by Walt Noon

Outfitting Your "Mad" Scientist's Lair!

Graphics by Matthew Roddy

This Halloween is your time to cackle, throw back the curtains, and reveal wild arcs of electricity surging through your house!

Well, unless I miss my guess, that time of year is coming again. The time of year when it's possible to let the real "mad scientist" in you out, and not worry about the neighbors having you committed. A time when you can let your technical skills place you where you really belong; not behind a computer screen or over some smoky perf board, but in the electrical wizard's role!

This year is your time to cackle, throw back the curtains, and reveal wild arcs of electricity surging through your house!

Even though you find yourself in a burned lab coat, even though your hair may be standing on end, and even as you go wild with laughter, with two simple words with which you CAN'T be blamed! Repeat after me: *"Happy Halloween!"*

That's right, it's the perfect excuse to build that wonderful gadget you've always wanted to — a Tesla Coil!

I warn you now, these coils are *dangerous*. Not so much because they produce large electrical arcs in open air (that when properly handled are remarkably safe), but because these devices can be so exciting to build that they can become an **OBSESSION**. You may well be at risk for continuing your mad scientist activities beyond ...

Remember — using your Tesla Coil this Halloween will produce one other type of magic, one that it has for more than 100 years ...

While the parents may jump out of their socks, the children will light up with delight and interest!

You and I can smile knowing that we may have just added some future "mad scientists" to our ranks!

The Tesla Coil

The coil featured in this article is a classic, and a real performer for its size! In fact, though the secondary coil stands at just 12" high and 3" in diameter, it will easily produce 70,000-volt sparks arcing 4" even with a LOW POWER input transformer (such as an automotive coil or equivalent).

You can step the power up considerably with a larger input transformer and produce as much as 250,000 volts! At these voltages, sparks are thick, brilliant, and noisy, and discharges of half a foot are possible. Sparks of this order are suitable for terrifying the staunchest of trick-or-treaters.

When operating, many special effects are possible: The coil will light a florescent light bulb held in your hand with no wires attached! It will drive plasma displays, and cause other florescent or tube lights in the room to flicker.

If you're REALLY of the mad scientist variety, the arc can be taken to a metal object held in an outstretched hand. (This coil is high frequency, and will exhibit the "skin" effect in which the electricity can travel over your skin without shocking you. However, you MUST read the safety tips for doing this later in the article.)

Though you are free to build the coil "as is," I'd like to briefly go over each component and give you some design philosophy. Significant increases in output and efficiency can be had with some thought on your part. And, that's what these coils are all about!

Important Sources

Later in the article, I'll give some sources for parts, and my web address where you can download free design software for altering the dimensions of your coil and even trying out your own designs on screen before building them!

How it Works

There are only five basic components in simple Tesla coil design (see the schematic in Figure 1). These are: the line transformer, capacitor, spark gap, primary, and secondary windings.

You'll notice that in the design we're using there are also a pair of radio frequency chokes and a second spark gap for safety. (The second spark gap is not absolutely necessary for operation, in fact, many coil designers leave it out. However, it can be important for coil longevity. The secondary gap protects your line transformer.)

Most of the components of the coil can be made by hand. I'll give you a brief description of each part, what it does in the circuit, and what options are available.

The Line Transformer

The line transformer boosts the voltage from your wall current to between 2,000 and 10,000 volts depending on the transformer you decide to use (2,000 volts is about as low as you can go and still have a useful spark). Things don't really pick up with this coil until you get to around 6,000 volts on your line transformer.

Many Tesla builders feel that the size of the secondary coil and type of discharge terminal are the keys to a big spark, but even with some of the interesting trade-offs you can make in design, you can't escape the fact that you can't get more out than you put in, so, this is where you can make the biggest difference.

A neon sign transformer rated at 9,000 volts or better and around 30 milliamps is ideal. Neon transformers are nice because they can be dead-shorted without damage, though, transients in a Tesla circuit can still harm them over time. The more power you draw from your neon transformer, the less efficient it becomes. This can cost you a little at the output side as well, and is why some Tesla purists steer away from neon transformers.

People often use oil furnace ignition transformers with similar ratings, and even automotive coil type transformers (see details on this at the end of the article).

The automotive coil is nice because it's cheap and the sparks are safe, yet still impressive and entertaining. I often operate my coil for extended periods of experimentation with an auto coil type set-up. In a darkened room, the blue corona glow and subtle steamers of electricity are beautiful to watch. However — for special effects — your coil's output will be modest if you use an auto coil as compared to a neon transformer.

New neon transformers are relatively expensive, however, by poking around the Internet and Tesla groups (mentioned later), you can find some real bargains. Big Tesla systems use distribution transformers (as seen on your local telephone pole) which produce 17,000 volts or more, but you'll need a whole new design for that!

The Jacob's Ladder!

Before we go on, I should describe a quick stunt with a neon transformer that could be "must-have" equipment for your Halloween's lair.

Figure 2 shows a neon sign transformer. Connected to the transformer are two metal rods angled close together at the base and then slanting apart. (I usually use welding rods.)

This is a classic "Jacob's Ladder" in which a spark will form at the narrow point and rise with a loud crackle to the top and then repeat.

This is a simple, mesmerizing effect. Just make sure your transformer is grounded, and keep people clear of this somewhat dangerous spark. (The metal rods can be placed inside a large plexy tube for safety.)

The High Voltage Capacitor

The high voltage from the line transformer is

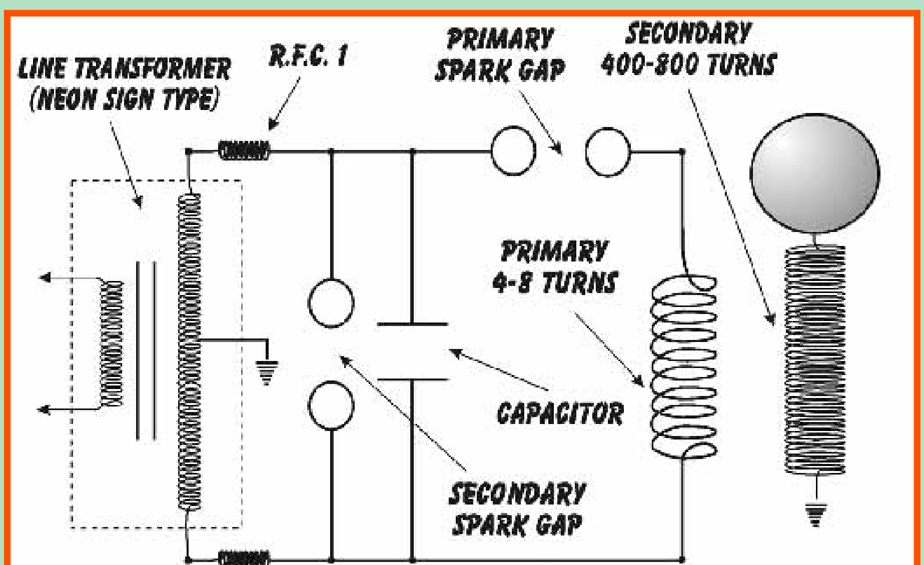


FIGURE 1

needed to supply enough energy to the capacitor so that it can "kick" out pulses at a very high speed (600 kHz is common) and not be depleted. The idea is that as a charge builds up in your capacitor, it eventually becomes large enough to arc across the spark gap.

For this coil, we'll assemble a capacitor rated at .0052 uF and at least 15,000 volts.

Commercial caps of this voltage are the best, but tend to be expensive. So, most builders create their own. See Figure 3A for a simple capacitor plan. (Figure 3B shows an exploded view.)

The capacitor is made by alternating five sheets of .032" polystyrene and four sheets of 10" square metal. Note in the "top view" that each metal plate does not go all the way across the polystyrene.

Copper or aluminum foil can be glued down and used for the plates. I personally use thin sheets of aluminum such as those used to patch the roof.

To keep my capacitor together, I glue it and sandwich it between two pieces of wood mounted under the coil.

Other configurations of this capacitor are possible so that its size and dimensions can be changed to fit your coil's housing. Other homemade high voltage capacitors are also possible using everything from rolled plates in PVC and oil to beer bottles. Handy calculations for all these caps are provided in the free software.

The Spark Gap

The spark gap acts as a high voltage switch (Figure 4). When energy in the capacitor is sufficiently high, it arcs across the gap and supplies power to the Tesla primary winding. This partially depletes the capacitor and thereby quenches itself, restarting the cycle.

The spark gap shown is the simplest, and works well. It's made from two bolts and two rounded screw-on caps. By threading the bolts back and forth, you can adjust the gap. The ideal gap for this coil should be around one millimeter, however, changing the gap will get wildly different results and I encourage you to do so!

The spark gap is a key place where coil efficiency can be improved. The faster the spark is quenched after firing, the better the Tesla secondary will oscillate! (A sloppy spark will cancel out some of the secondary coil's output.)

To quench the spark, many experimenters apply a blast of air from a compressor across the gap to literally blow out the spark. Others use a "multi gap" spark gap by having several points the spark must leap to in crossing the gap(s). I have heard of exotic spark gaps inside of vacuum chambers that increase efficiency by 50%!

I usually just use a gap as shown and it works quite well. Due to the heat and damage that an arc can do to a steel bolt head over time, I often make a trip to the welding store and use Tungsten welding rods instead of steel bolt heads.

The Primary Coil

The primary coil is just a few turns of heavy gauge wire. I like RadioShack's catalog #15-035.

Since this wire is bare, you will be able to tune your coil by sliding a wire along it until a point is found where the coil fires most efficiently.

To get nice even circles, I first wrapped the heavy gauge wire around a cylinder, then removed it and threaded it through the PVC posts seen in the photos.

In the photo, you'll also notice I had 12 turns of wire. This was simply for experimental purposes as I was playing with a wide variety of components. The coil was "tuned" with less than six windings, so I suggest you limit your primary to 6-½ or so windings. The spacing between each winding was approximately 2/16 of an inch.

The Secondary Coil

In my mind, this is where much of the magic happens!

Unlike a conventional transformer, a Tesla coil's output is not only related to the ratio of turns in the primary and secondary windings. In fact, the primary coil acts as a tuned radio transmitter, and the secondary a tuned radio receiver. When the high frequency wave emanating from the primary strikes the secondary — if they are properly in tune — the secondary will begin to oscillate powerfully.

This has been described to be like the effect of a child on a swing. If the child is pushed at just the right moment, the swing will gain in amplitude. If pushed at the wrong time, however, the swing will be deadened. (This is why quenching the gap and good tuning on the primary are so important.)

The secondary coil is simply a long winding of wire (typically 500 turns) wound tightly on a cylindrical form.

PVC is typically used, or very dry cardboard tubing with a few coats of shellac. Actually, the thinner and more electrically inert your form can be, the better. Many Tesla purists have attempted (and some succeeded) to wind a coil and remove the form altogether.

In the Tesla coil shown, I used a very thin butyrate tube from a local plastics store. It consists of 424 windings of #24 enameled wire tightly wound along a tube three inches in diameter and 12 inches long.

The top of the coil will have high energies so, the last few windings at the top are spaced slightly apart and can optionally be covered with a little corona dope. This prevents arcing between coils which can damage your secondary.

To protect the windings, I gave the coil several thick coats of epoxy, rotating it while the epoxy cured for an even finish. Shellac or varnish can also be used.

Odds and Ends

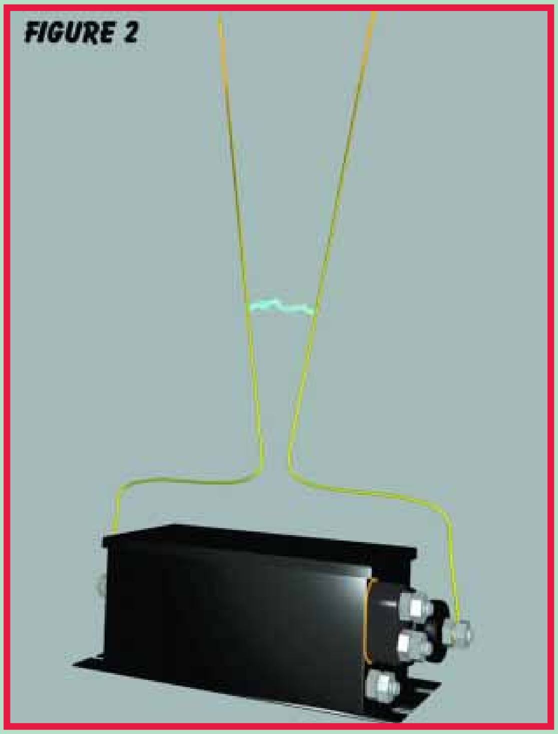
For a top discharge terminal, I used a smooth brass doorknob. All rough edges were coated with corona dope. An optimal discharge terminal should be at least the same diameter as your secondary coil, so I fell a little short here, but it worked well. Using a torroid-shaped top terminal instead of a sphere can make a dramatic improvement, as well. For the radio frequency chokes, I simply used 21 turns of #18 enameled wire on a common 1-½ inch diameter PVC tube.

Final Assembly

Assembly is straightforward from the schematic in Figure 1, and components are placed as shown in Figure 5. I used simple PVC pipes with end caps, and screwed the end caps to the board. This included the Tesla secondary coil for which I found a three-inch end cap to seat it in

The primary coil should have at least 2-½ inches of spacing between it and the secondary coil all the way around. Electrical strikes from the primary to the secondary can damage a coil over time. A ground rod should be attached to allow sparks to have a place to fly. It can be connected

FIGURE 2



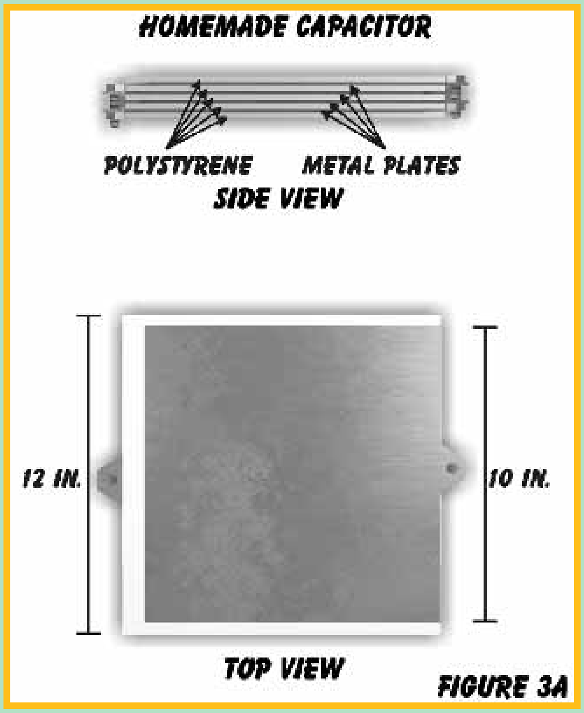


FIGURE 3A

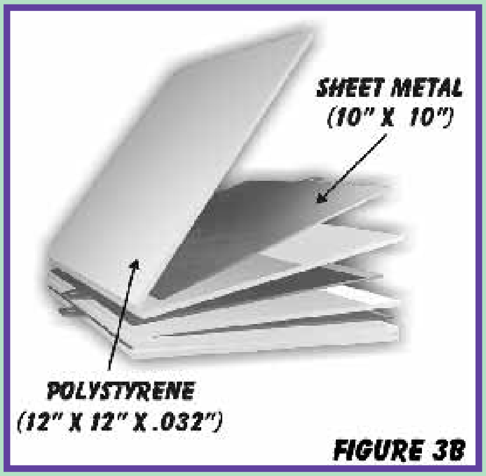


FIGURE 3B

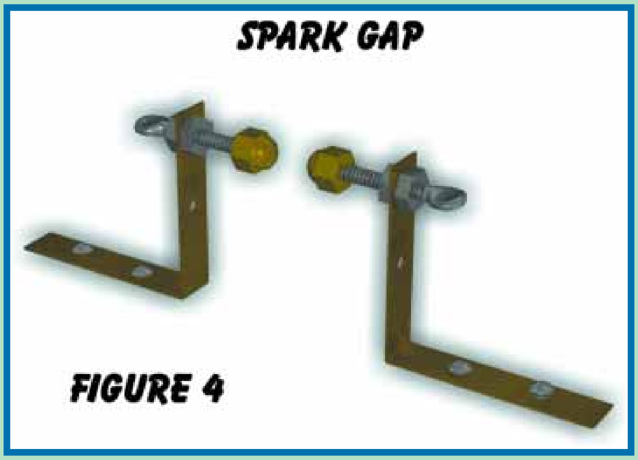


FIGURE 4

wires attached to your primary coil should be movable. Often an alligator clip is used. Attach this wire about 5-½ turns away from the other wire attached to your primary. Briefly run the coil and observe the spark length and character.

By moving this wire along your primary coil, you'll find a sweet spot where "spark" is at a maximum. This — and playing with spark gap distance — is all that is required to get the effect you want.

Tip: In the schematic, the bottom of the secondary coil is shown grounded. You can increase spark length by instead attaching this wire to the wire connecting RFC 2 and the primary. However, this makes the spark *dangerous*.

Let the Experiments Begin!

The stunts that can be pulled with your Tesla coil are endless. The simplest and most fun for this Halloween might be to hold a florescent tube in your hand and have it light with no wires when passed near the coil which is blasting away! You can create a stunning "electric chair" with sparks flying from the coil behind you while your victim's scream!

If you are using a low input coil like an auto coil or equivalent driver, sparks of four inches can be taken to the hand painlessly! Remember that you should have metal thimbles on your fingers or be holding some metal object since the sparks themselves can be warm.

Remember good electrical practice when doing any high power work. Tesla wore thick rubber sole shoes, and kept one hand in his pocket!

If you get the Tesla bug, many serious and bizarre experiments are possible from wireless power transmission, to passing a million volts safely through a person! I have even read accounts of temporarily, painlessly scrambling a person's nervous system.

If you visit the web page soon, I'll set up a mailing list for *Nuts & Volts* readers to keep you informed of upcoming Tesla events.

So, let's get winding our coils, and give our neighborhood friends a REAL shock this Halloween! **NV**

to the wire leading from RFC 2 to the primary. It can be bent in, to around four inches from the top discharge terminal.

If using a neon transformer, it is very good electrical practice to run your neon transformer from a variac (one rated at five amps would suffice) so that you can do low voltage testing, and control the output of your coil. A variac is simply a variable transformer that connects between the wall and your transformer and allows you to control power output. Several *Nuts & Volts* vendors advertise them, or look around the net to pick one up for less than $50.00.

Firing it up!

Now the fun begins! Your coil is complete except for tuning, which is easy to do. One of the

My address is:
walt@noonco.com
The web address for free Tesla software and info from me will be:
http://www.noonco.com/tesla

For construction of the article, I have available:

- **Precut polystyrene, $1.25 per sheet.**
- **A "Wire Kit" which includes all the wires needed, including the wire for the primary, the secondary, and the RFC chokes for $25.00.**
- **I also have a few of the "auto coil" line transformers for $34.00 *while they last.***

For those who don't have access to the web, I'll be happy to send out a sheet of sources with more Tesla info and experiments to anyone who writes by E-Mail.

FREE CATALOGS/FURTHER TESLA INFO SOURCES

TCBA NEWS is a practical newsletter on homemade coils published quarterly by Harry Goldman, 3 Amy Lane, Queensbury, NY 12804.

Lindsay Books, Inc., has many Tesla and unusual electrical reprints. Write to P.O. Box 538, Bradley, IL 60915.

International Tesla Society, P.O. Box 636, Colorado Springs, CO 80931.

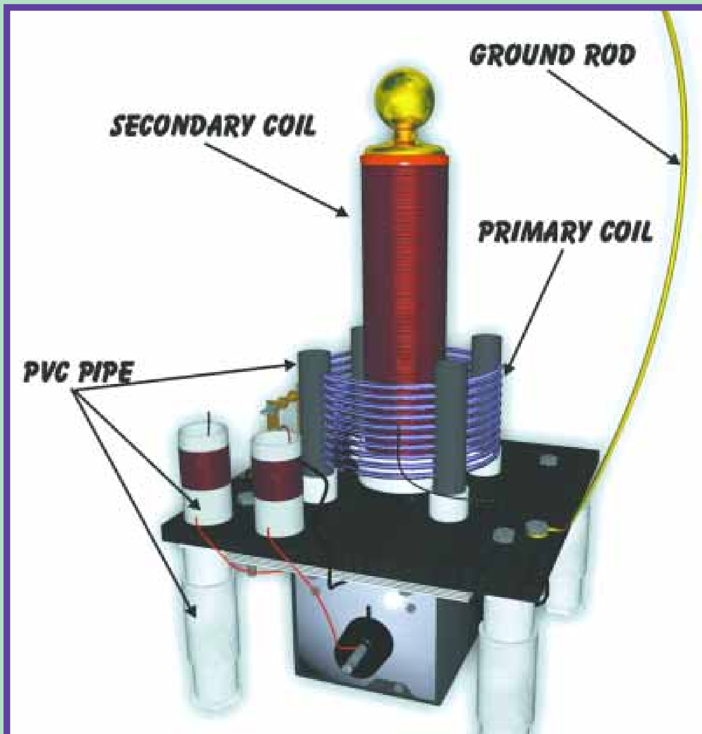


FIGURE 5

