their positive terminal. Non-polarized types can be connected either way round.

The capacitance (C) of a capacitor measures its ability to store charge and is stated in farads (F). The farad is sub-divided into smaller, more convenient units.

1 microfarad (1uf) = 1 millionth of a farad = 10^{-6} f

1 nanofarad (1 nf) = 1 thousand- millionth of a farad = 10^{-9} f

1 Pico farad (1pf) = 1 million-millionth of a farad = 10^{-12} f

In practice, capacitances range from 1 pf to about 150 000 uf: they depend on the area A of the plates (large A gives large C), the separation d of the plates (small d gives large C) and the material of the dielectric (e.g. certain plastics give large C).

When selecting a particular job, the factors to be considered are the value (again this is not critical in many electronic circuits), the tolerance and the stability. There are two additional factors.

(i) The working voltage. It is the largest voltage (d.c.or peak a.c.), which can be applied across the capacitor and is often marked on it, e.g. 30V wkg. It is exceeded, the dielectric breaks down and permanent damage may result.

(ii) The leakage current. No dielectric is a perfect insulator but the loss of charge through it as 'leakage current' should be small.

FIXED CAPACITORS

Fixed capacitors can be classified according to the dielectric used; their properties depend on this. The types described below in (i), (ii) and (iii) are non-polarized; those in (iv) are polarized.

(i) Polyester. Two strips of polyester film (the plastic dielectric) are wound between two strips of aluminum foil (the plates). Two connections, one to each strip of foil, form the capacitor leads. In the metallized version, films of metal are deposited on the plastic and act as the plates. Their good all-round properties and small size make them suitable for many applications in electronics. Values range from 0.01uf to 10mfd. or so and are usually marked (in pf) using the resistor colour code. Polycarbonate capacitors are similar to the polyester type; they have smaller leakage currents and better stability but cost more.

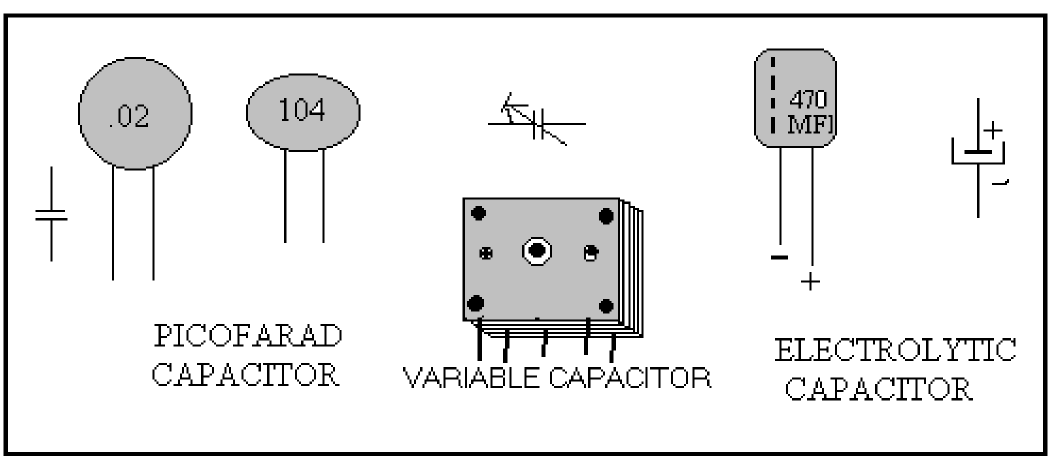
(ii) Mica. Mica is naturally occurring mineral, which splits into very thin sheets of uniform thickness. Plates are formed by depositing a silver film on the mica or by using interleaving sheets of aluminum foil. Their tolerance is low ($\pm$1%), stability and working voltage is high, leakage current low but they are used in radio frequency tuned circuits where low loss is important and are pictured in figs. Polystyrene capacitors have similar though not quite so good properties as mica types but are cheaper.

(iii) Ceramic. There are several types depending on the ceramic used. One type has similar properties to mica and is used in radio frequency circuits. In another type, high capacitance values are obtained with small size, but stability and tolerance are poor; they are useful where exact values are not too important. They may be disc, rod- or plate-shaped. A disc-shaped capacitor is shown in fig. Values range form 10pf to 1uf.

(iv) Electrolytic: In the aluminum type the dielectric is an extremely thin layer of aluminum oxide, which is formed electrolytically. Their advantages are high values (up to 150 000uF) in a small volume and cheapness. Their disadvantages are wide tolerance (-20 to +100% of the value printed on them), high leakage current and poor stability but they are used where these factors do not matter and high values are required, e.g. in power supplies.

Electrolytic are polarized. Usually their positive terminal is marked with a + or by a groove; often the aluminum can is the negative terminal. The d.c. Leakage current maintains the oxide layer; otherwise reversed polarity (or disuse) will cause the layer to deteriorate.

Tantalum electrolytic capacitors can be used instead of aluminum in low voltage circuits where values do not exceed about 100 uf. They have lower leakage currents.



TRANSISTORS

Transistors are the most important devices in electronics today. Not only are they made as discrete (separate) components but also integrated circuits (IC) may contain several thousands on a tiny slice of silicon. They are three-terminal devices, used as amplifiers and as switches. Non-amplifying components such as resistors, capacitors, inductors and diodes are said to be 'passive'; transistors are 'active' components.

The two basic types of transistor are:

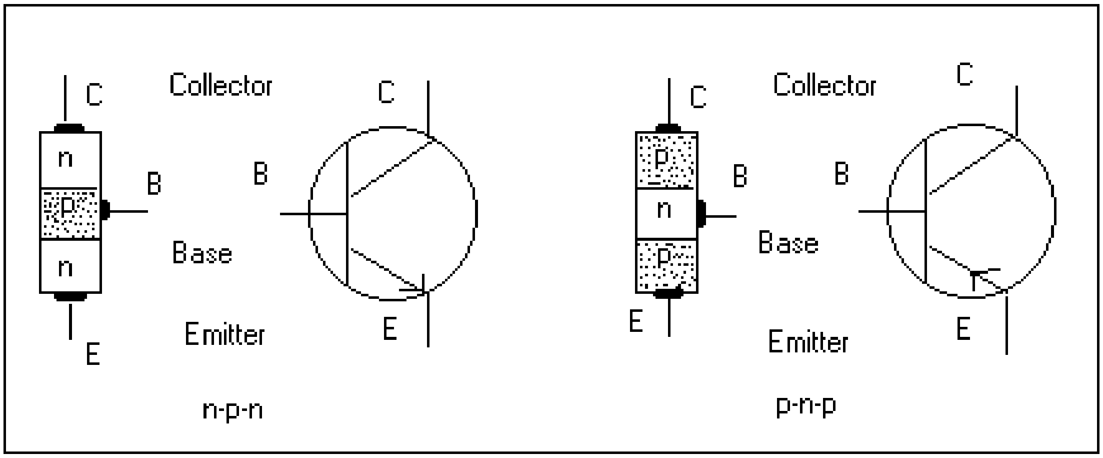
(a) The bipolar or junction transistor (usually called the transistor); its operation depends on the flow of both majority and minority carriers;

(b) The unipolar or field effect transistor (called the FET) in which the current is due to majority carriers only (either electrons or holes).

JUNCTION TRANSISTOR

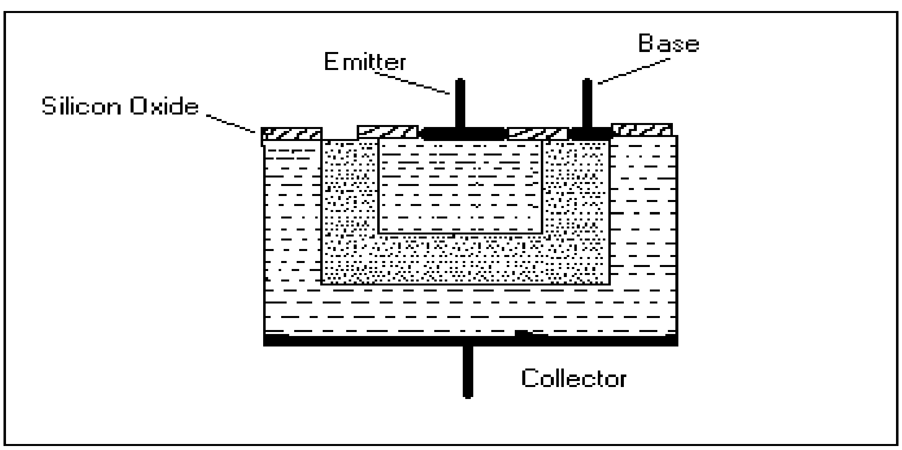
(i) CONSTRUCTION: The bipolar or junction transistor consists of two p-n junctions in the same crystal. A very thin slice of lightly doped p-or n-type semiconductor (the base B) is sand witched between two thicker, heavily doped materials of the opposite type (the collector C and emitter E).

The two possible arrangements are shown diagrammatically in fig with their symbols. The arrow gives the direction in which conventional (positive) current flows; in the n-p-n type it points from B to E and in the p-n-p type it points from E to B.



As with diodes, silicon transistors are in general preferred to germanium ones because they withstand with higher temperatures (up to about 175 ^{0}C compared with 75 ^{0}C) and higher voltages, have lower leakage currents and are better suited to high frequency circuits. Silicon n-p-n types, are more easily mass-produced than p-n-p type, the opposite is true of germanium.

A simplified section of an n-p-n silicon transistor made by the planar process in which the transistor is in effect created on one face (plane) of a piece of semi conducting material; fig. Shows a transistor complete with case (called the 'encapsulation') and three wire leads.



(ii) ACTION. An n-p-n silicon transistor is represented and is connected in a common emitter circuit; the emitter is joined (via batteries B1 and B2) to both the base and the collector. For transistor action to occur the base emitter junction must be forward biased, i.e. positive terminal of B1 to p- type base, and the collector base junction reverse biased, i.e. positive terminal of B2 to n- type collector.

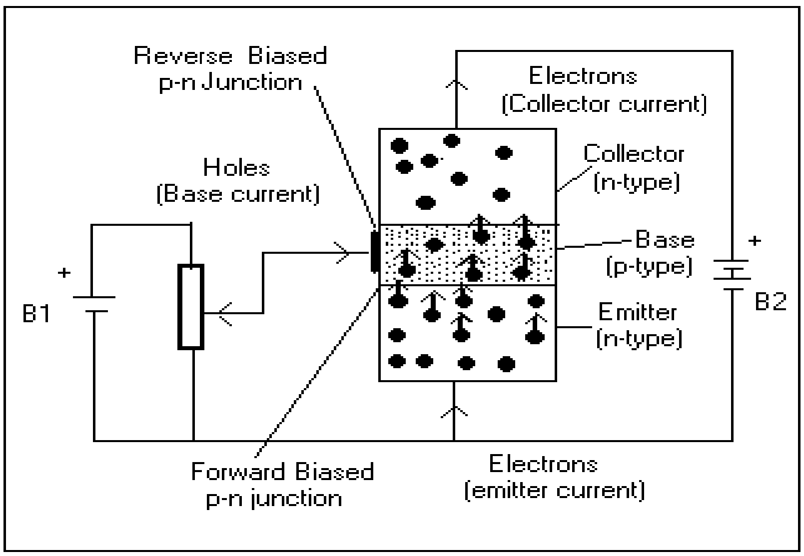
When the base emitter bias is about +0.6 V, electrons (the majority carriers in the heavily doped n type emitter) cross the junction (as they would in any junction diode) into the base. Their loss is made good by electrons entering the emitter from the external circuit to form the emitter current. At the same time holes from the base to the emitter, since the p- type base is lightly doped, this is small compared with the electron flow in the opposite direction, i.e. electrons are the majority carriers in an n-p-n transistor.

In the base, only a small proportion (about 1%) of the electrons from the emitter combine with the holes in the base because the base is very thin (less than millionth of a meter) and is lightly doped. Most of the electrons are swept through the base, because they are attracted by the positive voltage on the collector, and the cross base – collector junction to become the collector current in the circuit.

The small amount of electron – hole recombination, which occurs in the base, gives it a momentary negative charge, which is immediately compensated by battery B1 supplying it with (positive) holes. The flow of holes to the base from the external circuit creates a small base current. This keeps the base emitter junction forward biased and so maintains the larger collector current.

Transistor action is turning on (and controlling) of a large current through the high resistance (reverse biased) collector – base junction by a small current through the low – resistance (forward biased) base – emitter junction. The term transistor refers to this effect and comes from the two words ‘ transfer resistor’. Physically the collector is larger than the emitter and if one is used in place of the other the action is inefficient.

The behavior of a p-n-p transistor is similar to that of the n-p-n type but it is holes that are the majority carriers, which flow from the emitter to the collector and electrons, are injected into the base to compensate for recombination. To obtain correct biasing the polarities of both batteries must be reversed.

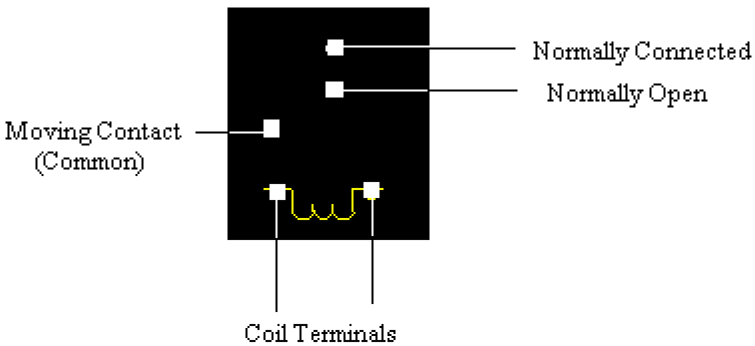


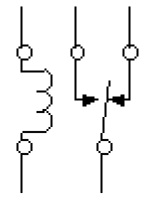
RELAY

Relay is a common, application of application of electromagnetism. It uses an electromagnet made from an iron rod wound with hundreds of fine copper wire. When electricity is applied to the wire, the rod become magnetic. A movable contact arm above the rod is then pulled toward; a small spring pulls the contract arm away from the rod until it closes, a second switch contact. By means of relay, a current circuit can be broken or closed in one circuit as a result of a current in another circuit. Relays can have several poles and contacts. The types of contacts could be normally open and normally closed. One closure of the relay can turn on the same normally open contacts; can turn off the other normally closed contacts

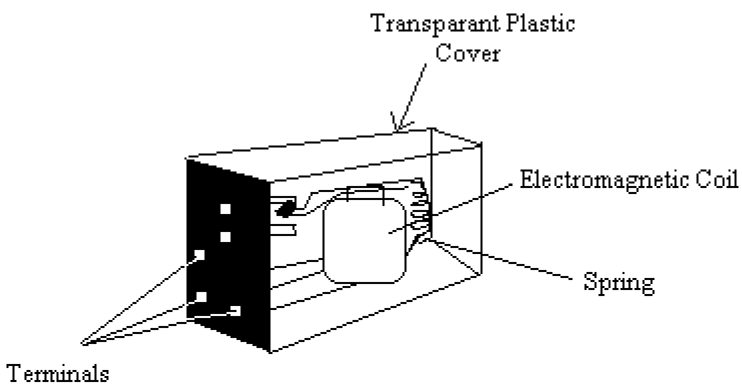
A relay is a switch worked by an electromagnet. It is useful if we want a small current in one circuit to control another circuit containing a device such as a lamp or electric motor which requires a large current, or if we wish several different switch contacts to be operated simultaneously.

The structure of relay and its symbol are shown in figure. When the controlling current flows through the coil, the soft iron core is magnetized and attracts the L-shaped soft iron armature. This rocks on its pivot and opens, closes or changes over, the electrical contacts in the circuit being controlled.





SYMBOL



DIODE

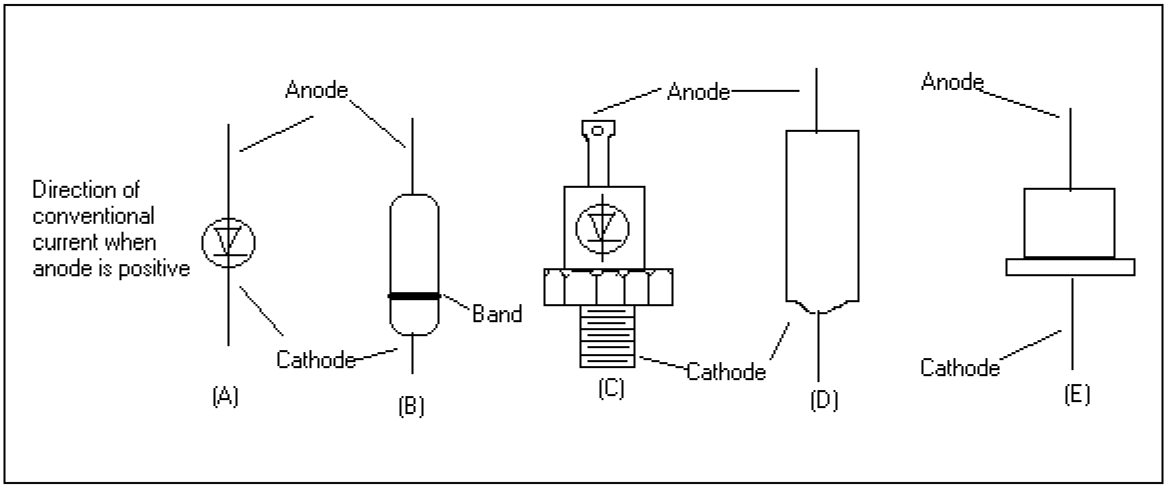
The simplest semiconductor device is made up of a sandwich of P- and N type semi conducting material, with contacts provided to connect the P-and N-type layers to an external circuit, this is a junction Diode. If the positive terminal of the battery is connected to the p-type material (cathode) and the negative terminal to the N-type material (Anode), a large current will flow. This is called forward current or forward biased.

If the connection is 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 converts ac into pulsating dc. Signal diodes are used in radio circuits fro detection, Zener diodes are used in the circuit to control the voltage.

A diode allows current to flow easily in one direction but not in the other, i.e. its resistance is low in the conducting or 'forward' direction but very high in the opposing or 'reverse' direction. Most semiconductor diodes are made from silicon or germanium.

A diode has two leads, the anode and the cathode: its symbol is given in fig (a). The cathode is often marked by a band at one end fig.(b); it is the lead by which conventional current leaves the diode when forward biased – as the arrow on the symbol shown. In some cases the arrow is marked on the diode fig.(c) or the shape is different (d), (e)



There are several kinds of diode, each with features that suit it for a particular job. Three of the main types are:

(a) The junction diode,
(b) The point-contact diode and
(c) The zener diode

Two identification codes are used for diodes. In the American system the code always starts with 1N and is followed by a serial number, e.g. IN 4001. in the continental system the first letter gives the semiconductor material (A=germanium, B= silicon) and the second letter gives the use. (A=signal diode, Y=rectifier diode, Z=Zener diode.). for example, AA119 is a germanium signal diode,. To complicate the situation some manufacturers have their own codes.

ZENER DIODE

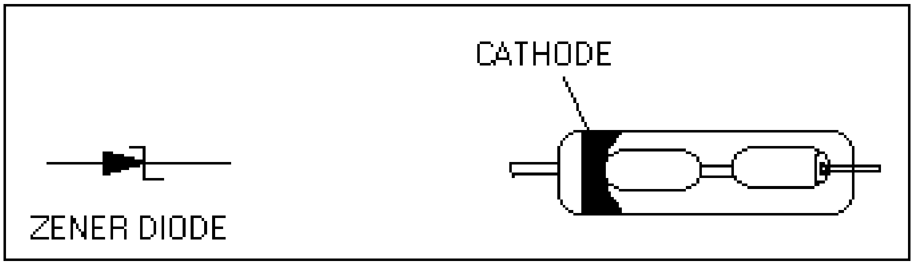
Zener diodes are very important because they are the key to voltage regulation. The chapter also includes opt electronic diodes, Scotty diodes, aviators, and other diodes.

A Zener diode is specially designed junction diode, which can operate continuously without being damaged in the region of reverse breakdown voltage. One of the most important applications of zener diode is the design of constant voltage power supply. The zener diode is joined in reverse bias to D.C. through a resistance of suitable value.

Small signal and rectifier diodes are never intentionally operated in the breakdown region because this may damage them. A zener diode is different; it is a silicon diode that the manufacturer has optimized for operation in the breakdown region, zener diodes work best in the breakdown region. Sometimes called a breakdown diode, the zener diode is the backbone of voltage regulators, circuits that hold the load voltage almost constant despite large changes in line voltage and load resistance.

Figure shows the schematic symbol of a zener diode; another figure is an alternate symbol. In the either symbol, the lines resemble a "z", which stands for zener. By varying the doping level of silicon diodes, a manufacturer can produce zener diodes with breakdown voltage from about 2 to 200V. These diodes can operate in any of three regions: forward, leakage, or breakdown.

Figure shows the V-I graph of a zener diode. In the forward region, it starts conduction around 0.7V, just like a ordinary silicon diode, In the leakage region (between zero and breakdown), it has only a small leakage or reverse current. In a zener diode, the breakdown has a very sharp knee, followed by an almost vertical Vz over most of breakdown region. Data sheets usually specify the value of Vz at a particular test current IzT.


CATHODE
ZENER DIODE

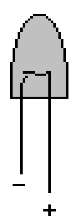
L.E.D.

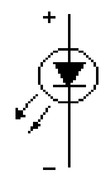
(LIGHT EMITTING DIODE)

Light emitting diode (LED) is basically a P-N junction semiconductor diode particularly designed to emit visible light. There are infrared emitting LEDs which emit invisible light. The LEDs are now available in many colour red, green and yellow,. A normal LED at 2.4V and consumes ma of current. The LEDs are made in the form of flat tiny P-N junction enclosed in a semi-spherical dome made up of clear coloured epoxy resin. The dome of a LED acts as a lens and diffuser of light. The diameter of the base is less than a quarter of an inch. The actual diameter varies somewhat with different makes. The common circuit symbols for the LED are shown in fig. 1. It is similar to the conventional rectifier diode symbol with two arrows pointing out. There are two leads- one for anode and the other for cathode.

LEDs often have leads of dissimilar length and the shorter one is the cathode. This is not strictly adhered to by all manufacturers. Sometimes the cathode side has a flat base. If there is doubt, the polarity of the diode should be identified. A simple bench method is to use the ohmmeter incorporating 3-volt cells for ohmmeter function. When connected with the ohmmeter: one way there will be no deflection and when connected the other way round there will be a large deflection of a pointer. When this occurs the anode lead is connected to the negative of test lead and cathode to the positive test lead of the ohmmeter.

(i) Action. An LED consists of a junction diode made from the semi conducting compound gallium arsenate phosphate. It emits light when forward biased, the colour depending on the composition and impurity content of the compound. At present red, yellow and green LEDs are available. When a p-n junction diode is forward biased, electrons move across the junction from the n-type side to the p-type side where they recombine with holes near the junction. The same occurs with holes going across the junction from the p-type side. Every recombination results in the release of a certain amount of energy, causing, in most semiconductors, a temperature rise. In gallium arsenate phosphate some of the energy is emitted as light, which gets out of the LED because the junction is formed very close to the surface of the material. An LED does not light when reverse biased and if the bias is 5 V or more it may be damaged.





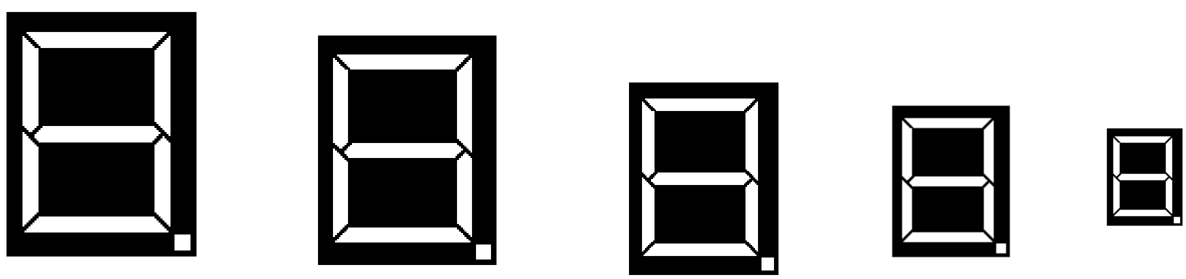
(ii) External resistor. Unless an LED is of the 'constant-current type' (incorporating an integrated circuit regulator for use on a 2 to 18 V d.c. or a. c. supply), it must have an external resistor R connected in series to limit the forward current, which typically, may be 10 mA (0.01 A). Taking the voltage drop (Vf) across a conducting LED to be about 1.7 V, R can be calculated approximately from:

$$R = \frac{(\text{supply voltage} - 1.7)\text{ V}}{0.01\text{A}}$$

For example, on a 5 V supply, R = 3.3/0.01 = 330 Ohm.

(iii) Decimal display. Many electronic calculators, clocks, cash registers and measuring instruments have seven-segment red or green LED displays as numerical indicators (Fig.). Each segment is an LED and depending on which segments are energized, the display lights up the numbers 0 to 9 as in Fig.. Such displays are usually designed to work on a 5 V supply. Each segment needs a separate current-limiting resistor and all the cathodes (or anodes) are joined together to form a common connection.

The advantages of LEDs are small size, reliability, longer life, small current requirement and high operating speed.



SEVEN SEGMENT DISPLAY

SOLDERING TECHNIQUES

Bad solder joints are often the cause of annoying intermittent faults. They can often be hard to find an cause circuit failure at the most inappropriate time. It’s much better to learn to make a good solder joints from day one.

Preparing the soldering iron:

- Wipe the tip clean on the wetted sponge provided.
- Bring the resin cored solder to the iron and ‘tin’ the tip of the iron.
- Wipe the excess solder of the tip using the wet sponge.
- Repeat until the tip is properly ‘tinned’.

SOLDERING COMPONENTS INTO THE PCB

- Bend the component leads at right angles with both bends at the same distance apart as the PCB pad holes.
- Ensure that both component leads and the copper PCB pads are clean and free of oxidization.
- Insert component leads into holes and bend leads at about 30 degrees from vertical.
- Using small angle cutters, cut the leads at about 0.1 - 0.2 of an inch (about 2 - 4 mm) above copper pad.
- Bring tinned soldering iron tip into contact with both the component lead and the PCB pad. This ensures that both surfaces undergo the same temperature rise.
- Bring resin cored solder in contact with the lead and the copper pad. Feed just enough solder to flow freely over the pad and the lead without a ‘blobbing’ effect. The final solder joint should be shiny and concave indicating good ‘wetting’ of both the copper pad and the component lead. If a crack appears at the solder to metal interface then the potential for forming a dry joint exists. If an unsatisfactory joint is formed, suck all the solder off the joint using a solder sucker or solder wick (braid) and start again.

PRECAUTIONS

1. Mount the components at the apron places before soldering. Follow the circuit description and components details, leads identification etc. Do not start soldering before making it confirm that all the components are mounted at the right place.
2. Do not use a spread solder on the board, it may cause short circuit.
3. Do not sit under the fan while soldering.
4. Position the board so that gravity tends to keep the solder where you want it.
5. Do not over heat the components at the board. Excess heat may damage the components or board.
6. The board should not vibrate while soldering otherwise you have a dry or a cold joint.
7. Do not put the kit under or over voltage source. Be sire about the voltage either is d.c. or a.c. while operating the gadget.
8. Do spare the bare ends of the components leads otherwise it may short circuit with the other components. To prevent this use sleeves at the component leads or use sleeved wire for connections.
9. Do not use old dark colour solder. It may give dry joint. Be sure that all the joints are clean and well shiny.
10. Do make loose wire connections specially with cell holder, speaker, probes etc. Put knots while connections to the circuit board, otherwise it may get loose.