

## IC 723 – GENERAL PURPOSE REGULATOR

Disadvantages of fixed voltage regulator:

1. Do not have the short circuit protection
2. Output voltage is not adjustable

These limitations can be overcome in IC723.

Features of IC723:

1. Unregulated dc supply voltage at the input between 9.5V & 40V
2. Adjustable regulated output voltage between 2 to 3V.
3. Maximum load current of 150 mA ( $I_{Lmax} = 150mA$ ).
4. With the additional transistor used,  $I_{Lmax}$  upto 10A is obtainable.
5. Positive or Negative supply operation
6. Internal Power dissipation of 800mW.
7. Built in short circuit protection.
8. Very low temperature drift.
9. High ripple rejection.

The simplified functional block diagram can be divided into 4 blocks.

1. Reference generating block
2. Error Amplifier
3. Series Pass transistor
4. Circuitry to limit the current

1. Reference Generating block:

The temperature compensated Zener diode, constant current source & voltage reference amplifier together form the reference generating block. The Zener diode is used to generate a fixed reference voltage internally. Constant current source will make the Zener diode to operate at a fixed point & it is applied to the Non – inverting terminal of error amplifier. The Unregulated input voltage  $\pm V_{cc}$  is applied to the voltage reference

amplifier as well as error amplifier.

Error Amplifier:

Error amplifier is a high gain differential amplifier with 2 input (inverting & Non-inverting). The Non-inverting terminal is connected to the internally generated reference voltage. The Inverting terminal is connected to the full regulated output voltage.

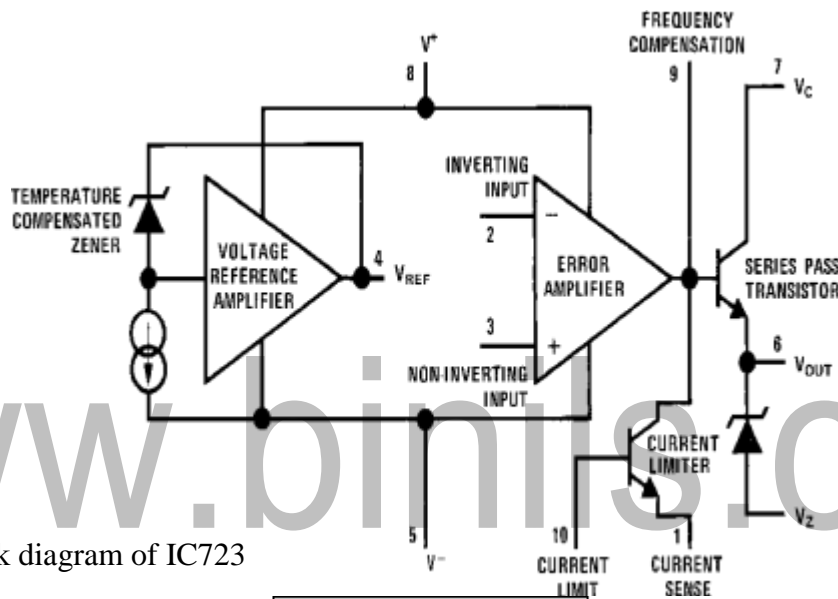


Fig: Functional block diagram of IC723

NC	1	IC 723	14	NC
Current limit	2		13	Frequency compensation
Current sense	3		12	+Vcc
Inverting Input	4		11	Vc
Non-Inverting Input	5		10	Vo
Vref	6		9	Vz
-Vcc	7		8	NC

Fig : Pin diagram of IC723

Series Pass Transistor:

Q1 is the internal series pass transistor which is driven by the error amplifier. This transistor actually acts as a variable resistor & regulates the output voltage. The collector of transistor Q1 is connected to the Un-regulated power supply. The maximum collector voltage of Q1 is limited to 36Volts. The maximum current which can be supplied by Q1 is 150mA.

Circuitry to limit the current:

The internal transistor Q2 is used for current sensing & limiting. Q2 is normally OFF transistor. It turns ON when the  $I_L$  exceeds a predetermined limit.

Low voltage , Low current is capable of supplying load voltage which is equal to or between 2 to 7Volts.

$$V_{load} = 2 \text{ to } 7V \quad I_{load} = 150mA$$

IC723 as a LOW voltage LOW current :

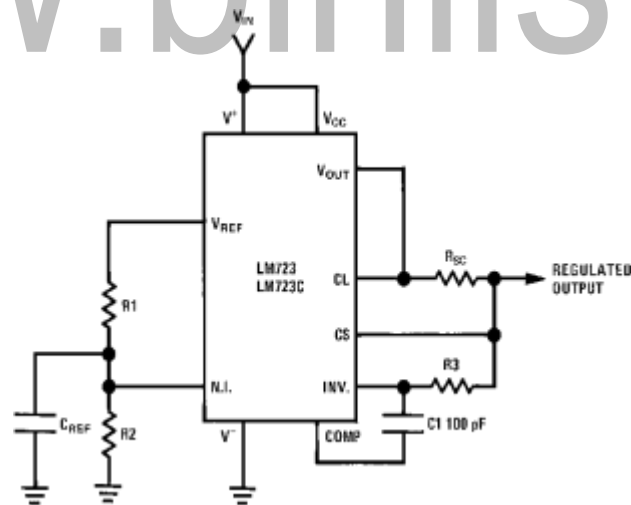


Fig: Typical circuit connection diagram

R1 & R2 form a potential divider between  $V_{ref}$  & Gnd.

The Voltage across R2 is connected to the Non – inverting terminal of the regulator IC

$$V_{\text{non-inv}} = \frac{R_2}{R_1} V_{\text{ref}}$$

Gain of the internal error amplifier is large

$$V_{\text{non-inv}} = V_{\text{in}}$$

Therefore the  $V_o$  is connected to the Inverting terminal through  $R_3$  &  $R_{SC}$  must also be equal to  $V_{\text{non-inv}}$

$$V_o = V_{\text{non-inv}} = \frac{R_2 R_1}{R_3} V_{\text{ref}}$$

$R_1$  &  $R_2$  can be in the range of  $1 \text{ K}\Omega$  to  $10 \text{ K}\Omega$  & value of  $R_3$  is given by

$$R_3 = R_1 \parallel R_2 = \frac{R_1 R_2}{R_1 + R_2}$$

$$R_3 \approx R_2$$

$R_{sc}$  (current sensing resistor) is connected between  $C_s$  &  $C_L$ . The voltage drop across  $R_{sc}$  is proportional to the  $I_L$ .

This resistor supplies the output voltage in the range of 2 to 7 volts, but the load current can be higher than 150mA.

The current sourcing capacity is increased by including a transistor Q in the circuit.

The output voltage,  $V_o = \frac{R_2}{R_1} V_{\text{ref}}$

IC723 as a HIGH voltage LOW Current:

This circuit is capable of supplying a regulated output voltage between the range of 7 to 37 volts with a maximum load current of 150 mA.

The Non – inverting terminal is now connected to  $V_{\text{ref}}$  through resistance  $R_3$ .

The value of  $R_1$  &  $R_2$  are adjusted in order to get a voltage of  $V_{\text{ref}}$  at the inverting terminal at the desired output.

$$V_{\text{in}} = V_{\text{ref}} = \frac{R_2}{R_1} V_o$$

$$R_1 \approx R_2$$

$$V_o = \frac{R_1 + R_2}{R_2} V_{\text{ref}}$$

$$V_o = [1 + \frac{R_1}{R_2}] V_{\text{ref}}$$

IC723 as a HIGH voltage HIGH Current:

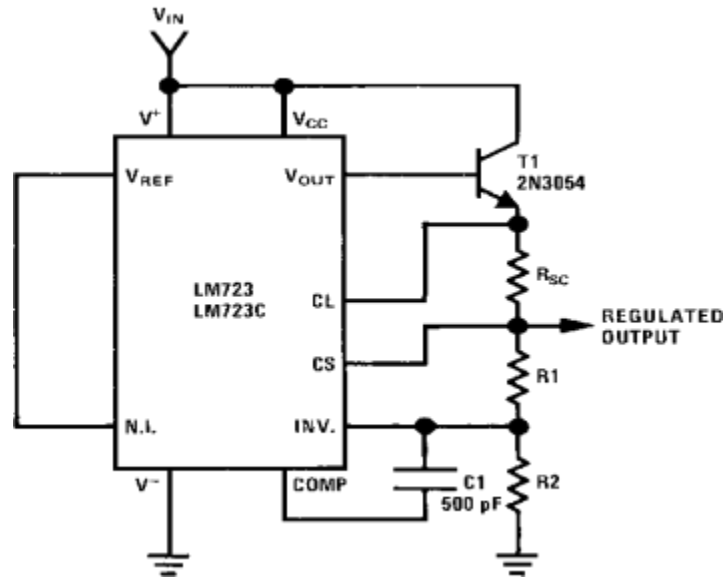


Fig: Typical circuit connection diagram

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An external transistor Q is added in the circuit for high voltage low current regulator to improve its current sourcing capacity.

For this circuit the output voltage varies between 7 & 37V.

Transistor Q increase the current sourcing capacity thus  $I_L(\text{MAX})$  is greater than 150mA.

The output voltage  $V_o$  is given by ,

$$V_o = \left( \frac{R_2}{R_1 + R_2} \right) V_{\text{ref}}$$

The value of  $R_{sc}$  is given by  $R_{sc} = 0.6 I_{\text{Limit}}$  \_\_\_\_\_

## UNIT-V

### LINEAR REGULATORS

- All electronic circuits need a dc power supply for their operation. To obtain this dc voltage from 230 V ac mains supply, we need to use rectifier.
- Therefore the filters are used to obtain a -steady dc voltage from the pulsating one.
- The filtered dc voltage is then applied to a regulator which will try to keep the dc output voltage constant in the event of voltage fluctuations or load variation.
- We know the combination of rectifier & filter can produce a dc voltage. But the problem with this type of dc power supply is that its output voltage will not remain constant in the event of fluctuations in an ac input or changes in the load current( $I_L$ ).
- The output of unregulated power supply is connected at the input of voltage regulator circuit.
- The voltage regulator is a specially designed circuit to keep the output voltage constant.
- It does not remain exactly constant. It changes slightly due to changes in certain parameters.

#### Factors affecting the output voltage:

- i)  $I_L$  (Load Current)
- ii)  $V_{IN}$  (Input Voltage)
- iii) T (Temperature)

#### IC Voltage Regulators:

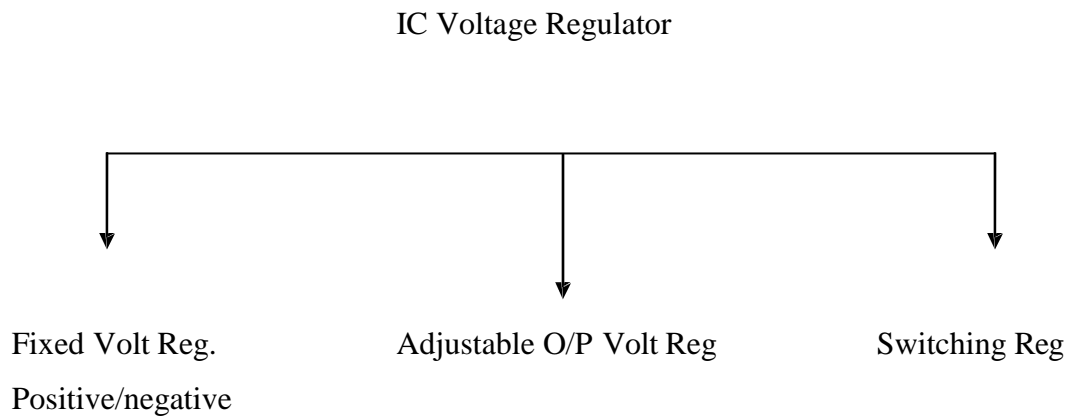
They are basically series regulators with all the basic blocks present inside the IC. Therefore it is easier to use IC voltage regulator instead of discrete voltage regulators.

#### Important features of IC Regulators:

1. Programmable output
2. Facility to boost the voltage/current

3. Internally provided short circuit current limiting
4. Thermal shutdown
5. Floating operation to facilitate higher voltage output

### Classifications of IC voltage regulators:



- Fixed & Adjustable output Voltage Regulators are known as Linear Regulator.
- A series pass transistor is used and it operates always in its active region.

#### Switching Regulator:

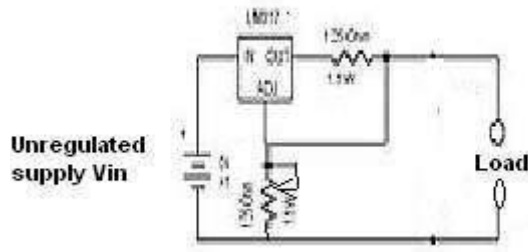
1. Series Pass Transistor acts as a switch.
2. The amount of power dissipation in it decreases considerably.
3. Power saving result is higher efficiency compared to that of linear.

#### Adjustable Voltage Regulator:

Advantages of Adjustable Voltage Regulator over fixed voltage regulator are,

1. Adjustable output voltage from 1.2v to 57 v
2. Output current 0.10 to 1.5 A
3. Better load & line regulation
4. Improved overload protection
5. Improved reliability under the 100% thermal overloading

Adjustable Positive Voltage Regulator (LM317):



- LM317 series adjustable 3 terminal positive voltage regulator, the three terminals are  $V_{in}$ ,  $V_{out}$  & adjustment (ADJ).
- LM317 requires only 2 external resistors to set the output voltage.
- LM317 produces a voltage of 1.25v between its output & adjustment terminals. This voltage is called as  $V_{ref}$ .
- $V_{ref}$  (Reference Voltage) is a constant, hence current  $I_1$  flows through  $R_1$  will also be constant. Because resistor  $R_1$  sets current  $I_1$ . It is called -current set/ or -program resistor.
- Resistor  $R_2$  is called as — Output set resistors, hence current through this resistor is the sum of  $I_1$  &  $I_{adj}$
- LM317 is designed in such as that  $I_{adj}$  is very small & constant with changes in line voltage & load current.
- The output voltage  $V_o$  is,  $V_o = R_1 I_1 + (I_1 + I_{adj}) R_2$ ----- (1)

Where  $I_1 = V_{ref}/R_1$

$$\begin{aligned} V_o &= (V_{ref}/R_1)R_1 + V_{ref}/R_1 + I_{adj} R_2 \\ &= V_{ref} + (V_{ref}/R_1)R_2 + I_{adj} R_2 \end{aligned}$$

$$V_o = V_{ref} [1 + R_2/R_1] + I_{adj} R_2$$
----- (2)

$R_1$  = Current ( $I_1$ ) set resistor



$R_2$  = output ( $V_o$ ) set resistor

$V_{ref} = 1.25v$  which is a constant voltage between output and ADJ terminals.

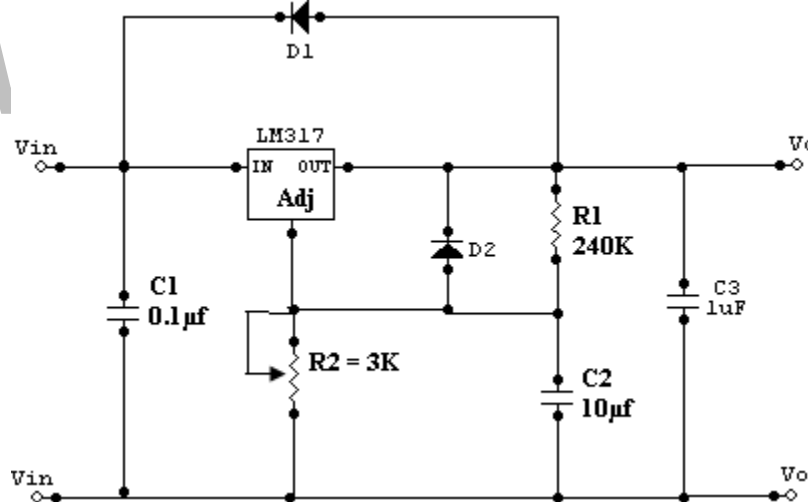
- Current  $I_{adj}$  is very small. Therefore the second term in (2) can be neglected.
- Thus the final expression for the output voltage is given by

$$V_o = 1.25v[1 + R_2/R_1] \dots \dots \dots (3)$$

Eqn (3) indicates that we can vary the output voltage by varying the resistance  $R_2$ .

The value of  $R_1$  is normally kept constant at 240 ohms for all practical applications.

### Practical Regulator using LM317:



- If LM317 is far away from the input power supply, then 0.1µf disc type or 1µftantalum capacitor should be used at the input of LM317.
- The output capacitor  $C_o$  is optional.  $C_o$  should be in the range of 1 to 1000µf.

- The adjustment terminal is bypassed with a capacitor C2 this will improve the ripple rejection ratio as high as 80 dB is obtainable at any output level.
- When the filter capacitor is used, it is necessary to use the protective diodes.
- These diodes do not allow the capacitor C2 to discharge through the low current point of the regulator.
- These diodes are required only for high output voltages (above 25v) & for higher values of output capacitance 25 $\mu$ f and above.

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## **MONOLITHIC SWITCHING REGULATOR [ $\mu$ A78S40]:**

The  $\mu$ A78S40 consists of a temperature compensated voltage reference, duty cycle controllable oscillator with an active current limit circuit, a high gain comparator, a high- current, high voltage output switch, a power switching diode & an uncommitted op-amp.

Important features of the  $\mu$ A78S40 switching regulators are:

- Step up, down & Inverting operation
- Operation from 2.5 to 40V input
- 80dB line & load regulations
- Output adjustable from 1.3 to 40V
- Peak current to 1.5A without external resistors
- Variable frequency, variable duty cycle device

The internal switching frequency is set by the timing capacitor  $C_T$ , connected between pin12 & ground pin 11. the initial duty cycle is 6:1. The switching frequency & duty cycle can be modified by the current limit circuitry,  $I_{PKsense}$ , pin14, 7 the comparator, pin9 & 10.

### **Comparator:**

The comparator modifies the OFF time of the output switch transistor Q1 & Q2.  
In the step

– up & step down modes, the non- inverting input(pin9) of the comparator is connected to the voltage reference of 1.3V (pin8) & the inverting input (pin10) is connected to the output terminal via the voltage divider network.

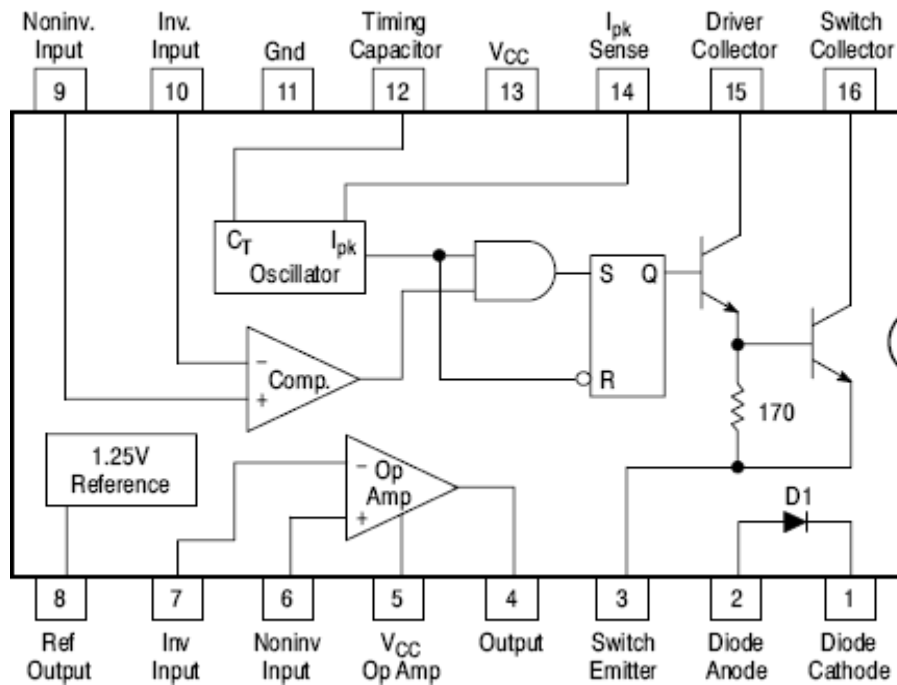
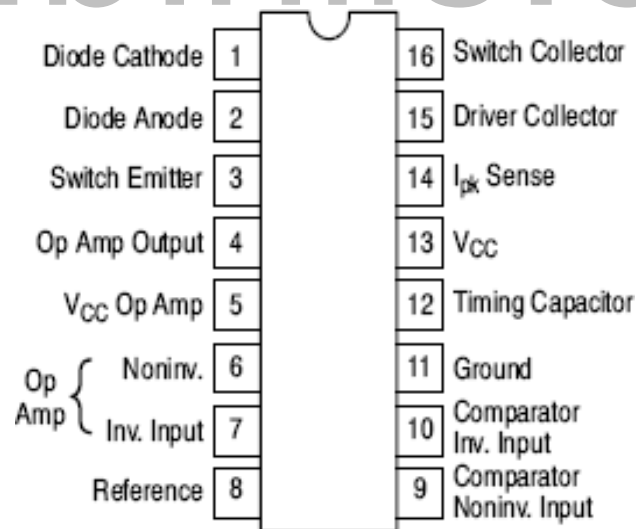


Fig: Functional block diagram of  $\mu A78S40$



- In the Inverting mode the non – inverting input is connected to both the voltage reference & the output terminal through 2 resistors & the inverting terminal is connected to ground.

- When the output voltage is correct, the comparator output is in high state & has no effect on the circuit operation.
- However, if the output is too high & the voltage at the inverting terminal is higher than that at the non-inverting terminal, then the comparator output goes low.
- In the LOW state the comparator inhibits the turn on of the output switching transistors. This means that, as long as the comparator output is low, the system is in off time.
- As the output current rises or the output voltage falls, the off time of the system decreases.
- Consequently, as the output current nears its maximum  $I_{O_{MAX}}$ , the off time approaches its minimum value.

In all 3 modes (Step down, step up, Inverting), the current limit circuit is completed by connecting a sense resistor  $R_{sc}$ , between  $I_{PK}$  sense &  $V_{cc}$ .

- The current limit circuit is activated when a 330mV potential appears across  $R_{sc}$ .
- $R_{sc}$  is selected such that 330mV appears across it when the desired peak current  $I_{PK}$ , flows through it.
- When the peak current is reached, the current limit circuit is turned on.
- The forward voltage drop,  $V_D$ , across the internal power diode is used to determine the value of inductor L off time & efficiency of the switching regulator.
- Another important quantity used in the design of a switching regulator is the saturation voltage  $V_s$ 
  - ✓ In the step down mode an -output saturation volt| is 1.1V typical, 1.3  $V_{MAX}$ .
  - ✓ In the step up mode an -Output saturation volt| is 0.45V typical, 0.7 maximum.

$$R_{sc} = \frac{330mV \text{ DesiredPeakCurrent}}{\quad}$$

- ✓ The desired peak current value is reached, the current limiting circuit turns ON & immediately terminates the ON time & starts OFF time.
- As we increase  $I_L$  (load current),  $V_{out}$  will decrease, to compensate for this, the ON time of the output is increased automatically.
- If the  $I_L$  decreased then  $V_{out}$  increased, to compensate for this, the OFF time of the output is increased automatically.

(i) **Step – Down Switching Regulator:**

- $C_T$  is the timing capacitor which decides the switching frequency.
- $R_{sc}$  is the current sensing resistance. Its value is given by

$$R_{sc} = \frac{330mV \text{ DesiredPeakCurrent}}{\quad}$$

- The Non-inverting terminal of the internal op-amp (pin9) is connected to the 1.3V reference (pin8).
- Resistances  $R_1$  &  $R_2$  form a potential divider, across the output voltage  $V_o$ . Their value should be such that the potential at the inverting input of the op-amp should be equal to 1.3V ref when  $V_o$  is at its desired level.

$$\bullet \quad V_{(-)} = 1.3V = \frac{R_2}{R_1 + R_2} V_o$$

Figure 6. Step-Down Converter

(ii) **Step – Up Switching Regulator:**

- Note that inductor is connected between the collectors of  $Q_1$  &  $Q_2$ .
- When  $Q_1$  is ON, the output is shorted & the collector current of  $Q_1$  flows through  $L$ .

- The diode D1 is reverse biased & Co supplies the load current.
- The inductor stores the energy. When the Q1 is turned OFF, there is a self induced emf that appears across the inductor with polarities.
- The output voltage is given by,

$$V_o = V_{in} + V_L$$

- Hence it will be always higher than  $V_{in}$  & step up operation is achieved.

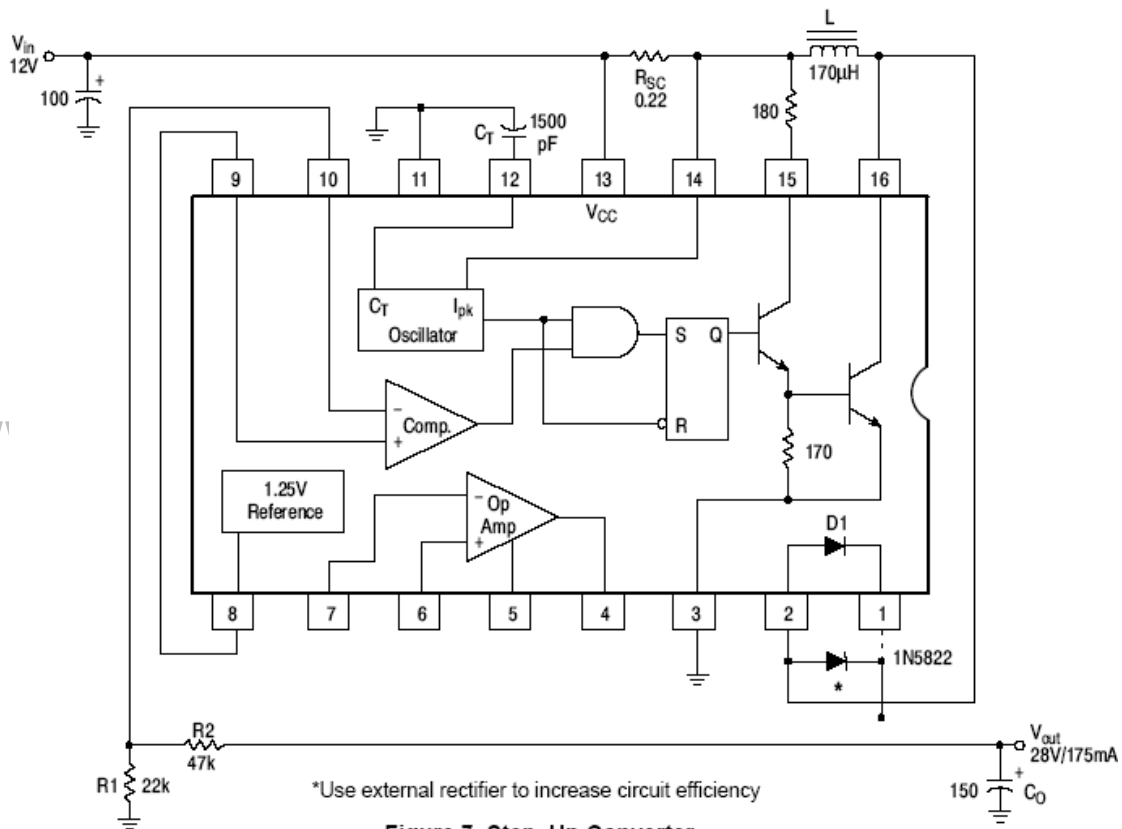
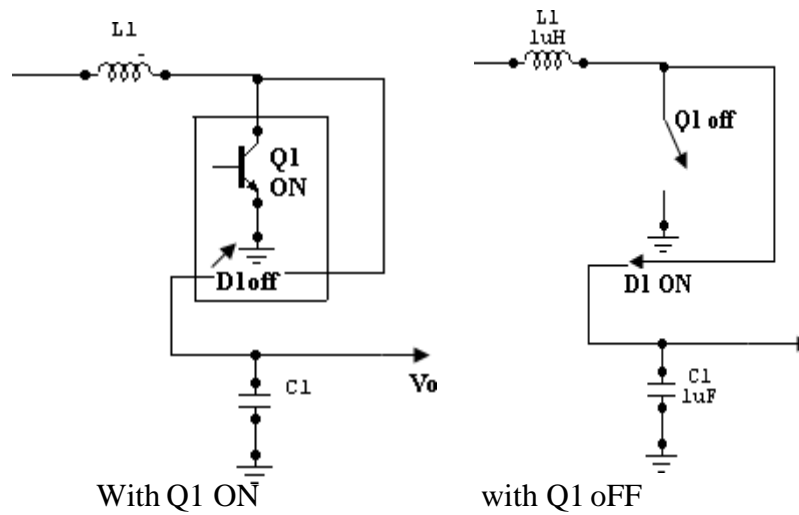
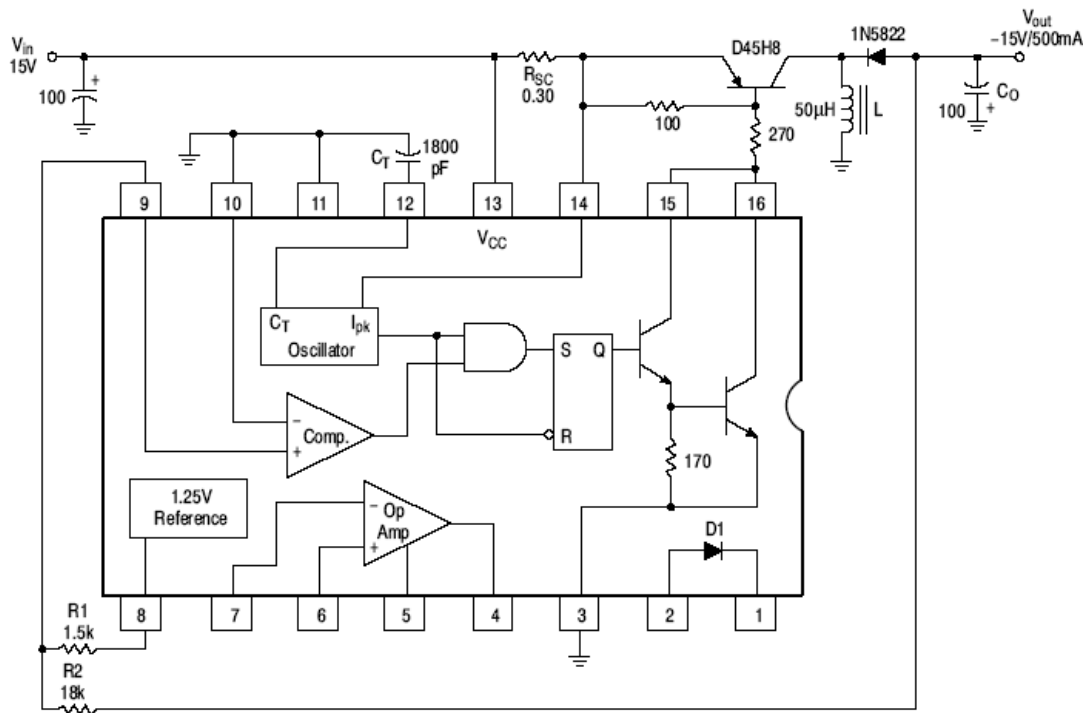


Figure 7. Step-Up Converter



(iii) **Inverting Switching Regulator:**

Inverting switching regulator converts a positive input voltage into a negative output voltage which is higher in magnitude.





### OPTOCOUPPLERS/OPTOISOLATORS:

- Opt couplers or Opt isolators is a combination of light source & light detector in the same package.
- They are used to couple signal from one point to other optically, by providing a complete electric isolation between them. This kind of isolation is provided between a low power control circuit & high power output circuit, to protect the control circuit.
- Depending on the type of light source & detector used we can get a variety of optocouplers. They are as follows,

- (i) LED – LDR optocoupler
- (ii) LED – Photodiode optocoupler
- (iii) LED – Phototransistor optocoupler

Characteristics of optocoupler:

- (i) Current Transfer Ratio (CTR)
- (ii) Isolation Voltage
- (iii) Response Time
- (iv) Common Mode Rejection

(i) Current Transfer Ratio:

It is defined as the ratio of output collector current ( $I_c$ ) to the input forward current ( $I_f$ )

$$CTR = I_c / I_f * 100\%$$

Its value depends on the devices used as source & detector.

(ii) Isolation voltage between input & output:

It is the maximum voltage which can exist differentially between the input & output without affecting the electrical isolation voltage is specified in K Vrms with a relative humidity of 40 to 60%.

(iii) Response Time:

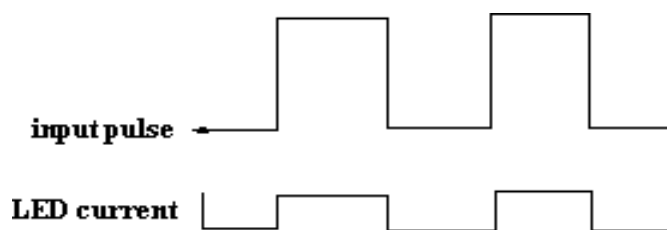
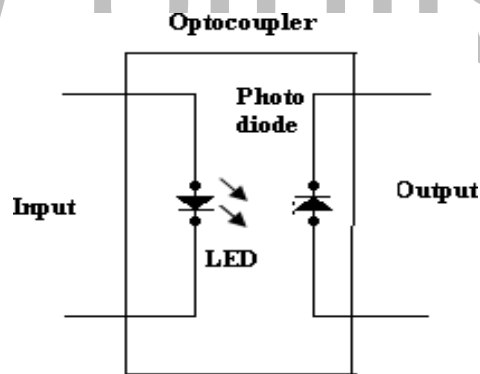
Response time indicates how fast an optocoupler can change its output state. Response time largely depends on the detector transistor, input current & load resistance.

(iv) Common mode Rejection:

Eventhough the optocouplers are electrically isolated for dc & low frequency signals, an impulsive input signal (the signal which changes suddenly) can give rise to a displacement current  $I_c = C_f \cdot dv/dt$ . This current can flow between input & output due to the capacitance  $C_f$  existing between input & output. This allow the noise to appear in the output.

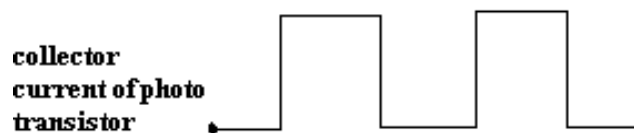
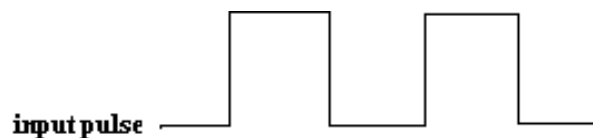
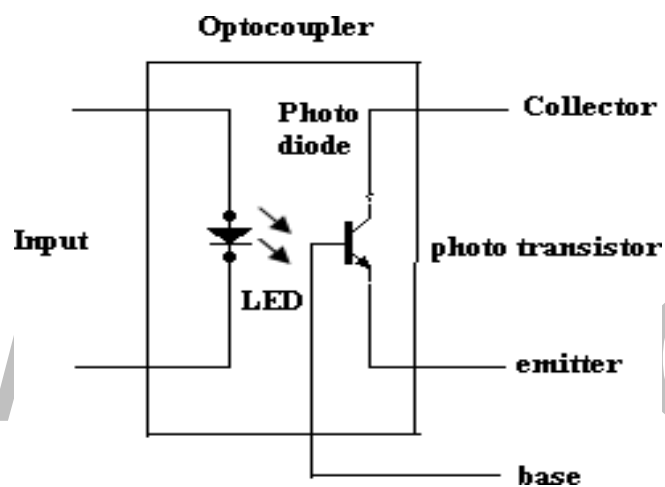
Types of optocoupler:

(i) LED – Photodiode optocoupler:



- LED photodiode shown in figure, here the infrared LED acts as a light source & photodiode is used as a detector.
- The advantage of using the photodiode is its high linearity. When the pulse at the input goes high, the LED turns ON. It emits light. This light is focused on the photodiode.
- In response to this light the photocurrent will start flowing through the photodiode. As soon as the input pulse reduces to zero, the LED turns OFF & the photocurrent through the photodiode reduces to zero. Thus the pulse at the input is coupled to the output side.

(ii) LED – Phototransistor Optocoupler:



- The LED phototransistor optocoupler shown in figure. An infrared LED acts as a light source and the phototransistor acts as a photo detector.
- This is the most popularly used optocoupler, because it does not need any additional amplification.
- When the pulse at the input goes high, the LED turns ON. The light emitted by the LED is

focused on the CB junction of the phototransistor.

- In response to this light photocurrent starts flowing which acts as a base current for the phototransistor.
- The collector current of phototransistor starts flowing. As soon as the input pulse reduces to zero, the LED turns OFF & the collector current of phototransistor reduces to zero. Thus the pulse at the input is optically coupled to the output side.

Advantages of Optocoupler:

- Control circuits are well protected due to electrical isolation.
- Wideband signal transmission is possible.
- Due to unidirectional signal transfer, noise from the output side does not get coupled to the input side.
- Interfacing with logic circuits is easily possible.
- It is small size & light weight device.

Disadvantages:

- Slow speed.
- Possibility of signal coupling for high power signals.

Applications:

Optocouplers are used basically to isolate low power circuits from high power circuits.

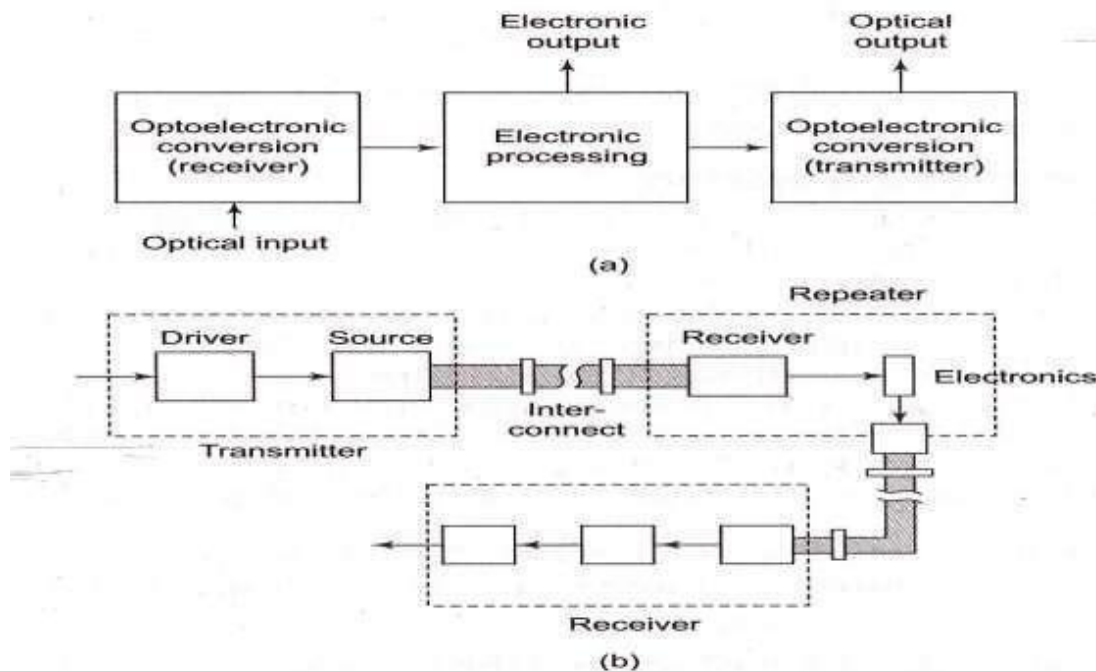
- At the same time the control signals are coupled from the control circuits to the high power circuits.
- Some of such applications are,
  - (i) AC to DC converters used for DC motor speed control
  - (ii) High power choppers
  - (iii) High power inverters
- One of the most important applications of an optocoupler is to couple the base driving signals to a power transistor connected in a DC-DC chopper.
- Note that the input & output waveforms are 180° out of phase as the output is taken at the

collector of the phototransistor.

### Optocoupler IC:

The optocouplers are available in the IC form MCT2E is the standard optocoupler IC which is used popularly in many electronic application.

- This input is applied between pin 1 & pin 2. An infrared light emitting diode is connected between these pins.
- The infrared radiation from the LED gets focused on the internal phototransistor.
- The base of the phototransistor is generally left open. But sometimes a high value pull down resistance is connected from the Base to ground to improve the sensitivity.
- The block diagram shows the opto-electronic- integrated circuit (OEIC) and the major components of a fiber-optic communication facility.



### FUNCTION GENERATOR IC 8038:

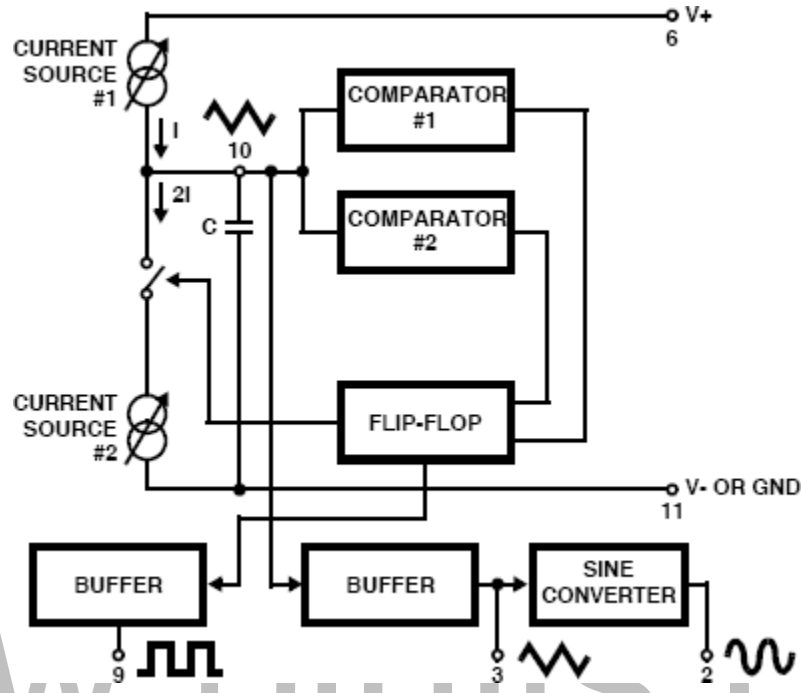
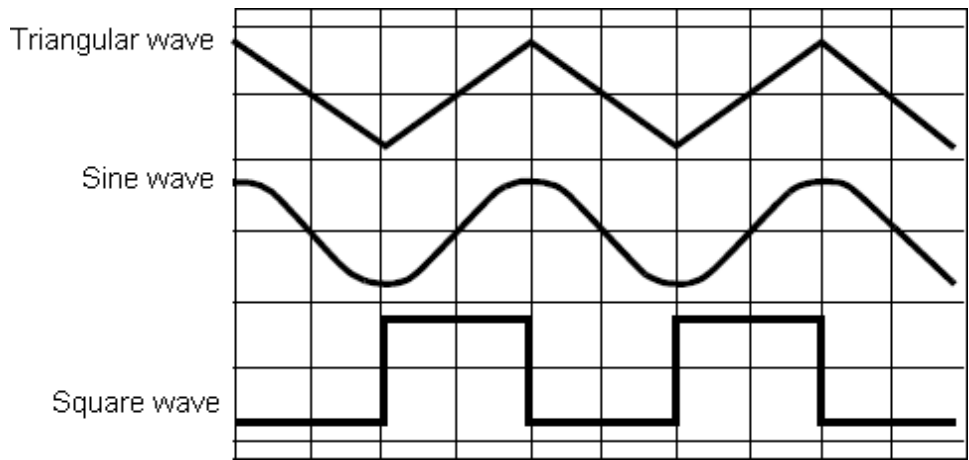


Fig: Functional block diagram of Function generator

#### Output Waveform:



It consists of two current sources, two comparators, two buffers, one FF and a sine wave converter.

Pin description:

Pin 1 & Pin 12: Sine wave adjusts:

The distortion in the sine wave output can be reduced by adjusting the 100K $\Omega$  pots connected between pin12 & pin11 and between pin 1 & 6.

Pin 2 Sine Wave Output:

Sine wave output is available at this pin. The amplitude of this sine wave is 0.22 Vcc.

Where  $\pm 5V \leq V_{cc} \leq \pm 15 V$ .

Pin 3 Triangular Wave output:

Triangular wave is available at this pin. The amplitude of the triangular wave is 0.33Vcc.

Where  $\pm 5V \leq V_{cc} \leq \pm 15 V$ .

Pin 4 & Pin 5 Duty cycle / Frequency adjust:

The symmetry of all the output wave forms & 50% duty cycle for the square wave output is adjusted by the external resistors connected from Vcc to pin 4. These external resistors & capacitors at pin 10 will decide the frequency of the output wave forms.

Pin 6 + Vcc:

Positive supply voltage the value of which is between 10 & 30V is applied to this pin.

Pin 7 : FM Bias:

This pin along with pin no8 is used to TEST the IC 8038.

Pin9 : Square Wave Output:

A square wave output is available at this pin. It is an open collector output so that this pin can be connected through the load to different power supply voltages. This arrangement is very

useful in making the square wave output.

Pin 10 : Timing Capacitors:

The external capacitor C connected to this pin will decide the output frequency along with the resistors connected to pin 4 & 5.

Pin 11 :  $-V_{EE}$  or Ground:

If a single polarity supply is to be used then this pin is connected to supply ground & if ( $\pm$ ) supply voltages are to be used then (-) supply is connected to this pin.

Pin 13 & Pin 14: NC (No Connection)

Important features of IC 8038:

1. All the outputs are simultaneously available.
2. Frequency range : 0.001Hz to 500kHz
3. Low distortion in the output wave forms.
4. Low frequency drift due to change in temperature.
5. Easy to use.

Parameters:

(i) Frequency of the output wave form:

- The output frequency dependent on the values of resistors R1 & R2 along with the external capacitor C connected at pin 10.
- If  $R_A = R_B = R$  & if  $R_C$  is adjusted for 50% duty cycle then

$$f_o = \frac{0.3}{RC} ; \quad R_A = R_1, R_B = R_3, R_C = R_2$$

(ii) Duty cycle / Frequency Adjust : (Pin 4 & 5):

Duty cycle as well as the frequency of the output wave form can be adjusted by controlling the



values of external resistors at pin 4 & 5.

- The values of resistors  $R_A$  &  $R_B$  connected between  $V_{cc}$  \* pin 4 & 5 respectively along with the capacitor connected at pin 10 decide the frequency of the wave form.
- The values of  $R_A$  &  $R_B$  should be in the range of  $1k\Omega$  to  $1M\Omega$ .

(iii) FM Bias:

- The FM Bias input (pin7) corresponds to the junction of resistors  $R_1$  &  $R_2$ .
- The voltage  $V_{in}$  is the voltage between  $V_{cc}$  & pin8 and it decides the output frequency.
- The output frequency is proportional to  $V_{in}$  as given by the following expression

For  $R_A = R_B$  (50% duty cycle).

$$f_o = \frac{1.5V_{in}}{CRAV_{cc}} \quad ; \text{ where } C \text{ is the timing capacitor}$$

- With pin 7 & 8 connected to each other the output frequency is given by

$$f_o = \frac{0.3}{RC}$$

where  $R = R_A = R_B$  for 50% duty cycle.

- This is because  $V_{in} = \frac{R_1}{R_1 + R_2} V_{cc}$

(iv) FM Sweep input (pin 8):

- This input should be connected to pin 7, if we want a constant output frequency.
- But if the output frequency is supposed to vary, then a variable dc voltage should be applied to this pin.
- The voltage between Vcc & pin 8 is called Vin and it decides the output frequency as,

1.5 Vin

$$f_o = \frac{1.5 V_{in}}{C R_A V_{cc}}$$

A potentiometer can be connected to this pin to obtain the required variable voltage required to change the output frequency.

[www.binils.com](http://www.binils.com)

## POWER AUDIO AMPLIFIER IC LM380:

### Features of LM380:

1. Internally fixed gain of 50 (34dB)
2. Output is automatically self centring to one half of the supply voltage.
3. Output is short circuit proof with internal thermal limiting.
4. Input stage allows the input to be ground referenced or ac coupled.
5. Wide supply voltage range (5 to 22V).
6. High peak current capability.
7. High impedance.
8. Low total harmonic distortion
9. Bandwidth of 100KHz at  $P_{out} = 2W$  &  $R_L = 8\Omega$

### Introduction:

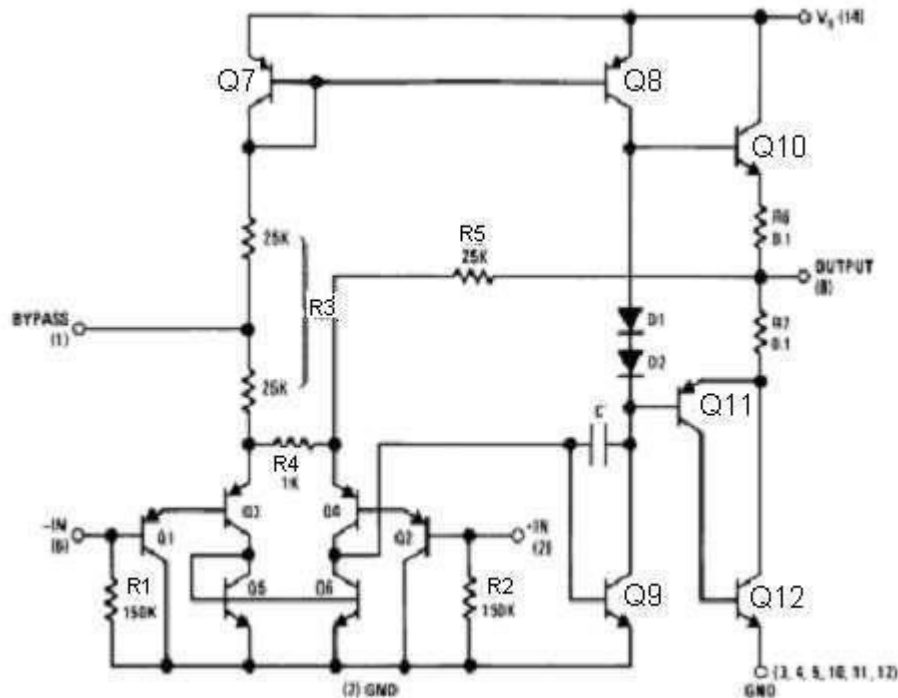
Small signal amplifiers are essentially voltage amplifiers that supply their loads with larger amplifier signal voltage.

On the other hand, large signal or power amplifiers supply a large signal current to current operated loads such as speakers & motors.

In audio applications, however, the amplifier called upon to deliver much higher current than that supplied by general purpose op-amps. This means that loads such as speakers & motors requiring substantial currents cannot be driven directly by the output of general purpose opo-amps.

However there are two possible solutions,

- To use discrete or monolithic power transistors called power boosters at the output of the op-amp
- To use specialized ICs designed as power amplifiers.



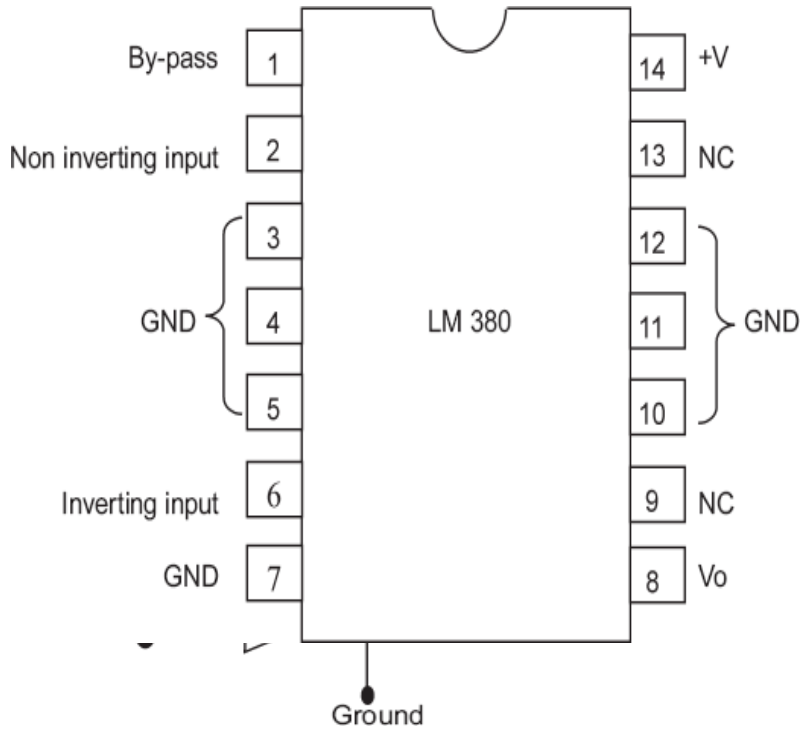


Fig : Block diagram  
Fig: Pin diagram

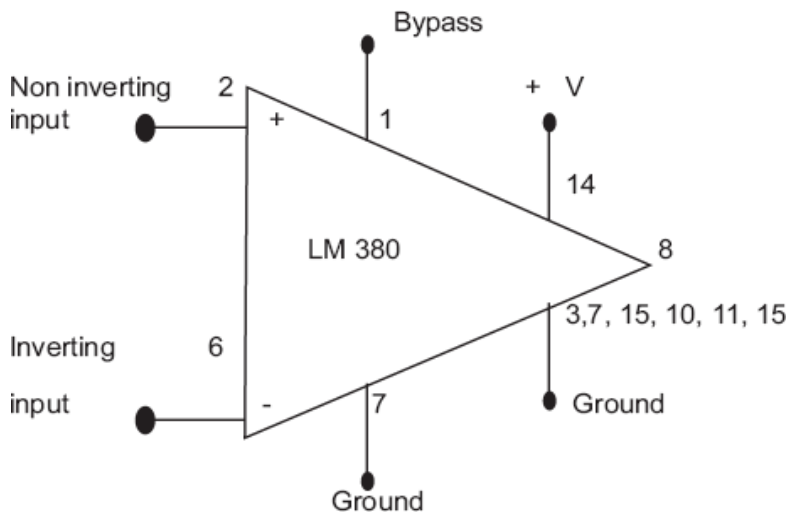


Fig : Block diagram

LM380 circuit description:

It is connected of 4 stages,

- (i) PNP emitter follower
- (ii) Different amplifier
- (iii) Common emitter
- (iv) Emitter follower

(i) PNP Emitter follower:

- The input stage is emitter follower composed of PNP transistors Q1 & Q2 which drives the PNP Q3-Q4 differential pair.
- The choice of PNP input transistors Q1 & Q2 allows the input to be referenced to ground i.e., the input can be direct coupled to either the inverting & non-inverting terminals of the amplifier.

(ii) Differential Amplifier:

- The current in the PNP differential pair Q3-Q4 is established by Q7, R3 & +V.
- The current mirror formed by transistor Q7, Q8 & associated resistors then establishes the collector current of Q9.
- Transistor Q5 & Q6 constitute of collector loads for the PNP differential pair.
- The output of the differential amplifier is taken at the junction of Q4 & Q6 transistors & is applied as an input to the common emitter voltage gain.

(iii) Common Emitter:

- Common Emitter amplifier stage is formed by transistor Q9 with D1, D2 & Q8 as a current source load.

- The capacitor C between the base & collector of Q9 provides internal compensation & helps to establish the upper cutoff frequency of 100 KHz.
- Since Q7 & Q8 form a current mirror, the current through D1 & D2 is approximately the same as the current through R3.
- D1 & D2 are temperature compensating diodes for transistors Q10 & Q11 in that D1 & D2 have the same characteristics as the base-emitter junctions of Q11. Therefore the current through Q10 & (Q11-Q12) is approximately equal to the current through diodes D1 & D2.

(iv) (Output stage) - Emitter follower:

- Emitter follower formed by NPN transistor Q10 & Q11. The combination of PNP transistor Q11 & NPN transistor Q12 has the power capability of an NPN transistors but the characteristics of a PNP transistor.
- The negative dc feedback applied through R5 balances the differential amplifier so that the dc output voltage is stabilized at  $+V/2$ ;
- To decouple the input stage from the supply voltage  $+V$ , by pass capacitor in order of micro farad should be connected between the by pass terminal (pin 1) & ground (pin 7).

The overall internal gain of the amplifier is fixed at 50. However gain can be increased by using positive feedback.

## SWITCHING REGULATOR:

An example of general purpose regulator is Motorola's MC1723. It can be used in many different ways, for example, as a fixed positive or negative output voltage regulator, variable regulator or switching regulator because of its flexibility.

To minimize the power dissipation during switching, the external transistor used must be a switching power transistor.

To improve the efficiency of a regulator, the series pass transistor is used as a switch rather than as a variable resistor as in the linear mode.

- A regulator constructed to operate in this manner is called a series switching regulator. In such regulators the series pass transistor is switched between cut off & saturation at a high frequency which produces a pulse width modulated (PWM) square wave output.
- This output is filtered through a low pass LC filter to produce an average dc output voltage.
  - Thus the output voltage is proportional to the pulse width and frequency.
  - The efficiency of a series switching regulator is independent of the input & output differential & can approach 95%

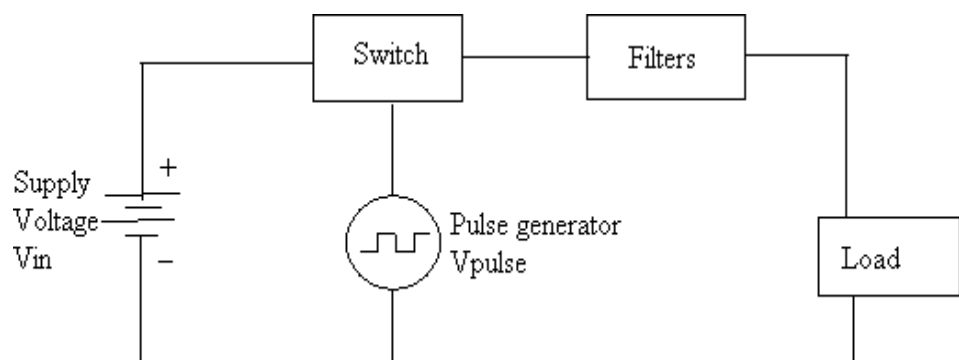


Fig : Basic Switching regulator



A basic switching regulator consists of 4 major components,

1. Voltage source  $V_{in}$
2. Switch  $S_1$
3. Pulse generator  $V_{pulse}$
4. Filter  $F_1$

### 1. Voltage Source $V_{in}$ :

It may be any dc supply – a battery or an unregulated or a regulated voltage. The voltage source must satisfy the following requirements.

- It must supply the required output power & the losses associated with the switching regulator.
- It must be large enough to supply sufficient dynamic range for line & load regulations.
- It must be sufficiently high to meet the minimum requirement of the regulator system to be designed.
- It may be required to store energy for a specified amount of time during power failures.

### 2. Switch $S_1$ :

It is typically a transistor or thyristor connected as a power switch & is operated in the saturated mode. The pulse generator output alternately turns the switch ON & OFF

### 3. Pulse generator $V_{pulse}$ :

It provides an asymmetrical square wave varying in either frequency or pulse width called frequency modulation or pulse width modulation respectively. The most effective frequency range for the pulse generator for optimum efficiency 20 KHz. This frequency is inaudible to the human ear & also well within the switching speeds of most inexpensive transistors & diodes.

- The duty cycle of the pulse wave form determines the relationship between the input & output voltages. The duty cycle is the ratio of the on time  $t_{on}$ , to the period  $T$  of the pulse waveform.

$$\text{Duty cycle} = \frac{t_{on}}{t_{on} + t_{off}}$$

- Switching regulator can operate in any of 3 modes

$$= \frac{t_{on}}{T} = t_{on} f.$$

Where  $t_{on}$  = On-time of the pulse waveform

$t_{off}$  = off- time of the pulse wave form

$T$  = time period =  $t_{on} + t_{off}$

= 1/frequency or

$T = 1/f$

- Typical operating frequencies of switching regulator range from 10 to 50kHz.
- Lower operating frequency improve efficiency & reduce electrical noise, but require large filter components (inductors & capacitors).

#### 4 Filter F1:

It converts the pulse waveform from the output of the switch into a dc voltage. Since this switching mechanism allows a conversion similar to transformers, the switching regulator is often referred to as a dc transformer.

The output voltage  $V_o$  of the switching regulator is a function of duty cycle & the input voltage  $V_{in}$ .

$V_o$  is expressed as follows,

$$V_o = \frac{t_{on}}{T} V_{in}$$

- This equation indicates that, if time period  $T$  is constant,  $V_o$  is directly proportional to the ON-time,  $t_{on}$  for a given value of  $V_{in}$ . This method of changing the output voltage by varying  $t_{on}$  is referred to as a pulse width modulation.
- Similarly, if  $t_{on}$  is held constant, the output voltage  $V_o$  is inversely proportional to the period  $T$  or directly proportional to the frequency of the pulse waveform. This method of varying the output voltage is referred to as frequency modulation (FM).

i) Step – Down

i) Step – Up

ii) Polarity inverting