20EC105
Linear Integrated Circuit Applications

Program Core

(Common to: B.Tech ECE & also its splns. AIML & IOT)

by

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20EC105 LIC Course Objectives (COs)

1. Illustrate and analyze the basic principles and important characteristics of Linear ICs.
2. Design and develop solutions using Integrated Circuits for specific applications.
3. Elucidate and design the interfacing applications through ICs that promote health and well-being.

Linear Integrated Circuit Applications (LICAs)

Semester	Hours/Week			C	Marks		
	L	T	P/D		CIE	SEE	Total
III	2	-	2	3	60	40	100
Pre-requisite	20ES103 Analog Circuit Analysis						
Note	1. Vide the R22 Course structure is L:T:P/D:C :: 2 : 0 : 2 : 3 2. R22 Lab Integrated Course Academic regulations apply						

Module I: Introduction to ICs (05 Hrs.)

- Integrated circuits - basics, types, block diagram, Features & Characteristics: DC and AC Characteristics, Modes of operation. Illustrative Example Overview of ICs (OPAMP IC, Timer IC, Regulator ICs, ADCs, DACs)

LIC: Syllabus & Course Brief (continued)

Module II: Linear Applications of Op-Amp. (06 Hrs.)

- Introduction, Inverting and Non-Inverting OPAMPs, Adder, Subtractor, Integrator, Differentiator, Instrumentation amplifier, Voltage follower, V-I/ I-V Converters. Filters First Order and Second Order Active Low Pass Filters; An overview of Band Pass, Band Reject, All Pass Filters.

Module III:Non-Linear Applications of Op-Amp (04 Hrs.)

- S/H Circuits, Comparators, Schmitt triggers, Waveform generators, Precision Rectifiers, Clippers and Clampers

LIC: Syllabus & Course Brief (continued)

Module IV: Special Purpose ICs (05 Hrs.)

- 555 timer: Functional diagram, Multi vibrators- Astable and Mono stable operations, Illustrative applications; Voltage Regulator ICs – Basics, 78xx/79xx series ICs, 723 General purpose regulator.

Module V:D-A and A-D Converters (05 Hrs.)

- DAC – basics, Weighted Resistor type, R-2R Ladder type;
- ADCs- basics, Parallel Comparator Type, Successive Approximation Register Type; ADC and DAC specifications and applications

LIC Practical -Experiments List:

1. OPAMP Inverting Amplifier
2. OPAMP Non-Inverting Amplifier
3. OPAMP Adder
4. OPAMP Subtractor
5. OPAMP Integrator,
6. OPAMP Differentiator,
7. OPAMP Voltage follower,
8. OPAMP Comparators,
9. OPAMP Schmitt triggers,
10. OPAMP Precision Rectifiers (Half wave/ Full Wave)
11. IC 555/ OPAMP Astable Multivibrator
12. IC 555/ OPAMP Monostable Multivibrator
13. IC 78xx/79xx series or IC 723 Voltage Regulator

Linear Integrated Circuits: Learning Resources

TEXT BOOKS

1. D.Roy Choudhry, Shail Jain, Linear Integrated Circuits, New Age International Pvt. Ltd., 2021, Sixth Edition ISBN 978-8122472127.
2. Sergio Franco, -Design with Operational Amplifiers and Analog Integrated Circuits, 4th Edition, Tata Mc Graw-Hill, 2016

REFERENCE BOOKS

1. A. Ramakant A. Gayakwad, -Operational Amplifiers and Linear IC, 4th Edition, Prentice Hall / Pearson Education, 2015
2. B. S.Salivahanan & V.S. Kanchana Bhaskaran, -Linear Integrated Circuits, TMH,3rd Edition, 2018

Useful Links

1. https://nptel.ac.in/courses/108/108/108108111/
2. https://nptel.ac.in/courses/117/107/117107094/
3. https://onlinecourses.nptel.ac.in/noc20_ee13/preview

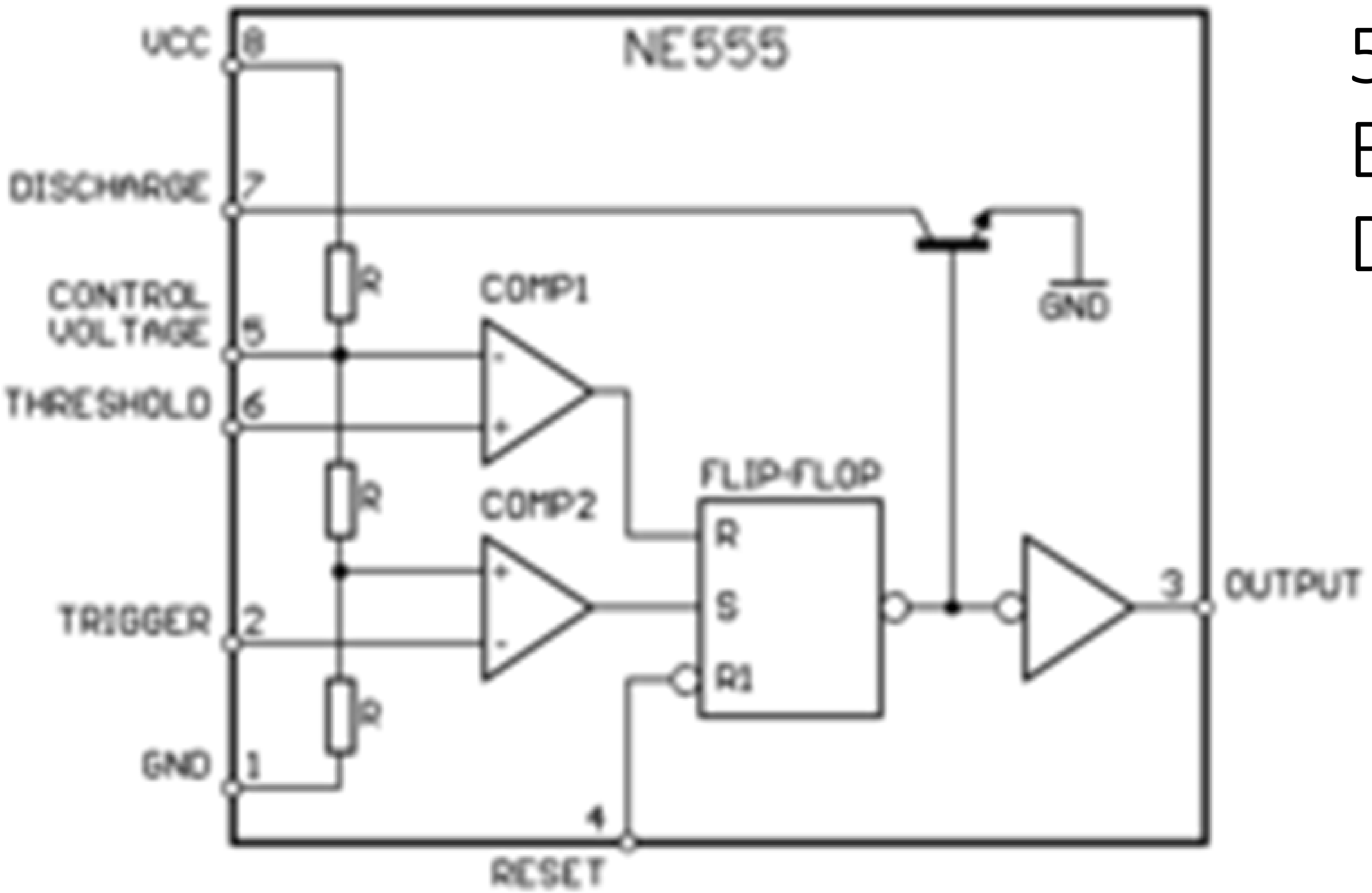
M_IV: Special Purpose ICs

- 555 timer: Functional diagram,
  - Multi vibrators-
    - Astable and Mono stable operations,
    - Illustrative applications;
- Voltage Regulator ICs
  - Basics,
  - 78xx/79xx series ICs,
  - 723 General purpose regulator

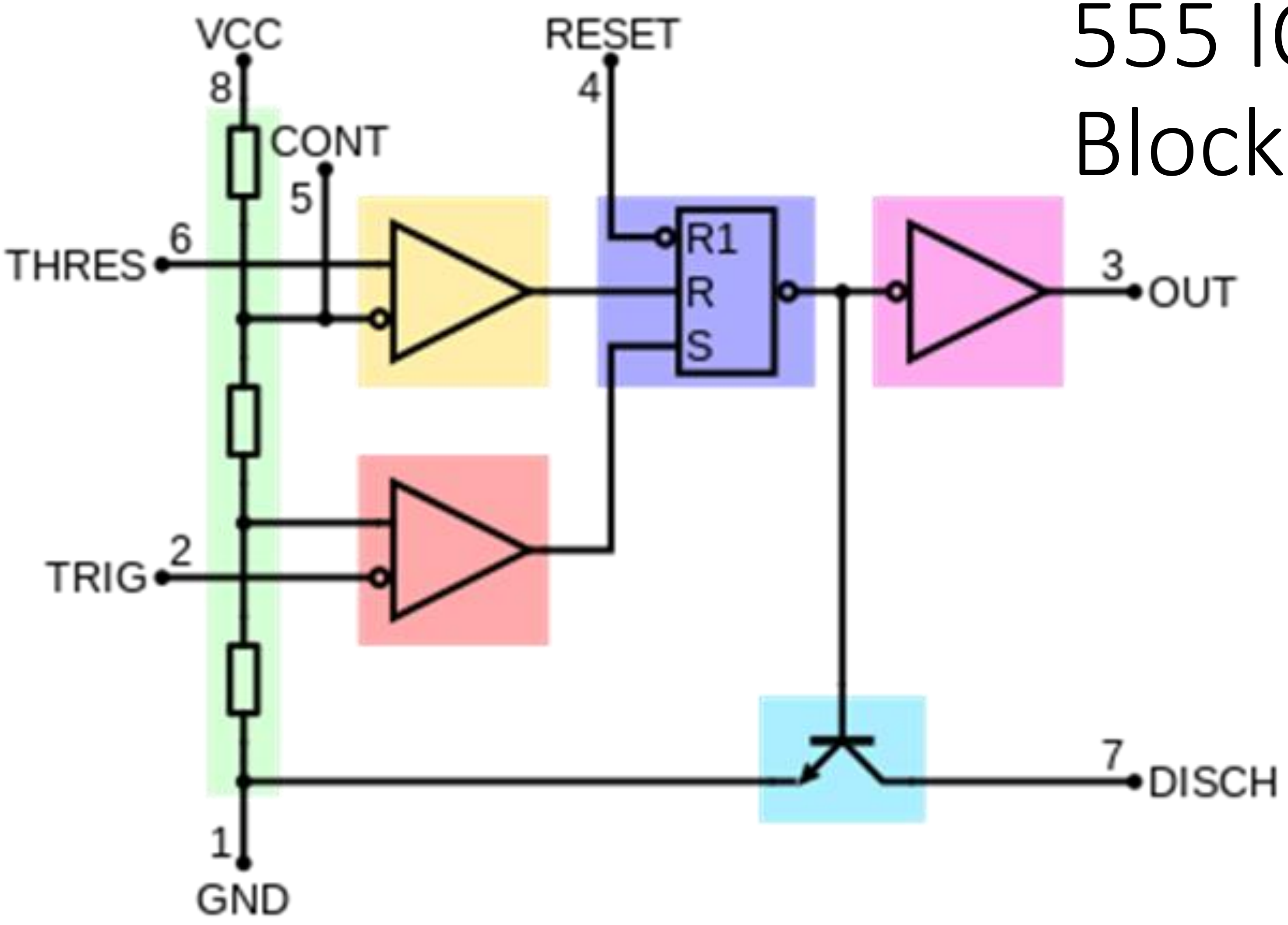
Timer IC 555 – An Introduction

- First Design of 555 timer IC was reviewed in 1971; The 555 timer was manufactured by 12 companies in 1972, and it became a best-selling product; It’s an 8-pin package.
- NE555 is a commercial Timer with temperature range, 0 °C to +70 °C; although several variations exist.
- Low-power CMOS versions of the 555 are now available,
  - Intersil’s ICM7555 and TIs LMC555, TLC555, TLC551.
- It consists of: 25 transistors, 2 diodes, and 15 resistors on a silicon chip packaged into an 8-pin dual in-line package (DIP-8)

555 IC Block Diagram

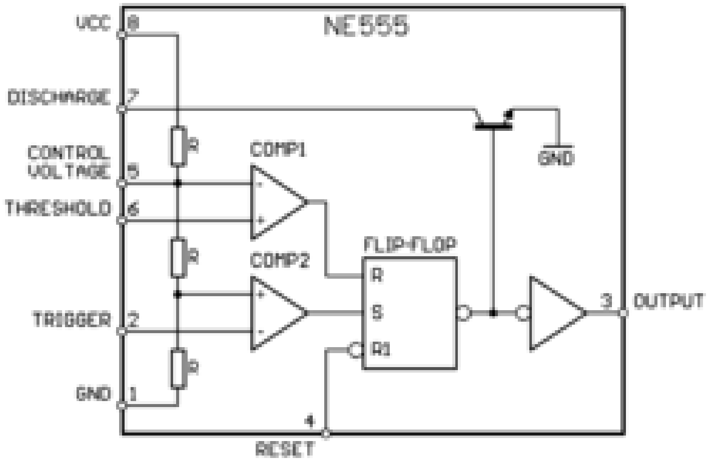


555 IC Functional Blocks



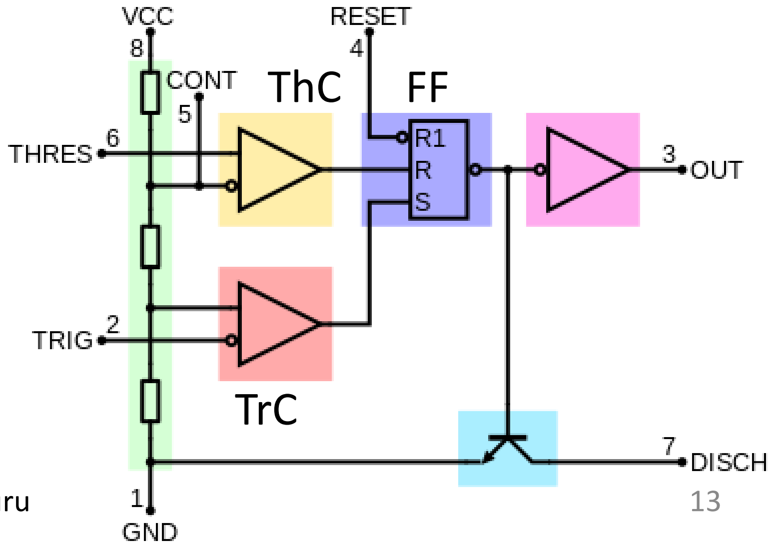
555 IC Block Diagram

- Voltage divider: Between the positive supply voltage V_{CC} and the ground GND(#1) is a voltage divider consisting of three identical resistors (5 kΩ for bipolar timers, 100 kΩ or higher for CMOS) to create reference voltages for the comparators.
  - CONTROL is connected between the upper two resistors, allowing an external voltage to control the reference voltages:
  - When CONTROL is not driven, this divider creates an upper reference voltage of 2⁄3 VCC and a lower reference voltage of 1⁄3 VCC.
  - When CONTROL is driven, the upper reference voltage will instead be $V_{CONTROL}$ and the lower reference voltage will be 1⁄2 $V_{CONTROL}$.
- Threshold comparator (ThC): The comparator's negative input is connected to voltage divider's upper reference voltage, and the comparator's positive input is connected to THRESHOLD (#6).
- Trigger comparator (TrC): The comparator's positive input is connected to voltage divider's lower reference, and the comparator's negative input is connected to TRIGGER (#2).

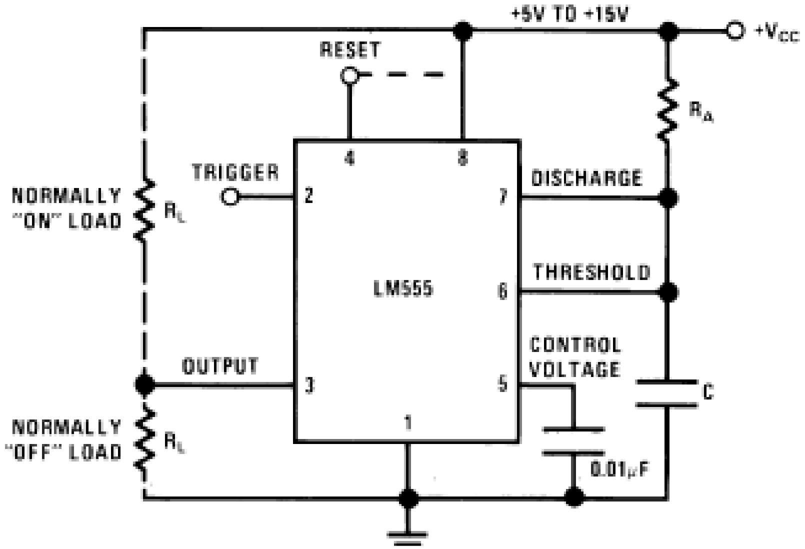


555 IC Block Diagram

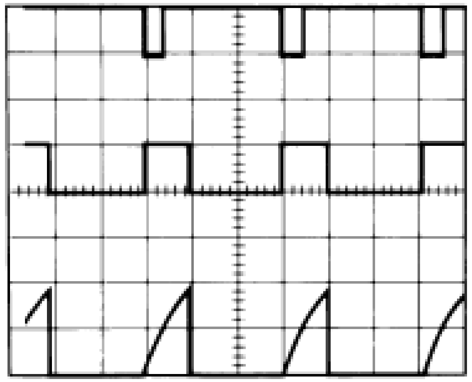
- Flip-flop (FF): An SR flip-flop stores the state of the timer and is controlled by the two comparators. RESET (#4) overrides the other two inputs, thus the flip-flop (and therefore the entire timer) can be reset at any time.
- Output(#3): The output of the flip-flop is followed by an output stage with push–pull (P.P.) output drivers that can supply up to 200 mA for bipolar timers, lower for CMOS timers.
- Discharge: Also, the output of the flip-flop turns on a transistor that connects DISCHARGE (#7) to the ground.



Monostable



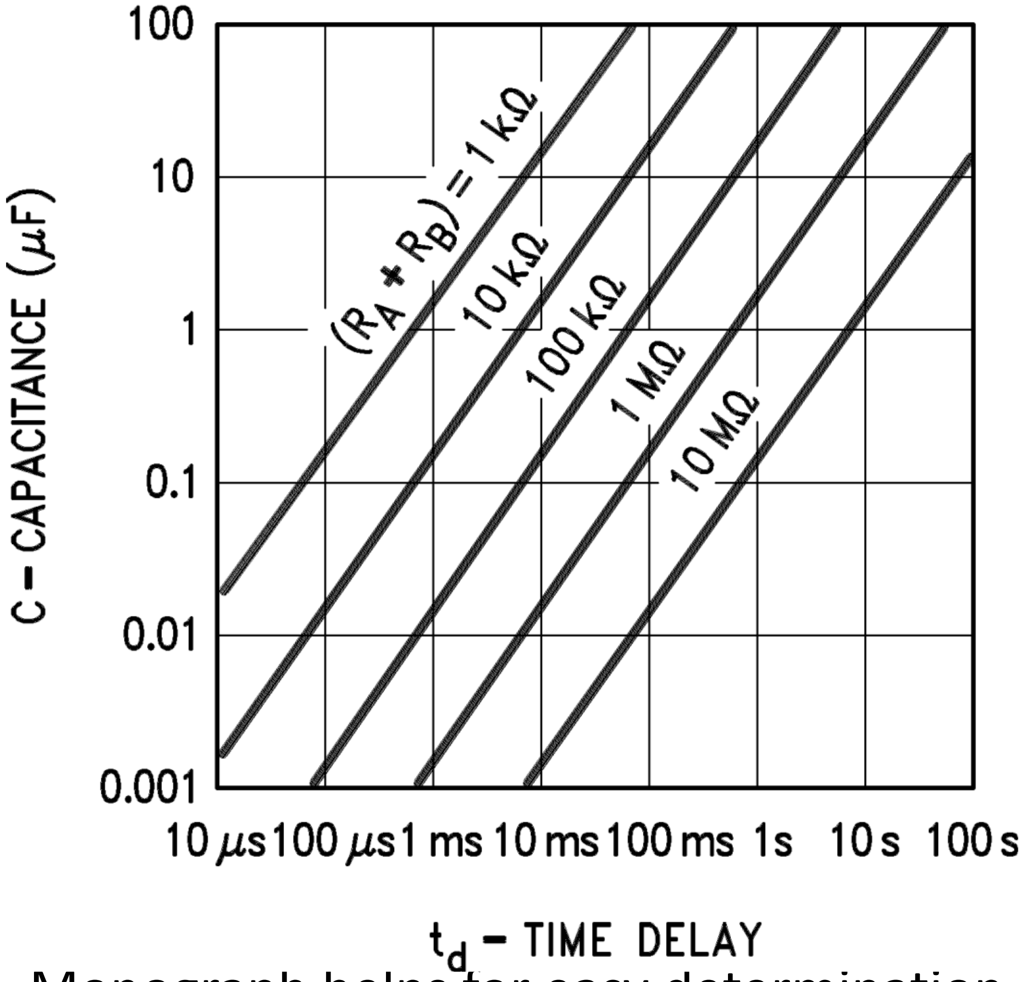
V_{CC} = 5 V; TIME = 0.1 ms/DIV; R_A = 9.1 kΩ; C = 0.01 μF



Top Trace: Input 5V/Div; Middle Trace: Output 5V/Div; Bottom Trace: Capacitor Voltage 2V/Div

- The external capacitor is initially held discharged by a transistor inside the timer. Upon application of a negative trigger pulse of less than 1/3 VCC to pin 2, the flip-flop is set which both releases the short circuit across the capacitor and drives the output high.
- The voltage across the capacitor then increases exponentially for a period of t = 1.1 R_AC, at the end of which time the voltage equals 2/3 V_{CC}.
- The comparator then resets the flip-flop which in turn discharges the capacitor and drives the output to its low state.
- Fig. below shows the waveforms generated in this mode of operation. Since the charge and the threshold level of the comparator are both directly proportional to supply voltage, the timing interval is independent of supply.
- During the timing cycle when the output is high, the further application of a trigger pulse will not effect the circuit
- So long as the trigger input is returned high at least 10 μs before the end of the timing interval.
- However the circuit can be reset during this time by the application of a negative pulse to the reset terminal (pin 4). The output will then remain in the low state until a trigger pulse is again applied
- When the reset function is not in use, it is recommended to connect the Reset pin to V_{CC} to avoid any possibility of false triggering

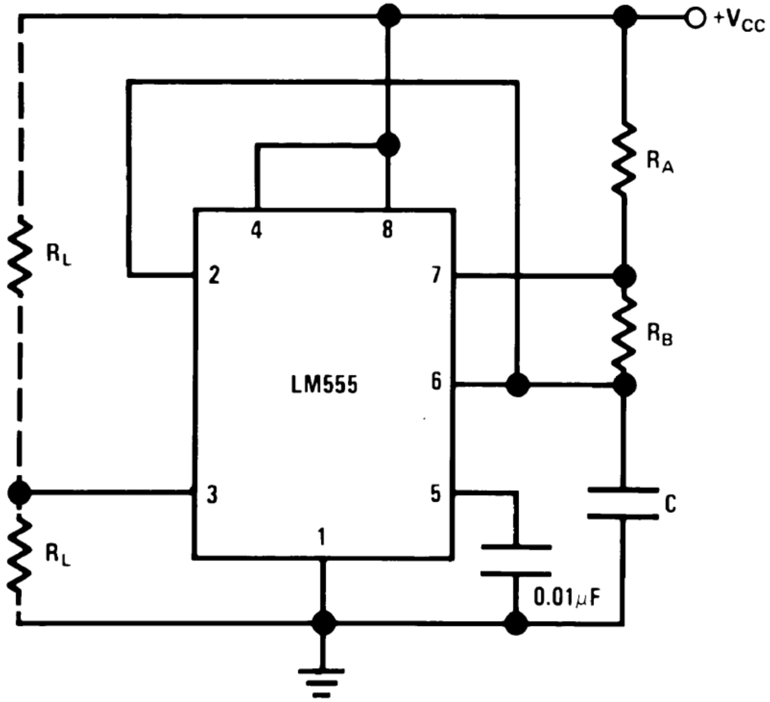
Time Delay Monograph



- Monograph helps for easy determination of R, C values for various time delays

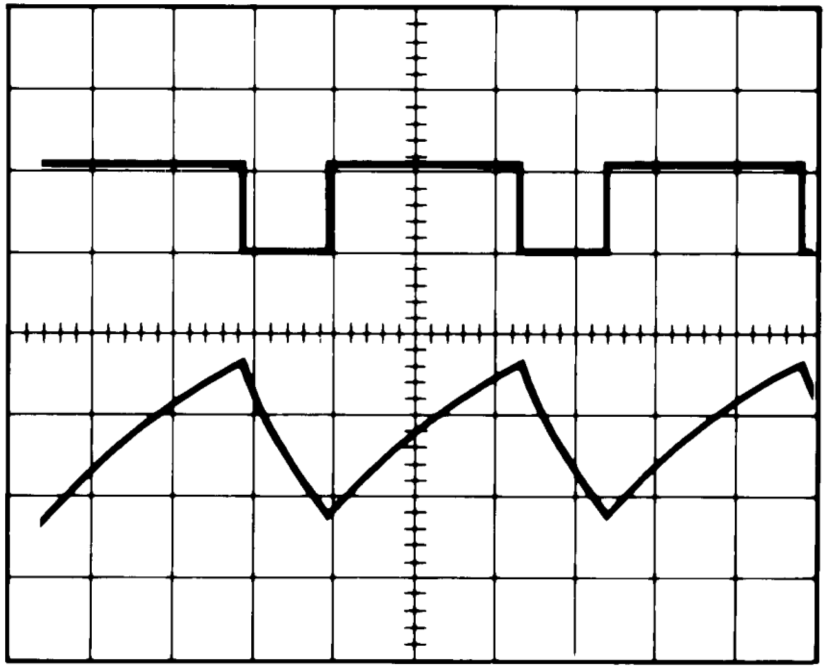
Astable

- When pins 2 and 6 connected, as in above circuit, it triggers itself and runs freely as a multivibrator.
- The external capacitor charges through $R_A + R_B$ and discharges through R_B. Thus the duty cycle may be precisely set by the ratio of these two resistors.
- the capacitor charges and discharges between 1/3 V_{CC} and 2/3 V_{CC}. As in the triggered mode, the charge and discharge times, and therefore the frequency are independent of the supply voltage



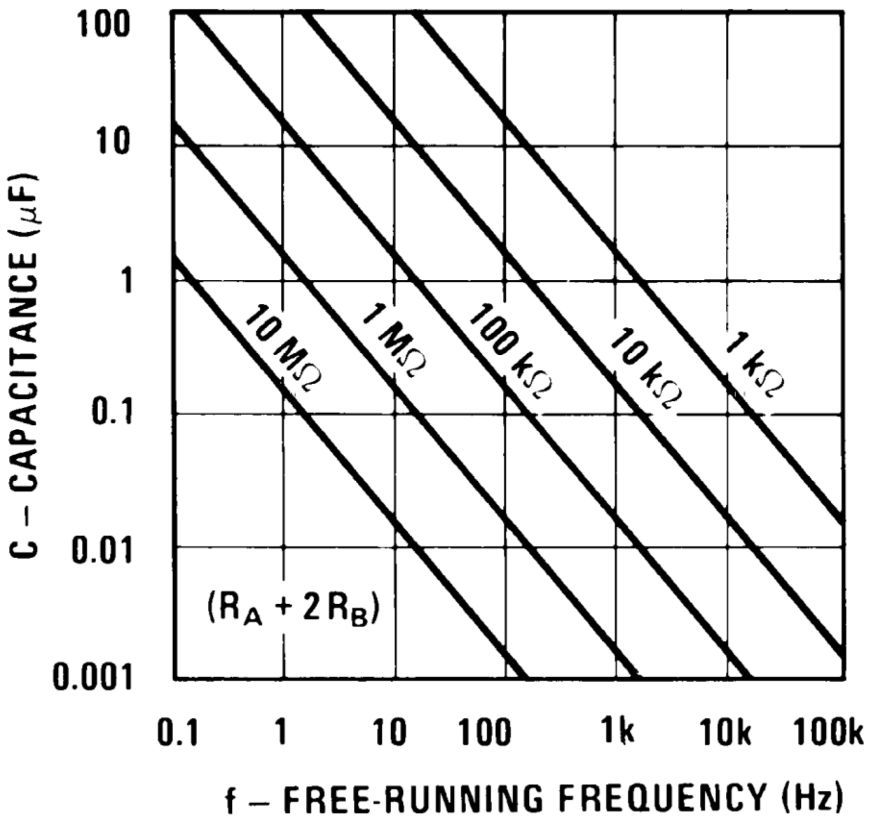
Astable: Waveforms

- The charge time (output high): t_1=0.693 (R_A +R_B) C; The Discharge time (output low): t_2 = 0.693 (R_B) C; The total Time period: T = t_1 + t_2
- The freq. of osc. = f = 1/T; The Duty Cycle, D =
- R_B / (R_A+2R_B)

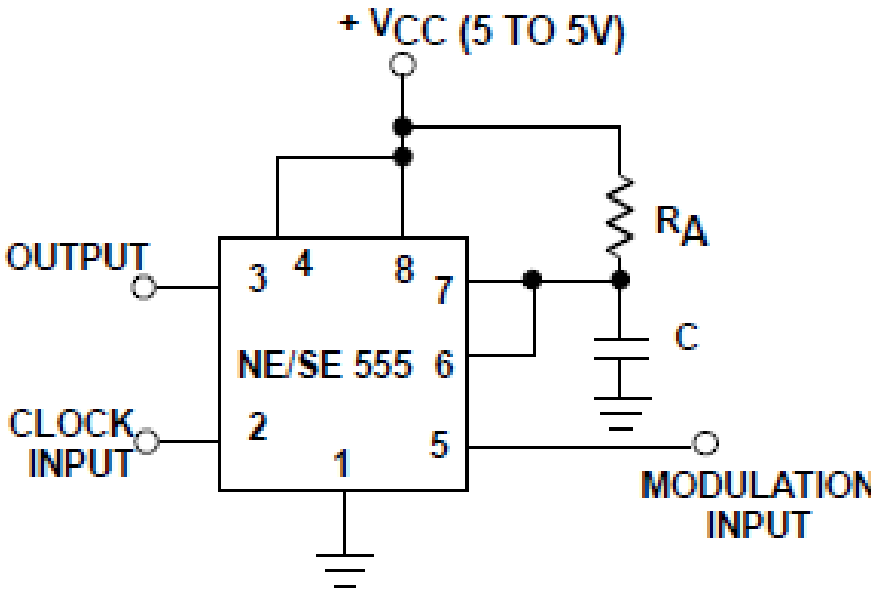


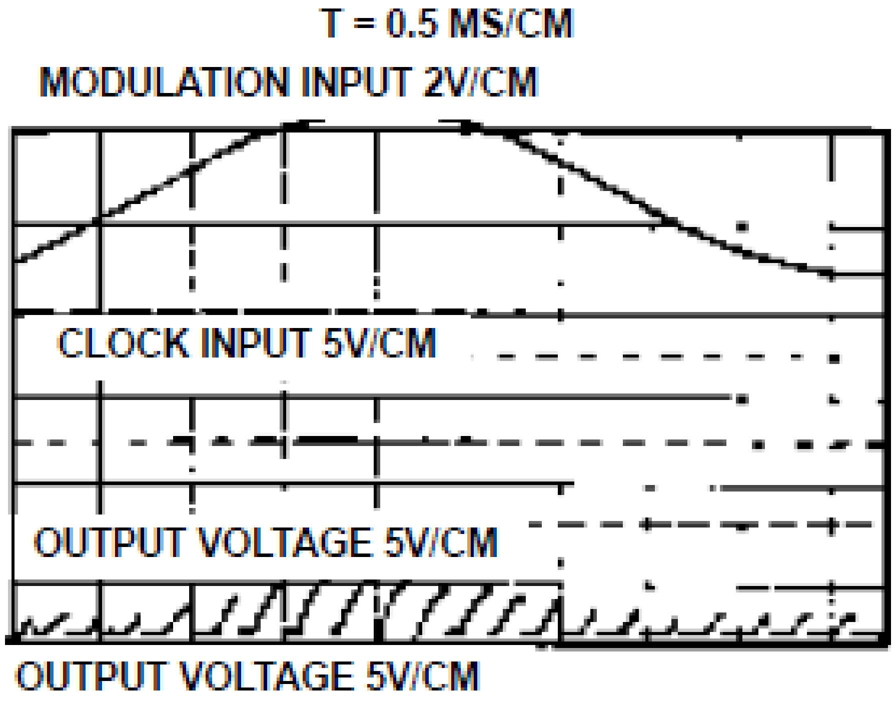
Top Trace: Output 5V/Div
Bottom Trace: Capacitor Voltage 1V/Div.
V_{CC} = 5V; TIME = 20ms/DIV;
R_A = 3.9 kΩ; R_B = 3kΩ; C= 0.01 mF

A monograph to quickly find R and C values



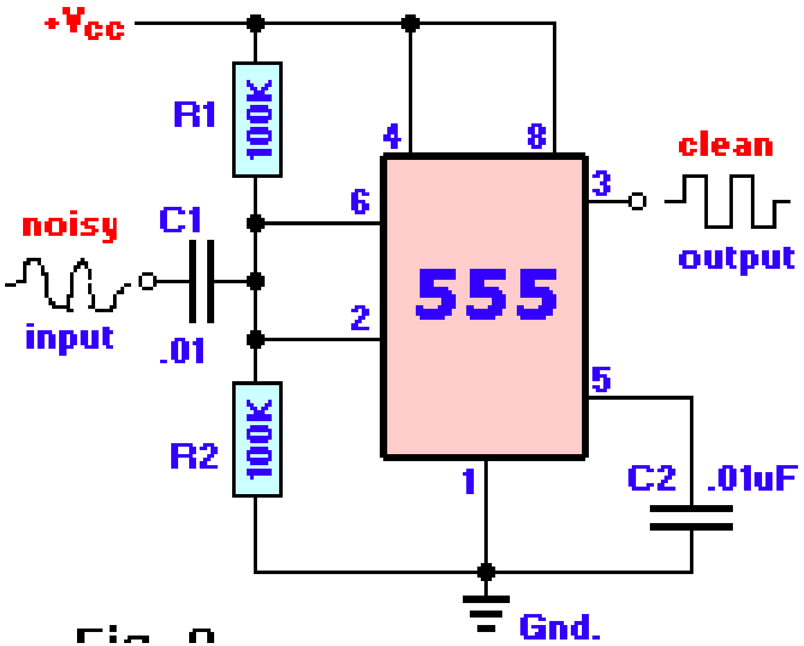
Pulse Width Modulator





- In this application, the timer is connected in the monostable mode as shown.
- The circuit is triggered with a continuous pulse train and the threshold voltage is modulated by the signal applied to the control voltage terminal (Pin 5).
- This has the effect of modulating the pulse width as the control voltage varies. Figure below shows the actual waveform generated with this circuit

Schmitt Trigger



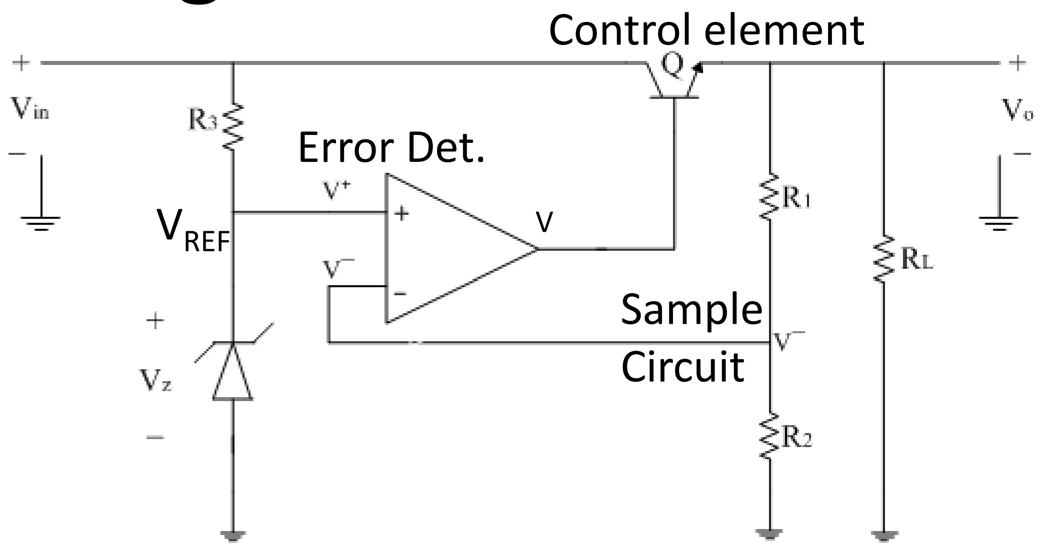
- As long as R1 equals R2, the 555 will automatically be biased for any supply voltage in the 5 to 16 volt range. (Advanced Electronics: It should be noted that there is a 180-degree phase shift.)
- It
  - Is A very simple, but effective circuit
  - cleans up any noisy input signal in a nice, clean and square output signal.
  - In radio control (R/C) it will clean up noisy servo signals caused by rf interference by long servo leads.
  - also lends itself to condition 60-Hz sine-wave reference signal taken from a 6.3 volt AC transformer before driving a series of binary or divide-by-N counters.
- **The major advantage:** unlike a conventional multivibrator type of squarer (which divides the input frequency by 2) this method simply squares the 60-Hz sine wave reference signal without division.

IC 723 Voltage Regulator

Voltage Regulator Basics

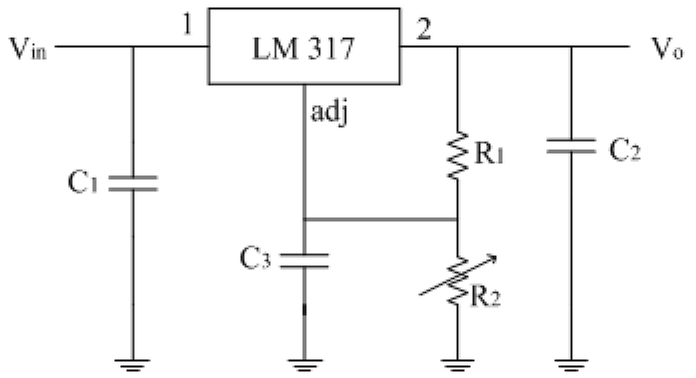
- A voltage regulator is a component of the power supply unit that ensures a steady constant voltage supply through all operational conditions. It regulates voltage during power fluctuations and variations in loads.
- Types: AC Voltage Regulators; DC Voltage Regulators
    - step regulators/ Switching voltage regulators in which switches regulate the current supply
        - Three types of switching regulators: Step up, Step down, and Inverter voltage regulators
    - Induction regulators, in which an induction motor supplies a secondary, continually adjusted voltage to even out current variations in the feeder line
- It could use a simple feed-forward design or may include negative feedback;
- Without (an automatic) voltage regulator, output voltage can:
    - sag, spike or surge and damage electrical devices
- Servo voltage regulators are known for their high accuracy. The regulator is accurate up to ±1% for input voltage variations of up to ±50%. They are also fairly reliable and cost-efficient.
- Employed in chargers of Mobiles; Computers, Laptops, Televisions,

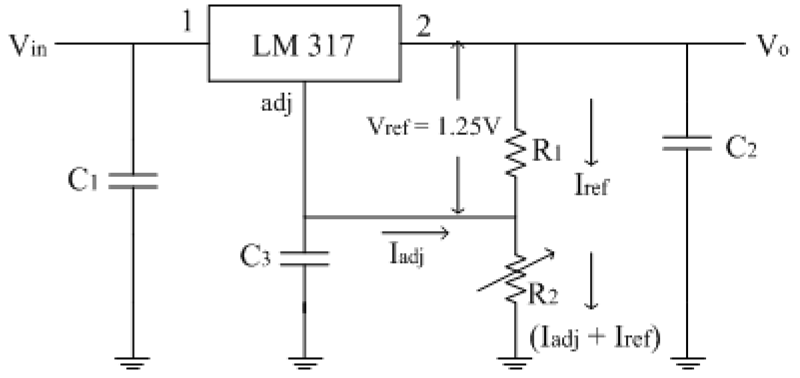
Series OP-Amp regulator



- The transistor Q conduct according to the forward bias voltage at the base.
  - so, V_O remain constant.
- When V_O increases, the voltage sensed by the divider network (V^-) is raises;
  - so, is applied at the inverting i/p of the comparator
- OP-Amp compares the fed-back V^-, with the Zener generated: V_{REF}.
- OP-Amp's output "V" is the control from op-amp; as it controls the conduction of the transistor Q. Thus the output voltage is maintained at a constant level.
- In view of Virtual Short, $V^-=V^+=V_Z=[V_O/(R_1+R_2)]\ R_2$. $\therefore V_O=[1+R_1/R_2]\ V_Z$.

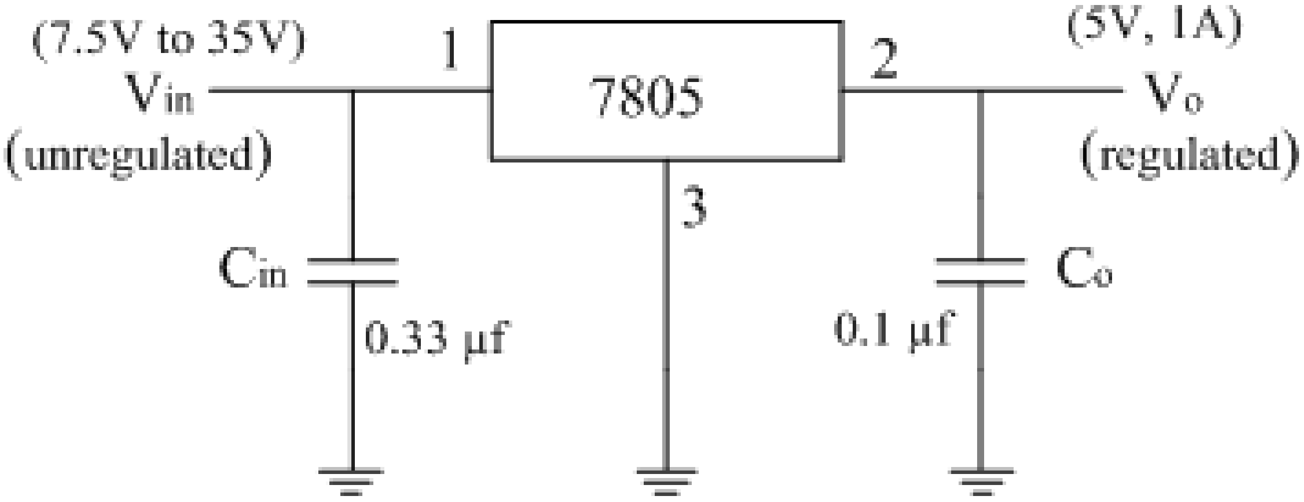
three terminal regulators





- Three terminal adjustable Voltage regulator ICs; LM317
- LM317: Standard Configuration
  - V_O can be varied from 1.2V to 37V (depends on the resistor values)
  - IC can provide I_L up to 1.5A.
  - IC is operated as a floating regulator since the adjustment terminal is not connected to ground; but floats to whatever voltage is across R2 allowing output to be much higher than that of a fixed voltage regulator.
- a constant 1.25V reference voltage (Vref) is maintained by the regulator between the output terminal and the adjustment terminal

3 terminal Fixed Voltage Regulator



- 78XX series: +ve voltage regulators
  - IC 7805, IC 7812, IC 7815
- 79XX series: -ve voltage regulators
  - IC 7905, IC 7912, IC 7915

IC 723

- Features of IC 723:
  - It works as voltage regulator at output voltage ranging from 2 to 37 volts at currents up to 150 mA.
  - It can be used at load currents greater than 150 mA with use of suitable NPN or PNP external pass transistors.
  - Input and output short-circuit protection is provided.
  - It has good line and load regulation (0.03%).
  - Wide variety of applications of series, shunt, switching and floating regulator.
  - Low temperature drift and high ripple rejection.
  - Low standby current drain.
  - Small size, lower cost.
  - Relative ease with which power supply can be designed.
  - It provides a choice of supply voltage.

Functional Block Diagram

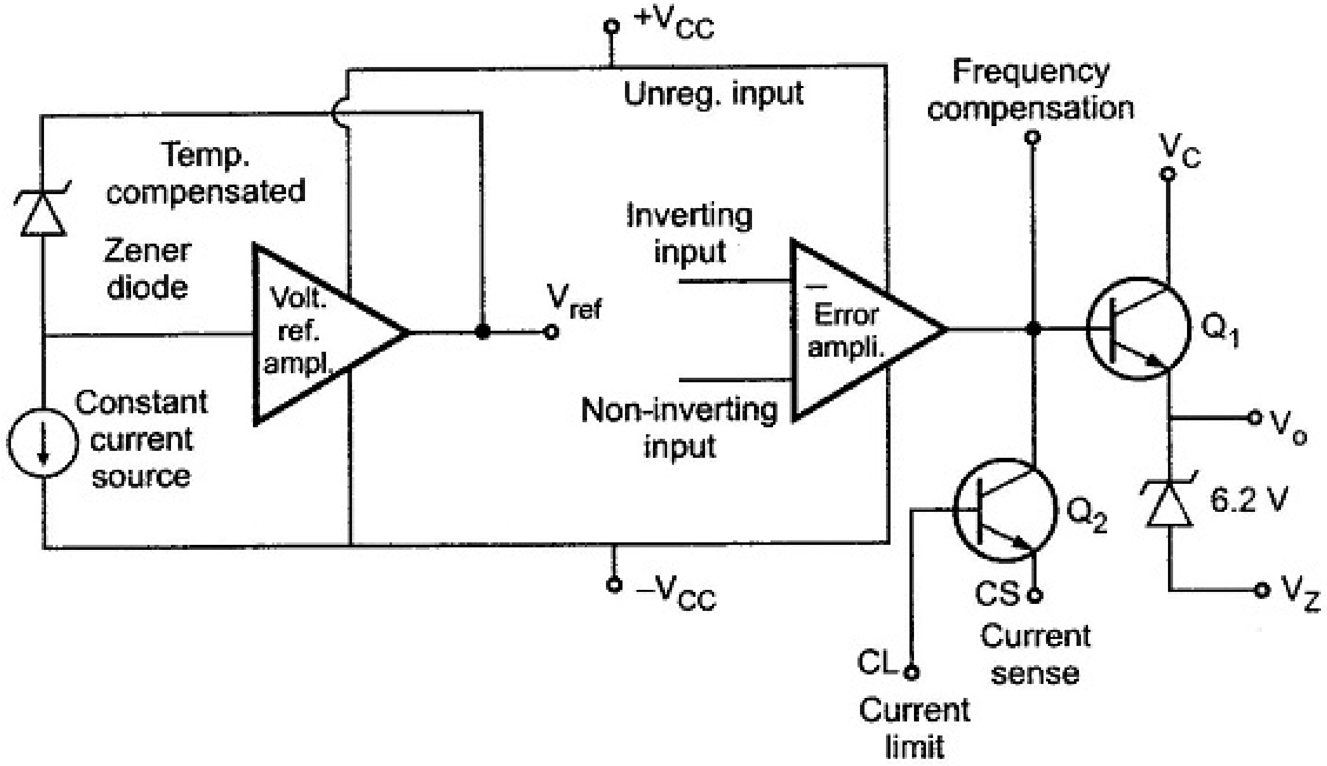


Fig. 2.110 Functional block diagram

- four major blocks:
  - Temperature compensated voltage reference source, which is zener diode.
    - to get a fixed voltage from zener diode, the constant current source forces the zener to operate at a fixed point
  - An op-amp circuit used as an error amplifier.
    - Output voltage is compared with this temperature compensated reference potential of the order of 7 volts. For this Vref is connected to the non-inverting input of the error amplifier
    - This error amplifier is high gain differential amplifier.
    - It’s inverting input is connected to the either whole regulated output voltage or part of that from outside. For later case a potential divider of two scaling resistors is used.
    - Scaling resistors help in getting multiplied reference voltage or scaled up reference voltage
  - A series pass transistor capable of a 150 mA output current.
  - Transistor used to limit output current.

More simplified form

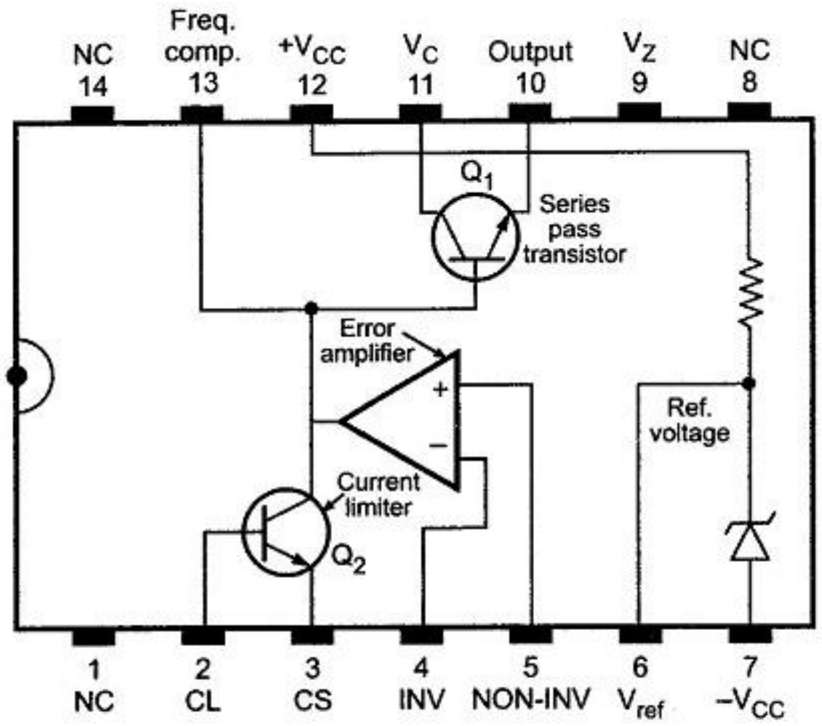


Fig. 2.111 Simplified internal structure of IC 723

- Error amplifier
  - controls the series pass transistor Q1, which acts as variable resistor. The series pass transistor is a small power transistor having about 800 mW dissipation.
  - The unregulated power supply source (< 36V d.c.) is connected to collector of series pass transistor.:
- Transistor Q2
  - acts as current limiter in case of short circuit condition. It senses drop across Rsc placed in series with regulated output voltage externally
- The frequency compensation terminal controls the frequency response of the error amplifier. The required roll-off is obtained by connecting a small capacitor of 100 pF between frequency compensation and inverting input terminals.
- Both noninverting and inverting terminals of the error amplifier are available on outside pins of IC 723.
  - Due to this, device becomes versatile and flexible to use. Only restriction is that internal reference voltage is 7 volts and therefore we have to use two different circuits for getting regulated outputs of below 7 volts and above 7 volts.

IC Regulators and Advantages

- IC Regulators:
  - The discrete component regular circuit such as zener voltage regulator is not much used in practice. Nowadays the circuits are integrated and are available in the form of small IC packages.
- Advantages of IC regulators:

1. It is very easy to use.
2. It greatly simplifies the power supply design.
3. IC regulators are small in size thus overall size of the power supply can be reduced.
4. Cost is very less.
5. IC regulators are versatile.
6. IC regulators are provided with features like built in protection, programmable output, current/voltage boosting, internal short circuit, current limiting etc