IC 723 – General Purpose Regulator

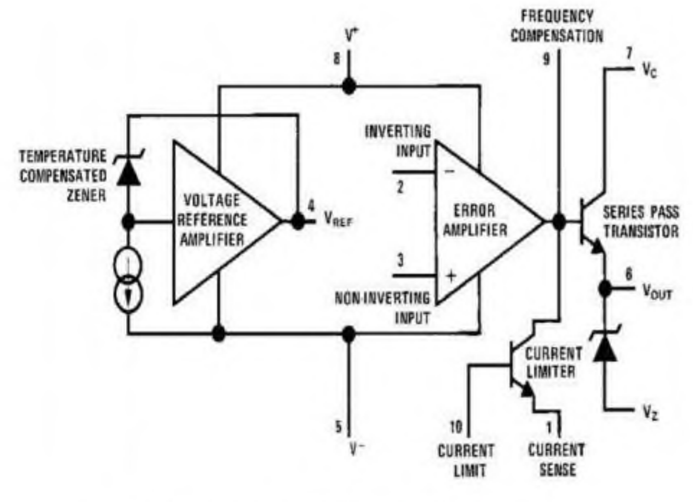
Disadvantages of fixed voltage regulator:

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

These limitations can be overcomes 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 (ILmax = 150mA).
4. With the additional transistor used, ILmax 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.



Functional block diagram of IC723

The simplified functional block diagram can be divided in to 4 blocks.

1. Reference Generating block:

The temperature compensated Zener diode, constant current source & voltage reference amplifier together from 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 affixed point & it is applied to the Non – inverting terminal of error amplifier. The Unregulated input voltage ±Vcc is applied to the voltage reference amplifier as well as error amplifier.

2. 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.

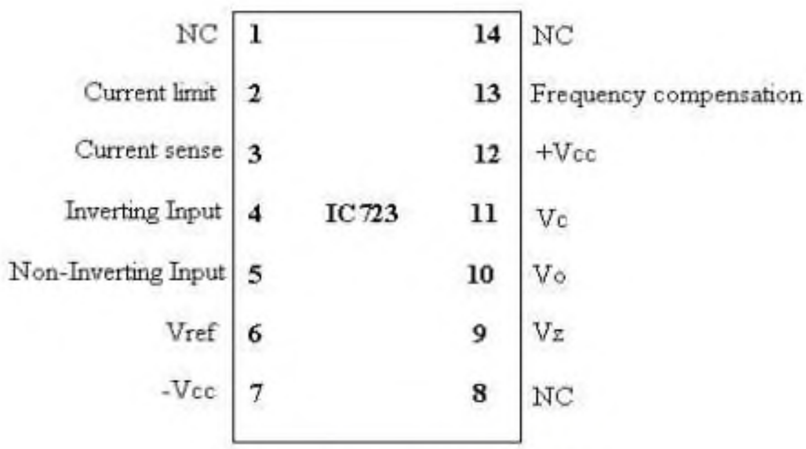
3. Series Pass Transistor:

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.

4. Circuitry to limit the current:

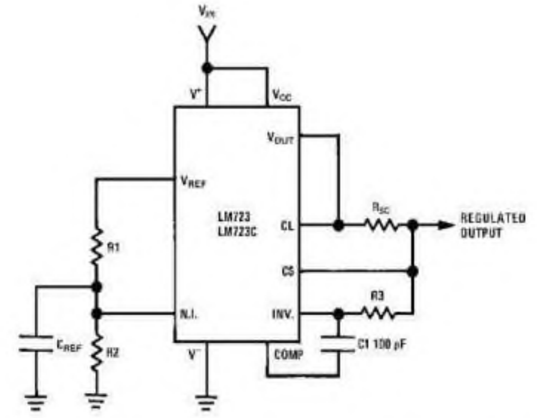
The internal transistor Q2 is used for current sensing & limiting. Q2 is normally OFF transistor. It turns ON when the IL exceeds a predetermined limit.Low voltage, Low current is capable of supplying load voltage which is equal to or between 2 to 7Volts.

V_{load} = 2 to 7V and I_{load}= 50mA



Pin diagram of IC723

IC723 as a LOW voltage LOW current:



Typical circuit connection diagram

- R_1 & R_2 from a potential divider between V_{ref} & Gnd.
- The Voltage across R_2 is connected to the Non – inverting terminal of the regulator

  I_C $V_{non-inv} = R_2/(R_1+R_2)$ Vref
- Gain of the internal error amplifier is large

  $V_{non-inv} = V_{in}$
- Therefore the Vo is connected to the Inverting terminal through R_3 & R_{SC} must also be equal to $V_{non-inv}$

$$V_o = V_{non-inv} = R_2/(R_1+R_2)\ V_{ref}$$

R_1 & R_2 can be in the range of 1 KΩ to 10KΩ & value of R3 is given by

$$R_3 = R_1 || R_2 = R_1R_2/(R_1+R_2)$$

Rsc (current sensing resistor) is connected between Cs & CL. The voltage drop across Rsc is proportional to the IL.

- 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 , Vo $=R_2/(R_1+R_2)\ V_{ref}$

IC723 as a HIGH voltage LOW Current:

- This circuit is capable of supplying a regulated output voltage between the ranges of 7 to 37 volts with a maximum load current of 150 mA.
- The Non – inverting terminal is now connected to V_{ref} through resistance R_3.
- The value of R_1 & R_2 is adjusted in order to get a voltage of Vref at the inverting terminal at the desired output.

$$V_{in} = V_{ref} = R_2/(R_1+R_2)V_0$$

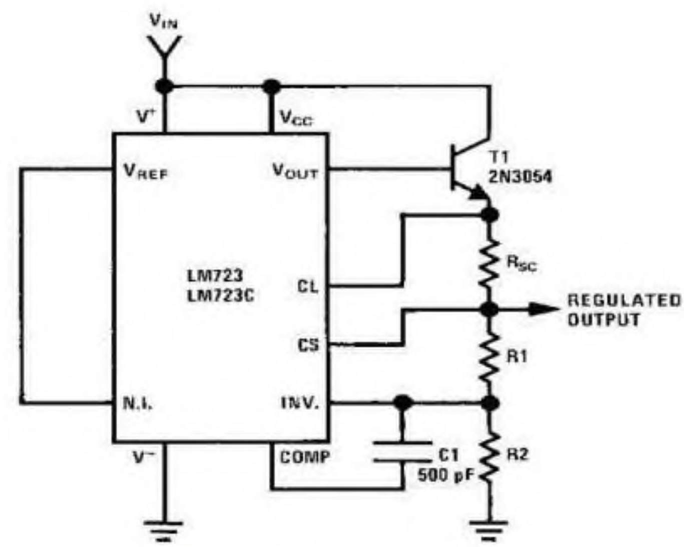
$$V_o = [1+R_1/R_2]\ V_{in}$$

- Rsc is connected between CL & Cs terminals as before & it provides the shortCircuit current limiting Rsc =0.6/Ilimit
- The value of resistors R3 is given by ,

$$R_3 = R_1 \| R_2 = R_1R_2/(R_1+R_2)$$

IC723 as a HIGH voltage HIGH Current:

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



Typical circuit connection diagram

- For this circuit the output voltage varies between 7 & 37V.
- Transistor Q increase the current sourcing capacity thus IL (MAX) is greater than 150mA.
- The output voltage Vo is given by ,

$$V_0 = V_o = [1+R_1/R_2]\ V_{in}$$

$$Rsc = 0.6/I\ limit$$

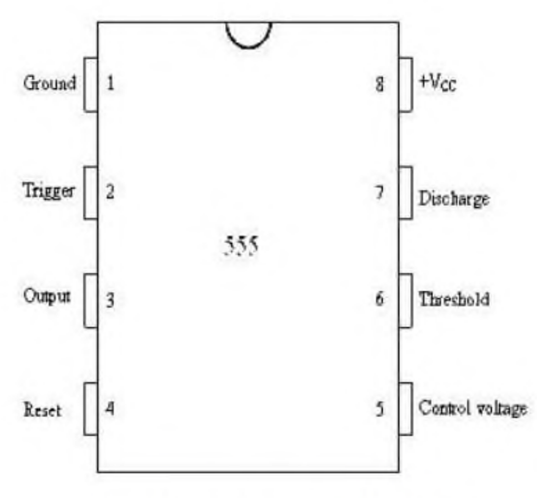
The 555 Timer IC

The 555 is a monolithic timing circuit that can produce accurate & highly stable time delays or oscillation. The timer basically operates in one of two modes: either

(i) Monostable (one - shot) multivibrator or
(ii) Astable (free running) multivibrator

The important features of the 555 timer are these:

1. It operates on +5v to +18 v supply voltages
2. It has an adjustable duty cycle
3. Timing is from microseconds to hours
4. It has a current o/p



Pin configuration of 555 timer

Pin description:

Pin 1: Ground:

All voltages are measured with respect to this terminal.

Pin 2: Trigger:

The o/p of the timer depends on the amplitude of the external trigger pulse applied to this pin.

Pin 3: Output:

There are 2 ways a load can be connected to the o/p terminal either between pin3 & ground or between pin 3 & supply voltage

(Between Pin 3 & Ground ON load) (BetweenPin 3 & + Vcc OFF load)

1. When the input is low:

The load current flows through the load connected between Pin 3 & +Vcc in to the output terminal & is called the sink current.

2. When the output is high:
   The current through the load connected between Pin 3 & +Vcc (i.e. ON load) is zero. However the output terminal supplies current to the normally OFF load. This current is called the source current.

Pin 4: Reset:

The 555 timer can be reset (disabled) by applying a negative pulse to this pin. When the reset function is not in use, the reset terminal should be connected to +Vcc to avoid any false triggering.

Pin 5: Control voltage:

An external voltage applied to this terminal changes the threshold as well as trigger voltage. In other words by connecting a potentiometer between this pin & GND, the pulse width of the output waveform can be varied. When not used, the control pin should be bypassed to ground with 0.01 capacitor to prevent any noise problems.

Pin 6: Threshold:

This is the non inverting input terminal of upper comparator which monitors the voltage across the external capacitor.

Pin 7: Discharge:

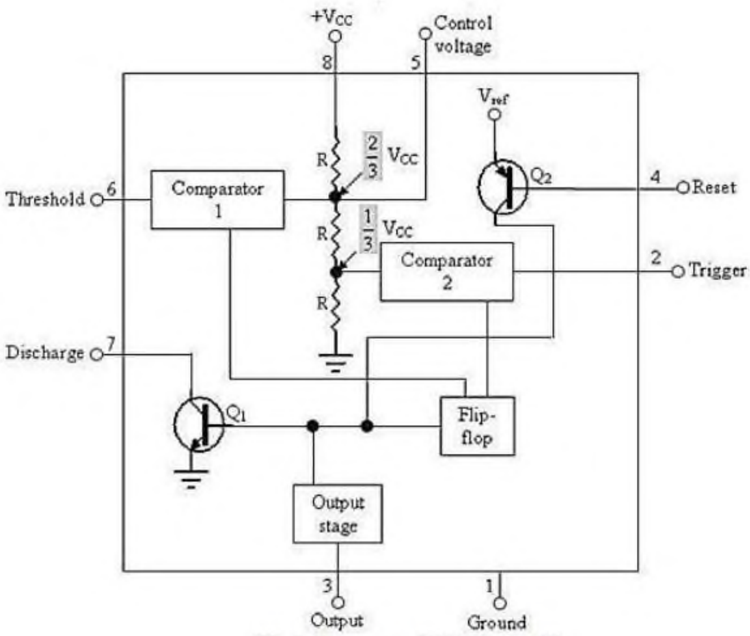
This pin is connected internally to the collector of transistor Q1.

When the output is high Q1 is OFF.

When the output is low Q is (saturated) ON.

Pin 8: +Vcc:

The supply voltage of +5V to +18V is applied to this pin with respect to ground.



Block **Diagram of 555 Timer IC**

From the above figure, three 5k internal resistors act as voltage divider providing bias voltage of 2/3 Vcc to the upper comparator & 1/3 Vcc to the lower comparator. It is possible to vary time electronically by applying a modulation voltage to the control voltage input terminal (5).

(i) In the Stable state:

The output of the control FF is high. This means that the output is low because of power amplifier which is basically an inverter. Q = 1; Output = 0

(ii) At the Negative going trigger pulse:

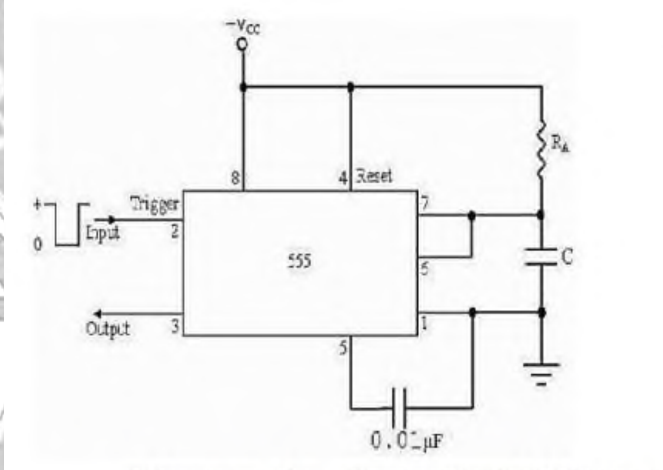
The trigger passes through (Vcc/3) the output of the lower comparator goes high & sets the FF. Q = 1; Q = 0

(iii) At the Positive going trigger pulse:

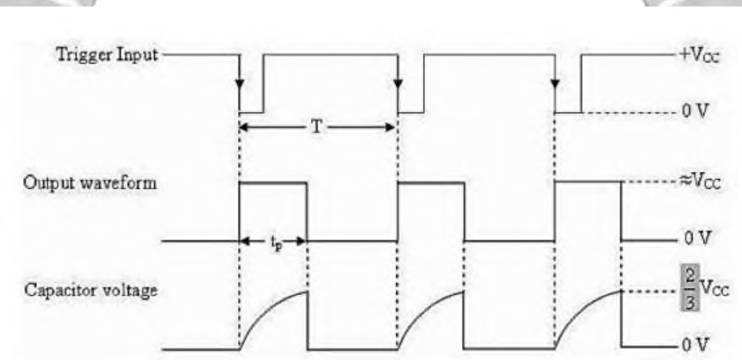
It passes through 2/3Vcc, the output of the upper comparator goes high and resets the FF. Q = 0; Q = 1

The reset input (pin 4) provides a mechanism to reset the FF in a manner which overrides the effect of any instruction coming to FF from lower comparator.

Monostable Operation:



555 connected as a Monostable Multivibrator



Waveforms of monostable multivibrators

Initially when the output is low, i.e. the circuit is in a stable state, transistor Q1 is ON & capacitor C is shorted to ground. The output remains low. During negative going trigger pulse, transistor Q1 is OFF, which releases the short circuit across the external capacitor C & drives the output high. Now the capacitor C starts charging toward Vcc through RA. When the voltage across the capacitor equals 2/3 Vcc, upper comparator switches from low to high. i.e. Q = 0, the transistor Q1 = OFF ; the output is high.

Since C is unclamped, voltage across it rises exponentially through R towards Vcc with a time constant RC (fig b) as shown in below. After the time period, the upper comparator resets the FF, i.e. Q = 1, Q1 = ON; the output is low.[i.e discharging the capacitor C to ground potential (fig c)]. The voltage across the capacitor as in fig (b) is given by

$$V_c = V_{cc}(1-e^{-t/RC}) \ldots\ldots (1)$$

Therefore At t = T, Vc = 2/3 Vcc

$$2/3\, V_{cc} = V_{cc}(1-e^{-T/RC})$$

or

$$T = RC \ln (1/3)$$

Or

$$T = 1.1RC \text{ seconds} \ldots\ldots (2)$$

If the reset is applied Q2 = OFF, Q1 = ON, timing capacitor C immediately discharged. The output now will be as in figure (d & e). If the reset is released output will still remain low until a negative going trigger pulse is again applied at pin 2.

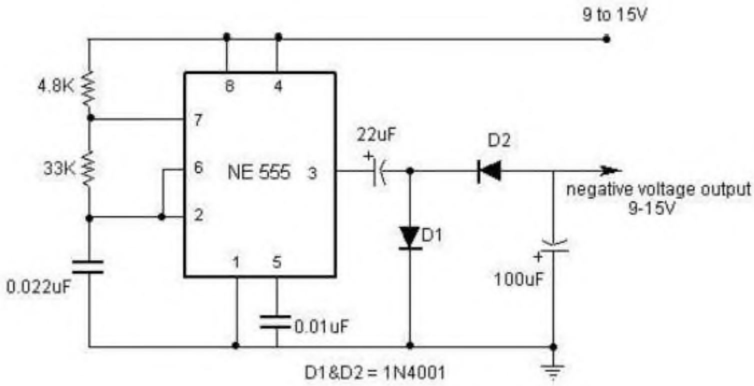
Applications of Monostable Mode of Operation:

(a) Frequency Divider:

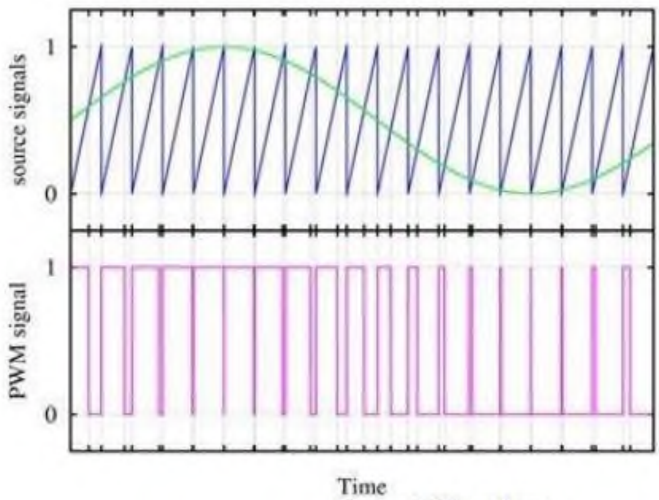
The 555 timer as a monostable mode. It can be used as a frequency divider by adjusting the length of the timing cycle tp with respect to the time period T of the trigger input. To use the monostable multivibrator as a divide by 2 circuit, the timing interval tp must be a larger than the time period of the trigger input. [Divide by 2, tp> T of the trigger]

By the same concept, to use the monostable multivibrator as a divide by 3 circuit, tp must be slightly larger than twice the period of the input trigger signal & so on, [divide by 3 tp > 2T of trigger]

(b) Pulse width modulation:



Pulse Width Modulation



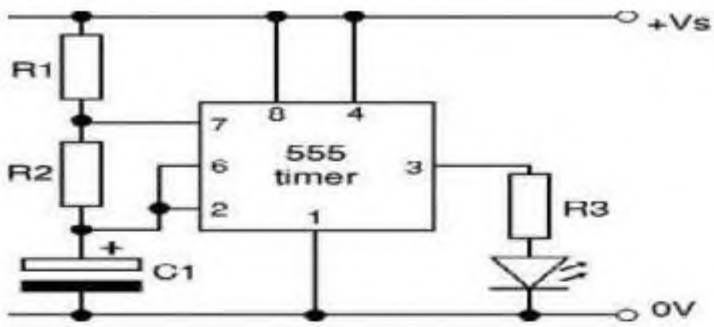
Output Waveform

Pulse width of a carrier wave changes in accordance with the value of a incoming (modulating signal) is known as PWM. It is basically monostable multivibrator.A modulating signal is fed in to the control voltage (pin 5). Internally, the control voltage is adjusted to 2/3 Vcc externally applied modulating signal changes the control voltage level of upper comparator. As a result, the required to change the capacitor up to threshold voltage level changes, giving PWM output.

(c) Pulse Stretcher:

This application makes use of the fact that the output pulse width (timing interval) of the monostable multivibrator is of longer duration than the negative pulse width of the input trigger. As such, the output pulse width of the monostable multivibrator can be viewed as a stretched version of the narrow input pulse, hence the name “Pulse stretcher”.

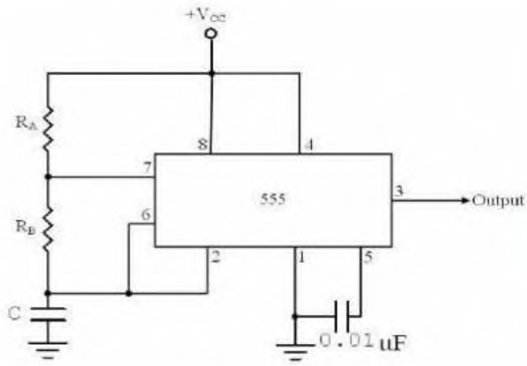
Often, narrow –pulse width signals are not suitable for driving an LED display, mainly because of their very narrow pulse widths. In other words, the LED may be flashing but not be visible to the eye because its on time is infinitesimally small compared to its off time. The 55 pulse stretcher can be used to remedy this problem. The LED will be ON during the timing interval tp = 1.1RAC which can be varied by changing the value of RA & C.



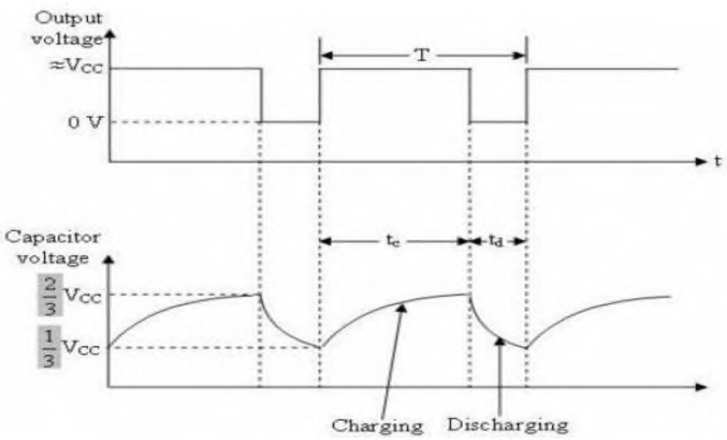
Pulse Stretcher

The 555 timer as an Astable Multivibrator:

An Astable multivibrator, often called a free running multivibrator, is a rectangular wave generating circuit. Unlike the monostable multivibrator, this circuit does not require an external trigger to change the state of the output, hence the name free running. However, the time during which the output is either high or low is determined by 2 resistors and capacitors, which are externally connected to the 55 timer.



Astable Multivibrator



Waveforms of Astable multivibrator

The above figures show the 555 timer connected as an astable multivibrator and its model graph

Initially, when the output is high :

Capacitor C starts charging toward Vcc through RA & RB. However, as soon as voltage across the capacitor equals 2/3 Vcc. Upper comparator triggers the FF & output switches low.

When the output becomes Low:

Capacitor C starts discharging through RB and transistor Q1, when the voltage across C equals 1/3 Vcc, lower comparator output triggers the FF & the output goes high. Then cycle repeats. The capacitor is periodically charged & discharged between 2/3 Vcc & 1/3 Vcc respectively. The time during which the capacitor charges from 1/3 Vcc to 2/3 Vcc equal to the time the output is high & is given by

tc = (RA+RB)C ln 2 ....(1) Where [ln 2 = 0.69]

= 0.69 (RA+RB) C

Where RA & RB are in ohms. And C is in farads.

Similarly, the time during which the capacitors discharges from 2/3 Vcc to 1/3 Vcc is equal to the time, the output is low and is given by,

tc = RB C ln 2

td = 0.69 RB C...............................(2)

where RB is in ohms and C is in farads.

Thus the total period of the output waveform is

T = tc + td = 0.69 (RA+2RB) C ....(3)

This, in turn, gives the frequency of oscillation as, f_0 = 1/T = 1.45/(RA+2RB)C .... (4)

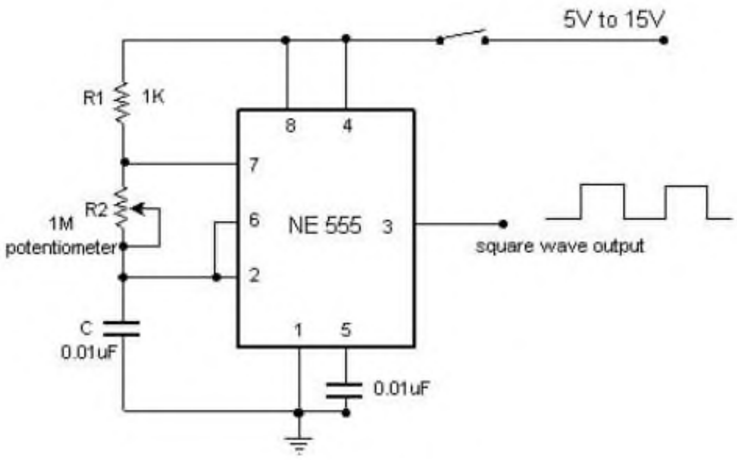
Equation 4 indicates that the frequency f 0 is independent of the supply voltage Vcc. Often the term duty cycle is used in conjunction with the astable multivibrator. The duty cycle is the ratio of the time tc during which the output is high to the total time period T. It is generally expressed as a percentage.

% duty cycle = (tc / T)* 100

% DC = [(RA+RB)/ /(RA+2RB)] * 100

Astable Multivibrator Applications:

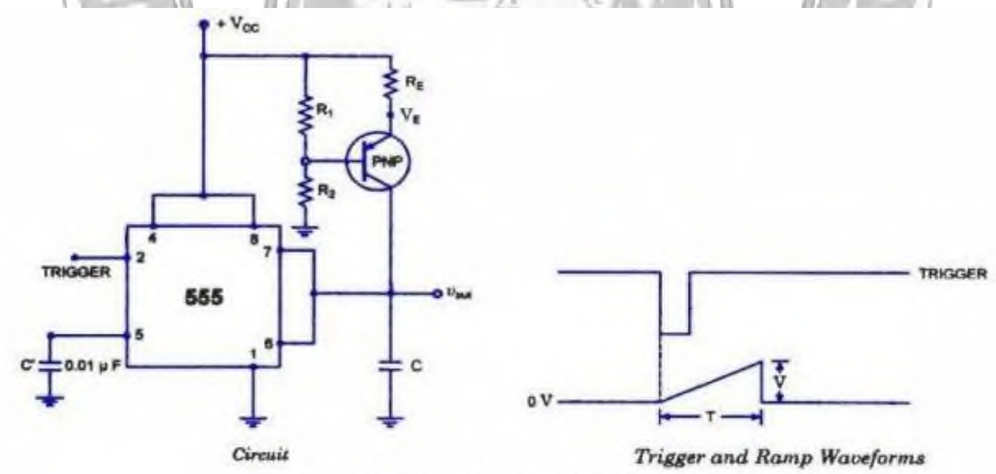
(a) Square wave oscillator:



Square Wave Oscillator

Without reducing RA = 0 ohm, the astable multivibrator can be used to produce square wave output. Simply by connecting diode D across Resistor RB. The capacitor C charges through RA & diode D to approximately 2/3Vcc & discharges through RB & Q1 until the capacitor voltage equals approximately 1/3Vcc, then the cycle repeats.To obtain a square wave output, RA must be a combination of a fixed resistor & potentiometer so that the potentiometer can be adjusted for the exact square wave.

(b) Free – running Ramp generator:



Ramp Generator Using The Timer 555

- The astable multivibrator can be used as a free – running ramp generator when resistor
- RA & RB is replaced by a current mirror.
- The current mirror starts charging capacitor C toward Vcc at a constant rate.
- When voltage across **C equals to 2/3 Vcc**, upper comparator turns transistor Q1 ON and C rapidly discharges through transistor Q1.
- When voltage across **C equals to 1/3 Vcc**, lower comparator switches transistor OFF & then capacitor C starts charging up again.
- Thus the charge – discharge cycle keeps repeating.

- The discharging time of the capacitor is relatively negligible compared to its charging time.

The time period of the ramp waveform is equal to the charging time & is approximately is given by,

$$T = VccC/3I_C$$

$$I_C = (Vcc - V_{BE})/R = \text{constant current}$$

Therefore the free – running frequency of ramp generator is

$$f_0 = 3I_C/ Vcc\ C$$

Isolation amplifier

An isolation amplifier or a unity gain amplifier provides isolation from one fraction of the circuit to another fraction. So, the power cannot be drawn, used and wasted within the circuit. The main function of this amplifier is to increase the signal. The same input signal of the op-amp is passed out exactly from the op-amp as an output signal. These amplifiers are used to give an electrical safety battier as well as isolation. These amplifiers protect the patients from the outflow of current. They crack electrical signal's ohmic continuity among input & output and isolated power supply can be provided for both the input and output. So, the low-level signals can be amplified.

An isolation amplifier can be defined as, an amplifier which doesn't have any conductive contact among input as well as output sections. Consequently, this amplifier gives ohmic isolation among the i/p & o/p terminals of the amplifier. This isolation must have less leakage as well as a high amount of dielectric breakdown voltage. The typical resistor and capacitor values of amplifier among the input & output terminals are resistor should have 10 Tera Ohms and capacitor should have 10 picofarads.

These amplifiers are frequently used when there is extremely huge common-mode voltage disparity among input & output side. In this amplifier, the ohmic circuitry is not there from input ground to output ground.

Isolation Amplifier Design Methods

There are three kinds of design methods are used in isolation amplifiers which include the following.

- Transformer Isolation
- Optical Isolation
- Capacitive Isolation

1). Transformer Isolation

This type of isolation uses two signals like PWM or frequency modulated. Internally, this amplifier includes 20 KHz oscillator, rectifier, filter, and transformer to give supply to every isolated stage.

- The rectifier is used as an input to the main op-amp.
- Transformer links the supply.
- The oscillator is used as an input to the secondary op-amp.
- An LPF is used for removing the components of other frequency.
- The advantages of transformer isolation mainly include high CMRR, linearity, and accuracy.
- The applications of transformer isolation mainly include medical, nuclear and industrial.

2). Optical Isolation

In this isolation, the l signal can be changed from biological to light signal with LED for further process. In this, the patient circuit is input circuit whereas the output circuit can be formed by a phototransistor. These circuits are operated with a battery. The i/p circuit changes the signal into the light as well as the o/p circuit changes the light back to the signal.

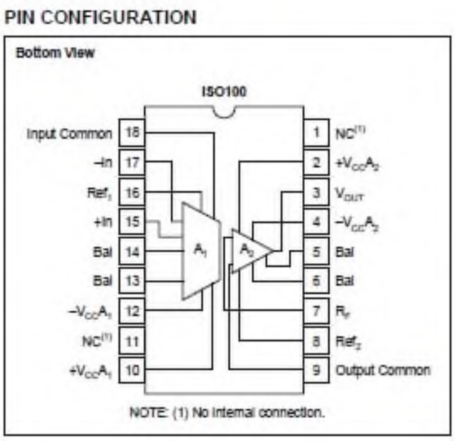
- The advantages of optical isolation mainly include;
- By using this we can obtain amplitude and original frequency.
- It connects optically without the need of modulator otherwise demodulator.
- It improves the safety of the patient.

The applications of transformer isolation mainly include process control in industries, data acquisition, measurements of biomedical, monitoring of the patient, interface element, test equipment, controlling of SCR, etc.

3). Capacitive Isolation

- It uses frequency modulation and the input voltage's digital encoding.
- The input voltage can be changed to relative charge over the switched capacitor.
- It includes circuits like modulator as well as a demodulator.
- The signals are sent across a differential capacitive barrier.
- For both sides, separate supplied are given.
- The advantages of capacitive isolation mainly include;
- This isolation can be used to remove ripple noises
- These are used for analog systems
- It includes linearity and high-gain stability.
- It gives high immunity to magnetic noises
- By using this, noise can be avoided.
- The applications of capacitive isolation mainly include data acquisition, interface element, monitoring of the patient, EEG, and ECG.

IC ISO 100 Isolation Amplifier



FEATURES

- EASY TO USE, SIMILAR TO AN OP AMP
- VOUT/IIN = RF, Current Input
- VOUT/VIN = RF/RIN, Voltage Input
- 100% TESTED FOR BREAKDOWN:
- 750V Continuous Isolation Voltage
- ULTRA-LOW LEAKAGE: 0.3mA, max, at
- 240V/60Hz
- WIDE BANDWIDTH: 60kHz
- 18-PIN DIP PACKAGE

Operation of ISO100

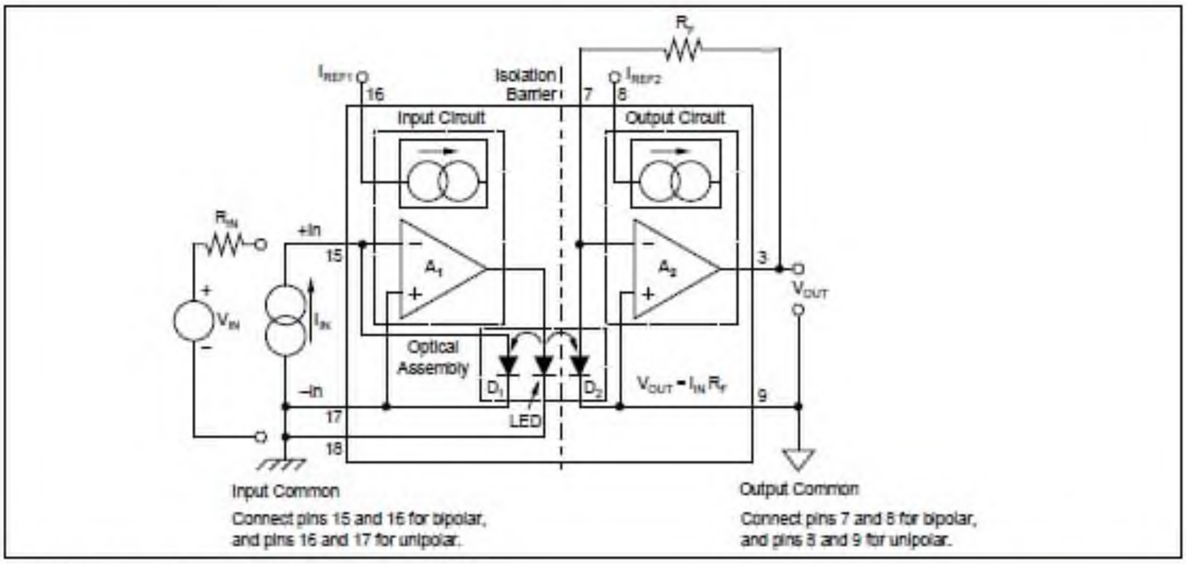


FIGURE 1. Simplified Block Diagram of the ISO100.

In Figure 1, assume a current, IIN, flows out of the ISO100 (IIN must be negative in unipolar operation). This causes the voltage at pin 15 to decrease. Because the amplifier is inverting, the output of A1 increases, driving current through the LED. As the LED light output increases, D_1 responds by generating an increasing current. The current increases until the sum of the currents in and out of the input node (–Input to A1) is zero. At that point, the negative feedback through D_1 has stabilized the loop, and the current I_{D1} equals the input current plus the bias current. As a result, no bias current flows in the source. Since D_1 and D_2 are matched (I_{D1} = I_{D2}), I_{IN} is replicated at the output via D_2. Thus, A_1 functions as a unity-gain current amplifier, and A_2 is an current-to-voltage converter, as described below. Current produced by D_2 must either flow into A_2 or R_F. Since A_2 is designed for low bias current (»10nA), almost all of the current flows through R_F to the output. The output voltage then becomes:

$$V_O = (I_{D2})R_F = (I_{D1} \pm I_{OS})R_F = -(-I_{IN})R_F = I_{IN}R_F \quad (1)$$

where, I_{OS} is the difference between A_1 and A_2 bias currents.

For input voltage operation I_{IN} can be replaced by a voltage source (V_{IN}) and series resistor (R_{IN}), since the summing node of the op amp is essentially at ground. Thus,

$$I_{IN} = V_{IN}/R_{IN}.$$

Unipolar operation does have some constraints, however. In this mode the input current must be negative so as to produce a positive output voltage from A_1 to turn the LED on. A current more negative than 20nA is necessary to keep the LED turned on and the loop stabilized. When this condition is not met, the output may be in determinant. Many sensors generate unidirectional signals, e.g., photoconductive and photodiode devices, as well as some applications of thermocouples. However, other applications do require bipolar operation of the ISO100.

BIPOLAR OPERATION

To activate the bipolar mode, reference currents as shown in Figure 1 are attached to the input nodes of the op amps. The input stage stabilizes just as it did in unipolar operation. Assuming $I_{IN} = 0$, the photodiode has to supply all the I_{REF1} current. Again, due to symmetry, $I_{D1} = I_{D2}$. Since the two references are matched, the current generated by D_2 will equal I_{REF2}. This results in no current flow in RF, and the output voltage will be zero. When IIN either adds or subtracts current from the input node, the current D_1 will adjust to satisfy $I_{D1} = I_{IN} + I_{REF1}$. Because I_{REF1} equals I_{REF2} and I_{D1} equals I_{D2}, a current equal to I_{IN} will flow in R_F. The output voltage is then VO = $I_{IN}R_F$. The range of allowable I_{IN} is limited. Positive I_{IN} can be as large as IREF1 (10.5mA, min). At this point, D_1 supplies no current and the loop opens. Negative I_{IN} can be as large as that generated by D_1 with maximum LED output (recommended 10mA, max).

DC ERRORS

Errors in the ISO100 take the form of offset currents and voltages plus their drifts with temperature. These are shown in Figure 2. *A_1 and A_2*— assumed to be ideal amplifiers. *V_{OSO} and V_{OSI}*—the input offset voltages of the output and input stage, respectively. V_{OSO} appears directly at the output, but, VOSI appears at the output as $V_{OSI}\frac{□}{□□}$,

see equation (2).

I_{OS}—the offset current. This is the current at the input necessary to make the output zero. It is equal to the combined effect of the difference between the bias currents of A_1 and A_2 and the matching errors in the optical components in the unipolar mode. *I_{REF1} and I_{REF2}*—reference currents that, when connected to the inputs, enable bipolar operation. The two currents are trimmed, in the bipolar mode, to minimize the $I_{OS\ BIPOLAR}$ error. *I_{D1} and I_{D2}*—currents generated by each photodiode in response to the light from the LED.

Ae—gain error.

$$Ae = |\ \text{Ideal gain/Actual gain}\ | - 1$$

The output then becomes:

$$V_{OUT} = R_F[(\frac{VIN+VOS}{□□} - I_{REF1} \pm I_{OS})(1 + Ae) + I_{REF2}] \pm V_{OSO} \quad (2)$$

The total input referred offset voltage of the ISO100 can be simplified in the unipolar case by assuming that Ae = 0 and

$V_{IN} = 0$:

$$V_{OUT} = R_F\,[\,\frac{\pm V_{OSI}}{□□} \pm I_{OS\ UNIPOLAR}] \pm V_{OSO} \quad (3)$$

This voltage is then referred back to the input by dividing by R_F/R_{IN}.

$$V_{OS}\,(R_{TI}) = (\pm V_{OSI}) \pm R_{IN}\,(I_{OS\ UNIPOLAR}) + V_{OSO}/(R_F/R_{IN})$$

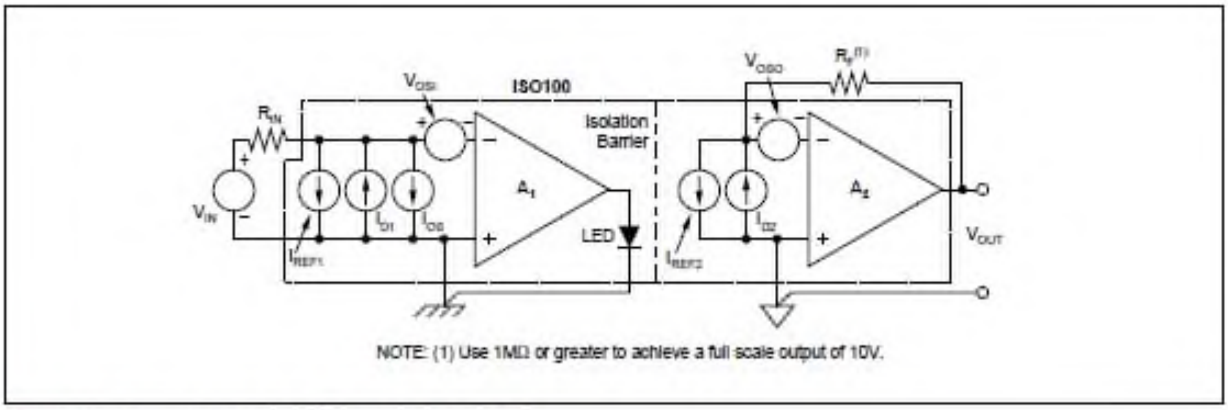


FIGURE 2. Circuit Model for DC Errors in the ISO100.

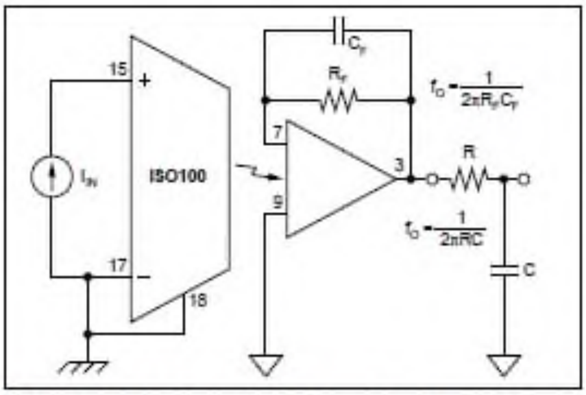


FIGURE 4. Two Circuit Techniques for Reducing Noise in the Unipolar Mode.

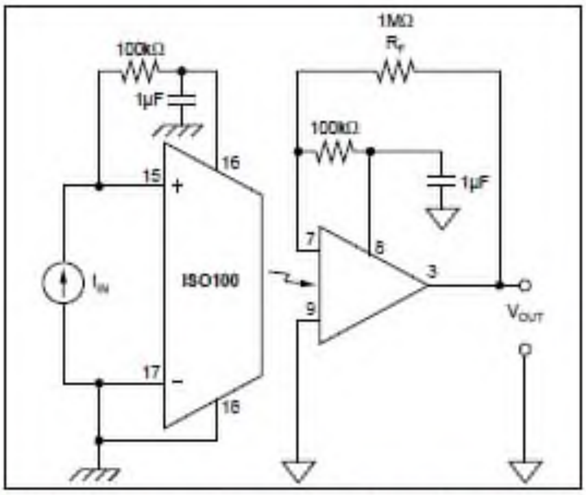


FIGURE 5. Circuit Techniques for Reducing Noise from the Current Sources in the Bipolar Mode.