UNIT- 5

Application ICs

1. Voltage Regulator
2. Power Amplifier
3. Function Generator
4. Switching Regulator
5. Opto Coupler.

IC Voltage Regulators

The function of a voltage Regulator is to provide a stable dc voltage for powering other electronic circuits. A voltage regulator should be capable of providing substantial output current.

Voltage Regulators can be classified as

a) Series Regulator
b) Switching Regulator

Series Regulators

Series Regulators use a power transistor connected in series b/w the unregulated dc input and load, o/p voltage is controlled by continuous voltage drop taking place across series pass transistor.

(2)

→ The transistor conducts in the active or linear region, these regulators are also called linear regulators

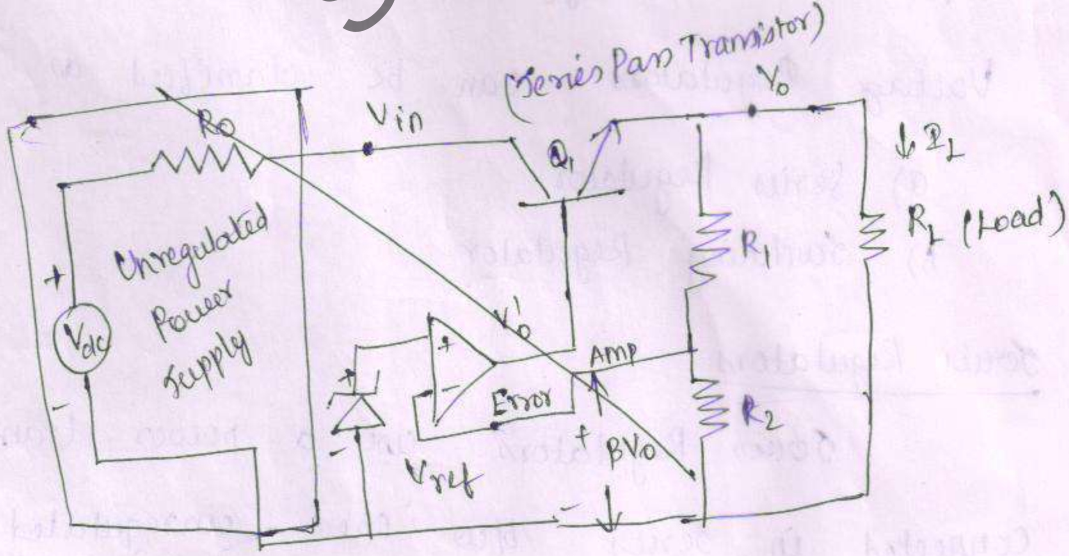
→ Linear voltage regulators are 78xx, 79xx series, 723IC.

Switching Regulator

Can operate power transistor as a high frequency on/off switch, so power transistor does not conduct current continuously.

Series op-amp Regulator

Stable dc voltage ac line voltage variations



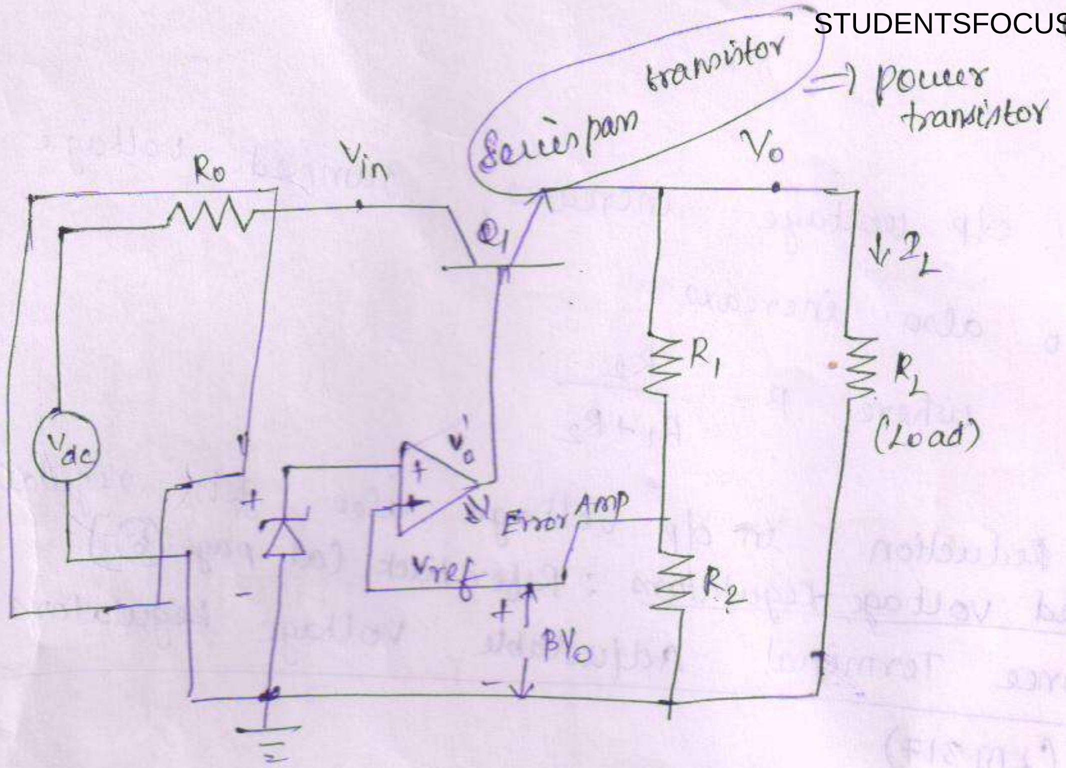


Fig 1: A regulated Power supply

A regulated power supply using discrete components and circuit consists of following four parts

a) Reference voltage circuit
b) Error Amplifier
c) series pass transistor
d) Feedback n/w.

→ Power transistor Q_1 is in series with unregulated dc voltage V_{in} and regulated o/p voltage V_o.

→ Q_1 is also connected as an emitter follower and provides sufficient current gain to drive the load.

→ Sampled voltage is compared with reference voltage V_{ref}.

∴ o/p voltage increases, sampled voltage βV_0 also increases

where $\beta = \frac{R_2}{R_1 + R_2}$

→ Reduction in o/p voltage also gets regulated

Fixed voltage Regulators : Refer back (at page 6)

Three Terminal Adjustable Voltage Regulators (LM 317)

→ Adjustable voltage regulators, output voltage can be adjusted 1.2V upto 57V. The adjustable voltage regulators have become more popular because of versatility & reliability

→ LM317 series is most commonly used general purpose adjustable voltage Regulator.

Advantages :-

→ Improved system Performance
→ Improved overload protection
→ Improved system reliability

→ LM317 series regulators available in standard transistor packages and it has 3 terminals.

→ The three terminals are V_{IN}, V_{OUT} & Adjustment (ADJ)

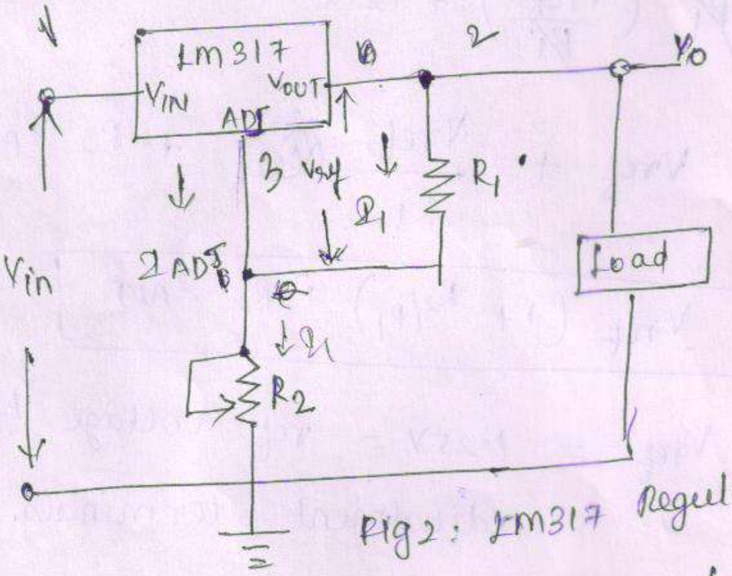


Fig 2: LM317 Regulator

* Requires only 2 external resistors to set o/p voltage.
* Vref is impressed across Resistor R_1 & voltage is constant, the current I_1 is also constant for a given value of R_1.
* R_1 set I_1 ⇒ current set or program resistor
* LM317 is designed as I_{ADJ} is very small and constant with line & load changes.

o/p voltage $V_0 = R_1 I_1 + R_2 (I_1 + I_{ADJ})$ → ①

where $I_1 = \frac{V_{ref}}{R_1}$ (R_1 – I_1 set resistor
R_2 – o/p set resistor
I_{ADJ} – Adjustment pin current)

sub $I_1 = \frac{V_{ref}}{R_1}$ in (1)

$$V_0 = R_1 \left(\frac{V_{ref}}{R_1}\right) + R_2 (I_1 + I_{ADJ})$$

$$V_0 = V_{ref} + \frac{V_{ref}}{R_1} R_2 + R_2 I_{ADJ}$$

$$V_0 = V_{ref} (1 + R_2/R_1) + R_2 I_{ADJ}$$

where V_{ref} = 1.25V = ref voltage b/w o/p and adjustment terminals.

Application of IC voltage regulators ⇒ (After 723 General purpose regulators)

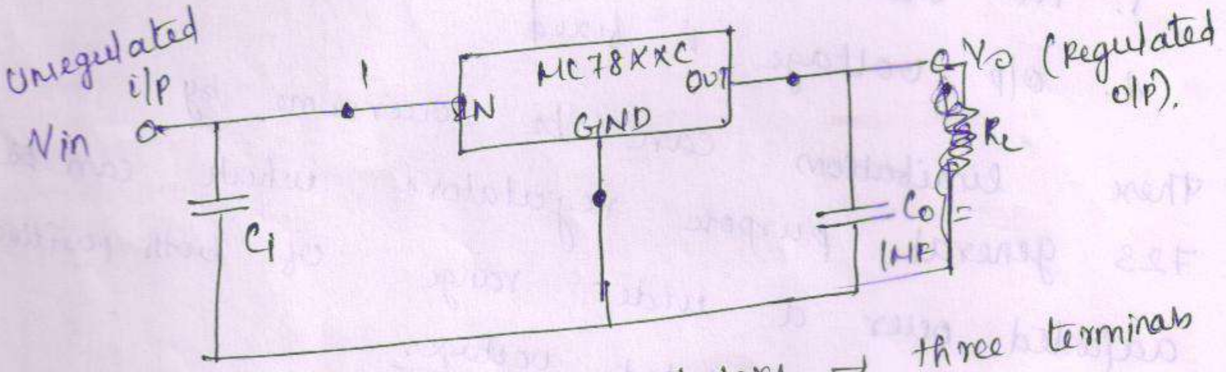
1. Easy to use
2. It greatly simplifies power supply design
3. IC voltage regulators are versatile
4. Used for local regulation ⇒ low current, powers

Three Terminal Fixed voltage Regulators

→ 78XX series are three terminal, positive fixed voltage regulators with seven o/p voltage options available such as 5, 6, 8, 12, 15, 18 & 24V

In 78XX, the last 2 nos XX indicate o/p voltage. eg 7815 represents 15V regulator

These regulators are 2 types of package
Metal package (T_0 - 3type)
Plastic package (T_0 - 220 type)



→ Three terminal voltage regulators → three terminals o/p, Vin (unregulated) & V_0 (regulated) & common or ground terminal, ⇒ no feedback connection.

→ capacitor to cancel inductive effects due to long distribution leads

characteristics

Four characteristics of 3 terminal IC regulator

1) V_0 : fixed o/p voltage as specified by manufacturer (78xx has 5, 6, 8 etc)

2) $V_{in} > V_0$ +2Volts [2 mov more than V_0)
ie if $V_0 = 7V$, $V_{in} = 5V$

3) I_{0max} : load current may vary from 0 to rated max o/p I

4. Thermal shutdown : IC has temperature sensor (built-in) which turns off IC when it becomes too hot. & o/p current will drop & remains until IC has cooled significantly

IC 723 General Purpose Regulator

~~Three terminal~~

Limitation of 3 terminal voltage regulators

1. No short circuit protection
2. o/p voltage is fixed

These limitations can be overcome by 723 general purpose regulators which can be adjusted over a wide range of both positive or negative regulated voltage.

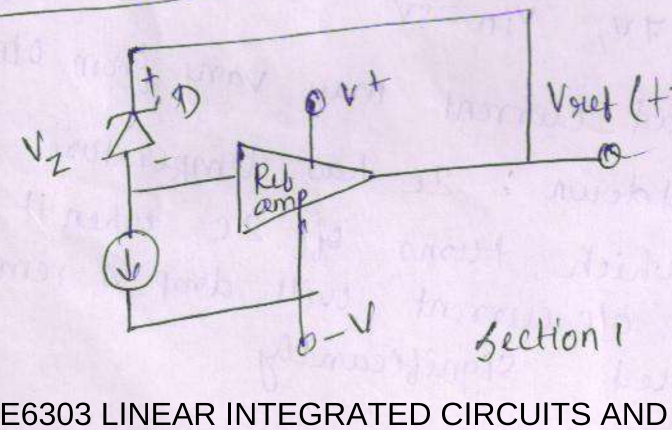
Important features of IC723

1) Works as a voltage regulator at o/p ranges from 2 to 37 volts at currents upto 150mA.

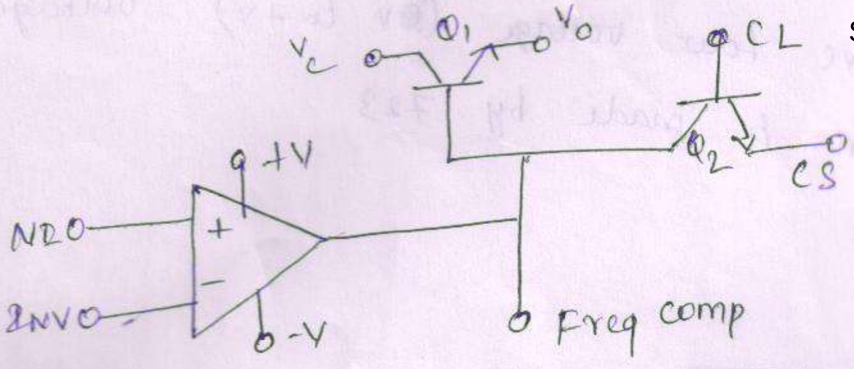
2) has good line and load regulation

3) Relative ease with which power supply can be designed and provides a choice of supply voltage.

Functional block diagram of IC723 voltage Regulator



Section 1



Section (2)

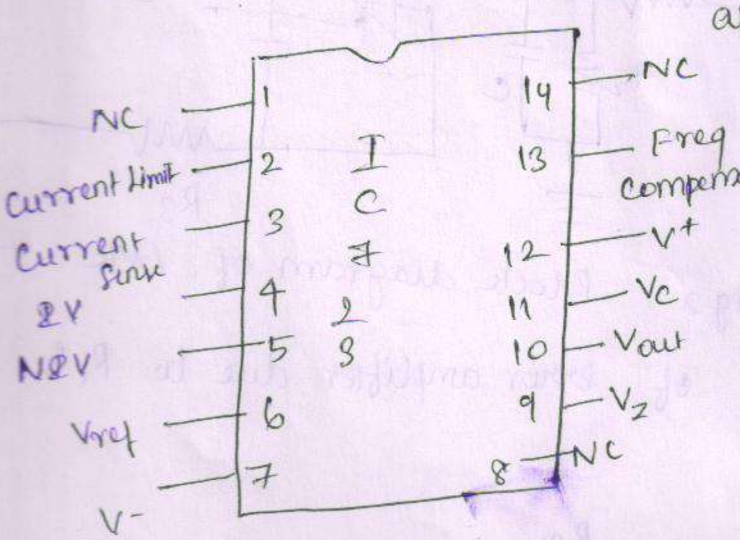
→ Two separate sections : 1) Zener diode, constant current source & reference amp.

2) Error amp, series pass transistor or power transistor (Q₁ & Q₂) (acts as switch or gate of electronic s/ls)
→ regulates current or voltage

→ Reference amplifier produces a fixed voltage of 7V at Vref. Constant current source produces Zener to operate at fixed point so Zener o/ps a fixed voltage. ~~(regulated)~~

→ Series pass transistor Q_1, current limit transistor Q_2.

Pin diagram of IC723



→ Error amplifier compares a sample of o/p voltage applied at INV i/p terminal to the ref voltage Vref applied at NI i/p terminal.

→ Error signal controls conduction of Q_1

1. Simple positive low voltage (2V to 7V) voltage Regulator can be made by 723

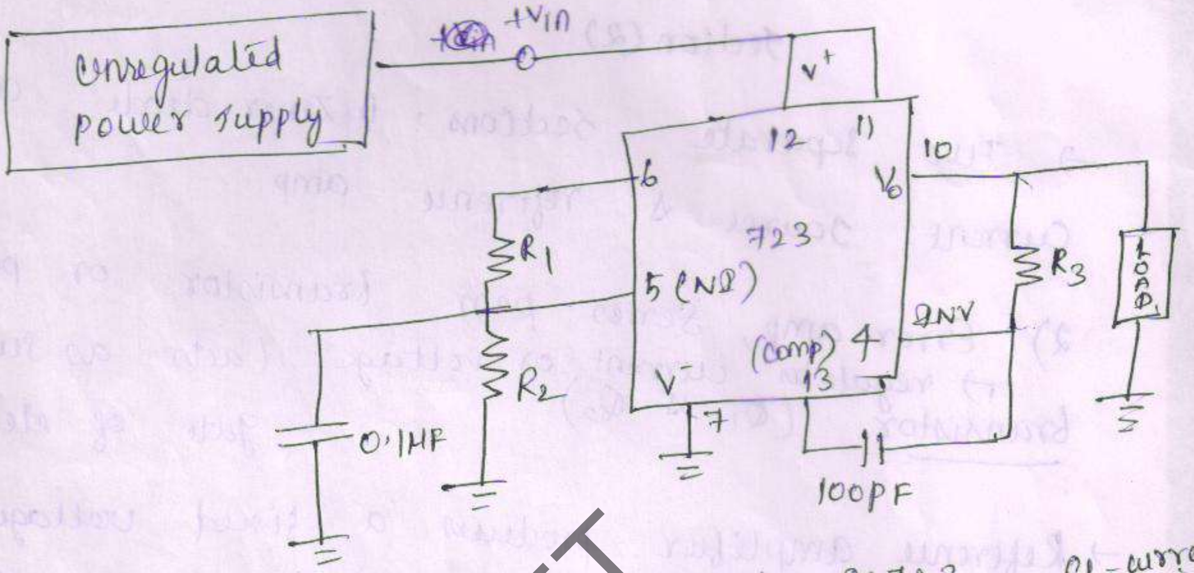


Fig1: Low voltage regulator using IC723

CL - current limit
CS - current sense

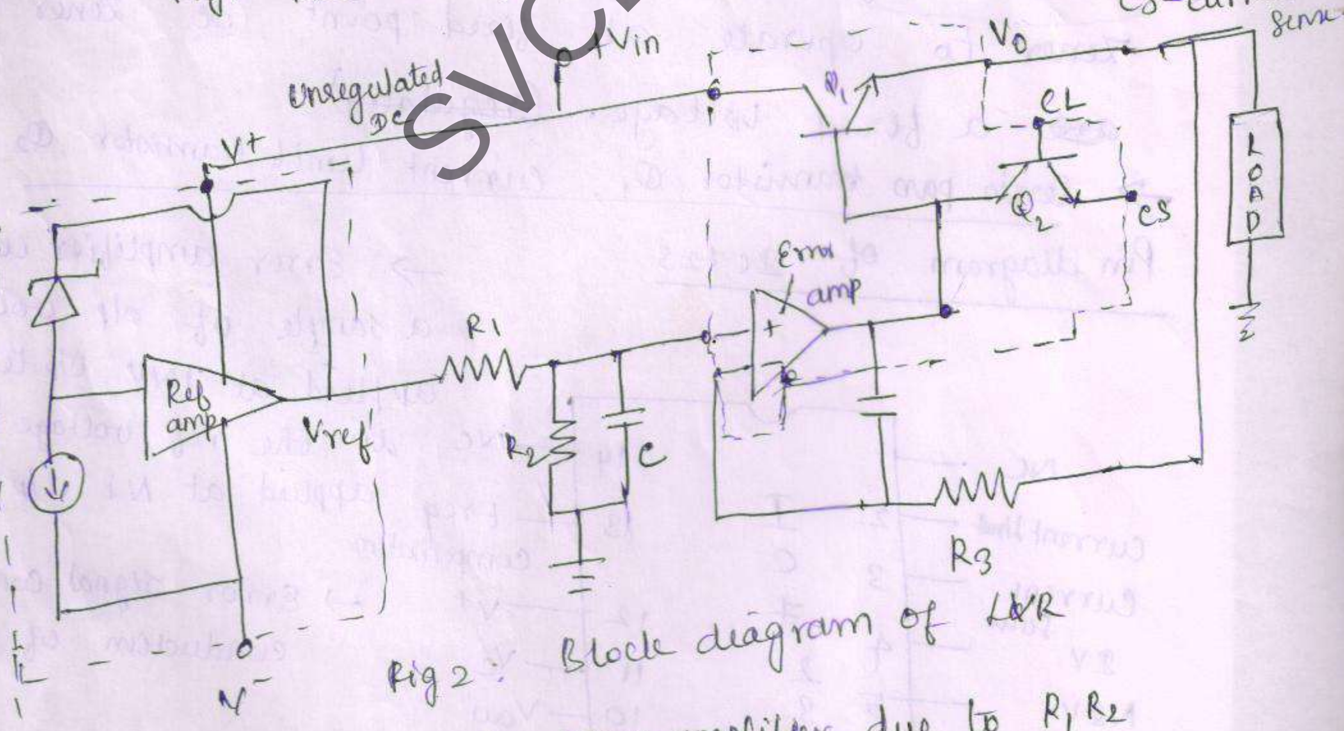


Fig 2: Block diagram of LVR

Voltage at NI of error amplifier due to $R_1 R_2$ divider is

$$V_{NI} = V_{ref} \frac{R_2}{R_1+R_2}$$

→ The difference b/w V_{N2} and o/p voltage V_o which is directly fedback to INV terminal is amplified by error amplifier

→ o/p of error amplifier drives the pass transistor Q_1 so as to minimize the difference b/w N2 and INV inputs of error amplifier

Q_1 is an operating emitter follower

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

→ o/p becomes low, voltage at INV terminal of error amplifier also goes down. ⇒ o/p of error amplifier become more positive, thereby driving Q_1 into conduction.

Q_1 drives more

→ This reduces voltage across Q_1 causing voltage across load current into load to increase.

→ initial drop in load voltage has been compensated or changes any increase in load voltage, or changes in o/p voltage, get regulated.

ref voltage = 7.15 ⇒ $V_o = 7.15 \frac{R_2}{R_1+R_2} < 7V$.

∴ it is low voltage 723 regulator.

A simple high voltage (>7V) voltage regulator can be made using 723

Functional diagram

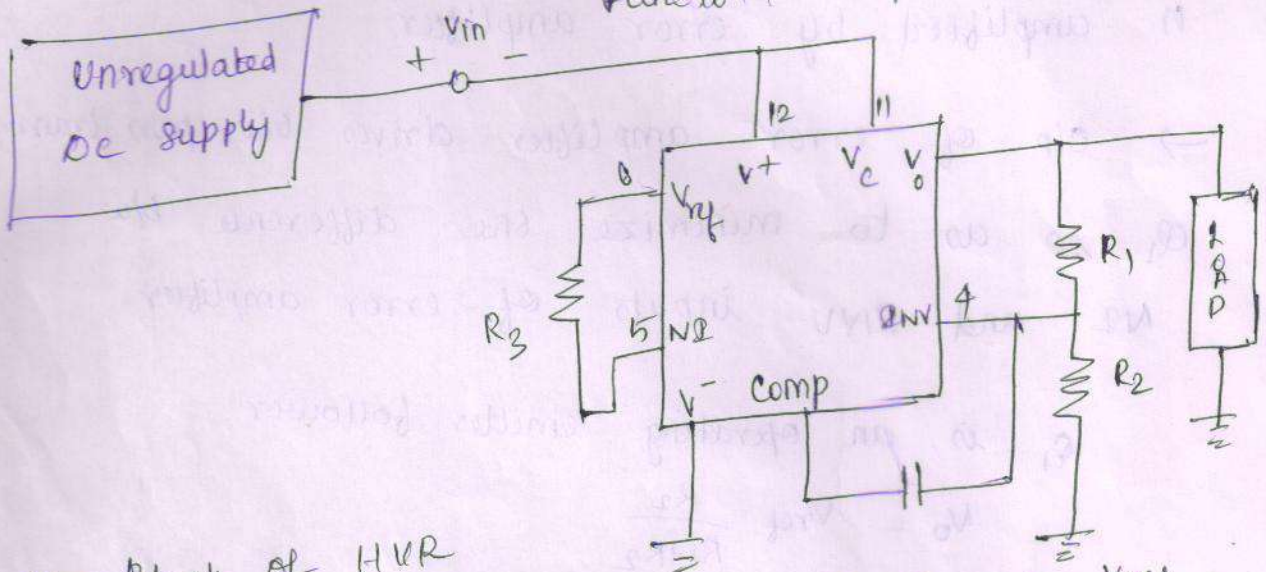


Fig 3 Block of HVR

The NI terminal is connected directly to Vref through R_3. So the voltage at NI is Vref

$$V_{NI} = V_{ref}$$

∴ error amplifier operates at Non inverting amplifier with gain $A_V = \left(1 + \frac{R_1}{R_2}\right)$

∴ o/p voltage $V_o = 7.15\left(1 + R_1/R_2\right)$

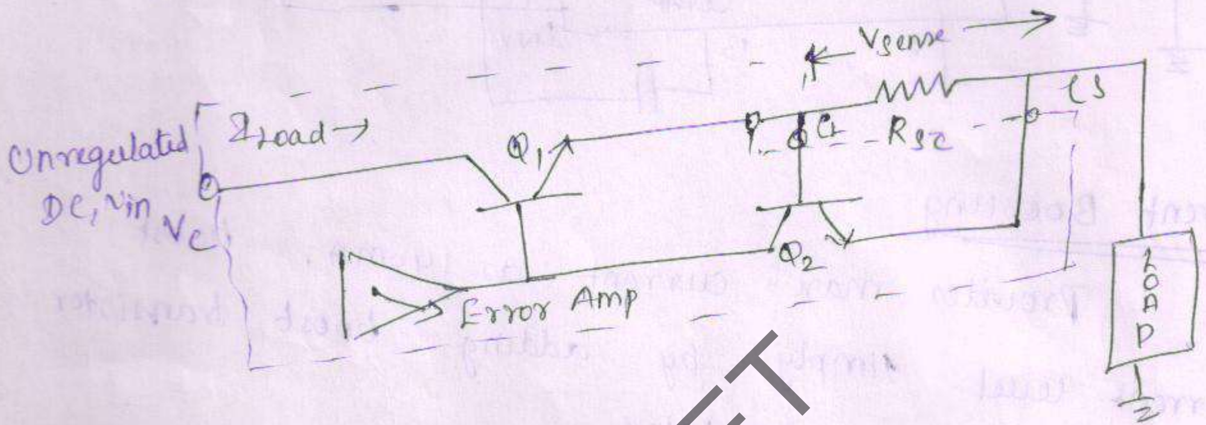
Protection circuit in Regulators

1. current limit protection (current sensing technique)
2. current foldback
3. current Boosting

Current Limit Protection

→ Load demands more current [Eg under short circuit condition, IC provides constant voltage getting hotter all time.

→ IC is provided with current limit facility



Current limiting facility ⇒ prevent load current from increasing above present value

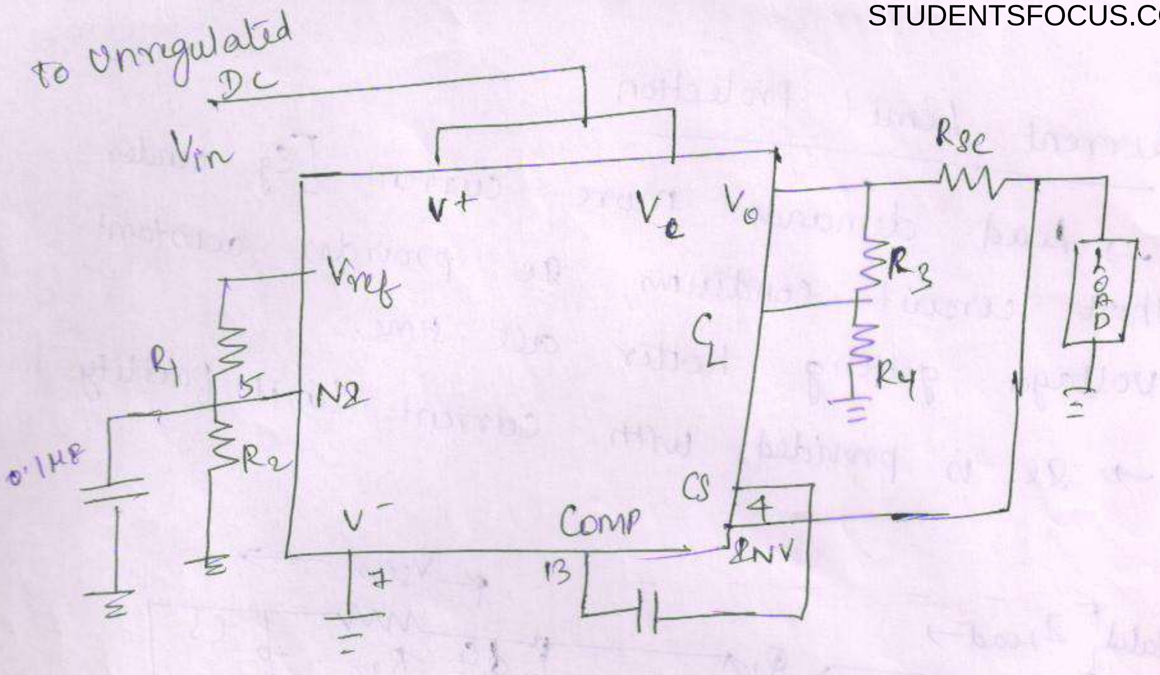
$$I_{limit} = \frac{V_{sense}}{R_{sc}}$$

current limiting ⇒ current. sensing technique.

Current Foldback

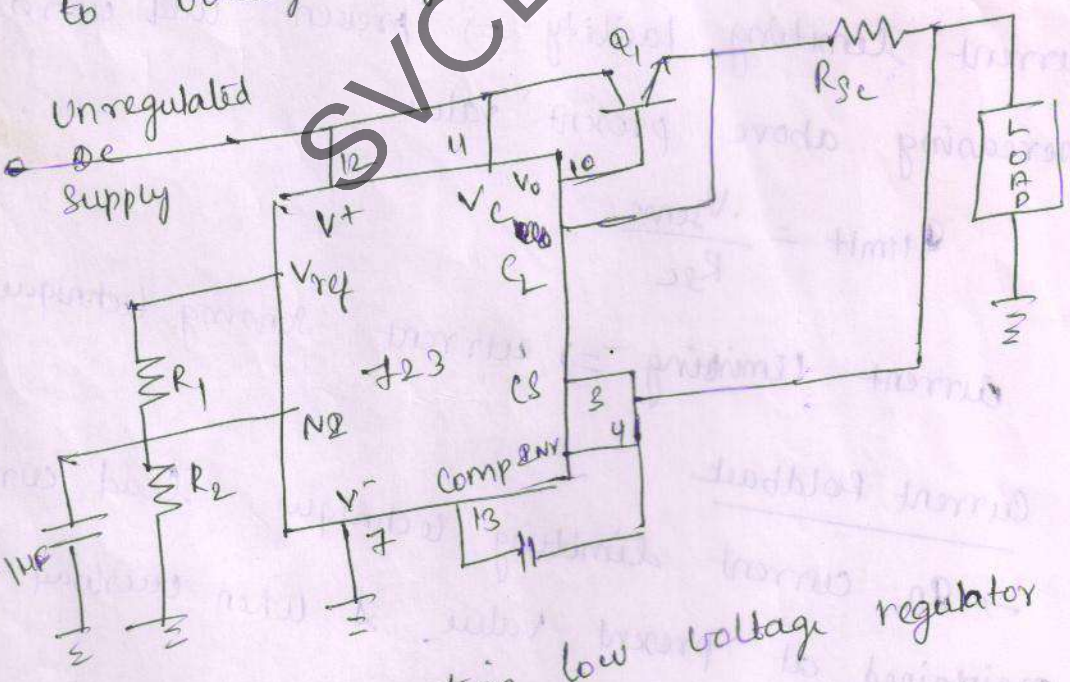
→ In current limiting technique, load current is maintained at present value & when overload condition occurs, V_0 drops to zero, max current flow through

→ Load is short circuited, one method is used to protect regulator to allow higher regulator. To protect regulator and to limit short circuit current and to limit short circuit current to load such method is current fold back



Current Boosting

provides max current as 140mA. boost current level simply by adding boost transistor Q_1 to voltage regulator



current Boosting low voltage regulator

~~$I_{load} = \beta_{pan\,T} \times I_{Q}(723)$~~ ⟹ Base current

Limitation of IC723 :-

1) No in built thermal protection
2) No short circuit current limits

~~Isolation Amplifier~~

Limitations of Linear Voltage Regulators

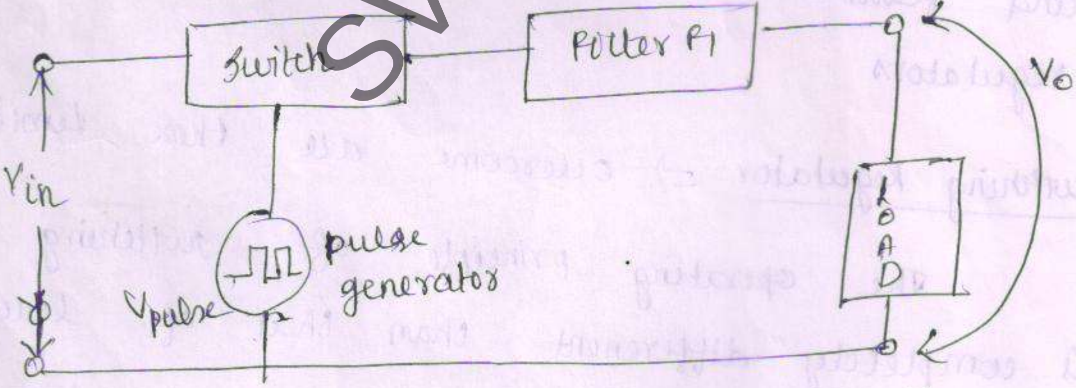
1. Efficiency is very low
2. Input must be greater than the output voltage
3. As large is the difference between input and output voltage, more is the power dissipated in the series pass transistor.
4. Need of dual supply is not economical and feasible to achieve with the help of linear regulators

Switching Regulator => overcome all these limitations

The operating principle of switching regulators is completely differenent than that of linear regulators. The switching regulators are also called as switch mode regulators. Such a switching regulator requires external transistor and a choke. The series pass transistor in such a regulator is used as a controlled switch and is operated in cut off or saturation region. Hence power transmitted across such a transistor is in the form of discrete pulses rather than a steady flow of current

When the transistor is operated in the cut off region, there is no current and dissipates no power. While when it is operated in the saturation region, a negligible voltage drop appears across it and hence dissipates very small power, providing maximum current to load. In any case, the power dissipated in the transistor is very small. Almost the entire power gets transmitted to the load. Hence efficiency of switching regulators is almost very high. Used for larger powers, large current

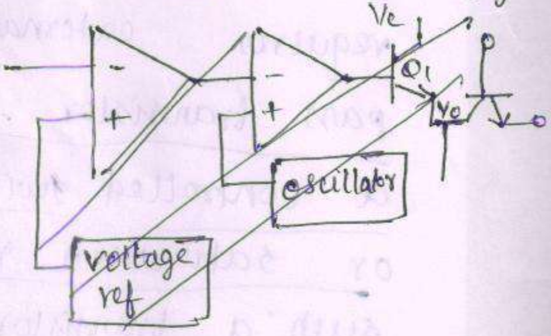
Basic Switching Regulator ⇒ batteries, phone chargers, personal computer

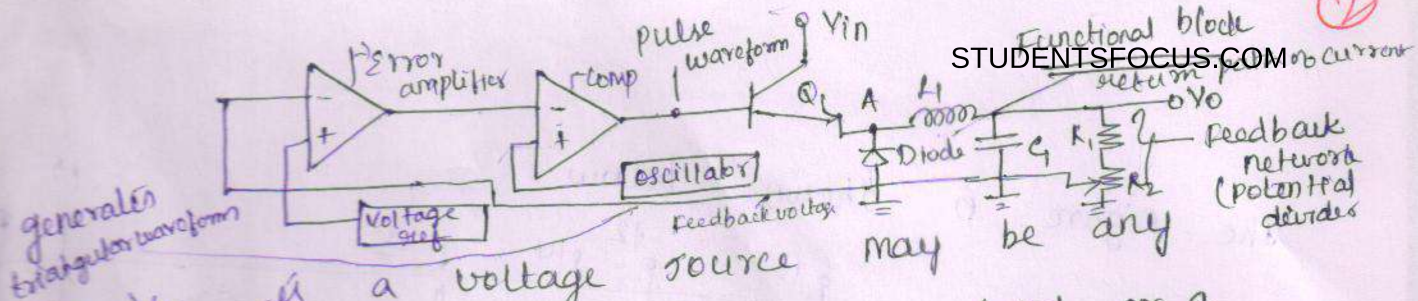


Basic switching regulator consists of four major components

a) Voltage source Vin
b) Switching transistor
c) Pulse generator, Vpulse
d) Filter F1

⇓ Functional block diagram shown in next page





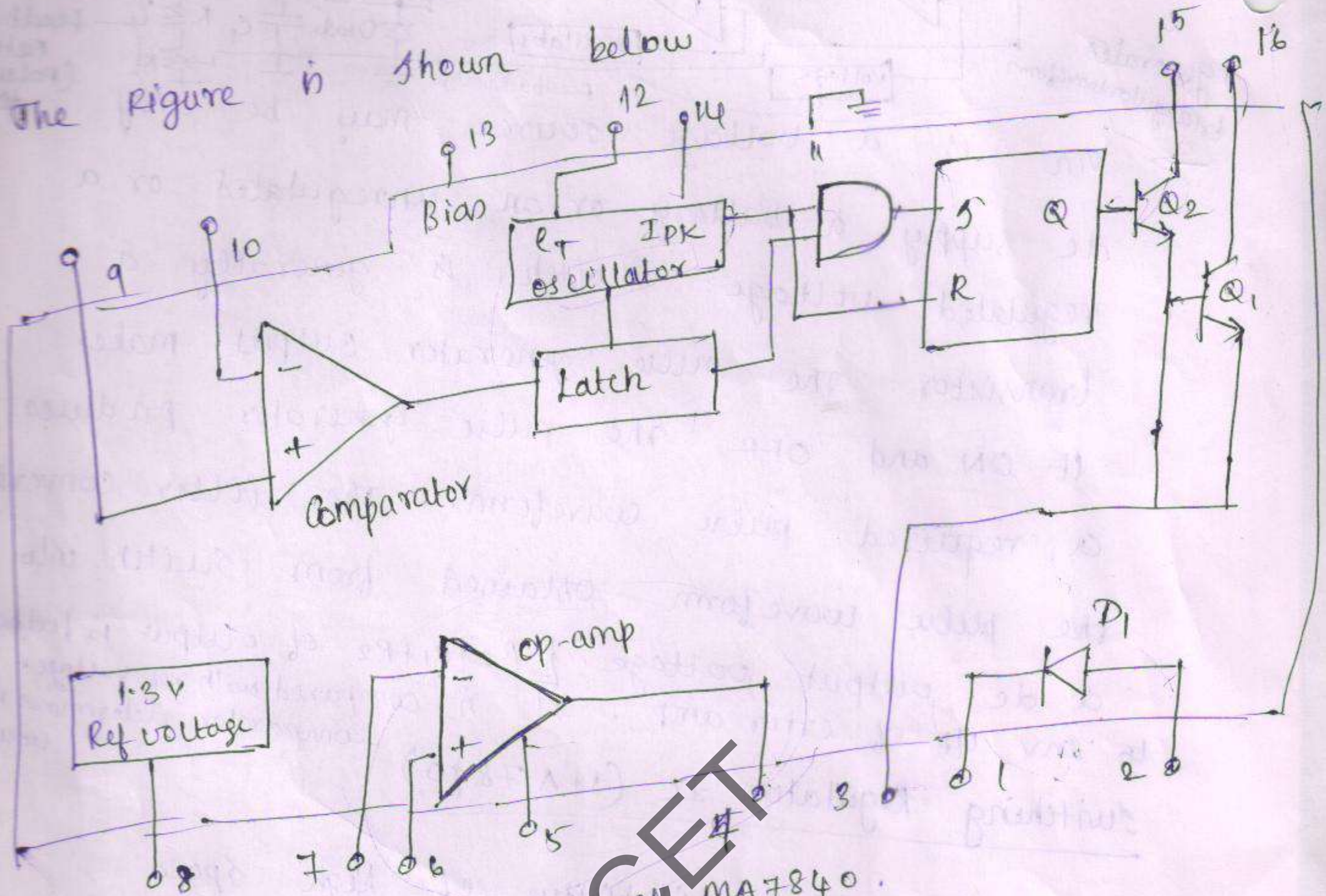
→ Vin is a voltage source may be any dc supply a battery or an unregulated or a regulated voltage. Switch is generally a transistor. The pulse generator output makes it ON and OFF. The pulse generator produces a required pulse waveform. The filter converts the pulse waveform obtained from switch into a dc output voltage. [R_2/R_1+R_2 of output is fedback to inv i/p of error amp. It is compared with ref voltage. comparator determines regulated voltage]

Switching Regulator IC (MA 7840)

Due to non availability of high speed switching transistors and low pan inductors, the design of switching regulator was much more complicated in earlier days. But due to IC technology, now a days it has become easy. → Integrated Regulators

The μA 7840 switching regulator consists of a temperature compensated voltage reference, controllable oscillator, high gain comparator, high voltage output switch, a power switching diode and an op-amp.

The figure is shown below



Block diagram of MA7840.
μA

→ It is a 16 pin dual package and is available as ceramic or plastic package

→ Initial switching frequency is set by C_T. The comparator controls the off time of switch transistor Q_1 & Q_2. when o/p is at desired value, comparator o/p is high and has no effect on circuit operation. But if o/p too high then voltage at inverting terminal is higher than the noninverting and comparator o/p goes low. In the low state comparator inhibits (prevent) the turn on of the switching transistors. So the comparator o/p is low, the system is in off state

(3)

→ As the output current rises or voltage decreases, the off time of system decreases,

→ The comparator can prevent several on cycles, one on cycle or any portion of on cycle.

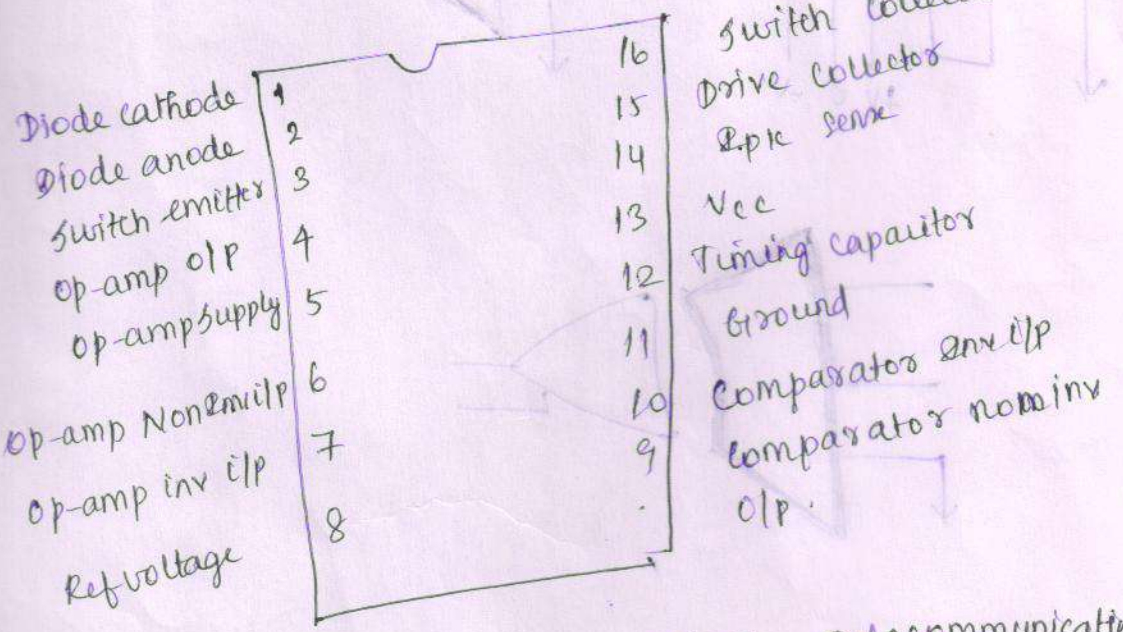
→ The current limit modifies the on time

→ The increased load results in more current which increases on time and provide less off time.

→ V_{sat} is voltage across Q_1 and Q_2 when the switch is closed or on. This is output saturation voltage.

→ power diode will find the regulator efficiency

→ ~~The letter~~ Pin diagram of MA7840

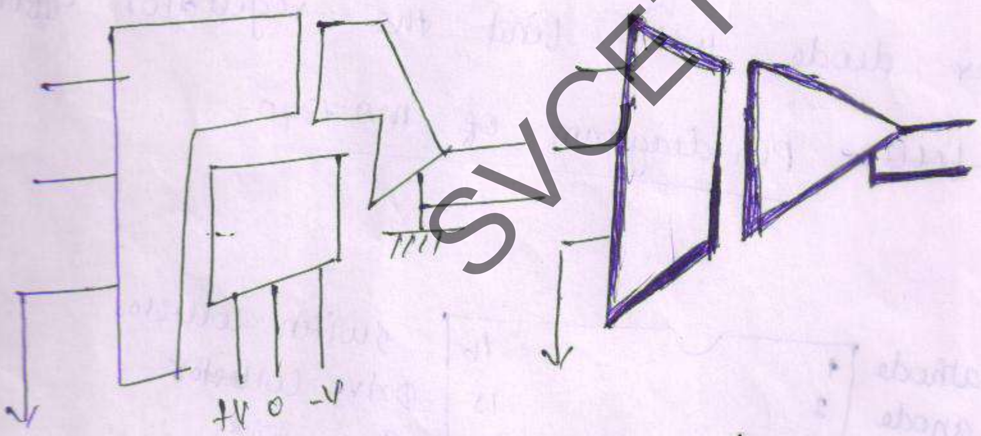


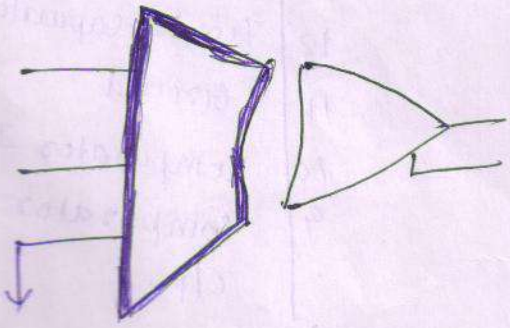
Application :- Battery Powered systems, Telecommunication circuits, Personal computers, printers, video games and automotive application.

Isolation Amplifiers

An Isolation amplifier is an amplifier that offers an ohmic or electrical isolation between its input and output terminals. Isolation amplifiers are often used when there is a very large common mode voltage difference b/we input and output side of device.

Different symbols used for Isolation Amplifier





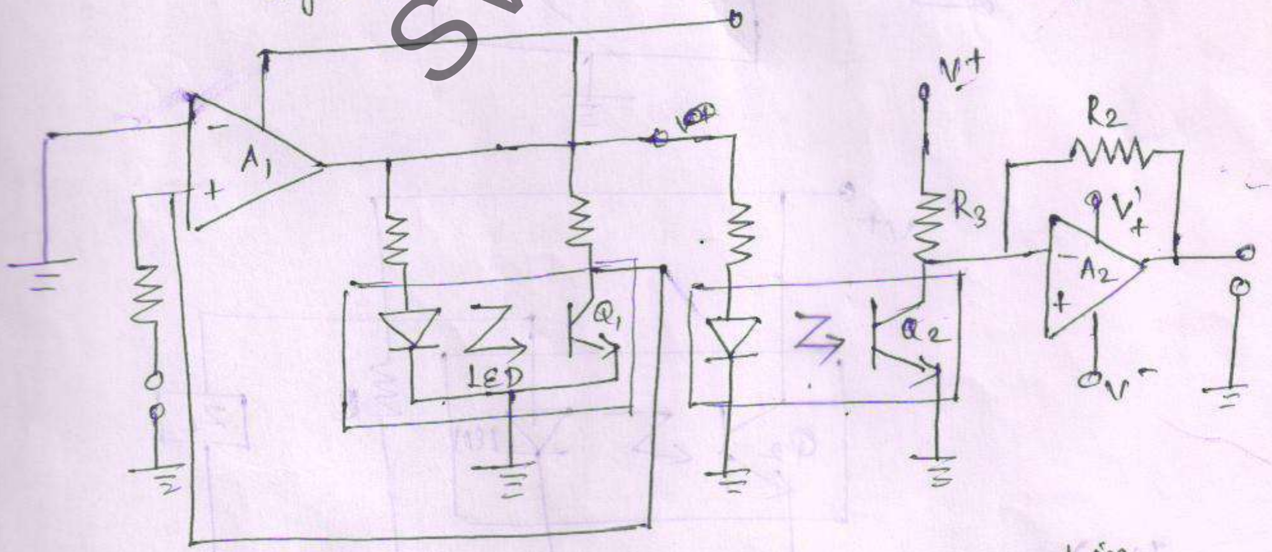
→ An important characteristics of an isolation amplifier is the linearity of the input to output transfer characteristics. There are various methods of obtaining high degree of linearity in isolation can be achieved by optically coupled devices or transformers. optically coupled isolation amplifiers

→ Such two examples of isolation amplifiers are discussed in following.

→ Fig 1 shows an isolation amplifier in which a LED-photo transistor couplers are used (semiconductor receives photons) as an opto isolators

Fig : LED-photo transistor Linearized isolation amplifier

1)

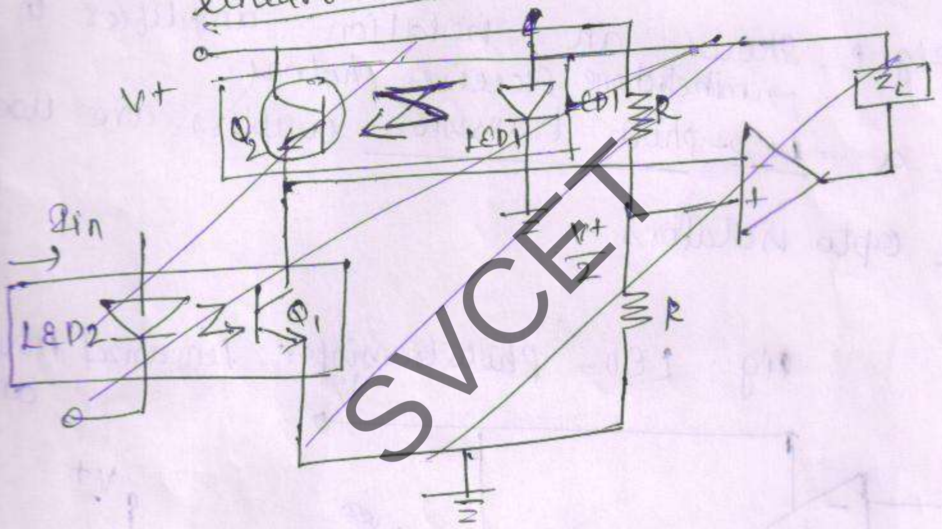


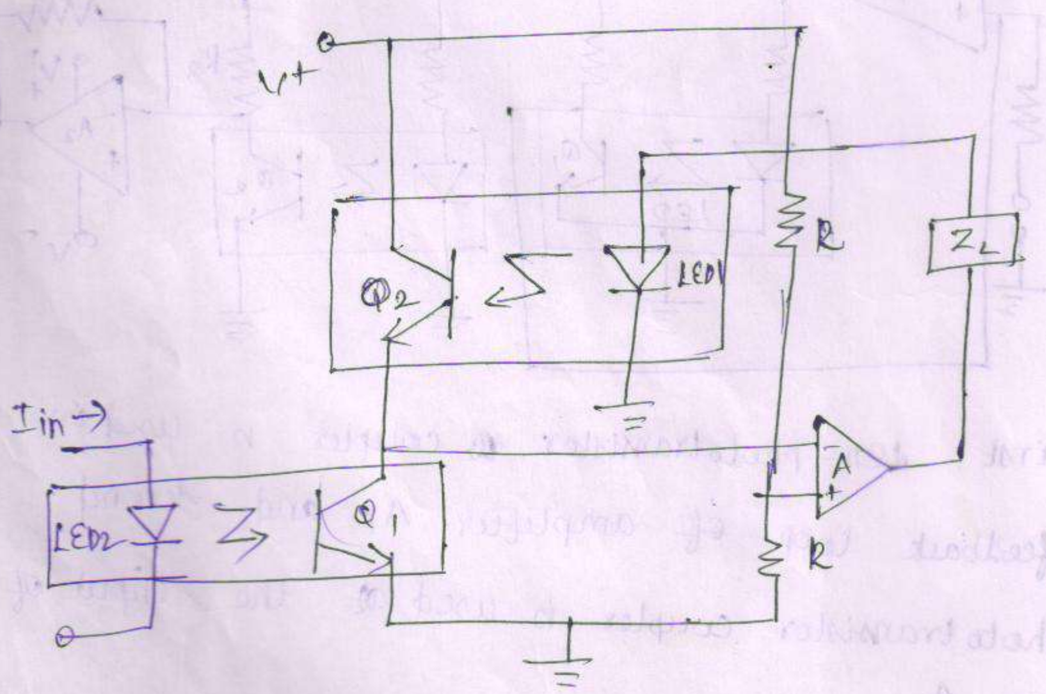
→ The First LED-phototransistor coupler is used in the feedback loop of amplifier A1 and second LED-phototransistor coupler is used at the input of amplifier A_2

→ Both LED – photo transistor couplers are used with matched characteristics are driven by the same amplifier A_1. Due to the matched characteristics of 2 LED – photo transistor pairs, the non linear characteristics and temperature dependence get compensated

2) Linearized current amplifier ①

Fig 2: Isolated current amplifier with feedback linearization





Isolation is provided by LED – phototransistor. opto coupler. The current through Q_1 & Q_2 is same because they are connected in series. Temperature get compensated by matched characteristics of LED and phototransistor pairs. To maintain the equal currents through Q_1 and Q_2, current through Z_L and LED1 is equal to current I_{in} through LED2.

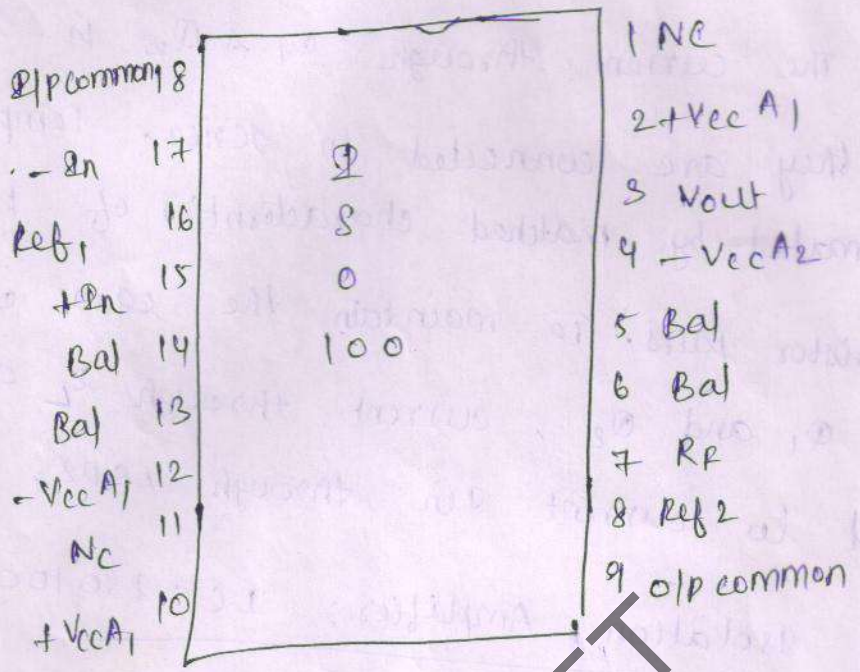
Type of isolation Amplifier IC : ISO 100

ISO 100 is an optically coupled isolation amplifier. High accuracy, linearity and time-temperature stability are achieved by coupling light from an LED back to the input as well as forward to output

Features :-

(i) Easy to use. Similar to an op-amp
(ii) 100% tested for break down
(iii) Wide Bandwidth

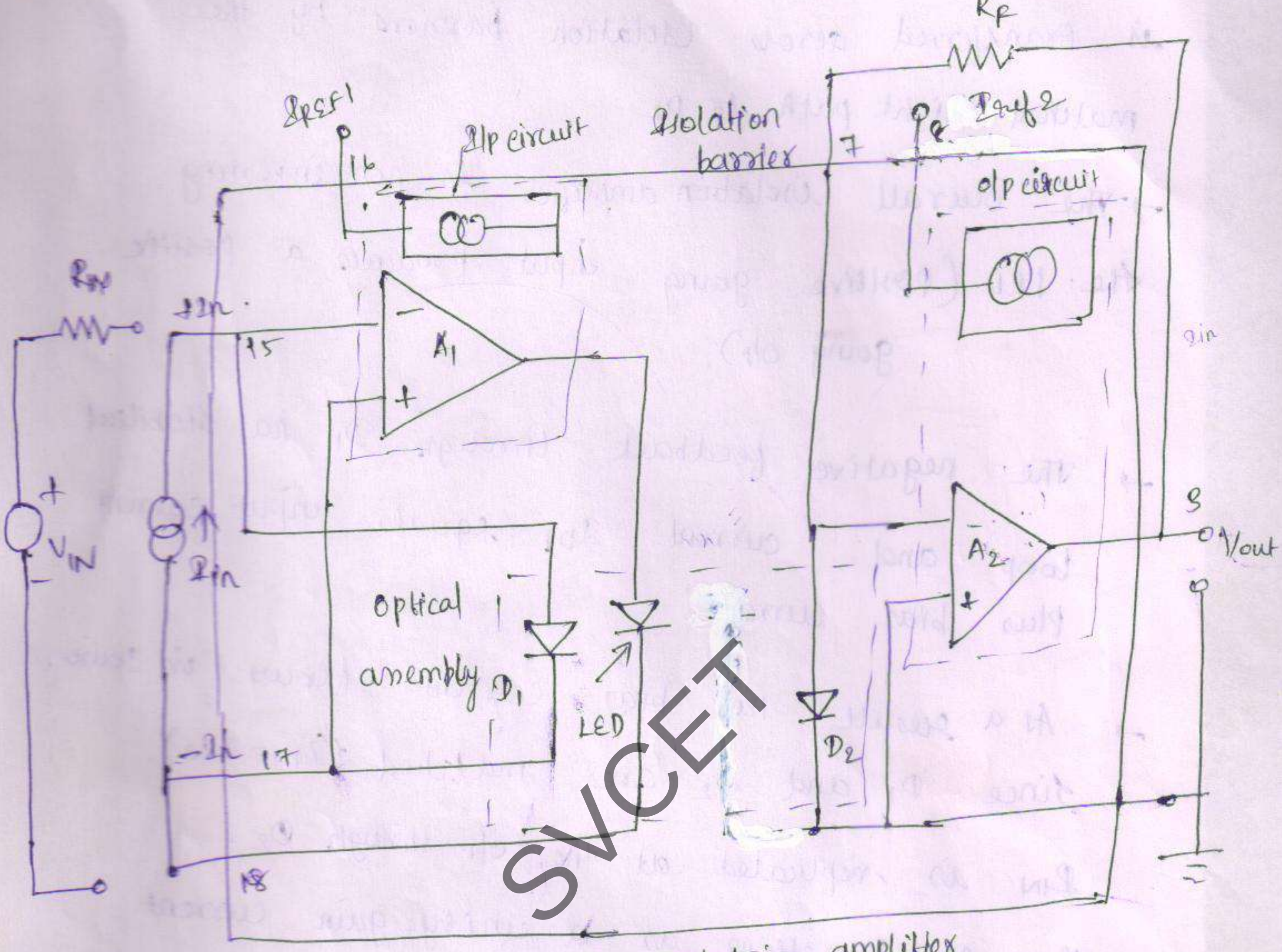
Pin Configuration and Block Diagram



Operation of ISO100

ISO 100 is fundamentally a unity gain current amplifier intended to transfer small signals b/w electrical circuits separately by high voltages or different references. O/P voltage is obtained by passing O/P current through R_f.

The ISO 100 uses single light emitting diode (LED) and a pair of photodiode detectors coupled together to isolate the output signal from input



Type of Isolation amplifier

→ I_{REF1} and I_{REF2} are required only for bipolar operation to generate a midscale reference.

→ The LED and photodiodes (→ converts light energy into electrical energy) (D_1 and D_2) are arranged, the same amount of light falls on each photodiode. Thus the currents generated by the diodes match very closely.

→ Negative feedback around A_1 occurs through the signal optical path formed by LED and D_1. The is transferred across isolation barriers by the matched light path to D_2

→ The overall isolation amplifier is non inverting the LED (positive going input produces a positive going o/p).

→ The negative feedback through D_1 has stabilized loop and current I_{D1} equals input current plus bias current.

→ As a result, no bias current flows in source. Since D_1 and D_2 are matched ($I_{D1} = I_{D2}$). I_{IN} is replicated at the o/p through D_2.

thus A_1 function as a unity gain current amplifier and A_2 is current to voltage converter

→ current produced by D_2 must either flow into A_2 or R_F. Since A_2 is designed for bias current, almost all of current flows through R_F to output.

o/p voltage $V_0 = I_{IN} R_F$.

<u>Characteristics</u>

1. CMRR (Common mode Rejection Ratio) change in applied common mode voltage and change in I_{OS}.

7

IMRR (Isolation Mode Rejection Ratio)

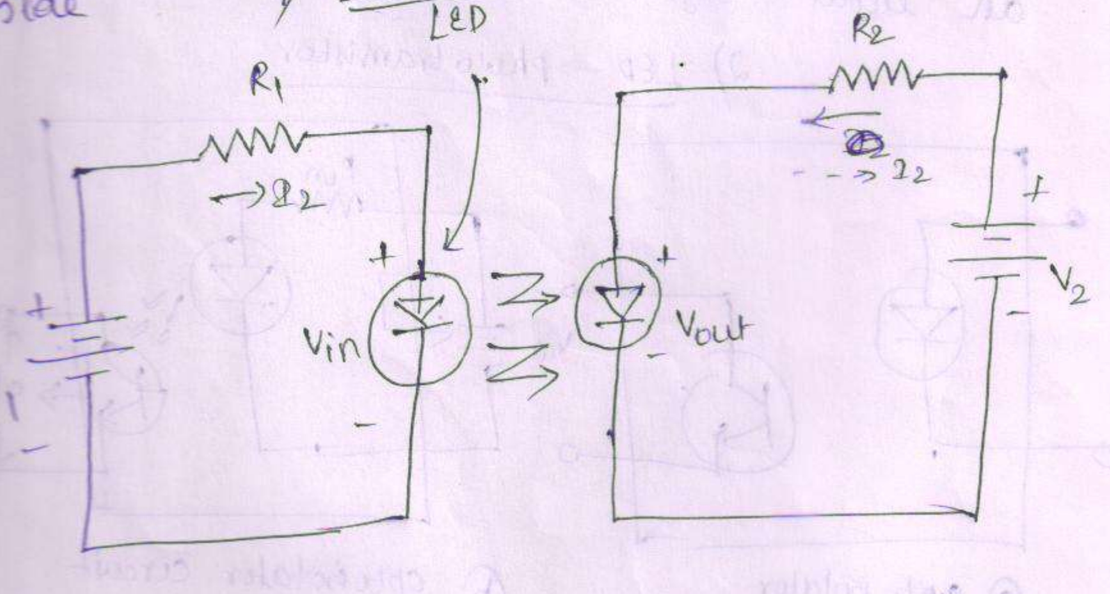
Relationship b/w a change in applied isolation mode voltage and change Ios required to maintain amplifier's o/p to zero.

opto coupler and opto electronic ICs

→ The combined package of LED and photodiode is called an optocoupler. It is also called an optoisolator or an ~~opto cou~~ optically coupled isolator.

→ The basic circuit consists of an LED on the input side and a photodiode on the output side

1) LED & photodiode



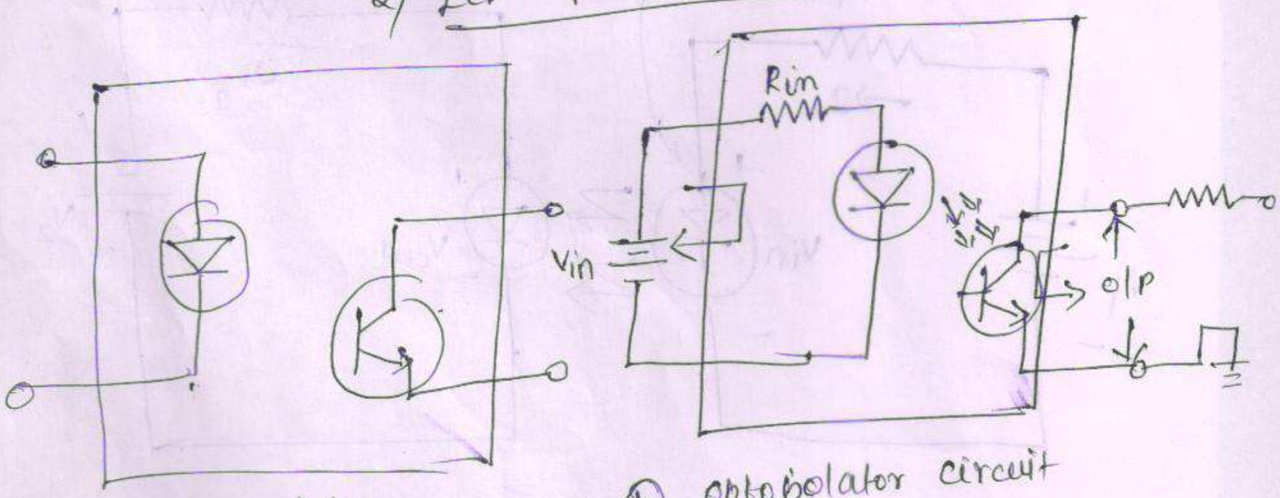
→ The source V_1 and series resistance R_1 decide the forward current I_1 through LED. Thus LED emits the light. This light is incident on a photodiode

→ A reverse bias current is set up in the output circuit. The output voltage is the difference b/w supply voltage V_2 and drop across resistor R_2

$$V_{out} = V_2 - I_2 R_2$$

→ If the input voltage is changed, the amount of light emitted by LED changes. This varies the reverse current in the output circuit and hence output voltage. This coupling between LED and photodiode is called optocoupler. As the name suggests this device can couple an input signal to output circuit

2) LED - phototransistor



ⓐ opto isolator ⓑ optoisolator circuit

→ ~~optoisolator~~ optocoupler consists of LED and phototransistor. When input voltage forward biases LED, the light emitted to the phototransistor turns it ON, the resulting current through external load

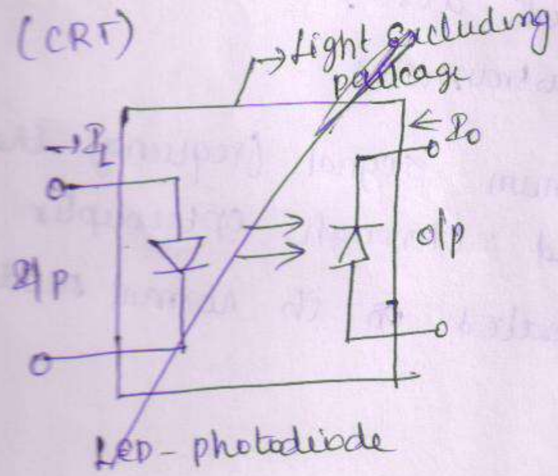
Types of optocouplers

Other than the combination of LED and phototransistor, ~~two more types of~~ other type of optocouplers ~~are~~ is

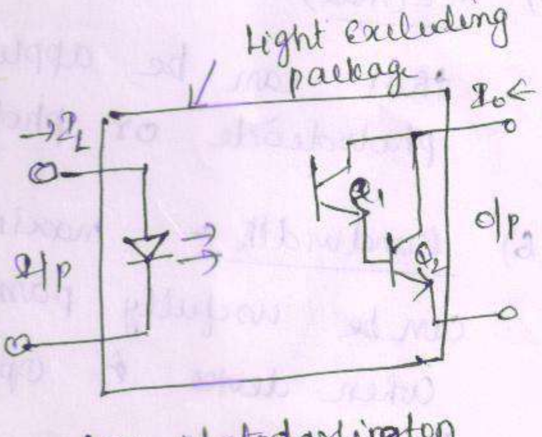
a) ~~LED - photodiode~~

b) LED - photodarlington

→ The input current which is the forward current of LED, results in emission of light by LED. This light is detected by photodiode and photodarlington to produce output current. The ratio of output current I_o to the input LED current I_L is called current transfer ratio (CRT)



LED - photodiode



LED - photodarlington

Characteristics of optocoupler

1) **Current Transfer Ratio (CTR)**

It refers to ratio of output collector current (I_C) to input forward current I_F

$$CTR = \frac{I_C}{I_F} \times 100$$

2) **Isolation voltages between I/P & O/P**

It is a factor in choosing a photo coupler.

3) **Response time**

The response time of a optocoupler depends mainly on the output phototransistor

4) **Common Mode Rejection Ratio**

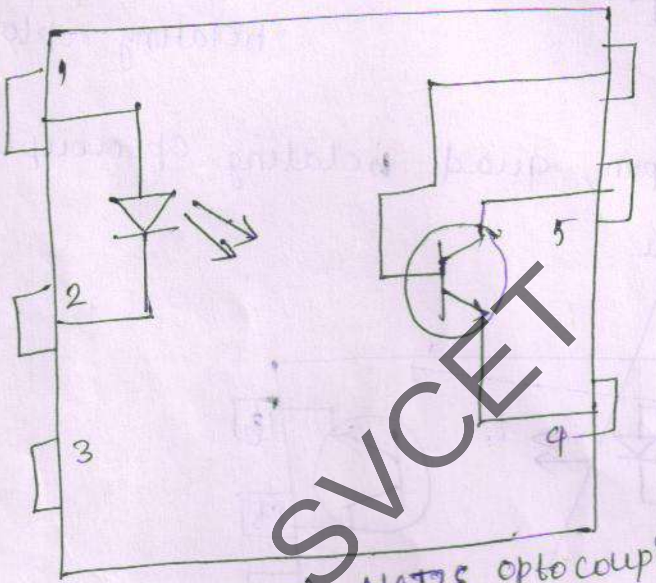
Photo couplers output is electrically isolated from its input for relatively low frequency signal, an impulsive input voltage may cause displacement current $C_{id} = C_f \, dv/dt$

5) **Vcc(max)** :- maximum allowable dc voltage that can be applied across the output photodiode or phototransistor

6) **Bandwidth** :- maximum signal frequency that can be usefully passed through optocoupler when device is operated in its normal mode

Opto Electronic IC

MCT2E is optically coupled isolator consisting of a Gallium Arsenide infrared emitting diode and an NPN silicon phototransistor, mounted



Circuit of MCT2E optocoupler

Features of IC opto coupler

1) Isolation voltage of ± 2500V
2) High dc current transfer ratio
3. Low cost dual in line package.

Various packages of IC optocoupler

In the six pin dual in line package, optocoupler with photodarlington is also available

(10)

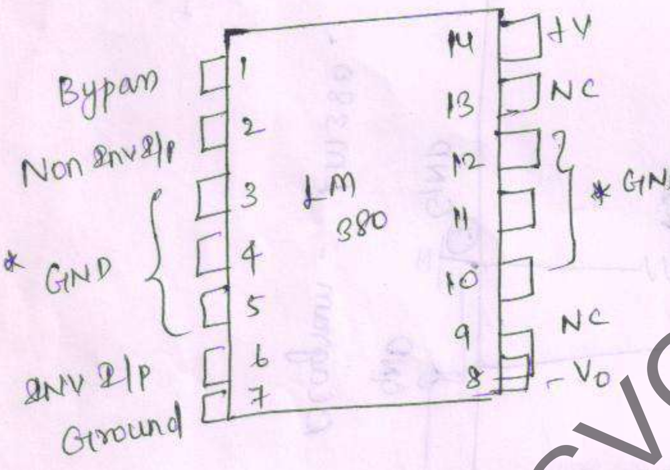
~~Audio Amp~~ Power Amplifier – basically used to amplify audio signals load to such are loudspeakers. Deliver various amount of power are nearly compact.

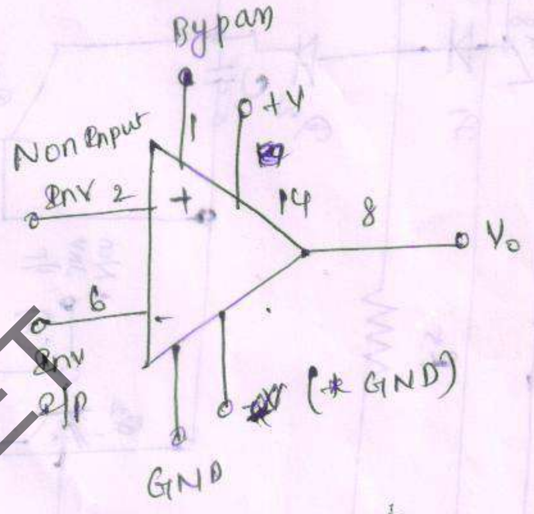
Features of LM 380 Power Audio Amplifier → popular power audio amplifier ⇒ Delivers 2.5 Watts min 8kΩ Load

→ High Impedance

→ Standard dual in-line package. 14 pins power amplifier also called as Large signal amplifier

LM380 pin diagram & circuit description:





DIP package of comprises heat sink. there is no need to use separate heat sink for audio amplifier (*) Gnd for heat sink.

Schematic Diagram of LM 380 –

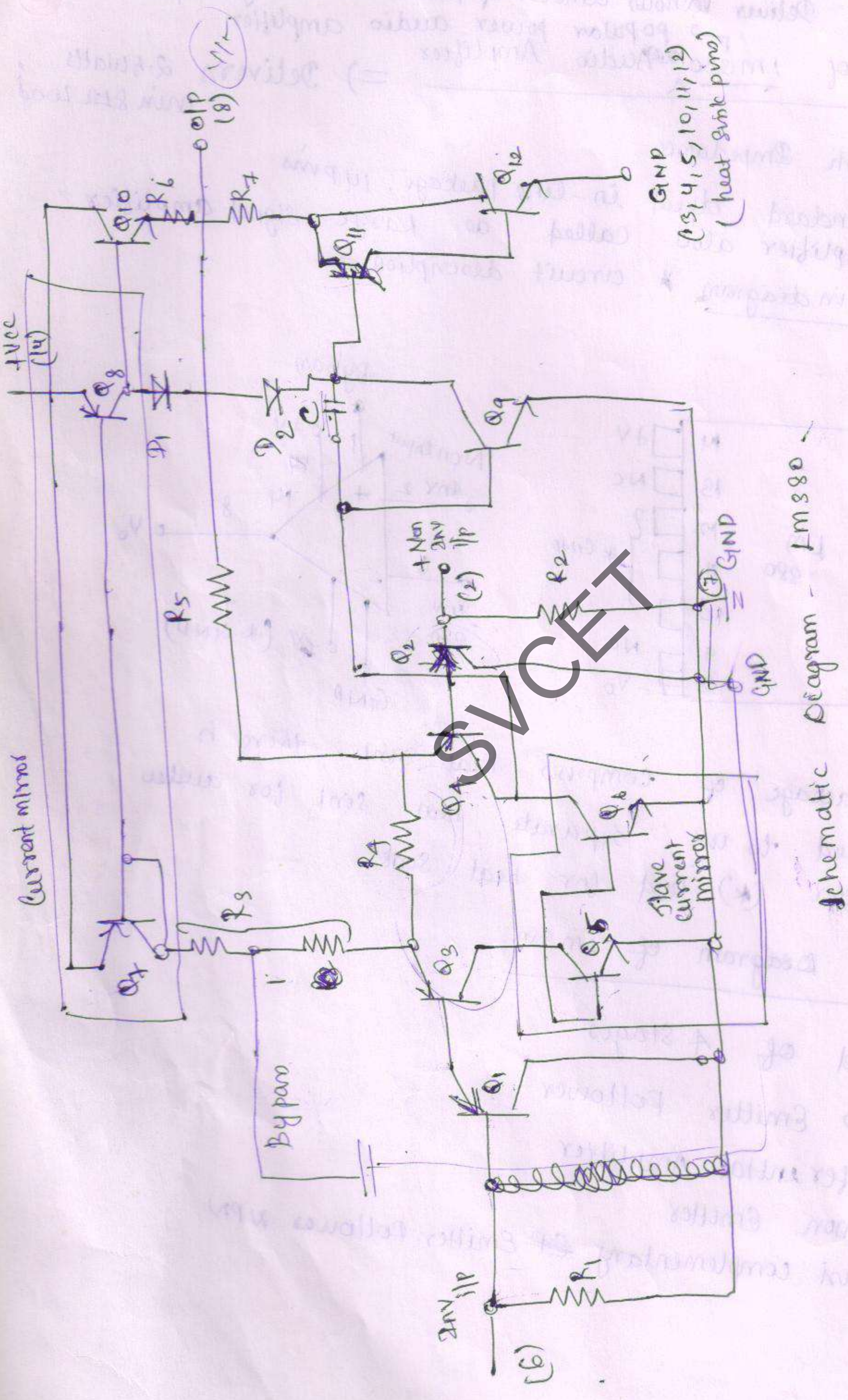
Compond of 4 stages

a) PNP Emitter Follower

b) Differential Amplifier

c) Common Emitter

d) Quasi complementary ~~EF~~ Emitter Follower NPN


Schematic Diagram - LM380
Current mirror
Slave current mirror
Bypass
+Vcc (14)
o/p (8)
GND
(3, 4, 5, 10, 11, 12) (heat sink pins)
+ Non inv i/p (2)
Inv i/p (6)

(4)

→ I/P is Emitter follower composed of PNP transistors [Q_1 & Q_2]. This drives $Q_3 - Q_4$, the differential amplifier. [Input is coupled through inv & Non inv terminal]

→ Q_1 & Q_2 allows input to be referenced to ground

→ i/p can be given to inverting or non inverting terminals. It is biased by R_3 & R_5

→ current in PNP differential pair $Q_3 - Q_4$ is established by Q_7, R_3 and $+V_{cc}$. current mirror formed by transistors Q_7, Q_8 and associated resistors then establishes collector current of Q_9

→ Q_5 & Q_6 constitute collector load. o/p of differential amplifier is taken at Q_4 & Q_6 transistor and applied to i/p of common emitter voltage gain (Q_9)

→ common Emitter Amplifier stage is formed by D_1, D_2 & Q_8 as current source load. provides Q_9 with common emitter voltage gain stage

→ C between collector & base of Q_9 provides internal compensation. [feedback capacitor used to stabilize amplifier against any type of oscillation]

→ R_6 & R_7 used as current limiting resistor.

→ Q_7 & Q_8 forms current mirror, the current through D_1 & D_2 is same as R_3

↳ temperature compensating diodes → for transistors Q_{10} & Q_{11} to avoid cross over distortion

~~current through Q_{10}~~, $Q_{11} - Q_{12}$ is approximately ~~∴ Q_{10} current through diodes~~ ~~equal to current through diodes.~~

→ o/p is false (quasi) complementary pair emitter follower formed by NPN transistors $Q_{10} - Q_{12}$. ~~The o/p~~

→ Combination of PNP Q_{11} & NPN Q_{12} has power capability of NPN but characteristics of PNP.

→ ~~o/p stage~~, o/p voltage is centered at one half supply voltage (+V), which allows max peak to peak voltage swing & therefore max ac o/p voltage.

→ negative to feedback applied through R_5 balances differential amplifier, so dc o/p voltage is stabilized at $+V/2$.

→ To decouple i/p stage from supply voltage +V, a bypass capacitor on the order of microfarads should be connected b/w bypass terminal (pin1) & ground (pin7).

→ voltage gain can be increased by positive feedback.

Applications of LM380 Audio Amplifier.

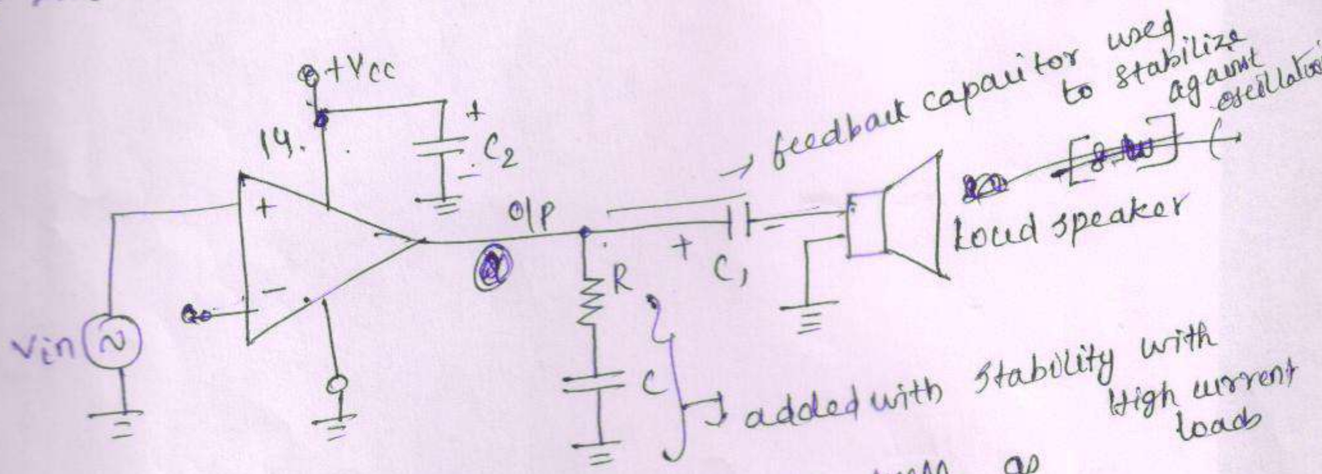
The number of external components used for LM380 is very less. It is used in consumer Applications.

1. LM380 as Audio power amplifier.
2. Bridge power audio amplifier
3. Intercom system

21

I LM380 as Audio Power Amplifier

The simplest and most basic application of LM380 is an audio power amplifier



→ The IC can used in inverting as well as non inverting configuration. In non inverting mode, inverting can be grounded through resistor or capacitor. In inverting mode, non inverting can be grounded through resistor or capacitor.

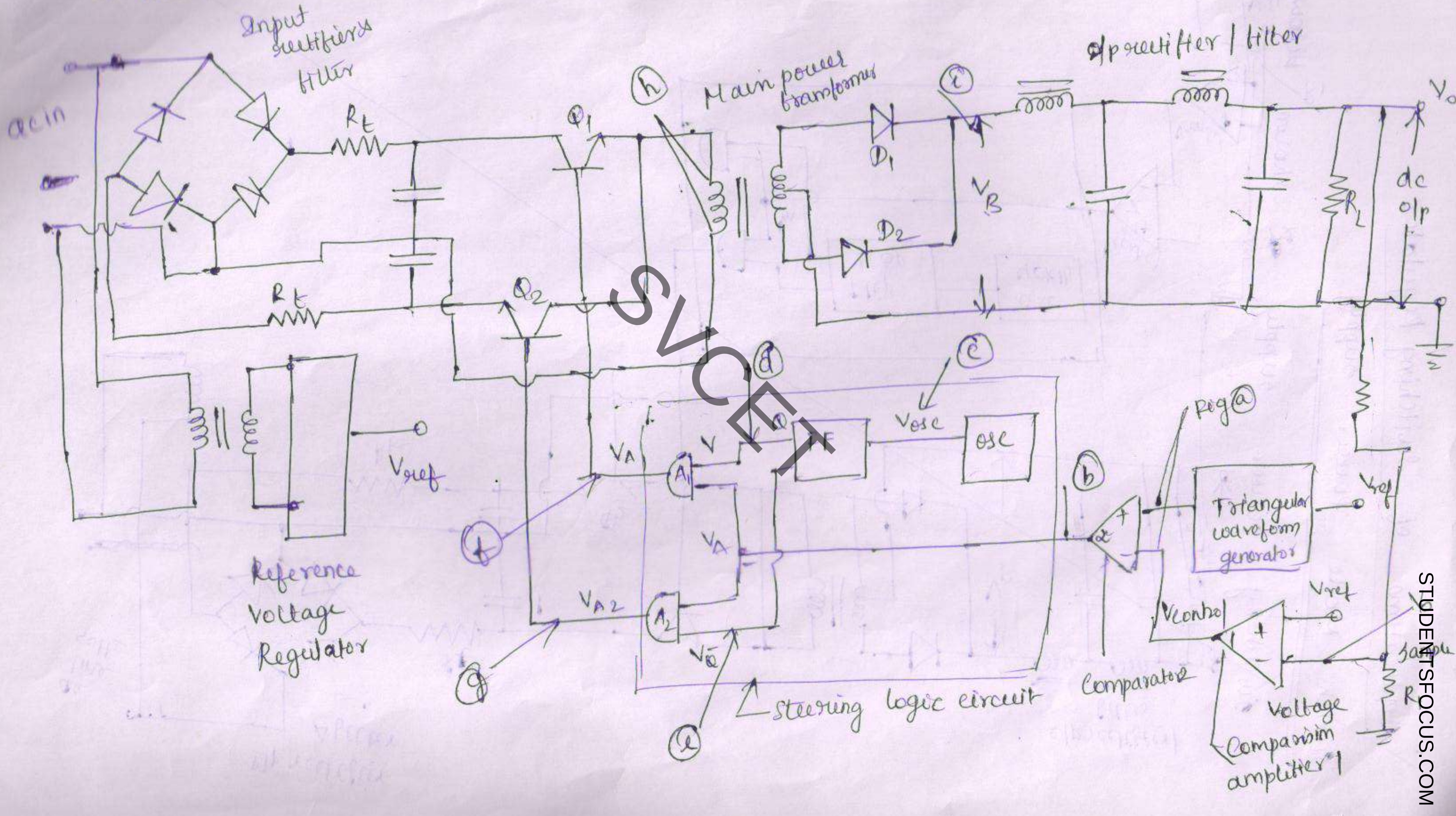
→ In both the configurations, supply voltage must be decoupled by connecting a capacitor between terminal +V and ground.

→ precautionary measure RC combination should be used as output to eliminate 5 to 10 MHz oscillation

→ The capacitor C_2 is used to eliminate effects of inductance in power supply leads

Switch mode Power supply — (100 - 240 V) AC [personal computers, Mobile phone chargers] [get power from most main electricity]

↳ Transformer is driven at much i/p than main. The switch mode power supply is shown below.



→ to achieve full wave rectification → value of property

1) The bridge rectifiers and capacitor filters are connected directly to ac line to give unregulated dc input. R_t – thermistor. limits high initial capacitor charge current. → reference regulator ⇒ power transistor

2) A regulated reference voltage, V_{ref} which serves as a power supply voltage. current small and power loss wont affect efficiency of switched mode power supply.

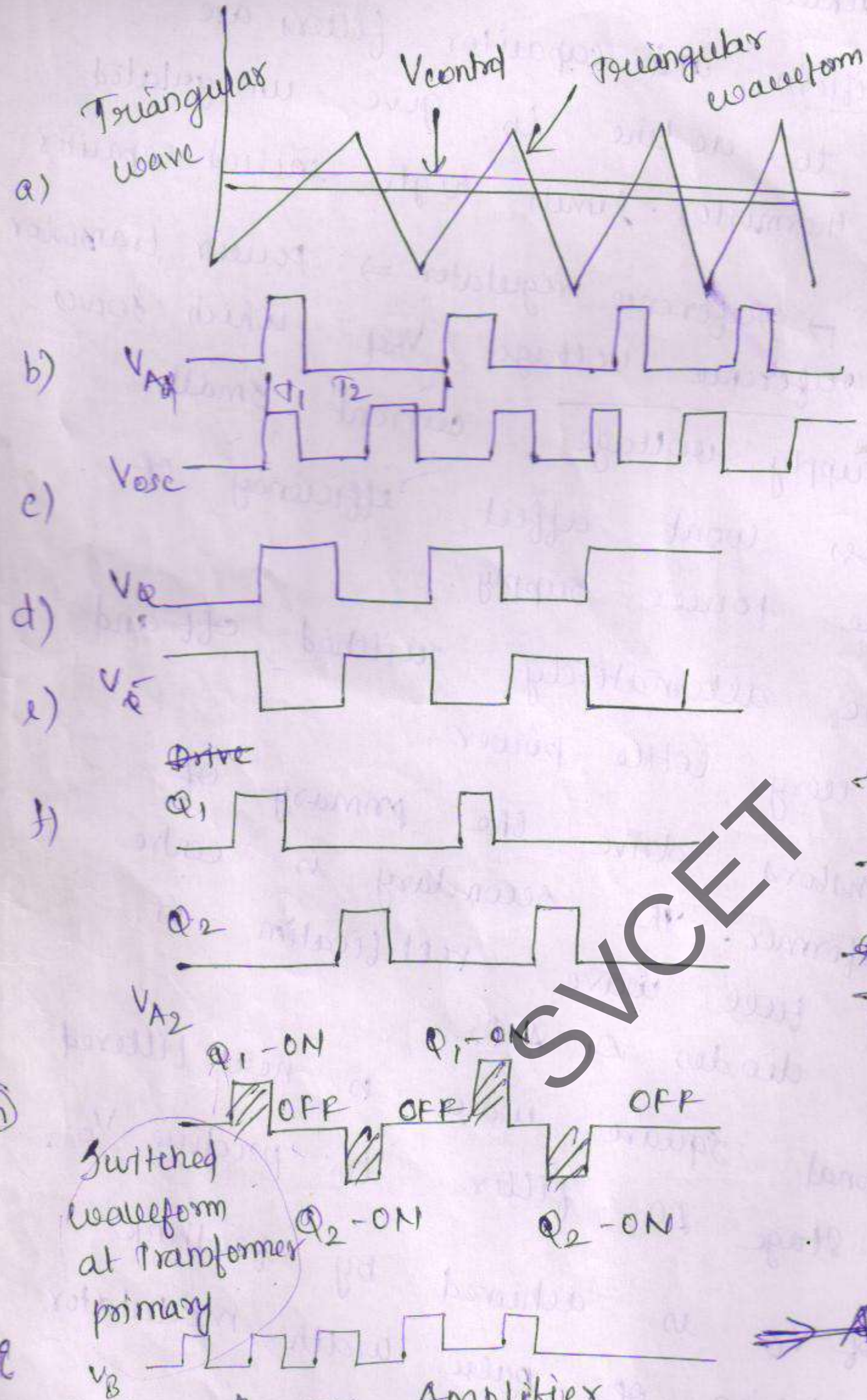
3) Q_1 & Q_2 are alternatively switched off and on. Dissipate very little power

4) These transistors drive the primary of main transformer. The secondary is centre tapped and full wave rectification is achieved by diodes D_1 & D_2

5) Unidirectional square wave is next filtered through a stage LC filter to produce V_o.

6) Regulation of V_o is achieved by feedback circuit consisting of pulse width modulator and steering logic circuit.

7) V_o is sampled by $R_1 R_2$ divider (voltage divider) is compared with V_{ref} in comparator1. o/p of voltage comparison is called $V_{control}$



→ Vcontrol is applied to − of comparator 2 & triangular wave is applied to +ve

→ comp 2 functions as pulse width modulator & its o/p square wave V_A

→ V_A produces V_Q, $V_{\bar{Q}}$ (V_A drives steering logic)

→ o/p V_{A1} & V_{A2} of AND A_1 & A_2 - Q1 or Q2 on, waveform 'll be square or V_B

→ If V_o ↑, Vcontrol ↑ will reduce pulse width

→ Reduction in pulse width lowers average value of dc o/p V_o.

→ ∴ initial ↑ in dc voltage gets nullified

~~→ After this Refer~~

Audio Power Amplifier

→ The power amplifier differ from general purpose op-amps in delivering various amounts of power are nearly compact.

→ LM380 is a popular power audio amplifier produced by National Semiconductor