JEPPIAAR INSTITUTE OF TECHNOLOGY

“Self-Belief | Self Discipline | Self Respect”

DEPARTMENT
OF
ELECTRICAL AND ELECTRONICS ENGINEERING

LECTURE NOTES
EE8451 – LINEAR INTEGRATED CIRCUITS AND APPLICATIONS
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UNIT V APPLICATION ICs 9

AD623 Instrumentation Amplifier and its application as load cell weight measurement - IC voltage regulators –LM78XX, LM79XX; Fixed voltage regulators its application as Linear power supply - LM317, 723 Variability voltage regulators, switching regulator- SMPS - ICL 8038 function generator IC.

AD623 INSTRUMENTATION AMPLIFIER AND ITS APPLICATION AS LOAD CELL WEIGHT MEASUREMENT:

- **An Instrumentation amplifier is an integrated circuit (IC) used to amplify a signal, which is a type of differential amplifier because it amplifies between two input signal.**
- **In industries, physical quantities are converted into electrical signals using transducers and the signal is amplified for signal processing. For this, an instrumentation amplifier is used instead of an Opamp.**
- **The importance of an instrumentation amplifier is that it can reduce unwanted noise that is picked up by the circuit. The ability to reject noise or unwanted signals common to all IC pins is called the CMRR.**
- **Always the input of an instrumentation amplifier is the output from the transducers and will a small signal. Instrumentation amplifiers don’t need input impedance that makes this amplifier suits for measurement purposes.**

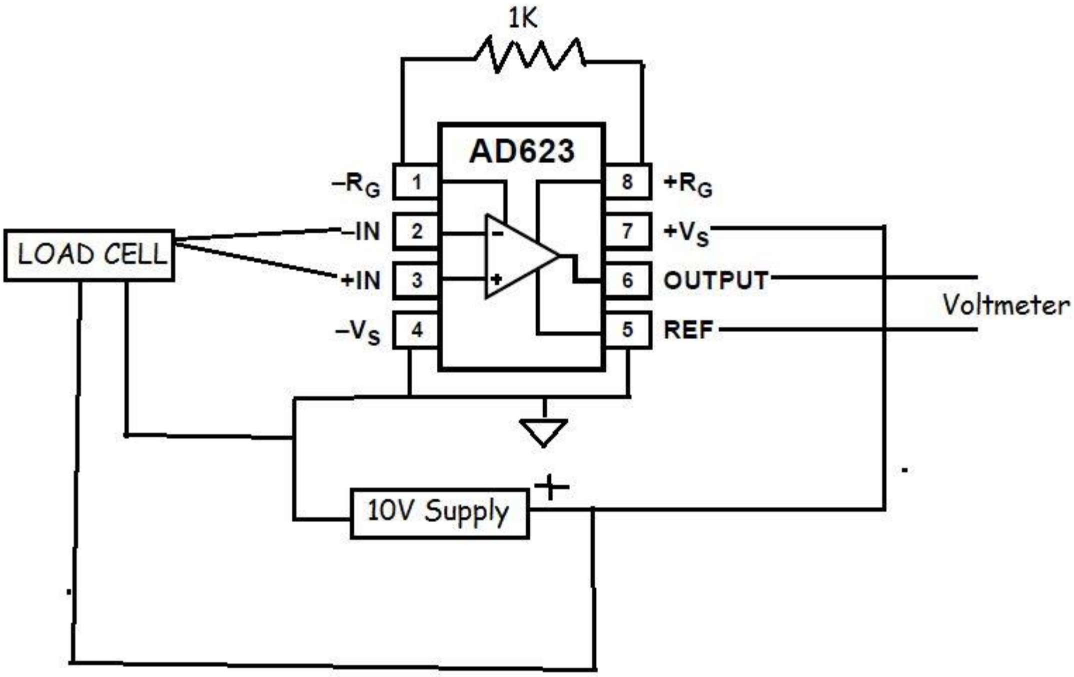
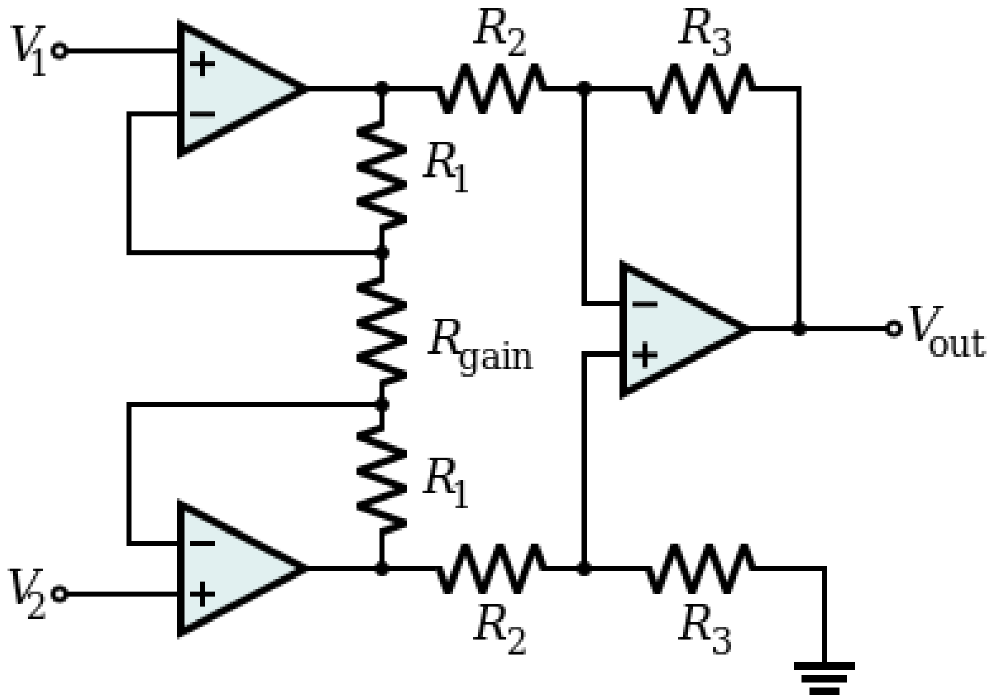


Fig. AD 623 instrumentation amplifier

- **The AD623 is an instrumentation amplifier based on the 3-op amp in-amp circuit, modified to ensure operation on either single- or dual-power supplies, even at common-mode voltages at, or even below, the negative supply rail (or below ground in single-supply operation).**
- **Other features include rail-to-rail output voltage swing, low supply current, microsmall outline packaging, low input and output voltage offset, microvolt/dc offset level drift, high common-mode rejection, and only one external resistor to set the gain.**

  The fig shown is a three-opamp instrumentation amplifier. In this circuit, a non inverting amplifier is connected to both inputs of the differential amplifier.



- **The two amplifiers at the left side are connected together to form a combined Non-inverting amplifier are gain buffers with Rgain is removed.**
- **The amplifier at the right side is a standard differential amplifier.The Rgain resistor increases the differention mode gain of the buffer pair amplifiers, this increase the CMRR of the amplifier. The gain of the circuit is:**

$$\frac{V_{\text{out}}}{V_2 - V_1} = \left(1 + \frac{2R_1}{R_{\text{gain}}}\right)\frac{R_3}{R_2}$$

- **The Rgain resistor increases the differention mode gain of the buffer pair amplifiers, this increase the CMRR of the amplifier.**

Main Features:

- **High CMRR:**
- **The ability of amplifier to ignore the large common signal and amplify the small signal.**

The CMRR should be infinity by idealy.

A good instrumentation amplifier must amplify only the differential input, completely rejecting common mode inputs.

High input impedence: Idealy the input impedence should be infinity.

The sensor connected to the amplifier cannot provide energy to amplifier,

so the amplifier input must have a high input impedence to avoid overloading of sensor.

DC coupled: Industrial low frequency requires a DC coupled amplifier.

This means no capacitor must be used at the input side.

Low output impedence: The output impedance of a good instrumentation amplifier must be

very low (ideally zero), to avoid loading effect on the immediate next stage.

Differential input: The noise generated at the senors is induced into both the inverting and non-inverting

terminals of differential input and it is subtracted from itselt by the op-amp.

Single ended output: The output of the instrumentation amplifier is single ended and designed to match with

displays and following amplifier.

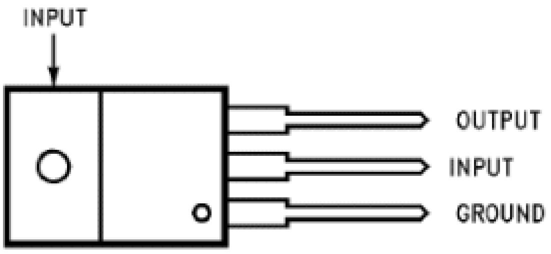
Higher slew rate: The slew rate of the instrumentation amplifier will be as high as possible to provide

maximum undistorted output voltage swing.

APPLICATIONS:

- **Strain gauge bridge interface for pressure and temperature sensing.**
- **A variety of low side and high side current sensing application**
- **Medical instrumentation, used in ECG connection**
- **Current/voltage monitoring**
- **Audio application involving weak audio signal**
- **High speed signal conditioning**

The LM78XX series of three terminal positive regulators are available in the TO-220 package. Each type employs internal current limiting, thermal shut down and safe operating area protection, making it essentially indestructible. If adequate heat sinking is provided, they can deliver over 1A output current. These devices can be used with external components to obtain adjustable voltages and currents. Available output voltages: 5, 6, 8, 9, 10, 12, 15, 18, and 24V. Figure 2 shows the electrical connection for the LM78XX series.



Front View

- Pin locations LM79XX negative voltage regulators

The LM79XX series of 3-terminal regulators is available with fixed output voltages of -5V, -12V, and -15V. These devices need only a compensation capacitor (1uF solid tantalum or 25uF aluminum electrolytic) at the output.

The LM79XX series is packaged in the TO-220 power package and is capable of supplying 1.5A of output current with proper heat sinking. Like the LM78XX series they hey employ internal current limiting safe area protection and thermal shutdown for protection against virtually all overload conditions. Figure 3 shows the electrical connections on the LM79XX series and how they differ from the LM78XX series.

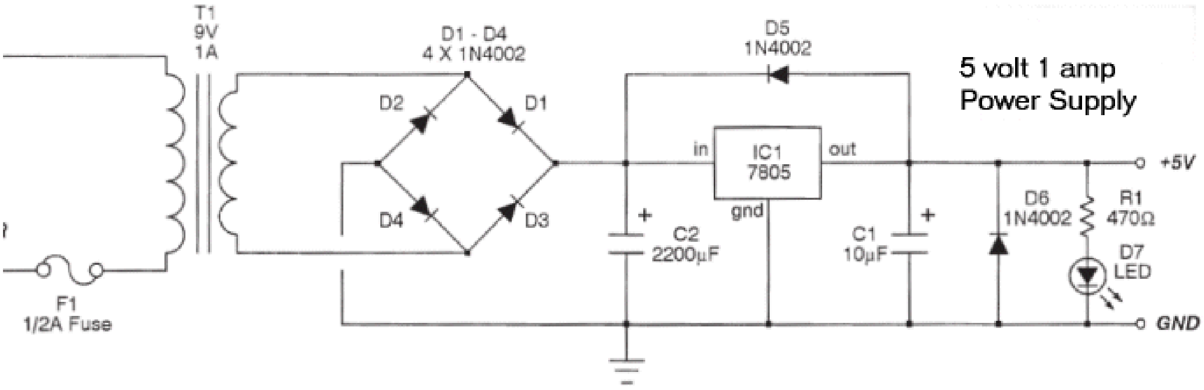


Figure 4

Figure 4 shows a basic 5 volt general purpose power supply. Any of the other positive regulators will work the same way as long as one observes proper input voltage levels and component ratings.

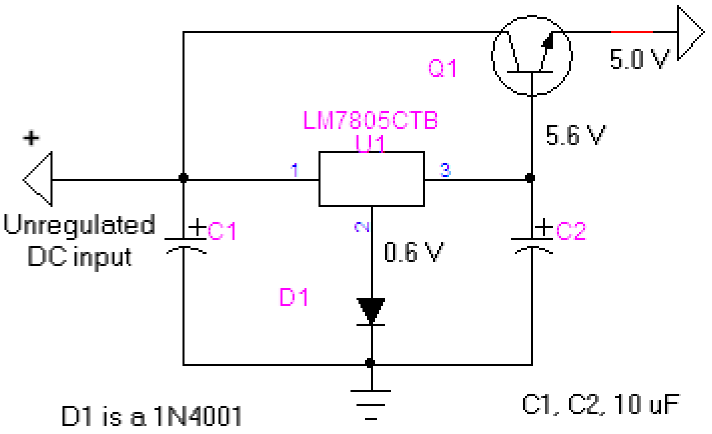


Figure 5

In figure 5 we have added a NPN pass transistor such as a 2N3055 to boost output current to several amps. Diode D1 was added to compensate for the voltage drop across the base-emitter junction of Q1.

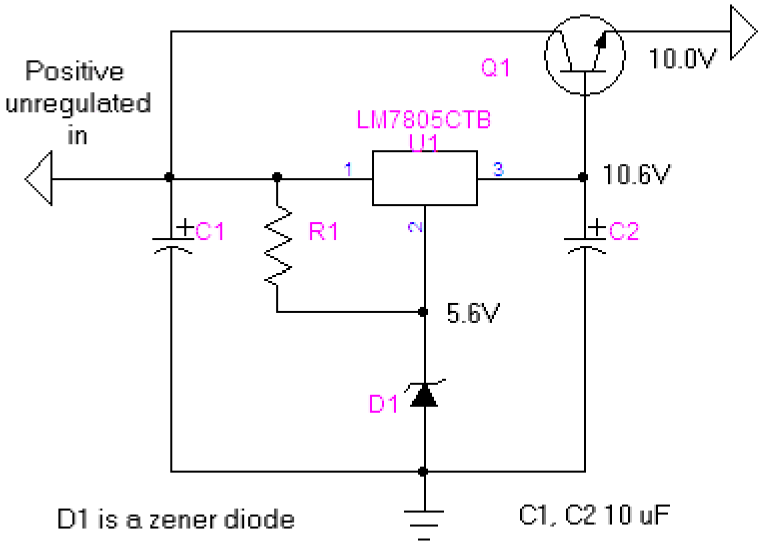
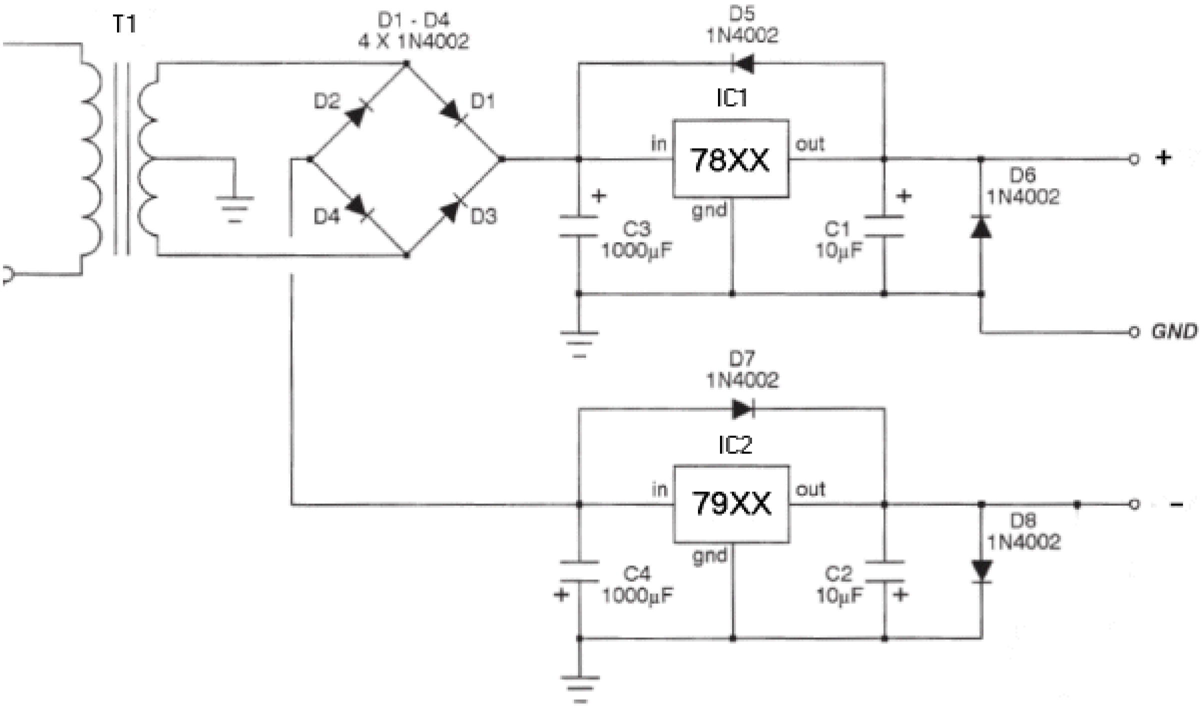
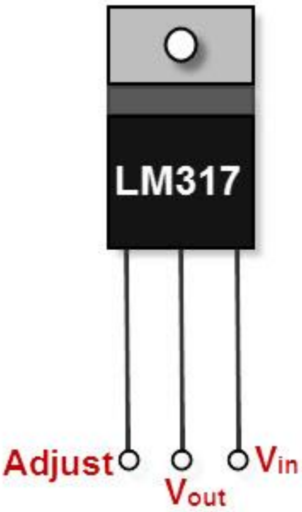


Figure 6

In figure 6 we have added a 5.6 volt zener diode for D1. By using zeners we can produce any number of odd voltage requirements. Q1 works the same as in figure 5 or could be left out and a 5 volt zener used if current requirement is under 1 amp.



M317 Voltage Regulator



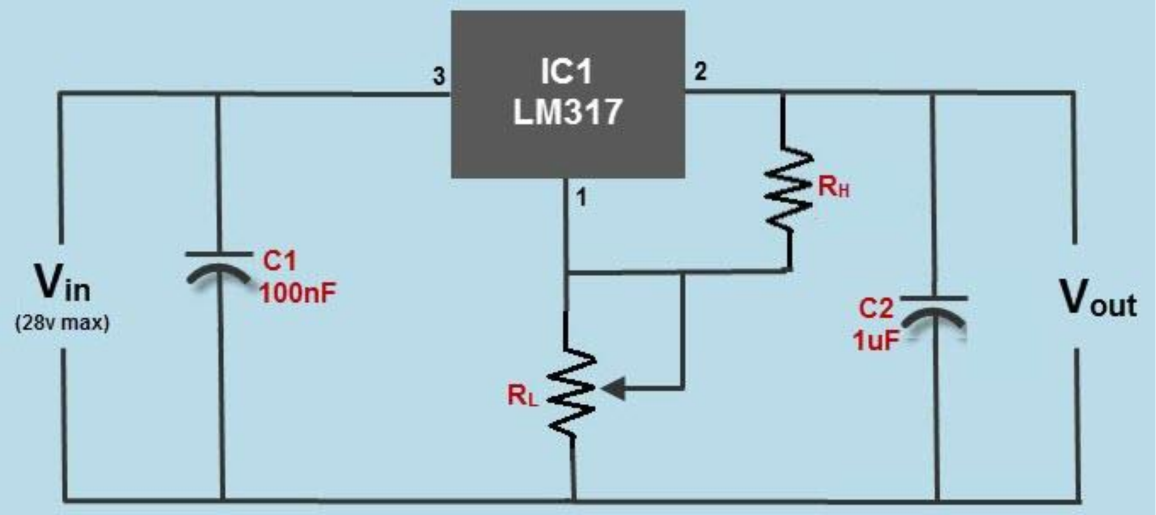
LM317 Voltage Regulator

It is a type of positive-linear-voltage regulators used for voltage regulation, which is invented by Robert C. Dobkin and Robert J. Widlar while they worked at the National Semiconductor in 1970. It is a three-terminal-adjustable-voltage regulator and is easy to use because to set the output voltage it requires only two external resistors in the LM317 voltage regulator circuit. It is majorly used for local and on-card regulation. If we connect a fixed resistor between the output and adjustment of the LM317 regulator, then the LM317 circuit can be used as a precision current regulator.

LM317 Voltage Regulator Circuit

The three terminals are input pin, output pin, and adjustment pin. The LM317 circuit is shown in the below figure is a typical configuration of the LM317 voltage regulator circuit diagram including the decoupling capacitors. This LM317 circuit is capable to provide variable DC power supply with an output of 1A and can be adjusted up to 30V. The circuit consists of a low-side resistor and high-side resistor connected in series forming a resistive voltage divider which is a passive linear circuit used to produce an output voltage which is a fraction of its input voltage.

Decoupling capacitors are used for decoupling or to prevent undesired coupling of one part of an electrical circuit from another part. To avoid the effect of noise caused by some circuit elements over the remaining elements of the circuit, the decoupling capacitors in the circuit are used for addressing the input noise and output transients. A heat sink is used with the circuit to avoid the components getting overheated due to more power dissipation.



LM317 Voltage Regulator Circuit

Features

There are some special features of the LM317 regulator and a few are as follows:

- It is capable of providing an excess current of 1.5A, hence it is conceptually considered as an operational amplifier with an output voltage ranging from 1.2V to 37V.
- The LM317 voltage regulator circuit internally consists of thermal overload protection and short circuit current limiting constant with temperature.
- It is available in two packages as 3-Lead Transistor Package and surface mount D2PAK-3.
- Stocking many fixed voltages can be eliminated.
-

Working of Voltage Regulator LM317 Circuit

The LM317 regulator can provide excess output current and hence with this capacity, it is conceptually considered as an operational amplifier. The adjustment pin is the inverting input of the amplifier and to produce a stable reference voltage of 1.25V, an internal bandgap reference voltage is used to set the non-inverting input.

The output pin voltage can be continuously adjusted to a fixed amount using a resistive voltage divider between the output and ground, which will configure the operational amplifier as a non-inverting amplifier.

A bandgap reference voltage is used to produce constant output voltage irrespective of the changes in supply power. It is also called a temperature-independent reference voltage frequently used in integrated circuits.

The output voltage (ideally) of the LM317 voltage regulator circuit

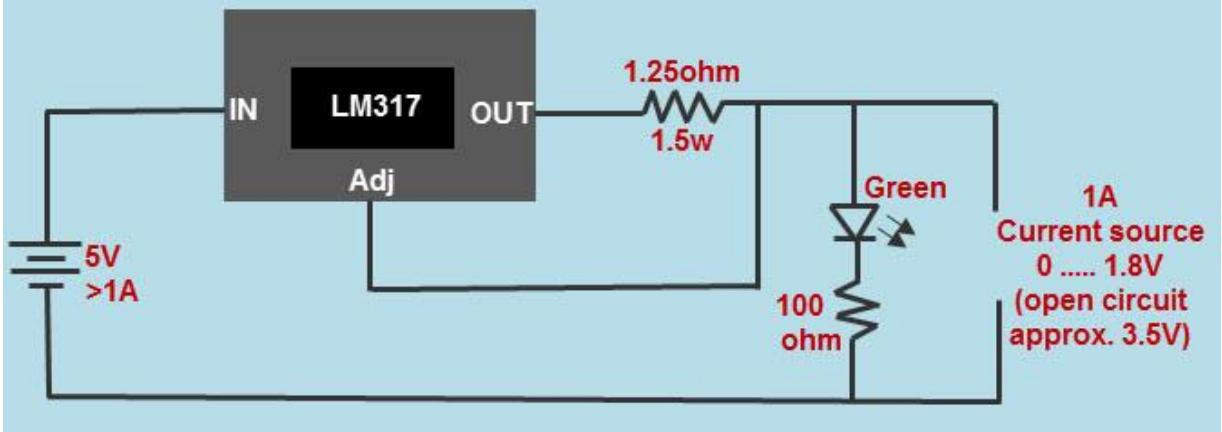
Vout = Vref * (1+ (RL/RH))

An error term is added because some quiescent current flows from the adjustment pin of the device.

Vout = Vref * (1+(RL/RH)) + IQR

For achieving more stable output, the LM317 voltage regulator circuit diagram is designed such that to make the quiescent current less than or equal to 100 micro Ampere. Thus, in all practical cases, the error can be ignored.

If we replace the low-side resistor of the divider from the LM317 voltage regulator circuit diagram with the load, then the resulting configuration of the LM317 regulator will regulate the current to a load. Hence, this LM317 circuit can be treated as LM317 Current Regulator Circuit.



LM317 Current Regulator

The output current is the voltage drop of reference voltage across the resistance RH and is given as

Output current in the ideal case is

Iout = Vref/RH

Considering the quiescent current, the output current is given as

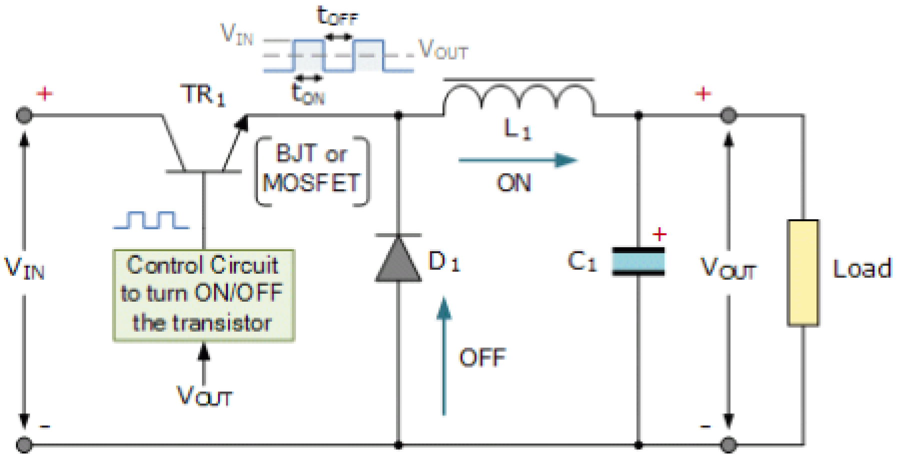
Iout = (Vref/RH) + IQ

These linear voltage regulators LM317 and LM337 are frequently used in DC-DC converter applications. Linear regulators naturally draw much current as they supply. The

power produced due to the multiplication of this current with the voltage difference between the input and output will be dissipated and wasted as heat.
Due to this, heat is required to be considered for significant design and leads to inefficiency. If the voltage difference increases, then the power wasted will increase, and sometimes this dissipated waste power will be more than the supplied power.

Even though this is insignificant, but as the linear voltage regulators with a few additional components is a simple way to obtain stable voltage, so, we must accept this trade-off. The switching voltage regulators are alternative for these linear regulators as these switching regulators are generally more efficient, but they require more number of components to design and thus need more space.

SWITCH MODE POWER SUPPLY:



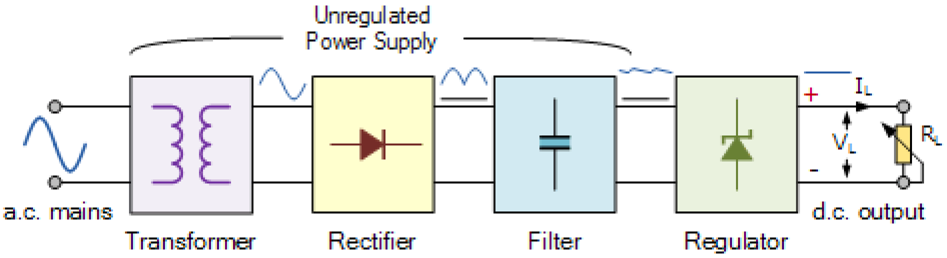
Linear voltage regulators are generally much more efficient and easier to use than equivalent voltage regulator circuits made from discrete components such a zener diode and a resistor, or transistors and even op-amps.

The most popular linear and fixed output voltage regulator types are by far the 78… positive output voltage series, and the 79… negative output voltage series. These two types of complementary voltage regulators produce a precise and stable voltage output ranging from about 5 volts up to about 24 volts for use in many electronic circuits.

There is a wide range of these three-terminal fixed voltage regulators available each with its own built-in voltage regulation and current limiting circuits. This allows us to create a whole host of different power supply rails and outputs, either single or dual supply, suitable for most electronic circuits and applications. There are even variable voltage linear regulators available as well providing an output voltage which is continually variable from just above zero to a few volts below its maximum voltage output.

Most d.c. power supplies comprise of a large and heavy step-down mains transformer, diode rectification, either full-wave or half-wave, a filter circuit to remove any ripple content from the rectified d.c. producing a suitably smooth d.c. voltage, and some form of voltage regulator or stabiliser circuit, either linear or switching to ensure the correct regulation of the power supplies output voltage under varying load conditions. Then a typical d.c. power supply would look something like this:

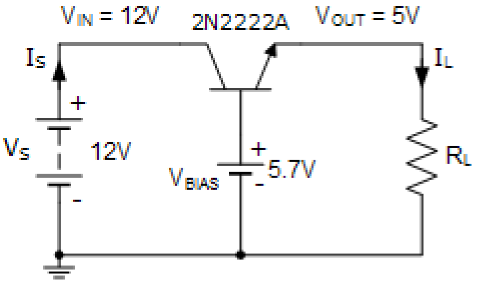
Typical DC Power Supply



These typical power supply designs contain a large mains transformer (which also provides isolation between the input and output) and a dissipative series regulator circuit. The regulator circuit could consist of a single zener diode or a three-terminal linear series regulator to produce the required output voltage. The advantage of a linear regulator is that the power supply circuit only needs an input capacitor, output capacitor and some feedback resistors to set the output voltage.

Linear voltage regulators produce a regulated DC output by placing a continuously conducting transistor in series between the input and the output operating it in its linear region (hence the name) of its current-voltage (i-v) characteristics. Thus the transistor acts more like a variable resistance which continually adjusts itself to whatever value is needed to maintain the correct output voltage. Consider this simple series pass transistor regulator circuit below:

Series Transistor Regulator Circuit



Here this simple emitter-follower regulator circuit consists of a single NPN transistor and a DC biasing voltage to set the required output voltage. As an emitter follower circuit has unity voltage gain, applying a suitable biasing voltage to the transistors base, a stabilised output is obtained from the emitter terminal.

Since a transistor provides current gain, the output load current will be much higher than the base current and higher still if a Darlington transistor arrangement is used.

Also, providing that the input voltage is sufficiently high enough to get the desired output voltage, the output voltage is controlled by the transistors base voltage and in this example is given as 5.7 volts to produce a 5 volt output to the load as approximately 0.7 volts is dropped across the transistor between the base and emitter terminals. Then depending upon the value of the base voltage, any value of emitter output voltage can be obtained.

While this simple series regulator circuit will work, the downside to this is that the series transistor is continually biased in its linear region dissipating power in the form of heat as a result of its V*I product, since all the load current must pass through the series transistor, resulting in poor efficiency, wasted power and continuous heat generation.

Also, one of the disadvantages that series voltage regulators have is that, their maximum continuous output current rating is limited to just a few amperes or so, so are generally used in applications where low power outputs are required. When higher output voltage or current power supplies are required, the normal practice is to use a switching regulator commonly known as a *switch-mode power supply* to convert the mains voltage into whatever higher power output is required.

Switch Mode Power Supplies, or **SMPS**, are becoming common place and have replaced in most cases the traditional linear ac-to-dc power supplies as a way to cut power consumption, reduce heat dissipation, as well as size and weight. Switch-mode power supplies can now be found in most PC's, power amplifiers, TV's, dc motor drives, etc., and just about anything that requires a highly efficient supply as switch-mode power supplies are increasingly becoming a much more mature technology.

By definition, a switch mode power supply (SMPS) is a type of power supply that uses semiconductor switching techniques, rather than standard linear methods to provide the required output voltage. The basic switching converter consists of a power switching stage and a control circuit. The power switching stage performs the power conversion from the circuits input voltage, V_{IN} to its output voltage, V_{OUT} which includes output filtering.

The major advantage of the switch mode power supply is its higher efficiency, compared to standard linear regulators, and this is achieved by internally switching a transistor (or power MOSFET) between its "ON" state (saturated) and its "OFF" state (cut-off), both of which produces lower power dissipation. This means that when the switching transistor is fully "ON" and conducting current, the voltage drop across it is at its minimal value, and when the transistor is fully "OFF" there is no current flow through it. So the transistor is acting like an ideal switch.

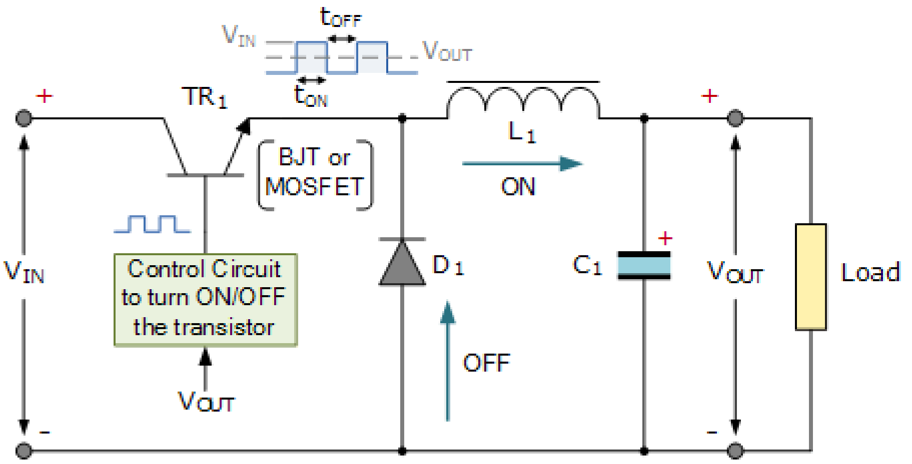
As a result, unlike linear regulators which only offer step-down voltage regulation, a switch mode power supply, can offer step-down, step-up and negation of the input voltage using one or more of the three basic switch mode circuit topologies: *Buck*, *Boost* and *Buck-Boost*. This refers to how the transistor switch, inductor, and smoothing capacitor are connected within the basic circuit.

Buck Switch Mode Power Supply

The **Buck switching regulator** is a type of switch mode power supply circuit that is designed to efficiently reduce DC voltage from a higher voltage to a lower one, that is it subtracts or "Bucks" the supply voltage, thereby reducing the voltage available at the output terminals without changing the polarity. In other words, the buck switching regulator is a step-down regulator circuit, so for example a buck converter can convert say, +12 volts to +5 volts.

The buck switching regulator is a DC-to-DC converter and one of the simplest and most popular type of switching regulator. When used within a switch mode power supply configuration, the buck switching regulator uses a series transistor or power MOSFET (ideally an insulated gate bipolar transistor, or IGBT) as its main switching device as shown below.

The Buck Switching Regulator



We can see that the basic circuit configuration for a buck converter is a series transistor switch, TR_1 with an associated drive circuit that keeps the output voltage as close to the desired level as possible, a diode, D_1, an inductor, L_1 and a smoothing capacitor, C_1. The buck converter has two operating modes, depending on if the switching transistor TR_1 is turned “ON” or “OFF”.

When the transistor is biased “ON” (switch closed), diode D_1 becomes reverse biased and the input voltage, V_{IN} causes a current to flow through the inductor to the connected load at the output, charging up the capacitor, C_1. As a changing current flows through the inductor coil, it produces a back-emf which opposes the flow of current, according to Faraday’s law, until it reaches a steady state creating a magnetic field around the inductor, L_1. This situation continues indefinitely as long as TR_1 is closed.

When transistor TR_1 is turned “OFF” (switch open) by the controlling circuitry, the input voltage is instantly disconnected from the emitter circuit causing the magnetic field around the inductor to collapse inducing a reverse voltage across the inductor. This reverse voltage causes the diode to become forward biased, so the stored energy in the inductors magnetic field forces current to continue to flow through the load in the same direction, and return back through diode.

Then the inductor, L_1 returns its stored energy back to the load acting like a source and supplying current until all the inductor’s energy is returned to the circuit or until the transistor switch closes again, whichever comes first. At the same time the capacitor also discharges supplying current to the load. The combination of the inductor and capacitor forms an LC filter smoothing out any ripple created by the switching action of the transistor.

Therefore, when the transistor solid state switch is closed, current is supplied from the supply, and when the transistor switch is open, current is supplied by the inductor. Note that the current flowing through the inductor is always in the same direction, either directly from the supply or via the diode but obviously at different times within the switching cycle.

As the transistor switch is being continuously closed and opened, the average output voltage value will therefore be related to the duty cycle, D which is defined as the conduction time of the transistor switch during one full switching cycle. If V_{IN} is the supply voltage, and the “ON” and “OFF” times for the transistor switch are defined as: t_{ON} and t_{OFF}, then the output voltage V_{OUT} is given as:

Buck Converter Duty Cycle

$$V_{OUT} = \frac{t_{ON}}{\left(t_{ON} + t_{OFF}\right)} \times V_{IN}$$

The buck converters duty cycle can also be defined as:

$$D = \frac{t_{ON}}{\left(t_{ON} + t_{OFF}\right)} = \frac{t_{ON}}{\text{Total Time}} = \frac{t_{ON}}{T}$$

$$\therefore\ D \approx \frac{V_{OUT}}{V_{IN}} \quad \text{or} \quad V_{OUT} = D\,V_{IN}$$

So the larger the duty cycle, the higher the average DC output voltage from the switch mode power supply. From this we can also see that the output voltage will always be lower than the input voltage since the duty cycle, D can never reach one (unity) resulting in a step-down voltage regulator. Voltage regulation is obtained by varying the duty cycle and with high switching speeds, up to 200kHz, smaller components can be used thereby greatly reducing a switch mode power supply’s size and weight.

Another advantage of the buck converter is that the inductor-capacitor (LC) arrangement provides very good filtering of the inductor current. Ideally the buck converter should be operated in a continuous switching mode so that the inductor current never falls to zero. With ideal components, that is zero voltage drop and switching losses in the “ON” state, the ideal buck converter could have efficiencies as high as 100%.

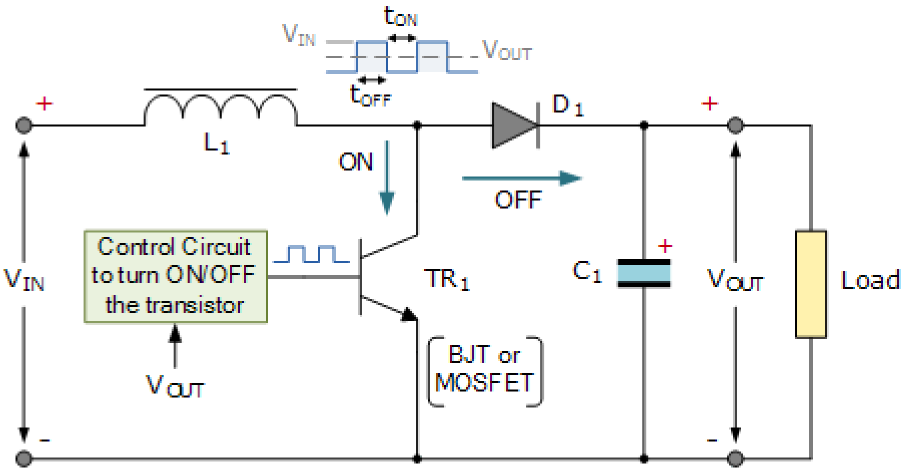
As well as the step-down buck switching regulator for the basic design of a switch mode power supply, there is another operation of the fundamental switching regulator that acts as a step-up voltage regulator called the Boost Converter.

Boost Switch Mode Power Supply

The **Boost switching regulator** is another type of switch mode power supply circuit. It has the same types of components as the previous buck converter, but this time in different positions. The boost converter is designed to increase a DC voltage from a lower voltage to a higher one, that is it adds too or “Boosts” the supply voltage, thereby increasing the available voltage at the output terminals without changing the polarity. In other words, the boost switching regulator is a step-up regulator circuit, so for example a boost converter can convert say, +5 volts to +12 volts.

We saw previously that the buck switching regulator uses a series switching transistor within its basic design. The difference with the design of the *boost switching regulator* is that it uses a parallel connected switching transistor to control the output voltage from the switch mode power supply. As the transistor switch is effectively connected in parallel with the output, electrical energy only passes through the inductor to the load when the transistor is biased “OFF” (switch open) as shown.

The Boost Switching Regulator



In the *Boost Converter* circuit, when the transistor switch is fully-on, electrical energy from the supply, V_{IN} passes through the inductor and transistor switch and back to the supply. As a result, none of it passes to the output as the saturated transistor switch effectively creates a short-circuit to the output. This increases the current flowing through the inductor as it has a shorter inner path to travel back to the supply. Meanwhile, diode D_1 becomes reverse biased as its anode is connected to ground via the transistor switch with the voltage level on the output remaining fairly constant as the capacitor starts to discharge through the load.

When the transistor is switched fully-off, the input supply is now connected to the output via the series connected inductor and diode. As the inductor field decreases the induced energy stored in the inductor is pushed to the output by V_{IN}, through the now forward biased diode. The result of all this is that the induced voltage across the inductor L_1 reverses and adds to the voltage of the input supply increasing the total output voltage as it now becomes, $V_{IN} + V_L$.

Current from the smoothing capacitor, C_1 which was used to supply the load when the transistor switch was closed, is now returned to the capacitor by the input supply via the diode. Then the current supplied to the capacitor is the diode current, which will always be ON or OFF as the diode is continually switched between forward and reverse status by the switching actions of transistor. Then the smoothing capacitor must be sufficiently large enough to produce a smooth steady output.

As the induced voltage across the inductor L_1 is negative, it adds to the source voltage, V_{IN} forcing the inductor current into the load. The boost converters steady state output voltage is given by:

$$V_{OUT} = V_{IN} \frac{1}{(1 - \text{duty cycle})} = V_{IN}\left(\frac{1}{1 - D}\right)$$

As with the previous buck converter, the output voltage from the boost converter depends upon the input voltage and duty cycle. Therefore, by controlling the duty cycle, output regulation is achieved. Not also that this equation is independent of the value of the inductor, the load current, and the output capacitor.

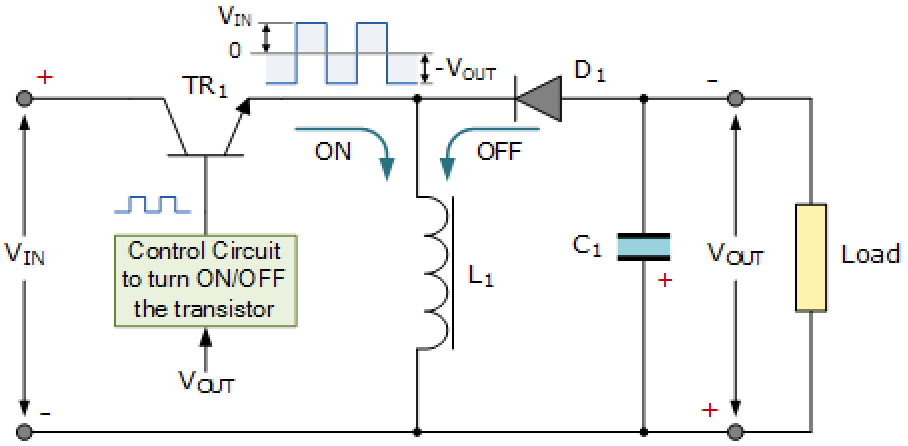
We have seen above that the basic operation of a non-isolated switch mode power supply circuit can use either a buck converter or boost converter configuration depending upon whether we require a step-down (buck) or step-up (boost) output voltage. While buck converters may be the more common SMPS switching configuration, boost converters are commonly used in capacitive circuit applications such as battery chargers, photo-flashes, strobe flashes, etc, because the capacitor supplies all of the load current while the switch is closed.

But we can also combine these two basic switching topologies into a single non-isolating switching regulator circuit called unsurprisingly, a *Buck-Boost Converter*.

Buck-Boost Switching Regulator

The **Buck-Boost switching regulator** is a combination of the buck converter and the boost converter that produces an inverted (negative) output voltage which can be greater or less than the input voltage based on the duty cycle. The buck-boost converter is a variation of the boost converter circuit in which the inverting converter only delivers the energy stored by the inductor, L_1, into the load. The basic buck-boost switch mode power supply circuit is given below.

The Buck-Boost Switching Regulator



When the transistor switch, TR_1, is switched fully-on (closed), the voltage across the inductor is equal to the supply voltage so the inductor stores energy from the input supply. No current is delivered to the connected load at the output because diode, D_1, is reverse biased. When the transistor switch is fully-off (open), the diode becomes forward biased and the energy previously stored in the inductor is transferred to the load.

In other words, when the switch is “ON”, energy is delivered into the inductor by the DC supply (via the switch), and none to the output, and when the switch is “OFF”, the voltage across the inductor reverses as the inductor now becomes a source of energy so the energy stored previously in the inductor is switched to the output (through the diode), and none comes directly from the input DC source. So the voltage dropped across the load when the switching transistor is “OFF” is equal to the inductor voltage.

The result is that the magnitude of the inverted output voltage can be greater or smaller (or equal to) the magnitude of the input voltage based on the duty cycle. For example, a positive-to-negative buck-boost converter can convert 5 volts to 12 volts (step-up) or 12 volts to 5 volts (step-down).

The buck-boost switching regulators steady state output voltage, V_{OUT} is given as:

$$V_{OUT} = V_{IN}\left(\frac{D}{1-D}\right)$$

Then the buck-boost regulator gets its name from producing an output voltage that can be higher (like a boost power stage) or lower (like a buck power stage) in magnitude than the input voltage. However, the output voltage is opposite in polarity from the input voltage.

Switch Mode Power Supply Summary

The modern switch mode power supply, or SMPS, uses solid-state switches to convert an unregulated DC input voltage to a regulated and smooth DC output voltage at different voltage levels. The input supply can be a true DC voltage from a battery or solar panel, or a rectified DC voltage from an AC supply using a diode bridge along with some additional capacitive filtering.

In many power control applications, the power transistor, MOSFET or IGFET, is operated in its switching mode were it is repeatedly turned “ON” and “OFF” at high speed. The main advantage of this is that the power efficiency of the regulator can be quite high because the transistor is either fully-on and conducting (saturated) or full-off (cut-off).

There are several types of DC-to-DC converter (as opposed to a DC-to-AC converter which is an inverter) configurations available, with the three basic switching power supply topologies looked at here being the *Buck*, *Boost*, and the *Buck-Boost* switching regulators. All three of these topologies are non-isolated, that is their input and output voltages share a common ground line.

Each switching regulator design has its own unique properties with regards to the steady-state duty cycles, relationship between the input and output current, and the output voltage ripple produced by the solid-state switch action. Another important property of these switch mode power supply topologies is the frequency response of the switching action to the output voltage.

Regulation of the output voltage is achieved by the percentage control of the time that the switching transistor is in the “ON” state compared to the total ON/OFF time. This ratio is called the duty cycle and by varying the duty cycle, (D the magnitude of the output voltage, V_{OUT} can be controlled.

The use of a single inductor and diode as well as fast switching solid-state switches capable of operating at switching frequencies in the kilohertz range, within the switch mode power supply design, allows for the size and weight of the power supply to be greatly reduced. This is because there would be no large and heavy step-down (or step-up) voltage mains transformers within their design. However, if isolation is required between the input and output terminals, a transformer must be included before the converter.

The two most popular non-isolated switching configurations are the buck (subtractive) and the boost (additive) converters.

The buck converter is a type of switch-mode power supply that is designed to convert electrical energy from one voltage to a lower one. The buck converter operates with a series connected switching transistor. As the duty cycle, $D < 1$, the output voltage of the buck is always smaller than the input voltage, V_{IN}.

The boost converter is a type of switch-mode power supply that is designed to convert electrical energy from one voltage to a higher one. The boost converter operates with a parallel connected switching transistor which results in a direct current path between V_{IN} and V_{OUT} via the inductor, L_1 and diode, D_1. This means there is no protection against short-circuits on the output.

By varying the duty cycle, (D) of a boost converter, the output voltage can be controlled and with $D < 1$, the DC output from the boost converter is greater than input voltage V_{IN} as a consequence of the inductors self-induced voltage.

Also, the output smoothing capacitors in **Switch-mode Power Supplies** is assumed to be very large, which results in a constant output voltage from the switch mode supply during the transistors switching action.

Function Generator IC 8038:

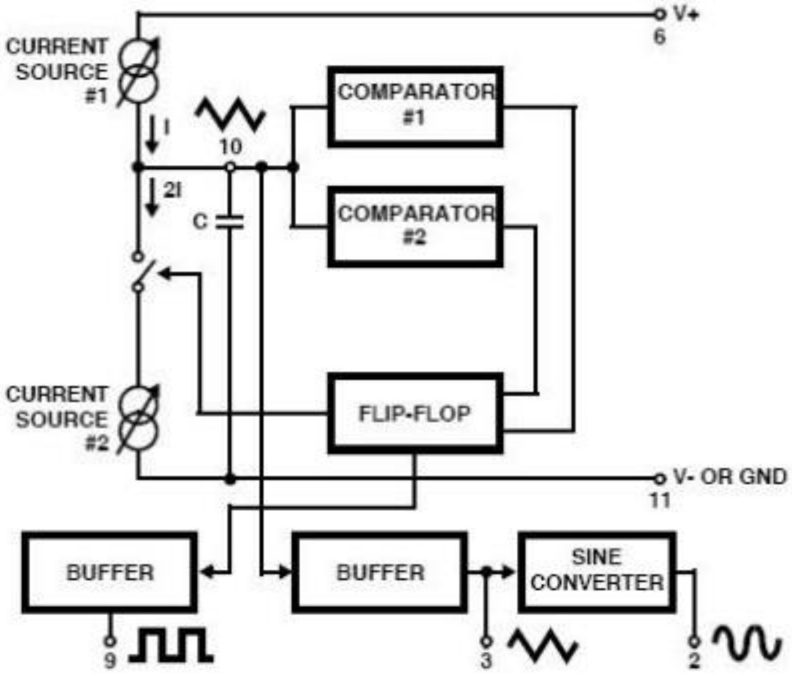


Fig.5.14 Functional block diagram of Function generator

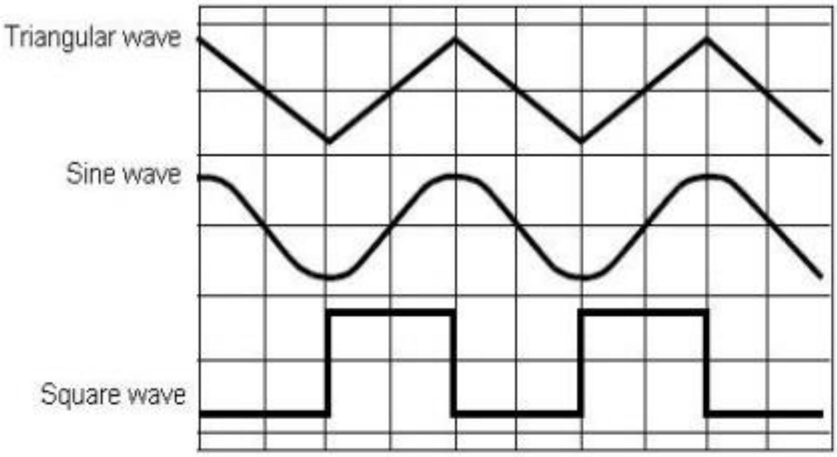


Fig. 5.15 Output Waveforms from Function Generator IC 8038

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 100KΩ 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 ± 5V ≤ Vcc ≤ ± 15 V.

- Pin 3 Triangular Wave output:

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

Where ± 5V ≤ Vcc ≤ ± 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 : -VEE or Ground:

If a single polarity supply is to be used then this pin is connected to supply ground & if (±) 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 drifts 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 RA= RB = R & if RC is adjusted for 50% duty cycle then f0= 0.3/RC; RA = R1, RB =

R3, RC= R2.

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

Duty cycle as well as the frequency of the output wave form can be adjusted by external resistors at pin 4 & 5.

The values of resistors RA & RB connected between Vcc pin 4 & 5 respectively along

with the capacitor connected at pin 10 decide the frequency of the wave form. The values of RA & RB should be in the range of 1kΩ to 1MΩ.

(iii)FM Bias:

- The FM Bias input (pin7) corresponds to the junction of resistors R1 & R2.

- The voltage Vin is the voltage between Vcc & pin8 and it decides the output frequency.

- The output frequency is proportional to Vin as given by the following expression.

For RA = RB (50% duty cycle).

f0= 5 Vin/CRAVcc ; where C is the timing capacitor.

· With pin 7 & 8 connected to each other the output frequency is given by f0= 0.3/RC where R = RA = RB for 50% duty cycle.

· This is because M Sweep input (pin 8):

- Vin=R1Vcc/R1+R2

- 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,

f_0=1.5 V_{in}/CR_AV_{CC}

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