Flyback Power Supply for Plasma Globe

Warning: This project involves High Voltage High Frequency Power. It is inherently dangerous and should be undertaken only by qualified individuals. By reading this document and undertaking this project, the reader accepts the risks and hazards associated with this project and frees the writer from any liability for damages or injuries resulting from use of this information.

This project is a power supply for a plasma globe. It can be built from parts in your basement, a broken TV set, and a few items from Allied Electronics and/or other sources.

Plasma is the lesser known 4th state of matter. Many educators still teach only the well known 3 states of matter. Interestingly, plasma comprises more than 99% of all matter in the universe (Stars are an example of plasma). Plasma is created when a gas is ionized. This project will ionize a noble gas at low pressure inside a sealed glass globe using high voltage and high frequency electricity.

Pictures and a movie of the finished product in operation are attached. The pictures were taken in absolute darkness to make the colors standout.

Basic construction of the device is a Flyback Transformer with (3) coils – Primary, Feedback, and Secondary. The Primary and Feedback consist of a minimal number of turns. The Secondary is a couple of thousand turns of #36 AWG wire. This device acts like an inductor not a transformer. The Flyback is wired so that the Feedback winding fires the gate of a transistor which turns the Primary winding off and induces current in the Secondary winding.

The combination of the Secondary winding and the plasma globe form an LC circuit that operates at its resonant frequency (Secondary winding the Inductor "L" and Plasma Globe the Capacitor "C"). In our case this frequency will be around 20 – 30 kHz. As previously mentioned, the device does not act like a transformer. If it did then the voltage step up would only be the ratio of the number of Secondary turns to the primary turns. In fact, because the circuit operates at resonance, the voltage gain is much greater and voltages of 8 to 10 kV are readily attained. The frequency is proportional to the inverse of the square root of the Secondary Inductance multiplied by the Plasma Globe capacitance. If you try to get more voltage by adding turns to the secondary, you will increase the secondary inductance (inductance is proportional to the square of the number of turns) and decrease the frequency. It is the combination of the high frequency AND high voltage that makes a spectacular plasma display, thus added turns will not be beneficial.

The schematic shows how to wire the simple circuit. The work is in the flyback. Remove a flyback out of a broken TV. Be careful to discharge any capacitors to avoid electric shock. Carefully remove the Ferrite Inductor Core halves from the flyback. It will consist of (2) U-Core halves with a thin plastic spacer in between. Try not to loose the spacers. They set the Core gap. Sometimes a metal clip holds the Cores together. Keep that also. Many times the Cores have glue holding them together and to the plastic flyback housing. Carefully scrape the glue away to separate the components. Be careful and take your time, the inductors will break easily. If you are lucky and find an old TV (pre 1968) you can likely use the secondary from the flyback. Newer TV's use a sealed epoxy flyback in a plastic housing. This may be discarded as it is of little use. Do cut and save the high voltage lead from it as you will need that.

Constructing the coil.

Two coil forms need to be made. An inner for the primary and feedback windings, and an outer for the secondary. The outer must be large enough to slide over the inner with its windings in place.

Find a dowel or round bar approximately the diameter of the Ferrite U-Core. Wrap it with tape if necessary to make its outside diameter just larger than the leg of the Ferrite U-Core where the coil will be placed. Wrap the dowel with a turn or two of wax paper and hold in place with tape. Get some brown paper (from grocery store bags) or very thin flexible cardboard (like that currently used inside some wrapping paper rolls). Cut a strip of brown paper that is nearly as wide as the height of the core. Cut its length so that it will wrap around the dowel about 4 times (If you use the thin cardboard 2 times may be sufficient). Apply a coating of 1 minute epoxy on the back of the brown paper (do not coat the first turn which will be in contact with the wax paper. Wrap the paper around the dowel on top of the wax paper and pull tight. Hold in place with masking tape and let it set. After it has set, pull it off the dowel, pull out the wax paper and trim the ends with a knife until it fits the U-Core. Cutting semi-circles for the top and bottom core sections makes it fit nicely. Now wrap 4 turns of #18 gauge enameled magnet wire on the coil form for the primary winding. Place the center of the turns directly over the core gap so that half the turns are on the upper core and half on the lower. Wrap 2 turns of #22 gauge enameled magnet wire on the coil form for the feedback winding. Put the feedback above or below the primary on the form. Hold the wire in place with electrical tape. You can salvage this wire from inductors and transformers in the old TV set. Take care in feeding the leads out vertically from the windings so that the secondary coil form can easily slide over. Identify the leads to avoid confusion later. It will simplify things if you wind the primary and feedback in the same direction.

Now you are ready to construct the secondary. Find another larger dowel so that you can construct a coil form that is large enough on the inside diameter to slide over the inner coils. Make a form as before with brown paper. You are going to wind about 1500 to 2000 turns of #36 gauge enameled magnet wire on this coil form to make the secondary. It will need to be done in layers. More narrow layers is better than a few wide layers. Wide layers result in a high voltage difference between the first turn of a given layer and the last turn of the layer above it. This can lead to breakdown of the insulation and failure of the coil. Unfortunately, a large number of layers will bring the secondary too close to the other side of the U-core and cause arcing from the secondary to the U-Core. Thus a balance must be struck between the too variables. Each layer will be coated with epoxy and allowed to set. Then a single wrap with slight overlap of epoxy coated brown paper will be placed over the layer to create a good surface for winding the next layer. Following this procedure each layer will be approximately .040" thick on the diameter (.020" on the radius). Thus, you can compute the maximum possible layers staying at least ¼" away (for small cores, more for big cores) from the opposite U-core leg. The #36 wire will lay down 175 turns per inch. Thus, if you wind the coil with a 1" height it will take 11-1/2 layers to get 2000 turns. To wind the coil, construct a hand crank from wood and wooden dowels that will slide in a piece of pvc pipe. Mount the pvc pipe in a vice and you have a simple coil winding device. Mount the coil form to the crank. Place the spool of wire on a dowel parallel with the coil form and start winding. Hold the wire at the starting point in place with tape. Use you thumb and fingernail to guide the wire into place with one hand as you wind the coil with the other. Lay the wire down neatly with one turn immediately adjacent to the next. Try to avoid overlaps. Do not put the spool on bearings and allow it to spin freely as it provides the tension to keep the coil tight by the friction of it sliding on its dowel as it turns. Be careful to maintain tension at all times or the coil will start to unravel and over-wrap. Until your technique is mastered, you may want to use small pieces of tape to hold sections of the coil in place as you complete them. At the end of a layer, hold the entire layer in place with a single piece of tape on the last few turns of the layer. Then coat the layer with a thin layer of epoxy and let it set. Cover this with a layer of brown paper (coated on the inside with epoxy) as previously discussed. The wire can pass through the brown paper overlap. Be careful to keep excess epoxy from getting on the outside of the brown paper layer as it will interfere with winding the next layer. Note that if the first layer was wound right to left, then the second layer will be wound from left to right, etc. When the last layer is complete coat with epoxy. The epoxy is insulation, any air gaps in the epoxy will result in corona forming during operation and eventual breakdown and failure. Great care during the construction phase will be rewarded later. Once you develop the technique, each layer can be put down in about 10 minutes.

When complete, assemble the coils onto the U-core and wire per the schematic. Attach/solder the salvaged high voltage wire to the wire from the last turn of the secondary and attach the wire from the first turn to ground. For testing connect the HV lead to a 4" or 6" diameter 60W (no smaller) decorator light bulb (It does not need to be a working bulb). Take care to maintain the orientation between the primary and feedback wiring (ie If you wound them in the same direction then the top of the primary goes to the collector and the top of the feedback goes to the base).

Apply power and move your hand around the periphery of the bulb to observe the plasma fingers jump from the electrode to the glass. Avoid holding your hand in a particular location for more than a moment as the plasma can burn through the glass (The local temperature of the plasma exceeds 10,000 Deg F). Keep your hands away from the base of the bulb, the secondary, and the HV lead or you will get a shock. The typical coil/core will produce about 8 to 10 KV at 25 kHz and 500uA. At this voltage and frequency there is no such thing as an insulator. Everything is a conductor. You can also be shocked on the primary and feedback side as noise from the resonant circuit is reflected.

The 12" plasma globe from my project was obtained from a surplus store, is filled with a mixture of Neon, Xenon, and Krypton gases, and is pumped down to about 400 mm water vacuum.

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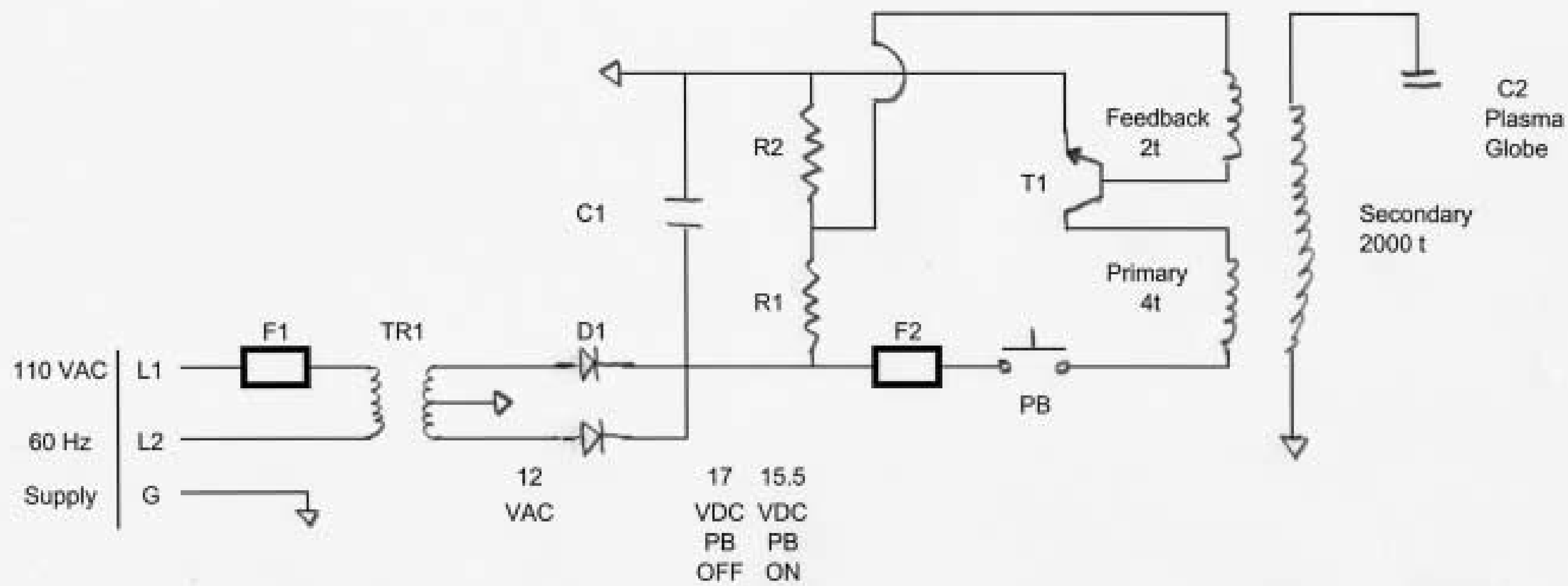
References:

Sam Barro's website Powerlabs.com

Flyback Power Supply Schematic



Flyback Power Supply Parts List

ID	Qty	Part#	Description
F1	1		Fuse 0.5 mA
TR1	1	Allied #836-6190	Transformer 115/60/1 prim - 24Vct sec 2A Hammond #166L24
D1	2	Allied #568-0141	Diode # 1N4001 ON Semiconductor
C1	1	Allied #857-0125	Capacitor 47000 uF 25Vdc Cornell Dubiler #CGS473U025V4C
F2	1		Fuse 4 Amp
PB	1	Allied #814-0001	Push Button-Momentary-Normally Open Idec #ABD110N-R
R1	1	Allied #296-0848	Resistor 560 Ohm 2 Watt
R2	1	Allied #296-0828	Resistor 27 Ohm 1 Watt
T1	1	Allied #568-7389	Transistor NPN 2N3055 TO-3 60V 15 A On Semiconductor
for T1	1	Newark #58F480	Heat Sink #623A Wakefield Engineering
for T1	1	Allied 619-1005	Kapton Insualtor for TO-3
for T1	1	Allied #796-2470	Thermal Compound GC Electronics
for T1	2		#6-32 x 1" lg nylon machine screw & nylon nut
C2	1		4" or 6" dia decorator lite bulb & base minimum 60 Watt
Coil	1	Allied #214-3598	#36 AWG Enameled Magnet Wire Belden #8058
Coil	1		Epoxy 1 minute setting time
Coil	1		Old TV Set
Coil	1		Brown Paper Bag