NEAR EAST UNIVERSITY

Faculty of Engineering

Department of Electrical and Electronic Engineering

HIGH VOLTAGE DC GENERATOR

Graduation Project
EE-400

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ABSTRACT

The importance of High Voltage DC generator has many aspects.High voltage DC generators are related with tesla coil.

Tesla coils were designed to be used instead of transmission lines.Tesla coil is built from inductor and capacitor which are main elements.An electric current is converted to magnetic field by inductor or magnetic field into current which is symbolized with B that is Gauss.The capacitor converts current into an electric field that is symbolized with V which is measured in volts.Both magnetic fields and electric fields are forms of stored energy that is symbolized with Joule.Meanwhile Tesla coil is composed of primary and secondary sides.The primary windings are less than secondary side.Tesla logic is resonance.If windings are not synchronıus neccessary is not voltage produced.There is used power transformator is step up transformator.

The High voltage DC generator and generator both can produce increase the voltage.but one of them is AC.one of them is DC.Tesla coil almost arisable 3.000.000 volts.But this Project only produce up to 10.000 volts.

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INTRODUCTION

Consumer electronic equipment like TVs, computer monitors, microwave ovens, and electronic flash units, use voltages at power levels that are potentially lethal. Even more so for industrial equipment like lasers and anything else that is either connected to the power line, or uses or generates high voltage.

Normally, these devices are safely enclosed to prevent accidental contact. However, when troubleshooting, testing, making adjustments, and during repair procedures, the cabinet will likely be open and/or safety interlocks may be defeated. Home-built or modified equipment, despite all warnings and recommendations to the contrary could exist in this state for extended periods of time or indefinitely.

Depending on overall conditions and your general state of health, there is a wide variation of voltage, current, and total energy levels that can kill.

Microwave ovens in particular are probably The most dangerous household appliance to service. There is high voltage up to 5,000 V or more at high current more than an amp may be available momentarily. This is an instantly lethal combination.

TVs and monitors may have up to 35 kV on the CRT but the current is low a couple of milliamps. However, the CRT capacitance can hold a painful charge for a long time. In addition, portions of the circuitry of TVs and monitors as well as all other devices that plug into the wall socket are line connected. This is actually more dangerous than the high voltage due to the greater current available and a few hundred volts can make you just as dead as 35 kV

Electronic flash units and strobe lights, and pulsed lasers have large energy storage capacitors which alone can deliver a lethal charge long after the power has been removed. This applies to some extent even to those little disposable pocket cameras with flash which look so innocent being powered from a single 1.5 V AA battery. Don't be fooled they are designed without any bleeder so the flash can be ready for use without draining the battery.

Even some portions of apparently harmless devices like VCRs and CD players or vacuum cleaners and toasters can be hazardous (though the live parts may be insulated or protected but don't count on it)

This information also applies when working on other high voltage or line connected devices like Tesla Coils, Jacobs Ladders, plasma spheres, gigawatt lasers, hot and cold fusion generators, cyclotrons and other particle accelerators, as well as other popular hobby type projects.

In addition, read the relevant sections of the document for your particular equipment for additional electrical safety considerations as well as non electrical hazards like microwave radiation or laser light.

1. INTRODUCTION TO TESLA COIL

1.1 Who is Nikola Tesla

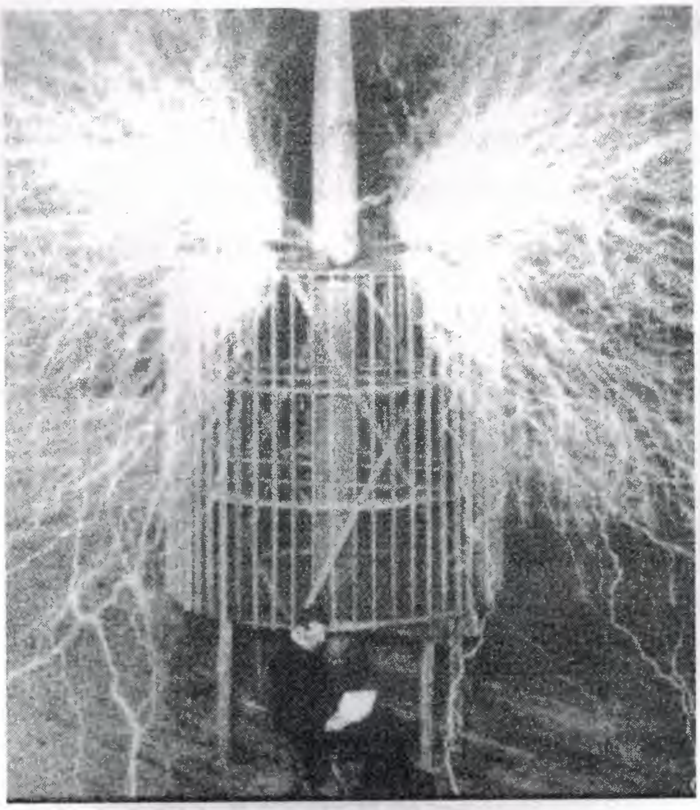

Figure 1.1 Nikola Tesla (1856-1943) and one of his coils, circa 1899 (double exposure).

Tesla was born to Serbian parents who lived in Croatia on July 10, 1856. He attended the polytechnic school in Graz, Austria for two years (he was forced to drop out from lack of funds) beginning in 1875, but was basically self taught. He worked in Germany, France and England before emigrating to America in June of 1884. He became an American citizen on July 30, 1891. Despite his many great inventions, he died a poor man on January 7, 1943.

His greatest inventions were the AC motor, conceived in 1882, and the polyphase system to generate and distribute AC power (which is used the world over today). Some of Tesla's other inventions include the steam turbine, VTOL aircraft and radio (Tesla first demonstrated radio in 1893, two years before Marconi's first demonstration, Tesla's patents were upheld by the U.S. Supreme court, over Marconi's, in 1963).

1.2 The Tesla Coil

The Oudin Oscillator is a high frequency current generator which uses the principles of electrical resonance to produce an antinode of high potential at the top of a large coil of wire. It is basically a high frequency Tesla transformer with the bottom end of the primary and secondary coils connected together and firmly grounded. The diagram below shows an Oudin coil that we have built for use at schools and public science shows.

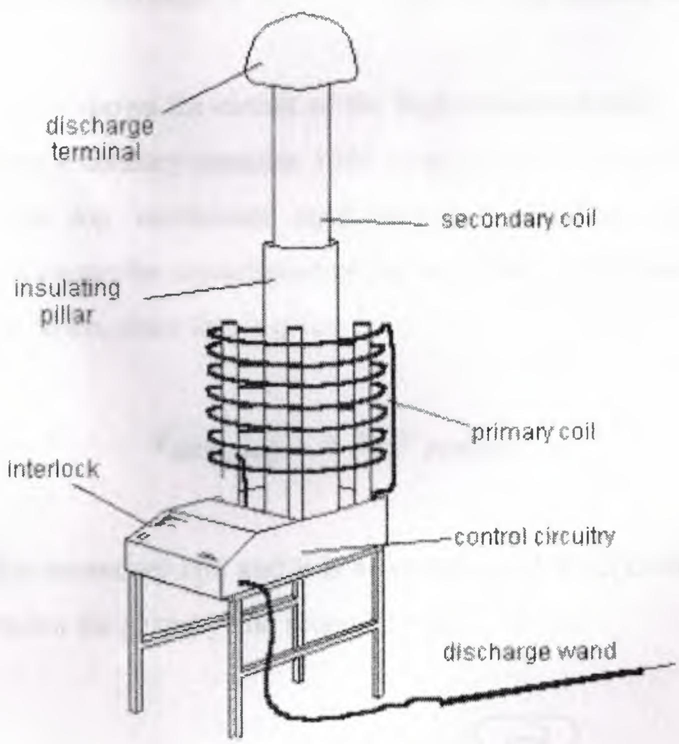

Figure 1.2 Illustration of a half-million Oudin Coil, designed and build at Glasgow University

The primary coil contains seven turns of wire arranged into a large inductor which has about 0.01mH inductance. It is connected to a capacitor back via a spark gap. The capacitor bank has capacitance 0.03uF and is rated to a peak voltage of 20kV. The capacitor is charged directly from a 12kV transformer capable of delivering up to 50mA of current. When the potential across the capacitor reaches around 10kV the spark gap breaks down and the capacitor discharges violently through the inductor followed by a rapid ring down of the LC circuit formed between the capacitor and primary coil through the ionised spark gap.

The frequency of the current produced is 184kHz defined by the self-resonant frequency of the secondary coil (which matches the resonant frequency of the primary oscillations for maximum effective Q of the coupled system). The corona streamers are at peak potentials of around a million volts. As well as high frequency discharge (which is best demonstrated in the absence of any room light) there is a disruptive transient discharge caused by the 100Hz spark exciter at the base of the coil. This discharge is extremely powerful and should not be drawn off except by using a wand that is well fixed to the bottom of the secondary coil. The high frequency corona can be taken by the hand without discomfort although it is best to draw off the corona using a firmly held metal rod.

The diagram below shows the circuit of the high tension circuitry of the Oudin oscillator. The Tesla coil secondary contains 1500 turns of wire insulated to withstand 3kV between turns. The top 'mushroom' terminal can be replaced with a smaller spherical electrode to decrease the capacitance of the secondary and hence increase the Q of the secondary ring down, since this is given by

$$V_{secondary} = kQV_{primary}$$

where Q is the Q of the secondary coil and k is a constant which depends on the turns ratio and coupling between the primary and secondary coil.

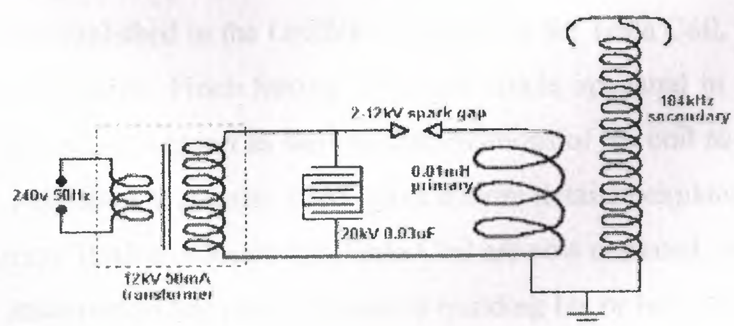

Figure 1.3 Oudin Oscillator High Tension Connections

When over-riding the spark excited Tesla action and incorporating a high frequency signal generator, the impedance matching is of crucial importance. The Q of the secondary may be several hundred and so the on-resonance primary voltage need only be a few tens of volts to achieve several hundreds of thousands of volts at the top electrode of the Tesla coil secondary. Many hundreds of thousands of volts can be achieved with a few hundred volts on resonance in the primary which must then have a Q of hundreds to keep the power demands of the primary high frequency supply to a reasonable value, say a few hundred Watts. In a practical design it would be advisable to produce a 300v 184kHz 1kW signal source, which although not a trivial project, is the key to coupling enough power to the secondary. The impedance of the primary on resonance must be at least 100 ohms. This is achievable using a good 1kV polypropylene capacitor and good connections throughout the primary resonant circuit. Provided that the primary circuit is exactly on resonance with the Tesla coil secondary's self resonance with whatever choice of electrode is preferred, then the potential at the top electrode of the Tesla secondary will be kQ times 300v. For example, to obtain a megavolt of 184kHz energy at the top of the Tesla secondary, it is required to have kQ = 3000. If the turns ratio can be assumed to contribute a factor of only 10, then the Q of the secondary needs to be at least 300 which the supplied polythene secondary certainly satisfies.

1.3 Tesla Coil's Care and Feeding

In 1937, a Tesla Coil was installed in the Hall of Science at the Griffith Observatory. To date, over 25 million visitors have watched it in operation, throwing its lighting-like discharges to the walls of the exhibit. In response to visitor interest, two articles have been published in the Griffith Observer on the Tesla Coil, which originally belonged to Dr. Frederick Finch Strong. The first article appeared in the April, 1948, issue, and it contained a diagram as well as specifications of the coil as it was then. The second article, published in August, 1965, gave a more detailed explanation and a more up-to-date diagram. Both articles on this Tesla Coil are now outdated, however.

The following information can guide anyone in building his or her own Tesla Coil, and so a few words of caution are in order. The currents involved in the operation of even the smallest Tesla Coil can be lethal. Even if one has experience with electronics, someone familiar with high tension currents should be consulted before starting construction.

Neither of the early articles in the Griffith Observer explained the most important concept behind the operation of a Tesla Coil. This is the phenomenon of resonance. Resonance can be demonstrated simply by using a set of tuning forks, each of a different pitch. These tuning forks are arranged so they are free to vibrate, and then a single note of music is sounded. If one tuning fork is tuned to exactly the same pitch as the musical note, the forks will vibrate while the other forks remain motionless and quiet. The most efficient transfer of this resonant power occurs only if the tuning fork (receiver) is tuned to the same frequency as the musical note (transmitter).

The Tesla Coil uses two windings of wire: one is the transmitter and the other is the receiver of resonant power. We shall call the transmitter of power the primary winding, and the receiver of this power the secondary winding. If a capacitor, which is capable of storing an electrical charge, is connected to the primary winding, a current flows through the primary and sets up a magnetic field around it. When this capacitor is depleted of charge, the magnetic field around the winding collapses, and a current flows back through the winding, but this time in the opposite direction. This current recharges the capacitor, and the process repeats itself until the oscillations finally die out. The resonant frequency at which these oscillations occur is given by the formula,

f0 = 1/(2 x Pi x sq. root LC)

where f0 equals the resonant frequency of the winding in cycles/second, L equals the winding's value' in Henries (the unit of inductance), and C equals the capacitor's value in farads (the unit of capacitance).

The secondary winding utilizes an electric property, the principle of mutual induction. Although this sounds complex, it really isn't. If we take a wire and run a current through it, a magnetic field forms around the wire. If we change the amount of current flowing through the wire, the strength of the magnetic field changes proportionately. Then, if we take another wire and place it within this changing magnetic field of the first wire, electricity will run through the second wire (even though it is not in physical contact with the first). So, electricity is being "induced" in the second wire because it is within the moving magnetic field, or influence, of the first wire.

The secondary winding of the Tesla Coil is located within the magnetic field of the primary winding. By mutual induction, it obtains a charge from the primary winding. The secondary winding consists of many turns of wire wound in a helix on some sort of cylindrical or conical form, with the bottom end of the wire being connected to the ground. The upper end is connected to a sphere (or some other type of elevated terminal).

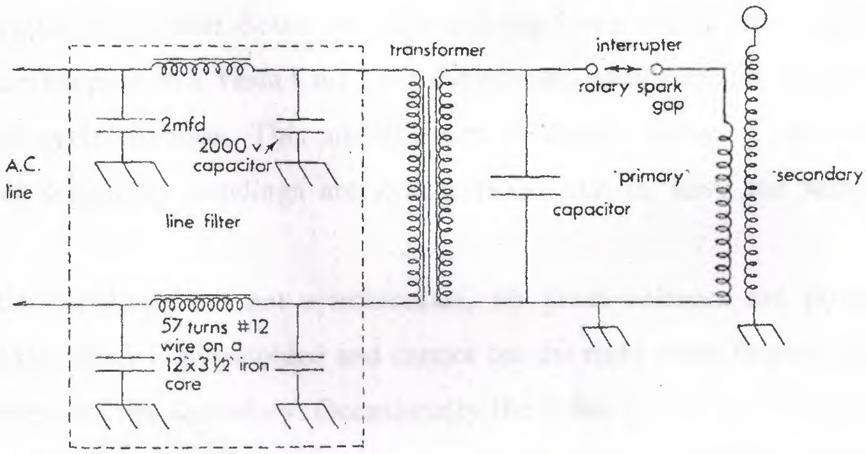

Figure 1.4 This is a schematic diagram of a Tesla Coil. Although the line noise filter is not necessary to the coil's operation, it is a nice feature, for it prevents static and hash from getting back onto the A-C line.

The secret of tuning the secondary winding to the primary winding was publicly revealed by Tesla in 1900. He wrote, "The exact attunement of the two circuits (windings) secures great advantages, and, in fact, it is essential in the practical use of the system In order to attain the best results it is essential that the length of wire, from the ground connection to the top, should be equal to one-quarter of the wavelength of the electrical vibration of the wire."

In other words, to make the secondary winding a resonant receiver of the primary winding, the length of the secondary winding must be related to the resonant frequency of the primary winding. This value can be found by Tesla's formula, f0 = c/4 x 1, where f0 again equals the resonant frequency of the winding in cycles per second, c is the speed of light in feet per second, and I is the length of the secondary winding in feet. By first building a primary winding and measuring its frequency on an oscilloscope, a secondary winding with the proper length of wire can be found by substituting into the above formula.

The simplest way to visualize the type of resonance in a Tesla Coil is to think of a child on a swing with the father pushing. The child and swing represent the secondary and the father, the primary, The motion begins with the first push with the child going forward, then returning. Just as the child is changing direction and about to go forward again, the father gives another push of equal force. This time the child goes higher. If the father keeps pushing in time with the child, using equal force on each push, he keeps adding energy to the system. Soon, the child is doing loops around the swing. The same sort of action happens in a Tesla Coil, with the primary adding energy to the secondary in time with each vibration. This amplification of energy occurs if, and only if, the primary and secondary windings are synchronous, that is, have the same resonant frequency.

If the windings are not synchronous, no great voltages are produced. For example, if the father is blindfolded and cannot see the right times to push, the primary is out-of-rune with the secondary. Occasionally the father pushes at the right time, but sometimes he stops the child altogether because he is trying to push forward when the swing is on the way back. The importance of exact tuning cannot be overemphasized.

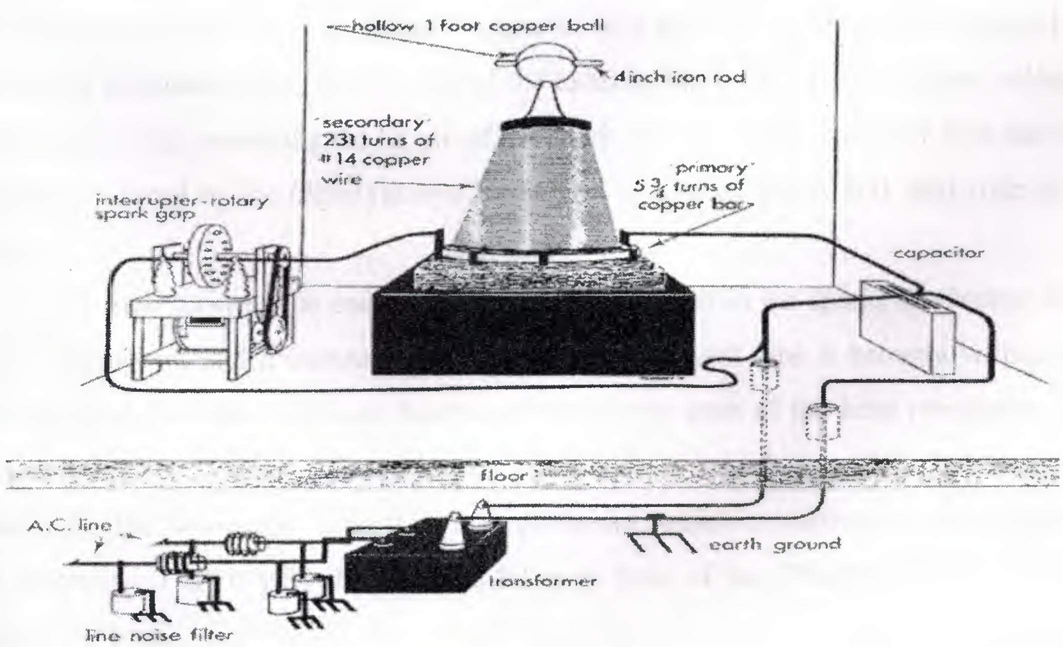

Figure 1.5 The Tesla Coil at Griffith Observatory

The Tesla Coil at Griffith Observatory operates on standard 117 volt 60 cycle alternating current. This voltage is stepped up by a transformer, which is oil encased and located beneath the floor of the exhibit, to 15,000 volts. This transformer is capable of delivering 2,000 watts of power, and it has a special type of winding, which is called current-limited. If more than 2,000 watts of power is attempted to be drawn from the transformer, the output voltage will drop to keep the output energy limited at the 2,000 watt peak. Luminous tube transformers, those used for neon signs, have this type of winding and are suitable for use in building a Tesla Coil.

Current from the transformer goes into charging a capacitor. This capacitor consists of copper plates sandwiched between sheets of glass in an oil-filled metal encasement. Located between the capacitor and the primary winding is a rotary spark gap, also called an interrupter. This spark gap has two electrodes, with a I-inch phenolic wheel containing 14 copper bars on its edge and situated in between the electrodes, The phenolic wheel turns at 1800 revolutions/minute, Every time one of its copper bars crosses between the two electrodes, a spark jumps across the electrodes, and this delivers a charge to the primary winding. The primary winding is 5-3/4 turns of 3/4 inch x 3/16 inch copper bar. The primary winding oscillates when the spark jumps across the interrupter because the spark is actually a set of bursts of alternating current, which flows back and forth from the capacitor to the primary.

With each pulse of the interrupter, the secondary winding builds up its oscillations until a burst of electricity bridges its way across each side of the copper ball to the two grounded plates at the walls of the exhibit. The only way to estimate voltages of this kind is by measuring the length of the spark that is produced, and we find that the voltage produced by the Observatory's Tesla Coil is approximately 200, 000 volts at its peak.

Though most of the energy produced is dissipated in the spark, an electric field is also produced, and it surrounds the coil. If a fluorescent tube is brought within this electric field, the tube lights up. Electricity travels the path of the least resistance, and within the electric field, it is easier for electricity to travel through a conductor of electricity (the fluorescent tube) than through the air, which is relatively a nonconductor of electricity. That is why the four gas tubes in front of the Observatory's Tesla Coil exhibit light up.

Though Tesla prophesied the development of such devices as television, robot war machines, radio telescopes, and the laser, and even though he was responsible for thousands of patents and inventions, to many people Dr. Nikola Tesla will always be remembered as the man who produced "lightning in his hands."

1.4 How Tesla Coils Work

A classic Tesla coil consists of two inductive-capacitive (LC) oscillators, loosely coupled to one another. An LC oscillator has two main components, an inductor (which has inductance, L measured in Henrys) and a capacitor (with capacitance C measured in Farads). An inductor converts an electrical current (symbol I, measured in Amperes) into a magnetic field (symbol B, measured in Tesla [yes, named in honor of Nikola Tesla]), or a magnetic field into a current. Inductors are formed from electrical conductors wound into coils. Capacitors consist of two or more conductors separated by an insulator. A capacitor converts current into an electric field (symbol V, measured in Volts) or an electric field into current. Both magnetic fields and electric fields are forms of stored energy (symbol U, measured in Joules). When a charged capacitor (U=CV2/2) is connected to an inductor an electric current will flow from the capacitor through the inductor creating a magnetic field (U=LI2/2). When the electric field in the capacitor is exhausted the current stops and the magnetic field collapses. As the magnetic field collapses, it induces a current to flow in the inductor in the opposite direction to the original current. This new current charges the capacitor, creating a new electric field, equal but opposite to the original field. As long as the inductor and capacitor are connected the energy in the system will oscillate between the magnetic field and the electric field as the current constantly reverses. The rate (symbol [Greek nu], cycles per second or Hertz) at which the system oscillates is given by (the square root of 1/LC)/2pi. One full cycle of oscillation is shown in the drawing below. In the real world the oscillation will eventually damp out due to resistive losses in the conductors (the energy will be dissipated as heat).

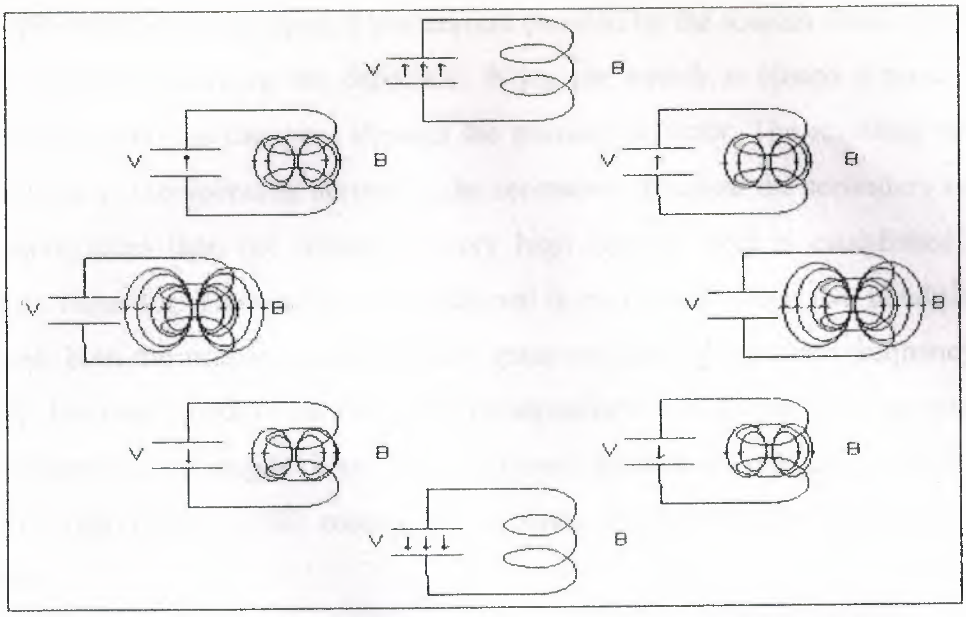

Figure 1.6 A Full cycle of oscillation

In a Tesla coil, the two inductors share the same axis and are located close to one another. In this manner the magnetic field produced by one inductor can generate a current in the other. The schematic below shows the basic components of a Tesla coil. The primary oscillator consists of a flat spiral inductor with only a few turns, a capacitor, a voltage source to charge the capacitor and a switch to connect the capacitor to the inductor. The secondary oscillator contains a large, tightly wound inductor with many turns and a capacitor formed by the earth on one end (the base) and an output terminal (usually a sphere or toroid) on the other.

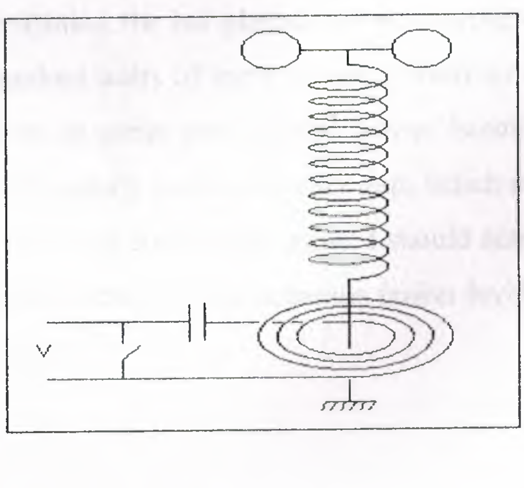

Figure 1.7 The secondary oscillator

While the switch is open, a low current (limited by the source) flows through the primary inductor, charging the capacitor. When the switch is closed a much higher current flows from the capacitor through the primary inductor. The resulting magnetic field induces a corresponding current in the secondary. Because the secondary contains many more turns than the primary a very high electric field is established in the secondary capacitor. The output of a Tesla coil is maximized when two conditions are met. First, both the primary and secondary must oscillate at the same frequency. And secondly, the total length of conductor in the secondary must be equal to one quarter of the oscillator's wave length. Wave length (Greek lambda, in meters) is equal to the speed of light (300,000,000 meters per second) divided by the frequency of the oscillator.

Tesla coils differ in the type of switch used, the physical size of the components and the input voltage. Automotive ignition coils typically have a twelve volt input and are switched by a distributor, with moving contacts. They provide an output of 15-20,000 volts. Television fly-back transformers produce lower outputs but usually have 120 volt inputs and are switched by transistors or, in very old sets, vacuum tubes. The classic Tesla coil is switched by a spark gap. In this case, the primary circuit is known as a tank circuit. In its simplest form, the spark gap switch has two conductors separated by an air gap. When the electric field stored in the capacitor reaches a level sufficient to ionize the air within the gap a highly conductive plasma is formed, effectively closing the switch. Spark gap switched coils operate with inputs of about 5-20,000 volts and produce outputs of 100,000 to several million volts. For the spark gap to be effective, it must be able to open rapidly after the primary oscillation has damped out, in order that the capacitor may recharge. This is achieved by several methods, all of which amount to ways of cooling and dissipating the hot plasma formed during conduction. The simple gap can switch a few hundred watts of input power. Forced air cooling of the gap and, or using a number of gaps in series can increase power handling to several thousand watts. Higher power levels usually require a rotary gap, which mechanically moves gap electrodes rapidly into and out of conduction range. I should note here that even at input power levels of a thousand watts, the instantaneous power levels during gap firing can reach a million watts or more.

1.5 Simplified Tesla Coil

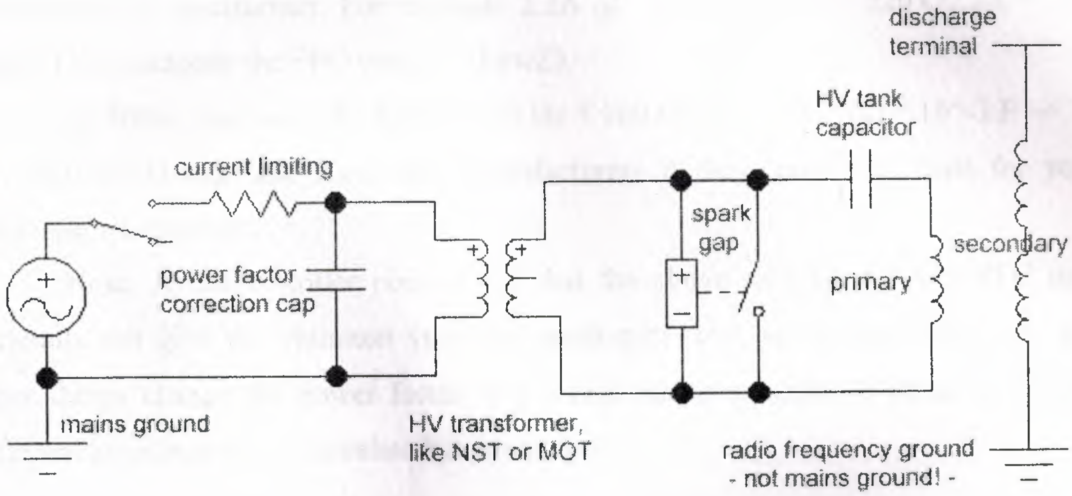

Figure 1.8 Simplified schematic diagram

1.5.1 Current Limiting

The Current limiting is only necessary for other transformers than neon sign transformers or transformers that do not have internal current limiting. A PFC capacitor on the mains side can act as "current limiting" to some extent. Otherwise, use resistive or additional inductive ballast (a MOT in series with shorted secondary winding).

1.5.2 Power Factor Correction

Power factor correction (PFC) shifts the VA rating of the transformer closer to actual input and/or output watts, and reduces input current needed. Reduced current is a benefit as all your switches, relais', fuse boxes and so on can be smaller - without PFC they would have to stand twice or more the current. Additionally, I^2*R losses in the wire resistances would be at least four times as high. So, you might want to minimize current draw...

For example a 400VA cos(phi)=0.55 transformer takes in about 0.55*400VA ~= 200W with and without a PFC, but without a PFC it will draw about 2A from a 200VAC line. With an exactly matching PFC the input current is just ~ 1A. The capacitors are non polar capacitors, and it seems like they are mostly oil filled wax-paper capacitors used with mains voltage motors.

Method: First calculate transformer input impedance according to the values written on the transformer. For example 2.2A @ 220V gives Z = 220V/2.2A = 100 Ohm. Then calculate the PFC with C = 1/(wZ).

At 50Hz, this would be 1/(2*pi* 50 Hz * 100 Ohm) = 1/(pi*10) * 10^-3 F ~= 31 uF. You could also ask neon sign manufacturers if they have PFC caps for your particular transformer.

Note: A fellow coiler pointed out that the above calculated 100% PFC may generally not give the optimum value for spark-gap coils, as the gap break rate and other things change the power factor. For a nice match it might be easier to try out different capacitances, or calculate by simulation.

1.5.3 Grounding

The only things that should/must be grounded to the mains grounding is the stuff on the mains side that you are going to touch (switches, dials, variac and so on).

The HV secondary side of the transformer must not be grounded at all, even if it is a center-tapped NST. Connecting together RF ground and any part of the HV primary, like done in some schematics, is absolutely lethal.

If you connected together the RF ground and some part of the HV primary circuit, you're a definite goner (=dead) should you come into contact with the secondary streamers (which can be lethal in any case, see 6 Skin effect).

The primary circuits capacitor energy would then flow partly (but partly is already enough) through your body towards the ground. Your pitiful 500..1000kOhm low-voltage body resistance is next to no obstacle for the high voltages - at 8kV, there could be potentially ~10 amps flowing through you, whereas even 5mA is enough to kill.

The Tesla coil secondary RF ground must be an own ground separate from mains ground. Reasons:

- This separate ground will sink RF current and voltage, which - if you used mains ground - would fry all equipment in your house, even the surge protectors.
- Also, the mains ground wire is way too thin, and would have a considerable impedance at the high frequencies present. High impedance is not nice, as the TC base

wouldn't be properly grounded then, and the wire would have a voltage drop from some 10s of kV on the base to 0V somewhere along the wire - i.e. the thin wire could still have a few kV some meters away from the coil base (corona, electrocution, damaged equipment etc).

• The other thing that is bad about a high impedance ground is that the zero voltage node will shift down along the wire to the place where the solid ground is. This will cause a phase shift also in the TC secondary, meaning you could get breakouts from any part along the coil, not just the top.

1.5.4 High Voltage Capacitor For Simlified Circuit

This has to be a HV pulse capacitor, able to give 100s of amps of current into a virtual short circuit and able to withstanding the forces resulting from this.

Additionally the capacitor should have minimal losses at radio frequency band - otherwise it will heat up and pop. Glass for example has huge losses at RF. That's why beer bottle (also called salt water) capacitors are not recommended.Capacitors values generally range from 1nF to 50nF.

The current trend is moving away from "self rolled" capacitors and beer bottle caps. Now one generally makes big HV pulse capacitors from an array built of generally available, "low" voltage and low cost capacitors. Non-electrolytic flash unit capacitors (Panasonic for one) seem to be good. Small radio frequency rated pulse capacitors are the definite ones to use.

You wire them up as an array: make a string of capacitors in series in such a manner that the summed up total voltage rating of the string is larger than the input voltage (t.ex. 20kVDC strings used in a HV cap for a 8kVAC NST). Then, connect so many strings in parallel (ends together) that you end up with the desired capacitance.

e.g: you want a 10nF cap and have a 8kVAC NST. NST will give SQRT(2)*8kVAC=12kV peak, and you need a bit larger than that, say 20kV strength. If you bought some pieces of 10 nF caps, rated 1kVDC, you'll first connect 20 in series. That is, hook them up in a string. The wires should be kept as short as possible. The total capacitance of one string is then Cstring = 10 nanoFarad / 20 = 0.5 nanoFarad, and the total voltage rating Vmax,string = 20 * Vmax, one capacitor = 20kVDC, as wanted.

Now, to get the full desired capacitance of 10nF, you have to hook a number of those strings up in parallel. One string was 0.5 nanoFarad, so you would need 10nF/0.5nF = 20 strings in parallel.

In total, you will need 20 strings times 20 caps/string = 400 caps. That is pretty many, so you need to find a place that sells these small pulse caps cheap, for < $1 per piece.But, the final MMC tank capacitor will be at least half cheaper than commercial HV pulse capacitors, and nevertheless performance wise very close to those commercial ones.

You should always have at least 5 strings in parallel (increase string length if necessary), because each string has to deliver huge currents. If you have multiple strings in series, each string will have to contribute less current and it will last longer than if you have just one string (which would blast in an instant.).

Together with the primary coil, the resonant frequency of this L-C circuit should be in the range 100kHz to 1MHz. Lower freq (~= less heat losses) is better for high power output and bigger diameter coils.

Resonant charging which is the HV cap can be charged efficiently to higher voltages (if it endures them), by charging it in resonance to the transformer, at line frequency. The drawback is that this will increase stress on the transformer. And, the extra voltage is not "free", so it needs several AC frequency cycles before the capacitor reaches the (over-)voltage and makes the spark gap fire. Anyway, see 7) Resonance.

Please Remember:

1) a HV capacitor will be lethal if you touch it.

2) HV caps can sometimes regain (lethal) charge if they stand around unused for a while and are not shorted out by connecting a wire between terminals.

3) a HV capacitor charged up using a 100kW transformer at 15kV is exactly as lethal as when it was charged with a tiny 50mW handheld flyback or ignition coil at 15kV (same amount of energy stored in all cases).

1.5.5 Filters

All filters are missing in the schematic. You should install mains RF filters and, if possible, high voltage radio frequency RC-style low pass filters between spark gap and transformer.

Choke filters are not recommended. They can cause additional voltage spikes. And insulation is also a problem if the chokes are too tight wound and too small - high voltage will jump over the choke then.

1.5.6 Skin Effect

High frequency current tends to flow closer to the surface of conductors, i.e. at very high frequencies a huge round 1m^2 area conductor will have current flow only on the surface - you could make the center hollow as the metal inside it conducts no current at all and only adds weight to the conductor.

Skin depth = depth at which current density is 1/e ~= 37% of maximum. There IS current flow at deeper than skin depth, even at four or five times skin depth, but it decreases fast.We can calculate the skin depth with:

Depth = 1 / SQRT (pi * freq * permeability * material conductivity)

Where:
Material conductivity = 1 / material resistivity
Permeability = 4*pi*10^-7 * conductor relative permeability freq = frequency of signal fed through the conductor

Remark: Use SI units! That's metric... Not webers, or inches, or anything more complicated.

Demostration with copper conductor and 800kHz. Copper has relative permeab. (to vacuum) of ~1, so permeability is vacuum permeability. Resistivity is 1.72*10^-6 ohm meter. Skin depth is thus 0.233 millimeters.

So, for good performance and only small losses in the HV primary circuit you don't need thick wire but a large surface area, like flat strips from alu foil, copper foil, etc for the NST filter->spark gap->cap->primary connectors.

The other thing is that skin effect applies not only to metals, but also includes blood vessels.

The streamers from the secondary are dangerous to even lethal, because the RF frequency lies outside the nerve cells detection ability which means that you don't notice that there are 100W of power travelling along your tissue and blood vessels, cooking you from inside out. Never do a stunt and touch or get close to the streamers! Instead, use long plastic rods with an end metal terminal that is connected to ground. With this, you can safely draw arcs off the coil.

1.5.7 Resonance

The goal in a TC is to make both the primary high voltage side L-C-circuit and the secondary coil L-Cself-capacitance - circuit resonant at the same frequency. In this way you get maximum power transfer from the primary tank cap to the secondary self capacitance. The secondary is series resonant, meaning low impedance and with high voltage accross components.The resonant frequency can be calculated with;

freq(res) = 1 / [2pi * square_root(L*C)]

In theory, the energy after the transfer from the tank capacitor to the secondary Cself remains about the same (W = 1/2 * C * U^2), but because the Cself is 1000 times smaller than the tank capacitor, the voltage accross the secondary is much higher.

Long streamers are generated by high voltage and high power, but also by growth of new streamers from the ends of previous ionized streamer channels - making it desireable to have the spark gap fire very fast.

The tank capacitor can be charged to higher voltage (resulting in more energy stored, according to power of ^2), taken the cap can stand the voltage. Raising the voltage is easiest done with resonant charging, where the impedance of the tank capacitor at line frequency matches the output impedance of the transformer.

For a 400VA 8kV 50mA transformer (Z=U/I=160 kOhm) at a mains frequency of 50 Hz such a tank cap would be near C=1/(wZ) = 1/(2*pi*50 Hz * 160 kOhm) = 20 nF. Note that resonant charging drops the transformer impedance, i.e. also the impedance seen from / reflected to the mains side.

The TC secondary acts similar like a 1/4 wave length resonator with standing waves. You'll have a constant zero voltage node at the grounded coil base and the first (low-high oscillating) maximum at the coil top. The secondary is roughly an inductance, so voltage leads 90 degrees to current, meaning at the coil base you have a (low-high oscillating) current maximum and at the top a constant current minimum.

There are of course also other wave modes, with more voltage maximums along the coil. If you put a large round plate through those parts of the coil, you'll get a multi-breakout-point coil, with streamers not just from the top capacitor. The problem is that you then have to eliminate strikes from the lowest inserted plate to the primary coil (if not, you would get constant white ground strikes...).

You can also build a 1/2 wave length resonator or twin coil - ground the middle of the coil, move the primary inductance to the coil middle, and add discharge terminals to both ends of the coil. Both ends will then have opposite voltage at any time. You can also split the coil and the primary inductance in two halves and move them apart.

1.5.8 Strike Rail

This one is absolutely necessary. Loop of thick, non-insulated tubing or thread that is placed 1-2" above the outer ends of your primary coil. The rail is grounded to RF ground. It will intercept any streamers should they try to strike your primary coil and try to fry you at the control board, all mains equipment, the tank cap and everything else.

1.5.9 Notes on Tuning

Tuning goes best with a sine wave signal generator (some mV or V) and a scope or spectrum analyzer connected to a small antenna. First determine the secondary resonant freq by feeding a sine signal to the secondary (with topload on), varying the frequency, and checking at which frequency you'll get the biggest spike on your spectrum analyzer or the highest amplitude on your scope. Then put the secondary in place, short out the spark gap and unconnect the transformer, and feed the same sine signal to the primary HV circuit. Adjust the tapping of the primary coil and possibly the height of your secondary until you see two maximum big spikes to the left and right of the secondary self resonant freq on your spectrum analyzer, but no peak at that self res.freq. Once that's done, your coil is optimally tuned.

2. GENERATING HIGH VOLTAGE

2.1 Generating High Voltage With The Popular Way

One of the cheapest and popular ways of generating high voltages at relatively low currents is the classic multistage diode/capacitor voltage multipler, known as Cockcroft Walton multiplier, named after the two men who used this circuit design to be the first to succeed in performing the first nuclear disintegration in 1932. James Douglas Cockcroft and Ernest Thomas Sinton Walton, in fact have used this voltage multiplier cascade for the research which later made them winners of the 1951 Nobel Prize in physics for "Transmutation of atomic nuclei by artificially accelerated atomic particles". Less known is the fact that the circuit was first discovered much earlier, in 1919, by Heinrich Greinacher, a Swiss physicist. For this reason, this doubler cascade is sometimes also

Unlike transformers this method eliminates the requirement for the heavy core and the bulk of insulation/potting required. By using only capacitors and diodes, these voltage multipliers can step up relatively low voltages to extremely high values, while at the same time being far lighter and cheaper than transformers. The biggest advantage of such circuit is that the voltage across each stage of this cascade, is only equal to twice the peak input voltage, so it has the advantage of requiring relatively low cost components and being easy to insulate. One can also tap the output from any stage, like a multitapped transformer. They have various practical applications and find their way in laser systems, CRT tubes, hv power supplies, LCD backlighting, power supplies, x-ray systems, travelling wave tubes, ion pumps, electrostatic systems, air ionisers, particle accelerators, copy machines, scientific instrumentation, oscilloscopes, and many other.

2.2 How It works

The Cockcroft Walton or Greinacher design is based on the Half-Wave Series Multiplier, or voltage doubler. In fact, all multiplier circuits can be derived from its operating principles. It mainly consists of a high voltage transformer Ts, a column of smoothing capacitors (C2,C4), a column of coupling capacitors (C1,C3), and a series connection of rectifiers(D1,D2,D3,D4). The following description for the 2 stage CW multiplier, assumes no losses and represents sequential reversals of polarity of the source transformer Ts in the figure shown below. The number of stages is equal to the number of smoothing capacitors between ground and OUT, which in this case are capacitors C2 and C4.

Figure 2.1 High Voltage Transformer

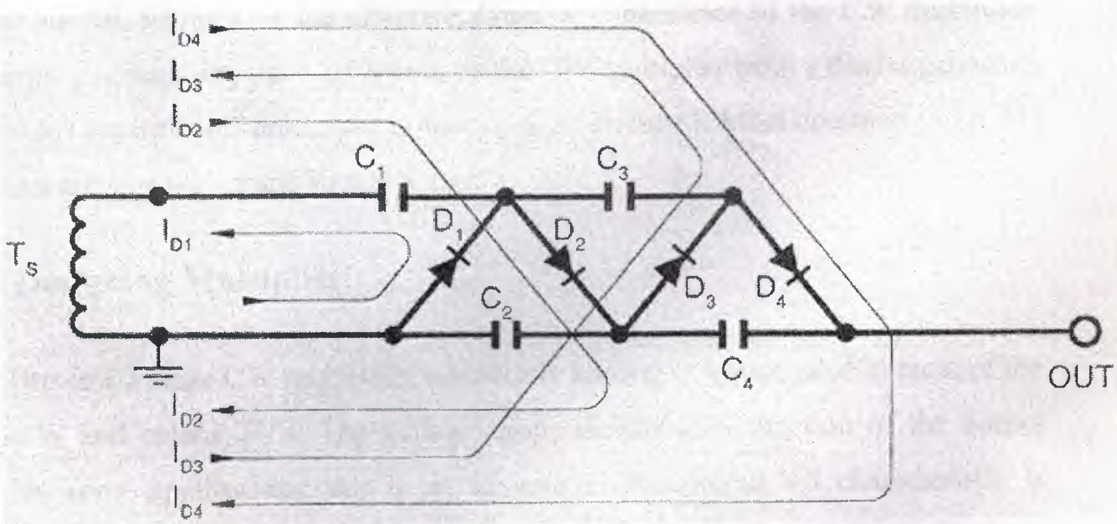

Figure 2.2 Two Stage Cockroft Walton Multiplier

- Ts=Negative Peak: C1 charges through D1 to Epk at current ID1
- Ts=Positive Peak: Epk of Ts adds arithmetically to existing potential C1, thus C2 charges to 2Epk through D2 at current ID2
- Ts=Negative Peak: C3 is charged to Epk through D3 at current ID3
- Ts=Positive Peak: C4 is charged to 2Epk through D4 at current ID4.

Output is then 2n*Epk where N = number of stages.

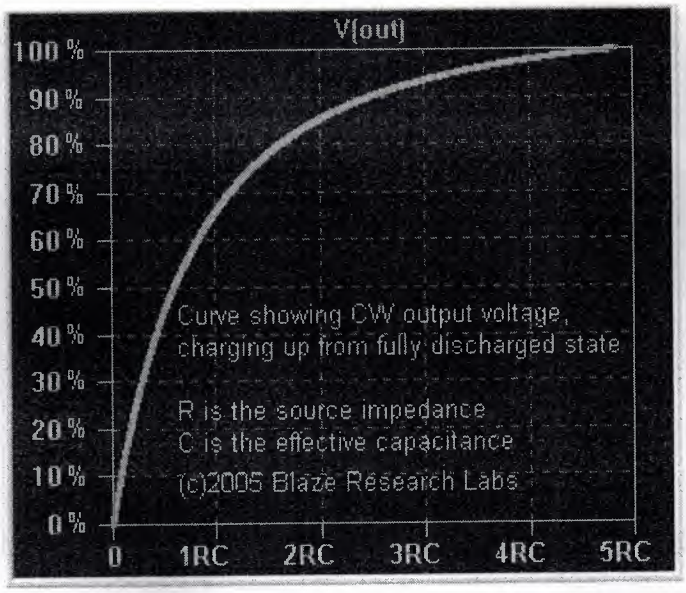

Figure 2.3 An RC Network Curve

In reality several cycles are required to reach full voltage. The output voltage closely follows the curve of an RC network as shown above. R is the output impedance of the ac source, whilst C is the effective dynamic capacitance of the CW multiplier. This charging occurs only upon switching on the CW multiplier from a discharged state, and does not repeat itself unless the output is short circuited. Most common input AC waveforms are sine waves and square waves.

2.3 Designing Multiplier

This is a 3 stage CW multiplier, commonly known as tripler, used in most of the early B&W and colour TV's. The voltage drops rapidly as a function of the output current. In some applications, this is an advantage. The output V/I characteristic is roughly hyperbolic, so it serves well for charging capacitor banks to high voltages at roughly constant charging power. Furthermore, the ripple on the output, particularly at high loads, is quite high.

This is a simulation of a 3 stage CW multiplier. The input is a sinewave 10kV peak voltage. Vn(n003), V(n005) and V(out) are the voltage levels at each stage, referenced to ground. Theoretically, V(out) = 2n*Epk= 2*3*10 = 60kV. As you can see from the below simulation.

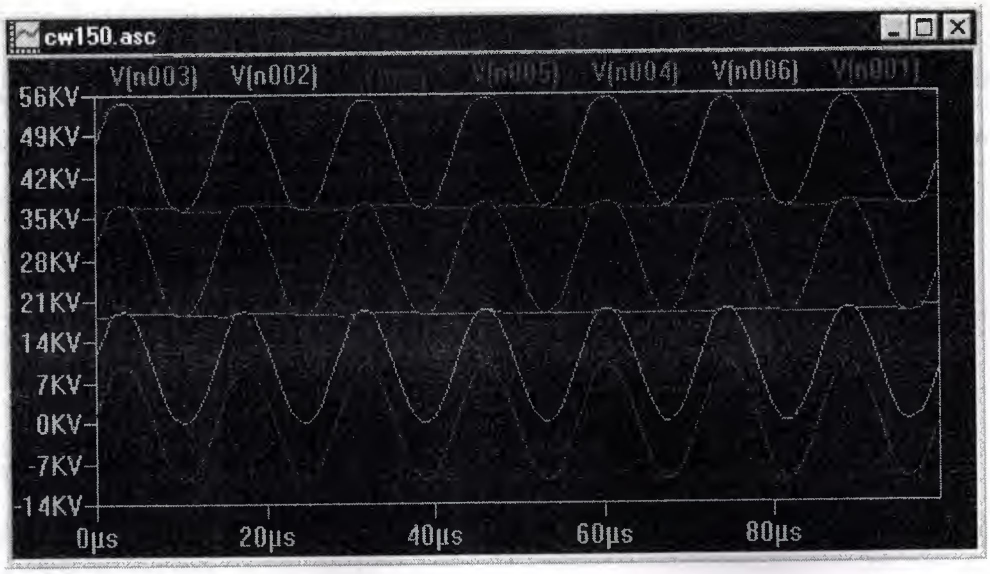

Figure 2.4 Output of 3 stage CW Multiplier

The loaded output never reaches this value due to the poor voltage regulation of the CW as discussed below.

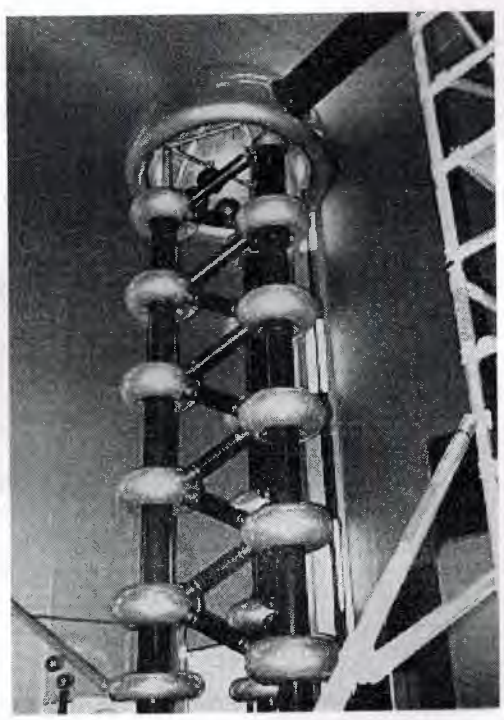

Figure 2.5 Multistage of cockroft

The output voltage (Eout) of each stage is nominally twice the peak input voltage (Epk). It is relatively easy to step the voltage by one order of magnitude (say 100kV to 1MV) with just 5 stages. This circuit is in fact frequently used to generate megavolts, and as shown above, although the actual components and physical dimensions get larger, the concept remains exactly the same.

Eout = 2n*Epk - VDrop   VDrop=0 under no load

e.g: In a 3 stage CW, the no load voltage Eout = 2 * 3 * Epk

If Epk was 10 kV, then the output of the circuit would be 60 kV. In practice, the output is lower due to the parameter VDrop, particularly with a large number of stages. Each diode drops the voltage across it by about 250v at its rated current and a power loss (250*Idiode) within each diode occurs during each charging cycle. For this reason, heat dissipation may become a problem with small diodes, which could be immersed in oil to alleviate this problem. Capacitors tend to be more efficient, and their only concern is their voltage rating.

Regulation and ripple calculations:

The voltage drop under load is mostly reactive and can be calculated as:

VDROP = [Iload/(6fC)] * (4n3 + 3n2 - n)

where:

I: load is the load current (Amps)

C: is the stage capacitance (Farads)

F: is the AC frequency (Hz)

N: is the number of stages.

Substitiuting for VDROP in the previous equation, we get:

$$Eout = 2n*Epk - [Iload/(6fC)] * (4n3 + 3n2 - n)$$

Example: A 3 stage CW, driven by a 70kHz peak voltage of 10kV, with capacitors value 390pF, and a load current of 10mA:

VDROP = [Iload/(6fC)] * (4 n3 + 3 n2 - n)

VDROP = 8kV

Eout = 60kV - 8kV = 52kV

The ripple voltage, in the case where all stage capacitances (C1 through C(2*n)) are equal, may be calculated from:

$$Eripple = [Iload/(2fC)]*n*(n+1)$$

In our example:

Eripple = [Iload/(2fC)]*n*(n+1)

Eripple = [10mA/(2*70E3*390E-12)]*3*4 = 2.2kV

So the output voltage will swing between 52kV and 49.8kV. Below is a SPICE simulation of our circuit example, being very close to our calculated ripple value.

As you can see from this equation, the ripple grows quite rapidly as the number of stages increases (as n squared, in fact). A common modification to the design is to make the stage capacitances larger at the bottom, with C1 & C2 = nC, C3 & C4 = (n-1)C

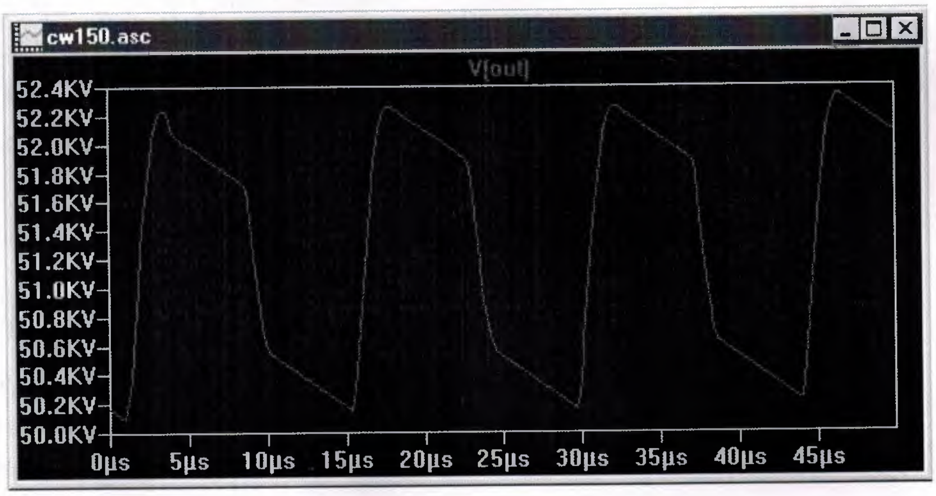

Figure 2.6 Shows output voltage of swing between 52KV and 49.8KV

For the above example, this modification will reduce the ripple voltage from 2.2kV to just 366V. Once a load is connected at the output, the output voltage decreases due to the voltage regulation mentioned above. Also, any small fluctuation of load impedance causes a large fluctuation in the output voltage of the multiplier due to the number of stages involved. For this reason, voltage multipliers are used only in special applications where the load is constant and has a high impedance or where voltage stability is not critical. Some engineers compensate for this fluctuation by incorporating a feedback loop, which varies the input voltage of the Cockcroft Walton multiplier according to the actual output voltage.

For large values of n ($\geq$5), the 3n2 and n terms in the voltage drop equation become small compared to the 4n3. Differentiating the EOUT equation without these negligible terms, with respect to the number of stages and equating to zero to find the peak of the curve, gives an equation for the optimum (integer) number of stages for the equal valued capacitor design:

d/dn{Eout} = d/dn{2n*Epk - [Iload/(6fC)] * (4n3)} = 0

2Epk = Iload/(6fC) * 3 * 4n2

Noptimum = INT[SQRT(Epk * fC/Iload)]

If we differentiate the Eout equation, this time including the 3n2 and n terms, we get a more accurate equation, also valid for n<5:

Noptimum = INT[SQRT(3Iload*(7Iload+48fC*Epk))/(12*Iload) -1/4]

If we drive our CW with an input voltage Epk=10kV and a load of 10mA, running at 70kHz and 390pF capacitors, Noptimum=INT[5.22]=5 (using the first equation), and Noptimum=INT[4.988]=5 (using the second equation) so we go for a 5 stage CW multiplier.

If we know the driving voltage Epk and the required output voltage Eout, we can also approximate the optimum number of stages from:

Noptimum = INT[3 EOut/4Epk] *(1)

2.4 The Full Wave CW

Increasing the frequency can dramatically reduce the ripple, and the voltage drop under load, which accounts for the popularity of driving a multipler stack with a switching power supply. A clever way to reduce ripple is to implement a full wave voltage doubler as shown below. This effectively doubles the number of charging cycles per second, and thus cuts down the voltage drop and ripple factor. The input is usually fed from a centre tapped ac transformer or MOSFET H-bridge circuits.

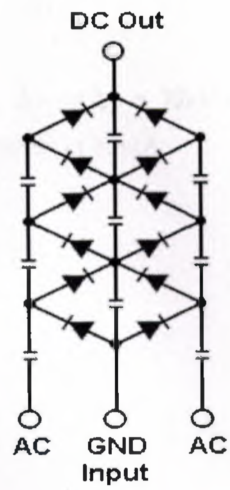

Figure 2.7 Full Wave Voltage Doubler

As with the classical CW, the full wave CW output voltage is given by:

Eout = 2n*Epk - VDrop

e.g: In a 3 stage full wave CW, the open circuit voltage (no voltage drop) :

Eout = 2 * 3 * Epk

If Epk was 10 kV, then the open circuit output voltage would be 60 kV. Regulation and ripple calculations for full wave CW. The voltage drop under load can be calculated as:

VDROP = [Iload/(6fC)] * (n3 + 2n)

where:
I: load is the load current (Amps)
C: is the stage capacitance (Farads)
f : is the AC frequency (Hz)
n : is the number of stages.
Substitiuting for VDROP in the previous equation, we get:

Eout = 2n*Epk - [Iload/(6fC)] * (n3 + 2n)

Example: A 3 stage full wave CW, driven by a 70kHz peak voltage of 10kV, with capacitors value 390pF, and a load current of 10mA:

VDROP = [Iload/(6fC)] * (n3 + 2 n)

VDROP = 2kV

Eout = 60kV - 2kV = 58kV

The ripple voltage, in the case where all stage capacitors are equal, may be calculated from:

Eripple = [Iload/(2fC)]*n

In our example:

Eripple = [Iload/(2fC)]*n

Eripple = [10mA/(2*70E3*390E-12)]*3 = 550v

The optimum number of stages for a given output and input voltage is given by:

Noptimum = INT[0.521 EOut/Epk]

The below shows that Cockroft Walton Multiplier capacitors connections which is ceramic capacitors and diodes.This is stage CW multiplier rated 75kV output at no load used to power output.

Figure 2.8 shows 5 stage CW multiplier rated 75 kV output at no load
Used to power output

2.5 High Voltage Capacitors

Morgan Electro Ceramic is a leader in the design and manufacture of advanced ceramic products with over 50 years experience in the manufacture of electroceramic materials and components for high voltage applications.

Live-Line Indication

To indicate the presence of voltage and for fault detection on power frequency high voltage distribution switchgear (6.6kV-36kV systems).

The capacitor is connected directly to the HV line and a small current (low voltage signal) is passed which illuminates a neon lamp mounted on the front panel of the switch.

Alternatively the low voltage signal may be used to feed a sensing circuit which monitors for supply failure and circuit condition.

The capacitor is normally contained within a resin moulding. Usually the moulding is made by the switch manufacturers themselves in a shape to suit their own particular needs but Morgan Electro Ceramics can offer certain complete mouldings or can advise on suitable sources.

2.5.1 Electrostatic Spray Guns

Dry powder paint spraying in automotive white goods or any other metal products requiring smooth uniform paint finish.

High Voltages can be produced from a relatively low voltage AC source using a Voltage Multiplier Assembly i.e. parallel stacks of series connected capacitors and cross connected diodes. These devices find their major application in electrostatic paint spraying equipment.

DC output voltages in excess of 100kV generate a corona discharge at the end of the spray gun and the resulting HV electric field causes the surrounding air to break down creating negatively charged ions. The ions attach themselves to the nearest object or surface and the particles of paint powder passing through this field become charged then attracted to the earthed workpiece.

The capacitor stack assembly consists of a number of series connected capacitor discs with a choice of intermediate metal fittings to which the diodes are attached.

A wide range of stacks of up to 12 discs in series are available with voltage ratings of the individual discs from 8 to 12kV DC and capacitance values from 125pF to 100OpF. Their compact size, low weight and ability to withstand the high voltages generated are the main reasons why these assemblies are used.

2.5.2 DC Power Supplies

Encapsulated High Voltage capacitor discs of the type shown can be used in voltage multiplier circuits for high voltage low power DC supplies such as those used in Medical scanners, X-Ray equipment and electrostatic precipitators.

Parallel strings of series connected capacitors with cross-connected diodes can be used in the multiplier circuit.

The equipment is usually non-portable and made up of large capacitance units - typically 150OpF upwards with voltage ratings of 20 to 40W.

You may also find the following sections of particular interest if you are associated with HV application.

2.6 Capacitor Hazards and Safety

Capacitors may retain a charge long after power is removed from a circuit; this charge can cause shocks (sometimes fatal) or damage to connected equipment. For example, even a seemingly innocuous device such as a disposable camera flash unit powered by a 1.5 volt AA battery contains a capacitor which may be charged to over 300 volts. This is easily capable of delivering an extremely painful, and possibly lethal shock.

Many capacitors have low equivalent series resistance (ESR), so can deliver large currents into short circuits, and this can be dangerous. Care must be taken to ensure that any large or high-voltage capacitor is properly discharged before servicing the containing equipment. For safety purposes, all large capacitors should be discharged before handling. For board-level capacitors, this is done by placing a bleeder resistor across the terminals, whose resistance is large enough that the leakage current will not affect the circuit, but small enough to discharge the capacitor shortly after power is removed. High-voltage capacitors should be stored with the terminals shorted to dissipate any stored charge.

Large oil-filled old capacitors must be disposed of properly as some contain polychlorinated biphenyls (PCBs). It is known that waste PCBs can leak into groundwater under landfills. If consumed by drinking contaminated water, PCBs are carcinogenic, even in very tiny amounts. If the capacitor is physically large it is more likely to be dangerous and may require precautions in addition to those described above. New electrical components are no longer produced with PCBs. ("PCB" in electronics usually means printed circuit board, but the above usage is an exception.)

2.7 Hazards Associated With High Voltage Capacitors

Above and beyond usual hazards associated with working with high voltage, high energy circuits, there are a number of dangers that are specific to high voltage capacitors. High voltage capacitors may catastrophically fail when subjected to voltages or currents beyond their rating, or as they reach their normal end of life. Dielectric or metal interconnection failures may create arcing within oil-filled units that vaporizes dielectric fluid, resulting in case bulging, rupture, or even an explosion that disperses flammable oil, starts fires, and damages nearby equipment. Rigid cased cylindrical glass or plastic cases are more prone to explosive rupture than rectangular cases due to an inability to easily expand under pressure. Capacitors used in RF or sustained high current applications can overheat, especially in the center of the capacitor rolls. The trapped heat may cause rapid interior heating and destruction, even though the outer case remains relatively cool. Capacitors used within high energy capacitor banks can violently explode when a fault in one capacitor causes sudden dumping of energy stored in the rest of the bank into the failing unit. And, high voltage vacuum capacitors can generate soft X-rays even during normal operation. Proper containment, fusing, and preventative maintenance can help to minimize these hazards.

3. HIGH VOLTAGE DC GENERATOR

3.1 DC Generator Definition

Voltage,by definition,is the elecrical pressure that causes current to flow through a conductor.When that pressure is sufficiently high,a high voltage is produced.But how do we define high voltages? Is 100,1000,10.000 volts considered high voltage? When compared to 10 volts,they all can be considered high voltage.

As far as safety goes,high voltage can be considered any voltage that endangers human life.it's obvious that 1000 volts poses a greater hazard than does 100 volts,but that doesn't mean that 100 volts is safe to handle.As far as safety goes,100 is still considered high voltage and that fact must be understood.

The Miniature High Voltage DC Generator,presented in this article,is capable of generating around 10.000 volts DC.So high voltage can ionize air and gases,charge high voltage capacitors,and also be used to power a small laser or image tube,and has many other application that are useful to both the experimenter and the researcher.

3.2 Circuit Description

The circuit is fed from a 12 volts DC power supply.The input to the circuit is then amplified to provide a 10.000 volts DC output.That's made possible by feeding the 12 volts output of the power supply to a DC to DC up converter.The output of up converter is then fed into a 10 stage,high voltage multiplier to produce an output of 10.000 volts DC.

Let's see how the circuit works.First let's start with named of a schmitt trigger integrated circuit.it is like U1-a,U1-b and U1-c (gates of 1,2,3).U1-a is set up as a square wave (pulsating DC) output.The output of U1 is fed to the input of U1-bto U1-f,which are connected in parallel to increase teh available drive current.

The pulsating output of the parallelled gates is fed to the base of Q1 ,causing it to toggle on and of in time with the primary winding of Transformator.The other end of transformator is connected directly to the positive terminal of the battery or power supply.This produces a driving wave in the primary windig of tansformator taht is similar to a square wave.

The on and off action of the transistor,caused by the pulsating g type signal applied to Q1,creates a rising and collapsing field in the primary winding of transformator (a small ferrite core step up transformer).That causes a pulsating signal,of opposite polarity,to be induced in transformator's secondary winding.The pulsating DC output of at the secondary winding of transformator (ranging from 800 to 1000 volts)is applied to a 10 stage voltage multiplier circuit that consisting of diodes (D1 through D10) and capacitors (C3 through C12).The multiplier circuit increases the voltage 10 times,producing and output of up to 10.000 volts DC.The multiplier accomlishes its task by charging the capacitors (C3 through C12),through the diodes (D1 through D10).The output is a series addition of all the capacitors in multiplier.

In order for the circuit to operate efficiently,the frequency of the square wave,and therefore the signal applied to the multiplier,must be considered.The output frequency of the oscillator (U1-a) is set by the combined values of R1,R5 and C1 (which with the values specified is approximately 15 KHz).Potantiometer R5 is used to fine tune the output frequency of oscillator,the lower the capacitive reactance in the multiplier.

Light Emitting diode (LED) serves as an input power indicator,while neon lamp (NE) indicates an output at the secondary of transformator.A good way to get maximum output at the multiplier is to connect an oscilloscope to the high voltage output of the multipier,via a high voltage probe,and adjust potentiometer R5 for the maximum voltage output.If you do not have the appropriate test gear ,you can place the output wire of multiplier about a half inch away from a ground wire and draw a spark,while adjusting R5 for a maximum spark output.

3.3 Cauntion

The output of multiplier will cause a strong electric shock.In addition,be aware that even after the multiplier has been turned off,there is still a charged stored in the high voltage capacitors,which depend on the state of discharge,can be dangerous if contacted.That caharge can be bled off by shorting the output of the circuit to ground.(In the fact,its a good idea to get in the habit of discharging all electronics circuit before handling or working on them).Also,U1 is a CMOS device and,as such,is static sensitive.It can handle a maximum input of 15 volts DC.You do not beyond the 15 volts

DC limit of the IC will be destroyed Diode D11 is used to prevent reverse polarity of the input voltage source.

As far as the voltage multiplier goes,the diodes and the capacitors must be rated for at least twice the anticipated input voltage,So,if we have a 1000 volt input,all of diodes and the capacitors must be rated for at least 2000 volts each of them.Because diodes eith that voltage rating can be hard to find and expensive,D1 through D10 are each really two series connected 1 amper,1000 volts rectifier diodes.

3.4 Constraction

The unit can be assembled on perfboard,as is the case with my prototype shown in the photo.Transistor (Q1) must be properly heat sinked or it will averheat quickly and self destruct.The multiplier must be assembled in such a way,so as to prevent any ion leakage.When a high voltage source is terminated at a sharp point,the density of charge is concentrated at that point.The ions both on the point and near the point are like caharges,so they repel aech other and quickly leak off.So it is very important When soldering he multiplier to keep all connections rounded by using enough solder to make a smooth,ball like joint.

The solder side of the multiplier should insulated to prevent contact with any metalic object.On the my prototype,a high voltage insulating compound was used on the solder side of the board.High voltage putty can also be used.Also in the prototype,the output of the circuit is simple a heavily shielded wire,like that used to feed high voltage to the anode on a TV picture tube.That type of wire can safely handle voltage in the 15.000 to 20.000 volt range,and will also help to prevent leakage.

3.5 Positive and Negative Ions

The polarity of the diodes in the multiplier will determine the polarity of ions.In the prototype,the multiplier is step up to generate positive ions.If the diodes were reversed,negative ions would be reproduced.In a positive ion generating multiplier,like that used in the my prototype,which generates approximately 10.000colts DC,the output is a shoch hazard.A negative ion generating multiplier with a -10.000 volt DC output,offers the same shock hazard as the positive +10.000 volt DC output.

3.6 Experiments

If we place the high voltage output wire about 1/2 to 1/4 inch from a groud wire,and we will draw a spark of 10.000 volts DC output.But Remember,the oscillator is built around a CMOS device,which is static sensitive,and any high voltage kickback will toast the unit.So when experimenting with the spark,do not use the circuit ground.A more reliable method would be to draw spark to an earth ground .

Flash Lamp Electric Storm: When the output of the Miniature High Voltage DC Generator is connected to a small flash tube,the high voltage ionized the Xenon gas in the tube,creating small electrical storm within the tube's glass envelope.

Getting Different Voltages: By tapping the multiplier circuit at various stages we will get output voltages ranging from 1.000 volts to 10.000 volts DC.For instance,by placing a tap at the cathodes of D2,D6,voltage of 2000 and 6000 volts are made possible.

3.7 Troublesshooting

If we get no output or a low output from the circuit,we can check that the input to logic gates is below 15 volts.The application of an input voltage exceeding that limit will blow out the IC.Also we can check the signal (with an oscilloscope) that we get a square wave output of approximately 12 KHz at pin 6 of U1.

The switching transistor must be mounted on a heat sink or it will overheat.Make sure the heat sink is of a suitable size to keep the transistor cool.If a 2KV diode is placed at the output of transformator T1,we should get an unloade output of approximately 800 to 1000 volts DC.If we have problem with the output of unit,it is best to disconnect the multiplier from the oscillator and check the output of the transformer.In that way we will know if the problem lies in the oscillator of the multiplier .

The multiplier components must be rated for at least twice the input voltage.The diodes and capacitors used in the multiplier circuit should be rated at 2000 volts DC.However,we may choose to do as the prototpye did.and use two series connected 1KV units for each diode in the multiplier to five an effective rating per pair of 2KV.

3.8 Safety

The output of the circuit is high voltage DC,which will cause an electric shock if touched.So we should use caution.Also with the circuit turned off,the capacitors in the multiplier are still charged,and will discharge through the path of least resistance our body.If we come in contact with the circuit.So discharge the circuit by connecting the output lead to ground with the power off.

The Miniature High Voltage DC Generator emits a fair amount of ozone.If the circuit is to be operated for a long period of time,make sure that we do so in a well ventilated room.Ozone is harmfull in moderate to large quantities.When drawing a spark discharge,the circuit emits radio and television interference (RFI).That can be seen as static lines on uor television set or heard as noise on our AM radio.

4. PICTURES ABOUT THE PROJECT

This application is used for an experimental.The circuit was made properly and being made carefully and insulated.Isolation is very important because if there is any touch that will be hazard.The below shows that on top of the circuit.

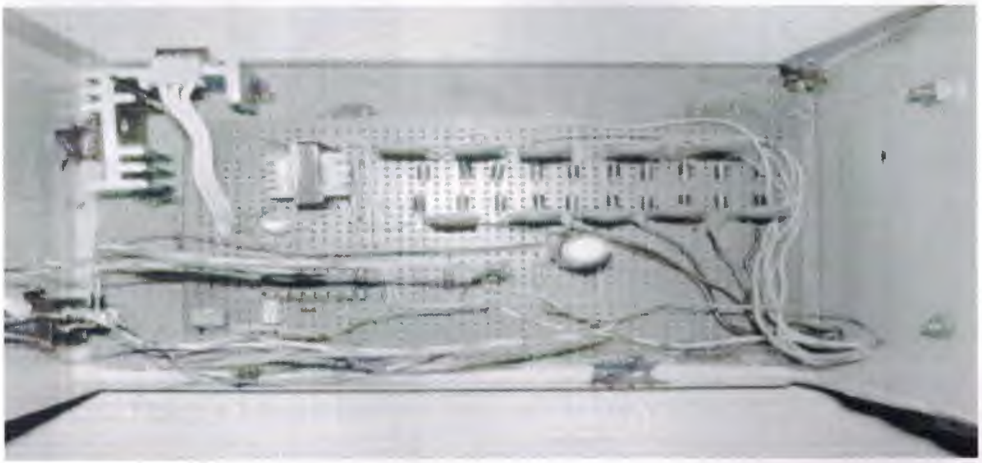

Figure 4.1 Shows top side of my Project

The below Picture is shows that ON and OFF action and input indicator and output indicator.First front of button I put into place the diyote for a reverse polarity.

Figure 4.2 Shows front side of my Project

The below Picture shows that back side of DC Generator.There is connection port and connection board from 1kV untill 10kV and That's made possible by feeding output of power supply.

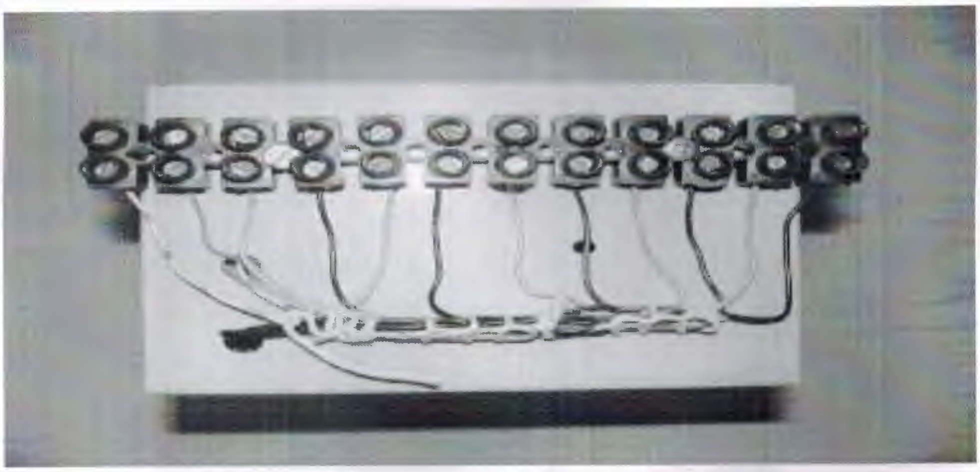

Figure 4.3 Shows back side from 1KV to 10KV of my Project

Tesla coil produced out spark.This experiment is made out of home.Because of arcs,there are dangerous spark affects and hazard for human life.

Figure 4.4 Shows tesla coil's spark moment

The below Picture shows taht impulse generator and used some application

The İmpulse Generator is used some measurements which is sensitive voltage measurement with spark gap.and many applications.

Figure 4.5 Shows that spark of impulse generator

CONCLUSION

The High voltage DC generator was used to experimental pupose in my project. As far as safety goes,high voltage can be considered any voltage that endangers human life.it's obvious that 1000 volts poses a greater hazard than does 100 volts,but that doesn't mean that 100 volts is safe to handle.As far as safety goes,100 is still considered high voltage and that fact must be understood.

That's made possible by feeding the 12 volts output of the power supply to a DC to DC up converter. The output of up converter is then fed into a 10 stage,high voltage multiplier to produce an output of 10.000 volts DC.The high voltage output wire about 1/2 to 1/4 inch from a groud wire,and we will draw a spark of 10.000 volts DC output. The multiplier components must be rated for at least twice the input voltage.The diodes and capacitors used in the multiplier circuit should be rated at 2000 volts DC.

As we saw that the High voltage DC generator is accomplished and we can draw spark 10.000 volts.

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