ISSN: 2349-5197
Impact Factor: 3.765

INTERNATIONAL JOURNAL OF RESEARCH SCIENCE & MANAGEMENT

HIGH VOLTAGE DC UP TO 2 KV FROM AC BY USING CAPACITORS AND DIODES IN LADDER NETWORK

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DOI: 10.5281/zenodo.1291902

Abstract
The aim of this project is designed to develop a high voltage DC around 2KV from a supply source of 230V AC using the capacitors and diodes in a ladder network based on voltage multiplier concept. The method for stepping up the voltage is commonly done by a step-up transformer. The output of the secondary of the step up transformer increases the voltage and decreases the current. The other method for stepping up the voltage is a voltage multiplier but from AC to DC. Voltage multipliers are primarily used to develop high voltages where low current is required. This project describes the concept to develop high voltage DC (even till 10KV output and beyond) from a single phase AC. For safety reasons our project restricts the multiplication factor to 8 such that the output would be within 2KV. This concept of generation is used in electronic appliances like the CRT's, TV Picture tubes, oscilloscope and also used in industrial applications. The design of the circuit involves voltage multiplier, whose principle is to go on doubling the voltage for each stage. Thus, the output from an 8 stage voltage multiplier can generate up to 2KV. As this is not possible to be measured by a standard multimeter, a potential divider of 10:1 is used at the output such that 200V reading means 2KV. Due to low input impedance of the multimeter, the reading would actually be approximately 7 times the input AC voltage. Further the project can be enhanced to generate the high voltage DC up to the range of 30-50 KV by increasing the number of stages. It can then be used for required industrial and medical applications.

Introduction
The first commercially used HVDC link in the world was built in 1954 between the mainland of Sweden and island of Gotland. Since the technique of power transmission by HVDC has been continuously developed. In India, the first HVDC line in Rihand-Delhi in 1991 i.e. 1500 KV, 800 Mkl, 1000 KM. In Maharashtra in between Chandrapur & Padaghe at 1500 KV & 1000 MV. Global HVDC transmission capacity has increase from 20 MW in 1954 to 17.9 GW in 1984. Now the growth of DC transmission capacity has reached an average of 2500 MW/year.The project is designed to develop a high voltage DC around 2KV from a supply source of 230V AC using the capacitors and diodes in a ladder network based on voltage multiplier concept. The method for stepping up the voltage is commonly done by a step-up transformer. The output of the secondary of the step up transformer increases the voltage and decreases the current. The other method for stepping up the voltage is a voltage multiplier but from AC to DC. Voltage multipliers are primarily used to develop high voltages where only low current is required. This project describes the concept to develop high voltage DC (even till 10KV output and beyond) from a single phase AC. For safety reasons our project restricts the multiplication factor to 8 such that the output would be within 2KV. This concept of generation is used in electronic appliances like the CRTs, TV Picture tubes, oscilloscope and also used in industrial applications. The design of the circuit involves voltage multiplier, whose principle is to go on doubling the voltage for each stage. Thus, the output from an 8 stage voltage multiplier can generate up to 2KV. As this is not possible to be measured by a standard multi meter, a potential divider of 10:1 is used at the output such that 200V reading means 2KV. Due to low input impedance of the multi meter, the reading would actually be approximately 6 to 7 times the input AC voltage.Further the project can be enhanced to generate the high voltage DC up to the range of 30-50 KV by increasing the number of stages. It can then be used for required industrial and medical applications.

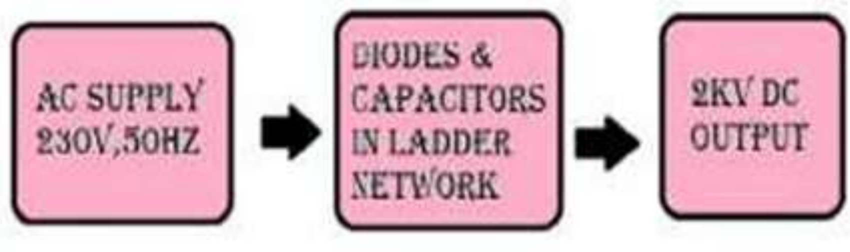


Fig . Block Diagram of Voltage Multiplier

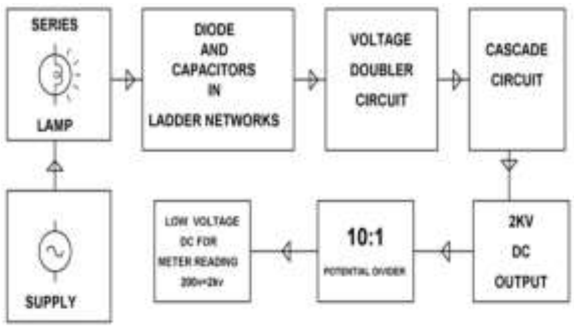
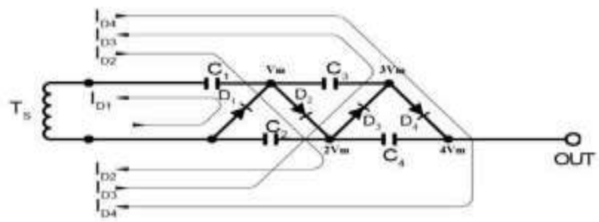


Fig:Working of Multiplier circuit:



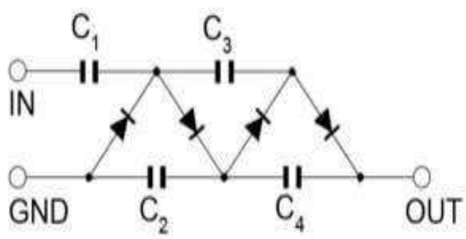
- When TS is Negative Peak - C1 charges through D1 to Vm
- When TS is Positive Peak - Vm of TS adds arithmetically to existing potential C1, thus C2 charges to 2Vm through D2.
- When TS is Negative Peak - C3 is charged to 2Vm through D3.
- When TS is Positive Peak - C4 is charged to 2Vm through D4.

Types of Multiplier Circuits

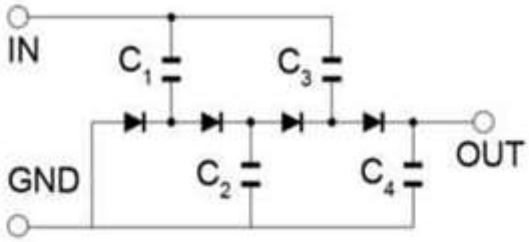
Half wave series.

- Half wave parallel.
- Full wave parallel.
- Full wave series parallel.

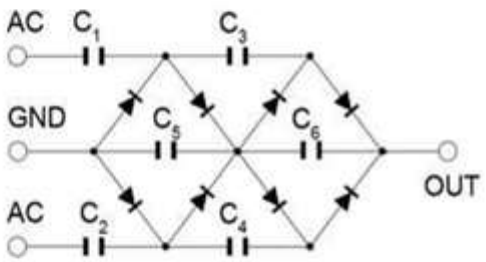
I.Half Wave Series



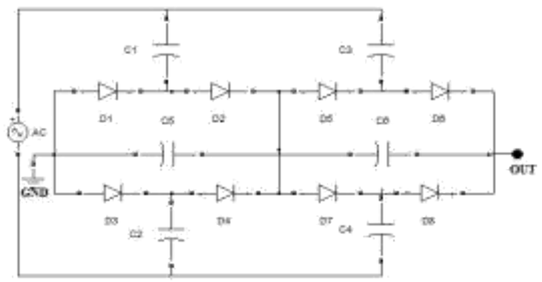
II. Half Wave Parallel:



III.Full Wave Parallel:



IV. Full Wave Series Parallel



Components of an HVDC transmission system:

To assist the designers of transmission systems, the components that comprise the HVDC system, and the options available in these components, are presented and discussed. The three main elements of an HVDC system are: the converter station at the transmission and receiving ends, the transmission medium, and the electrodes

Converter station:

The converter stations at each end are replica's of each other and therefore consists of all the needed equipment for going from AC to DC or vice versa. The main components of a converter station are:

Thyristor valves:

The thyristor valves can be build-up in different ways depending on the application and manufacturer. However, the most common way of arranging the thyristor valves is in a twelve-pulse group with three quadruple valves. Each single thyristor valve consists of a certain amount of series connected thyristors with their auxiliary circuits. All communication between the control equipment at earth potential and each thyristor at high potential is done with fiber optics.

VSC valves:

The VSC converter consists of two level or multilevel converter, phase-reactors and AC filters. Each single valve in the converter bridge is built up with a certain number of series connected IGBTs together with their auxiliary electronics. VSC valves, control equipment and cooling equipment would be in enclosures (such as standard shipping containers) which make transport and installation very easy. All modern HVDC valves are water-cooled and air insulated. Converter AC Filters Shunt capacitors or other reactive equipment Control system AC Bus DC Filter Smoothing reactor Converter Station Transmission line or cable (excluded if Back-to-Back)

Transformers:

The converter transformers adapt the AC voltage level to the DC voltage level and they contribute to the commutation reactance. Usually they are of the single phase three winding type, but depending on the transportation requirements and the rated power, they can be arranged in other ways

AC Filters and Capacitor Banks:

On the AC side of a 12-pulse HVDC converter, current harmonics of the order of 11, 13, 23, 25 and higher are generated. Filters are installed in order to limit the amount of harmonics to the level required by the network.. In the conversion process the converter consumes reactive power which is compensated in part by the filter banks and the rest by capacitor banks. In the case of the CCC the reactive power is compensated by the series capacitors installed in series between the converter valves and the converter transformer. The elimination of switched reactive power compensation equipment simplify the AC switchyard and minimize the number of circuit-breakers needed, which will reduce the area required for an HVDC station built with CCC. With VSC converters there is no need to compensate any reactive power consumed by the converter itself and the current harmonics on the AC side are related directly to the PWM frequency. Therefore the amount of filters in this type of converters is reduced dramatically compared with natural commutated converters.

DC filters:

HVDC converters create harmonics in all operational modes. Such harmonics can create disturbances in telecommunication systems. Therefore, specially designed DC filters are used in order to reduce the disturbances. Usually no filters are needed for pure cable transmissions as well as for the Back-to-Back HVDC stations. However, it is necessary to install DC filters if an OH line is used in part or all the transmission system The filters needed to take care of the harmonics generated on the DC end, are usually considerably smaller and less expensive than the filters on the AC side. The modern DC filters are the Active DC filters. In these filters the passive part is reduced to a minimum and modern power electronics is used to measure, invert and re-inject the harmonics, thus rendering the filtering very effective.

Conversion Process:

Operating (at a given time) with power flow from AC to DC is referred to as the rectifier at the heart of an HVDC converter station, the equipment which performs the conversion between AC and DC is referred to as the converter. Almost all HVDC converters are inherently capable of converting from AC to DC (rectification) and from DC to AC (inversion), although in many HVDC systems, the system as a whole is optimized for power flow in only one direction. Irrespective of how the converter itself is designed, the station that is and the station that is operating with power flow from DC to AC is referred to as the inverter.

Early HVDC systems used electro mechanical conversion (the Theory system) but all HVDC systems built since the 1940s have used electronic (static) converters. Electronic converters for HVDC are divided into two main categories:

- Line-commutated converters (LCC)
- Voltage-sourced converters, or current-source converters.

Line-Commutated Converters
Most of the HVDC systems in operation today are based on line-commutated converters.
The basic LCC configuration uses a three-phase bridge rectifier or six-pulse bridge, containing six electronic switches, each connecting one of the three phases to one of the two DC rails. A complete switching element is usually referred to as a valve, irrespective of its construction. However, with a phase change only every 60°, considerable harmonic distortion is produced at both the DC and AC terminals when this arrangement is used. A twelve-pulse bridge rectifier

An enhancement of this arrangement uses 12 valves in a twelve-pulse bridge. The AC is split into two separate three phase supplies before transformation. One of the sets of supplies is then configured to have a star (wye) secondary, the other a delta secondary, establishing a 30° phase difference between the two sets of three phases. With twelve valves connecting each of the two sets of three phases to the two DC rails, there is a phase change every 30°, and harmonics are considerably reduced. For this reason the twelve-pulse system has become standard on most line-commutated converter HVDC systems built since the 1970s.

With line commutated converters, the converter has only one degree of freedom – the firing angle, which represents the time delay between the voltage across a valve becoming positive (at which point the valve would start to conduct if it were made from diodes) and the thyristors being turned on. The DC output voltage of the converter steadily becomes less positive as the firing angle is increased: firing angles of up to 90° correspond to rectification and result in positive DC voltages, while firing angles above 90° correspond to inversion and result in negative DC voltages. The practical upper limit for the firing angle is about 150–160° because above this, the valve would have insufficient turnoff time.

Early LCC systems used mercury-arc valves, which were rugged but required high maintenance. Because of this, many mercury-arc HVDC systems were built with bypass switchgear across each six-pulse bridge so that the HVDC scheme could be operated in six-pulse mode for short periods of maintenance. The last mercury arc system was shut down in 2012.

The thyristor valve was first used in HVDC systems in 1972. The thyristor is a solid-state semiconductor device similar to the diode, but with an extra control terminal that is used to switch the device on at a particular instant during the AC cycle. Because the voltages in HVDC systems, up to 800 kV in some cases, far exceed the breakdown voltages of the thyristors used, HVDC thyristor valves are built using large numbers of thyristors in series. Additional passive components such as grading capacitors and resistors need to be connected in parallel with each thyristor in order to ensure that the voltage across the valve is evenly shared between the thyristors. The thyristor plus its grading circuits and other auxiliary equipment is known as a thyristor level.

Thyristor valve stacks for Pole 2 of the HVDC Inter-Island between the North and South Islands of New Zealand. The man at the bottom gives scale to the size of the valves.

Each thyristor valve will typically contain tens or hundreds of thyristor levels, each operating at a different (high) potential with respect to earth. The command information to turn on the thyristors therefore cannot simply be sent using a wire connection – it needs to be isolated. The isolation method can be magnetic but is usually optical. Two optical methods are used: indirect and direct optical triggering. In the indirect optical triggering method, low-voltage control electronics send light pulses along optical fibers to the high-side control electronics, which derives its power from the voltage across each thyristor. The alternative direct optical triggering method dispenses with most of the high-side electronics, instead using light pulses from the control electronics to switch light-triggered thyristors (LTTs), although a small monitoring electronics unit may still be required for protection of the valve.

In a line-commutated converter, the DC current (usually) cannot change direction; it flows through a large inductance and can be considered almost constant. On the AC side, the converter behaves approximately as a current source, injecting both grid-frequency and harmonic currents into the AC network. For this reason, a line commutated converter for HVDC is also considered as a current-source inverter.

Voltage-Sourced Converters
Because thyristors can only be turned on (not off) by control action, the control system has only one degree of freedom – when to turn on the thyristor. This is an important limitation in some circumstances.

With some other types of semiconductor device such as the insulated-gate bipolar transistor (IGBT), both turn-on and turn-off can be controlled, giving a second degree of freedom. As a result, they can be used to make self-commutated converters. In such converters, the polarity of DC voltage is usually fixed and the DC voltage, being smoothed by a large capacitance, can be considered constant. For this reason, an HVDC converter using IGBTs is usually referred to as a voltage sourced converter. The additional controllability gives many advantages, notably the ability to switch the IGBTs on and off many times per cycle in order to improve the harmonic performance. Being self-commutated, the converter no longer relies on synchronous machines in the AC system for its operation. A voltage sourced converter can therefore feed power to an AC network consisting only of passive loads, something which is impossible with LCC HVDC.

HVDC systems based on voltage sourced converters normally use the six-pulse connection because the converter produces much less harmonic distortion than a comparable LCC and the twelve-pulse connection is unnecessary.

Most of the VSC HVDC systems built until 2012 were based on the two level converter, which can be thought of as a six pulse bridge in which the thyristors have been replaced by IGBTs with inverse-parallel diodes, and the DC smoothing reactors have been replaced by DC smoothing capacitors. Such converters derive their name from the discrete, two voltage levels at the AC output of each phase that correspond to the electrical potentials of the positive and negative DC terminals. Pulse-width modulation (PWM) is usually used to improve the harmonic distortion of the converter.

Some HVDC systems have been built with three level converters, but today most new VSC HVDC systems are being built with some form of multilevel converter, most commonly the Modular Multilevel Converter (MMC), in which each valve consists of a number of independent converter sub modules, each containing its own storage capacitor. The IGBTs in each sub module either bypass the capacitor or connect it into the circuit, allowing the valve to synthesize a stepped voltage with very low levels of harmonic distortion.

Hardware Components
DIODES:
Diodes are used to convert AC into DC these are used as half wave rectifier or full wave rectifier. Three points must he kept in mind while using any type of diode.

- Maximum forward current capacity
- Maximum reverse voltage capacity
- Maximum forward voltage capacity

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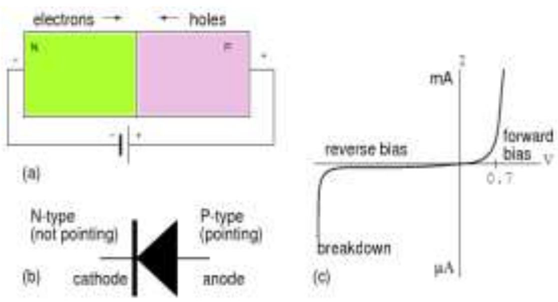
Fig:1N4007 diodes

The number and voltage capacity of some of the important diodes available in the market are as follows:
•Diodes of number IN4001, IN4002, IN4003, IN4004, IN4005, IN4006 and IN4007 have maximum reverse bias voltage capacity of 50V and maximum forward current capacity of 1 Amp.

•Diode of same capacities can be used in place of one another. Besides this diode of more capacity can be used in place of diode of low capacity but diode of low capacity cannot be used in place of diode of high capacity. For example, in place of IN4002; IN4001 or IN4007 can be used but IN4001 or IN4002 cannot be used in place of IN4007.The diode BY125made by company BEL is equivalent of diode from IN4001 to IN4003. BY 126 is equivalent to diodes IN4004 to 4006 and BY 127 is equivalent to diode IN4007.



Resistors:

A resistor is a two-terminal electronic component designed to oppose an electric current by producing a voltage drop between its terminals in proportion to the current, that is, in accordance with Ohm's law:

$$V = IR$$

Resistors are used as part of electrical networks and electronic circuits. They are extremely commonplace in most electronic equipment. Practical resistors can be made of various compounds and films, as well as resistance wire (wire made of a high-resistivity alloy, such as nickel/chrome).

Fig:Resistors

The primary characteristics of resistors are their resistance and the power they can dissipate. Other characteristics include temperature coefficient, noise, and inductance. Less well-known is critical resistance, the value below which power dissipation limits the maximum permitted current flow, and above which the limit is applied voltage. Critical resistance depends upon the materials constituting the resistor as well as its physical dimensions; it's determined by design.
Resistors can be integrated into hybrid and printed circuits, as well as integrated circuits. Size, and position of leads (or terminals) are relevant to equipment designers; resistors must be physically large enough not to overheat when dissipating their power.

A resistor is a two-terminal passive electronic component which implements electrical resistance as a circuit element. When a voltage V is applied across the terminals of a resistor, a current I will flow through the resistor in direct proportion to that voltage. The reciprocal of the constant of proportionality is known as the resistance R, since, with a given voltage V, a larger value of R further "resists" the flow of current I as given by Ohm's law:

$$I = \frac{V}{R}$$

Capacitors:

Fig.Capacitors

A capacitor or condenser is a passive electronic component consisting of a pair of conductors separated by a dielectric. When a voltage potential difference exists between the conductors, an electric field is present in the dielectric. This field stores energy and produces a mechanical force between the plates. The effect is greatest between wide, flat, parallel, narrowly separated conductors.

Multimeter:

A Millimeter or a multitester, also known as a VOM (volt-ohm-milliammeter),is an electronic measuring instrument that combines several measurement functions in one unit. A typical multimeter can measure voltage, current, and resistance. Analog millimeters use a micro ammeter with a moving pointer to display readings. Digital multimeters (DMM, DVOM) have a numeric display, and may also show a graphical bar representing the measured value. Digital millimeters are now far more common due to their cost and precision, but analog multimeters are still preferable in some cases, for example when monitoring a rapidly varying value.

A multimeter can be a hand-held device useful for basic fault finding and field service work, or a bench instrument which can measure to a very high degree of accuracy. They can be used to troubleshoot electrical problems in a wide array of industrial and household devices such as electronic equipment, motor controls, domestic appliances, power supplies, and wiring systems.

Multimeters are available in a wide range of features and prices. Cheap multimeters can cost less than US$10, while laboratory-grade models with certified calibration can cost more than US$5,000.

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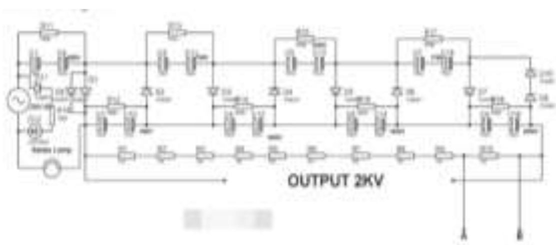
Fig:A 4 1/2 digit digital multimeter, the Fluke 87V

Lamps:
LAMP is an archetypal model of web service stacks, named as an acronym of the names of its original four open-source components: the Linux operating system, the Apache HTTP Server, the My SQL relational database management system(RDBMS), and the PHP programming language. The LAMP components are largely interchangeable and not limited to the original selection. As a solution stack, LAMP is suitable for building dynamic web sites and web applications.[1]Since its creation, the LAMP model has been adapted to other componentry, though typically consisting of free and open-source software. For example, an equivalent installation on the Microsoft Windows family of operating systems is known as WAMP and an equivalent installation on macOS is known as MAMP.

.

Fig lamp

Circuit diagram:



Circuit Explanation:
This project uses voltage multiplier circuit in multistage mode using a number of silicon diodes (D1-D8) and a set of electrolytic capacitors of 2 no's of 100uF/400V connected in series for each stage. Thus 16 capacitor of 100uF/400V are used for 8 stage voltage multiplication.
Thus if the input is 230Vrms the output will be approximately [sqrt 2 x 230 x 8 = app. 2.5KV]. In order to measure this voltage a potential divider arrangement comprising of 10 resistors in series is made such that the voltage across 1 resistor is 2.5/10=250V, Which can be easily read by any meter to indicate that the full voltage is approximately 2.5KV. The reading on a standard low cost multimeter however will indicate half the voltage because of its low input impedance. Thus a reading of 125V dc is equivalent to 2.5KV. One 500K resistor is

ISSN: 2349-5197
Impact Factor: 3.765

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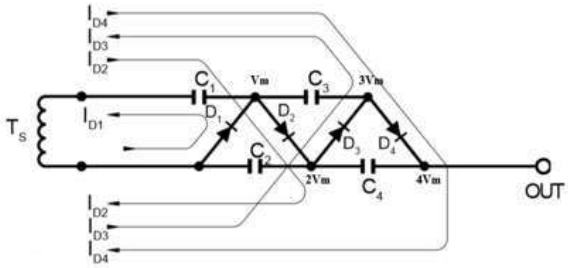
connected across each pair of capacitors to discharge them automatically after use, to prevent from high voltage electric shock.

Working of Multiplier Circuit:



- When TS is Negative Peak - C_1 charges through D_1 to V_m
- When TS is Positive Peak - V_m of TS adds arithmetically to existing potential C_1, thus C_2 charges to $2V_m$ through D_2.
- When TS is Negative Peak - C_3 is charged to $3V_m$ through D_3.
- When TS is Positive Peak - C_4 is charged to $4V_m$ through D_4.

Therefore, output voltage = $V_m * N$, Where N = the number of stages.

Types of Multiplier Circuits

- Half wave voltage doubler
- Full wave voltage doubler.

Half Wave Voltage Doubler:

As its name suggests, a half-wave voltage doubler is a voltage multiplier circuit whose output voltage amplitude is twice that of the input voltage amplitude. A half-wave voltage doubler drives the voltage to the output during either positive or negative half cycle. The half-wave voltage doubler circuit consists of two diodes, two capacitors, and AC input voltage source.

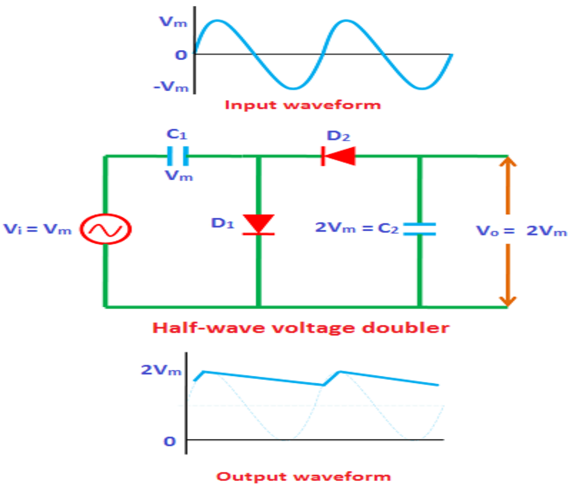


Fig.Half wave voltage doubler

During positive half cycle:

The circuit diagram of the half-wave voltage doubler is shown in the below figure. During the positive half cycle, diode D_1 is forward biased. So it allows electric current through it. This current will flows to the capacitor C_1 and charges it to the peak value of input voltage I.e. V_m.

However, current does not flow to the capacitor C_2 because the diode D_2 is reverse biased. So the diode D_2 blocks the electric current flowing towards the capacitor C_2. Therefore, during the positive half cycle, capacitor C_1 is charged whereas capacitor C_2 is uncharged.

During negative half cycle:
During the negative half cycle, diode D_1 is reverse biased. So the diode D_1 will not allow electric current through it. Therefore, during the negative half cycle, the capacitor C_1 will not be charged. However, the charge (V_m) stored in the capacitor C_1 is discharged (released).

On the other hand, the diode D_2 is forward biased during the negative half cycle. So the diode D_2 allows electric current through it. This current will flows to the capacitor C_2 and charges it. The capacitor C_2 charges to a value $2V_m$ because the input voltage V_m and capacitor C_1 voltage Vm is added to the capacitor C_2. Hence, during the negative half cycle, the capacitor C_2 is charged by both input supply voltage V_m and capacitor C_1 voltage V_m. Therefore, the capacitor C_2 is charged to $2V_m$.

If a load is connected to the circuit at the output side, the charge ($2V_m$) stored in the capacitor C_2 is discharged and flows to the output.

During the next positive half cycle, diode D_1 is forward biased and diode D_2 is reverse biased. So the capacitor C_1 charges to V_m whereas capacitor C_2 will not be charged. However, the charge ($2V_m$) stored in the capacitor C_2 will be discharged and flows to the output load. Thus, the half-wave voltage doubler drives a voltage of $2V_m$ to the output load.

The capacitor C_2 gets charged again in the next half cycle. The voltage ($2V_m$) obtained at the output side is twice that of the input voltage (V_m).

The capacitors C_1 and C_2 in half wave-voltage doubler charges in alternate half cycles.

The output waveform of the half-wave voltage doubler is almost similar to the half wave rectifier with filter. The only difference is the output voltage amplitude of the half-wave voltage doubler is twice that of the input voltage amplitude but in half wave rectifier with filter, the output voltage amplitude is same as the input voltage amplitude.

The half-wave voltage doubler supplies the voltage to the output load in one cycle (either positive or negative half cycle). In our case, the half-wave voltage doubler supplies the voltage to the output load during positive half cycles. Therefore, the output signal regulation of the half-wave voltage doubler is poor.

Full Wave Voltage Doubler:
The full-wave voltage doubler consists of two diodes, two capacitors, and input AC voltage source.
During positive half cycle:

During the positive half cycle of the input AC signal, diode D_1 is forward biased. So the diode D1 allows electric current through it. This current will flows to the capacitor C_1 and charges it to the peak value of input voltage i.e V_m.

On the other hand, diode D_2 is reverse biased during the positive half cycle. So the diode D_2 does not allow electric current through it. Therefore, the capacitor C_2 is uncharged.
During negative half cycle:
During the negative half cycle of the input AC signal, the diode D_2 is forward biased. So the diode D_2 allows electric current through it. This current will flows to the capacitor C_2 and charges it to the peak value of the input voltage I.e. V_m.

On the other hand, diode D_1 is reverse biased during the negative half cycle. So the diode D_1 does not allow electric current through it.

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Thus, the capacitor C_1 and capacitor C_2 are charged during alternate half cycles. The output voltage is taken across the two series connected capacitors C_1 and C_2.

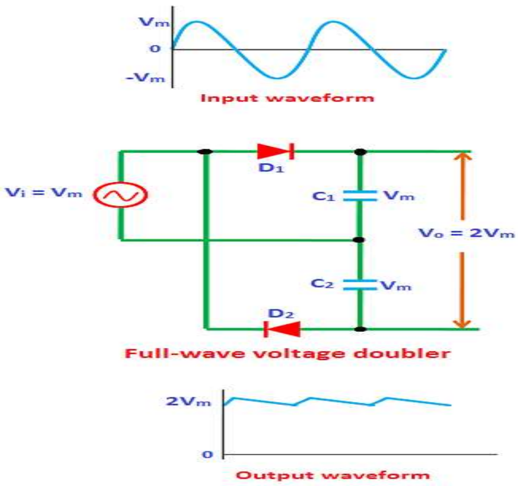

Fig.Full wave voltage doubler

If no load is connected, the output voltage is equal to the sum of capacitor C_1 voltage and capacitor C_2 voltage i.e. $C_1 + C_2 = V_m + V_m = 2V_m$. When a load is connected to the output terminals, the output voltage V_o will be somewhat less than $2V_m$.

The circuit is called full-wave voltage doubler because one of the output capacitors is being charged during each half cycle of the input voltage.

Experimental Result:

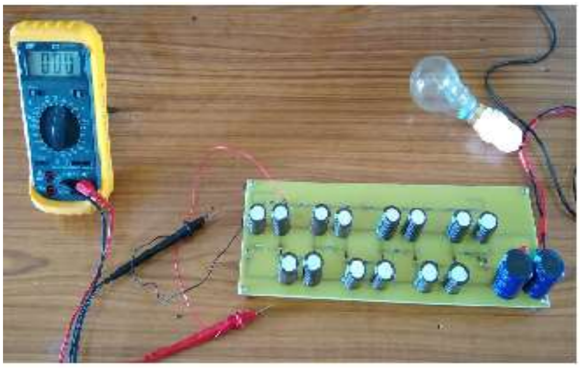

Fig:Without supply

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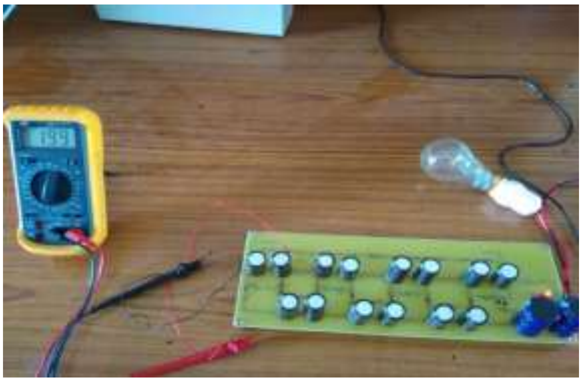

Fig:With supply

References

[1] Kwa-Sur Tam, And Eric Bloodworth , "Automated Topological Generation and Analysis of Voltage Multiplier Circuits", ieee transactions on circuits and systems, vol. 31, no. 3, march 1990.
[2] Kuffel, E. and M. Abdullah, 1984. High Voltage Engineering, Pergamon Press, Oxford.
[3] Saifali Dalakoti,"Design simulation and development of auxiliary power supply for standalone AMPS testing and IPPS development for LHCD system",Technical Training Program ,Institute for Plasma Research,Bhat, Gandhinagar ,2010
[4] Naidu, M.S. and V. Kamaraju, " High Voltage Engineering", Third Edition, McGraw- Hill Company Ltd, 2004.
[5] Koki Ogura, Enhui Chu, Manabu Ishitobi, Mantaro Nakamura and Mutsuo Nakaoka, Inductor Snubber-Assisted Series Resonant ZCS-PFM High Frequency Inverter Link DC-DC Converter with Voltage Multiplier , IEEE 2002