Tesla Plasma Speaker Project

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1 Introduction

I bought my "Geekcreit® DIY Mini Tesla Coil Module Unassembled 15W DC 15-24V 2A Plasma Speaker Electronic Kit" as a fun project. A bit of a disadvantage are the all-Chinese instructions. So I decided to document my progress so that others could, maybe, profit from that.

Figure 1: Mini Tesla Coil Module promotional picture

2 List of components

Item	Description	value	Amount		Item	Description	Value	Amount
R1 R4	Resistor	10K	2		C1	Capacitor (pol)	1 μF	1
R3 R5	Resistor	2K	2		C2	Capacitor	1 μF	1
Q1	MOSFET N-chan	IRF530	1		Q2	Transistor NPN	TIP41	1
LED	red LED	3 mm	2		L1	red wire for coil	50 cm	1
L2	Coil 350 Turns	827 μH	1		J1	Power Socket	5 x 2.1mm	1
J2	Audio socket	3.5 mm	1		–	Bolts	M3 x 6	6
–	Hex nuts (legs)	M3 x 10	4		–	Heatsink	25 x 23	2
–	Neon bulb	(test)	1		PCB	printed circuit board	75 x 40mm	1

3 Assembly of the components

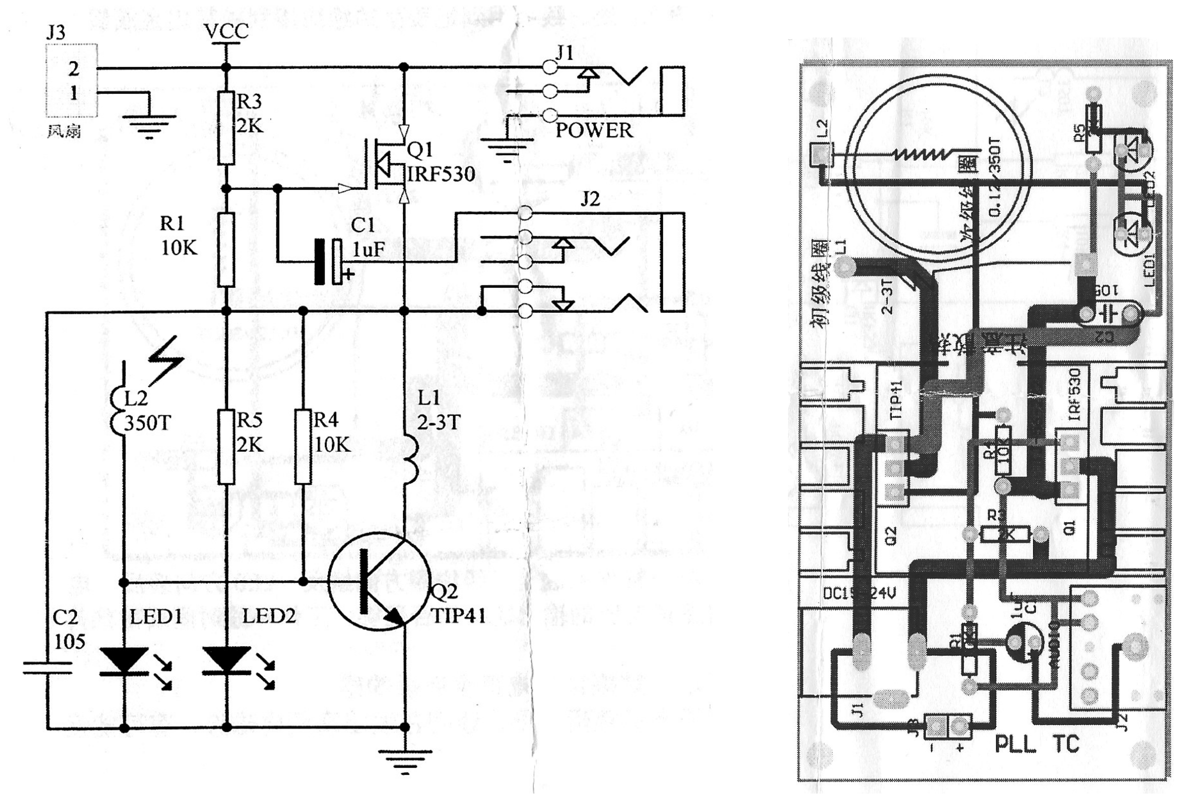
As you may have guessed, I do not read Chinese (yet). So for me the documentation consists of the schematic diagram, Figure 2a and a picture of the printed circuit board (PCB), Figure 2b.

The assembly of the PCB is pretty straightforward. Note the codes on the resistors are:

- 2 KΩ: red black black brown + a tolerance ring brown (1%);
- 10 KΩ: brown black black red + a tolerance ring brown.

If in doubt, use an Ohm-meter.

Start with the small components, the resistors, capacitors, the two light emitting diodes (LEDs). Mount them on the side of the PCB with the texts.



(a) The schematic diagram

(b) The PCB lay-out

Figure 2: Pictures in the Chinese manual

The components are clearly marked on the PCB. As far as ***polarity*** is concerned, the electrolytic capacitor, $C_1 = 1\ \mu$F, is marked on the minus side (light strip with – on it). Note the flat edges on the LEDs as marked on the PCB.

The second capacitor, $C_2 = 1\ \mu$F, is a yellow ceramic multilayer version is then soldered in place next to the location where the secondary coil will come.

Mount the MOSFET, IRF530 (Q1) and the transistor, TIP41 (Q2), to the aluminum heatsinks using two of the M3 bolts. The mounting pins should stick out below the heatsinks about 8 mm. If not, turn them 180°.

Then solder them in the correct locations marked on the PCB. Compare the labels with those on the transistor/MOSFET. Mount the four brass feet (long hex nuts) with the remaining four M3 bolts.

The large tubular secondary coil (L2): can be mounted using hot glue. Hold the coil in place and drop a liberal amount (0.5 cm^3) of hot glue down the center hole. Then move the coil bottom a little while the glue is still fluid, to make shure it touches the coil and the PCB. Then wait until it cools down. Only then solder the fragile bottom wire to the solder hole. The inductance of the coil measures $L_2 \approx 830$ μH.

The winding of the primary coil, L1 (2-3 Turns), is critical in the sense that the direction of winding is important. The picture in Figure 1 is correct. Start from the L1 solder hole near the location of C2, the yellow ceramic capacitor and the two LEDs. Seen from the top of the secondary coil, L2, now wind L1 CLOCKWISE around the secondary, L2. I used a short length of sanitary plastic pipe with a diameter of 32 mm to keep L1 separated from L2. You can mount it to the PCB with hot glue. But you need to leave enough space to be able to reach the soldering islands for L1. Either file some spacings in the pipe or you could use a short length of the pipe, e.g. 1 cm, and center it around L2 with the hot glue. I used two small cable ties to mount coil L1 in place as can be seen in Figure 3.

O.K. you notice the difference with the model shown in Figure 1. I mounted a small round metal box on top of the secondary coil, L2.

The type of box used for lip-balm or small peppermints. I did that because:

- It looks better compared to larger Tesla coils e.g. as on https://en.wikipedia.org/wiki/Tesla_coil;
- The wire at the top of L2 is as fragile as the one on the bottom. This metal box is more sturdy;
- The box will not affect the operation of the coil as this design is self-oscillating[1] and will find its own (resonant) operating frequency (see theory in Section 5.

Make a small hole (1 mm O.K.) near the edge in the bottom of the metal box. The tiny top wire of L2 will be soldered there later (on the inside of the box. First mount the box on top of L2 with hot glue. Take the lid off and put the end of the top L2 wire through the hole. lead it along the metal on the outside and cover with some hot glue. Connect the wire inside the box through a 1 mm hole in the bottom of the box. Then make another hole in the top-lid of the box and solder a small length of left over wire e.g. of C2 or one of the LEDs, on the inside so it will stick out like a needle (see Figure 3).

This completes the assembly.

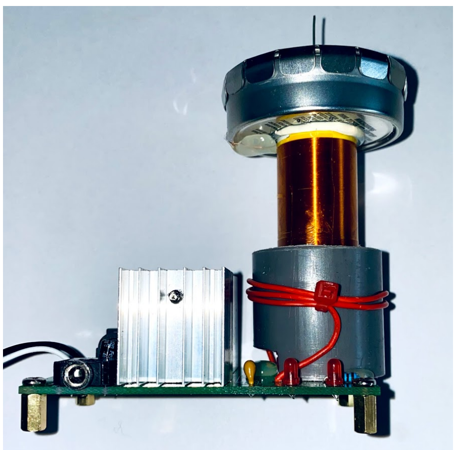


Figure 3: The finished Tesla coil/plasma speaker

[1] Well, it will increase the capacitance across L2 and hence reduce the resonant frequency. A higher capacitance will require a little more energy to reach a high voltage. See the theory in Section 5

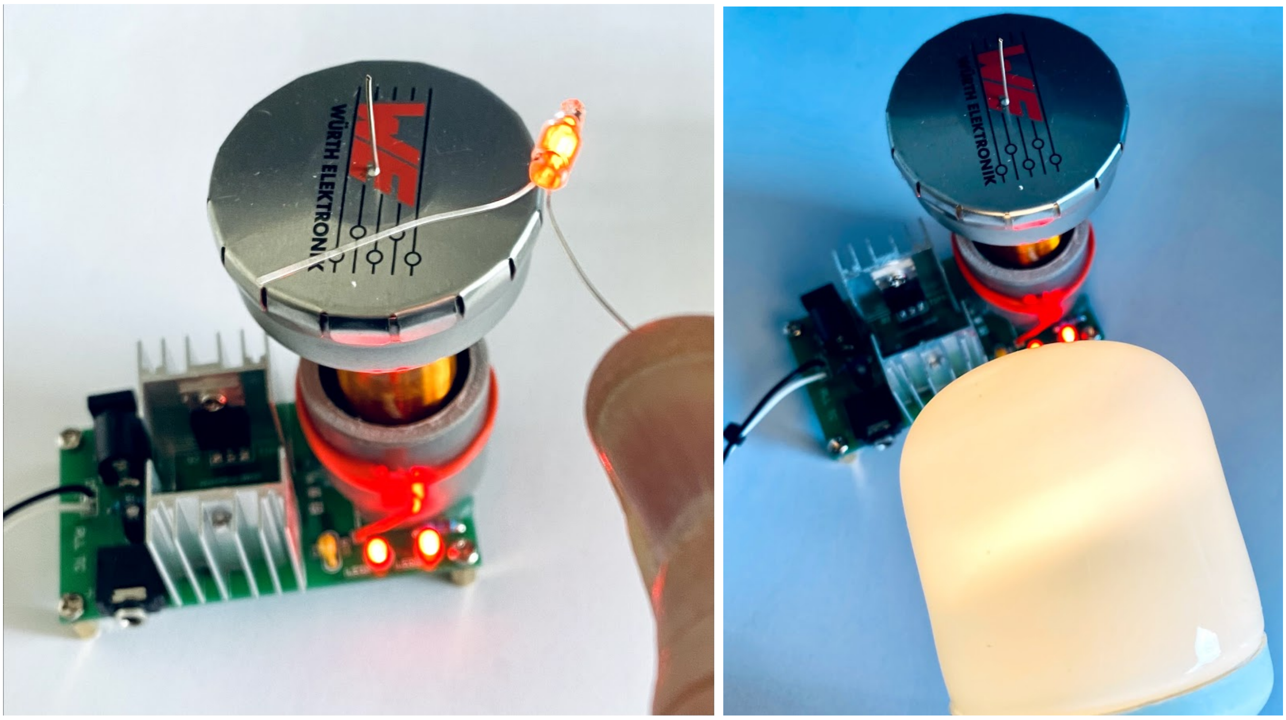
4 Setting to work the finished Plasma Speaker

Find a suitable power supply. An old laptop supply will work (usually 19 V). The connector may not fit the 5/2.1 mm power socket. Then replace the plug or use the actual wires and solder them to the PCB.

I used an adjustable laboratory supply and provided the Tesla coil PCB with two wires with banana plugs. The PCB has two soldering lugs near the power socket marked + and –.

If you connect the power supply, the machine should start working. Both LEDs should be lit. If only LED2 is on, you may have made a mistake with the coil L1 winding direction. If both LEDs are on, electronic equipment nearby may start to act weirdly. In my case, my computer monitor switched itself off and then on again. A sign of large electric fields in the neighborhood.

Now, find the small neon-bulb in the component bag and hold it in your hand near the metal box on top of L2, the "business end" of the plasma speaker. The bulb will light (no need to touch the metal box or wire). The effect is shown in Figure 4a. Or you could hold a compact fluorescent lamp (CFL) bulb near the metal box as shown in Figure 4b. The device draws about 0.7 A from the 24 V supply for these experiments.



(a) Using the included neon-bulb (b) Using a CFL bulb

Figure 4: The finished Tesla module working

5 Theory behind the Tesla coil

As mentioned in Section 3, the 350 turn secondary coil measures $L_2 \approx 830\ \mu$H. Given the measured $F_{OSC} = 3.3$ MHz, the equivalent capacitor, $C_{RES} = 2.8$ pF, in parallel to this secondary as calculated in Equation 1.

$$F_{OSC} = \frac{1}{2\pi\sqrt{L_2 C_{RES}}} = 3.3 \qquad \text{MHz}$$

$$C_{RES} = \frac{1}{(2\pi F_{RES})^2 L_2} = 2.8\ \text{pF} \qquad (1)$$

The basic circuit for the Tesla coil without the the audio option is shown e.g. at https://theorycircuit.com/mini-tesla-coil-circuit/ or at https://chinese-electronics-products-tested.blogspot.com/p/tesla-generator-kit-tested.html. The latter is the analysis of another Banggood product https://www.banggood.com/nl/DIY-Tesla-Coil-Module-Kit-Ion-Windmill-Tesla-Coil-ZVS-Technology-Physical-Electronics-Production-Parts-p-1578322.html?rmmds=detail-left-hotproducts&cur_warehouse=CN. The circuit diagram shown there looks like our diagram in Figure 2a after Q1 is replaced by a wire. I did that in my version after the IRF530 died of over-heating. The diode D1 on the website is our LED1.

This analysis shows that if you do not need the audio in the kit of Figure 1, you could short out the MOSFET by connecting its drain and source (the two wide [2 mm] traces). If you do this, the power supply should probably not be set higher than 15 V. Check the current drain.

The original Nikola Tesla coil also had a primary tuned circuit. In the last days of the nineteenth century there were no semiconductors. A mains transformer was used to obtain a fairly high voltage. This high voltage (at the mains frequency) was shunted by a spark gap and a series connection of a capacitor and the primary winding. As soon as the spark gap fired, the capacitor, charged to the spark gap voltage, and the primary coil together would produce a ringing wave. The field created by this primary resonator would excite the secondary circuit consisting of the secondary coil and the (parasitic) capacitance across it. The original Tesla coil would work only if the primary and secondary resonances would be the same. The early version of the Tesla coil is shown in [1, page 8].

Another interesting description of a smaller spark-gap model can be found in [2]. The current Banggood product, Figure 2a, actually feeds back the secondary coil current into the power transistor to create a self-oscillating design which makes sure the primary coil is excited at the resonant frequency of the primary. This simple circuit is not suited to drive high powered Tesla coils as the one described in [1] directly. One last hint: as described in [2, Section3.3.5, page 22-23], the coils L1 and L2 should not be coupled to tightly. After I pushed down the turns of L1 all the way to the bottom of L2, my sparks were twice as long! See Figure 5.

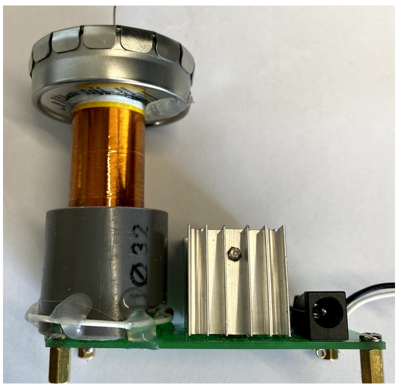


Figure 5: Lowered L1 winding reduces coupling, increases sparklength

References

[1] M. Denicolai, “Tesla transfromer for experimentation and research”, Ph.D. dissertation, Helsinki University of Technology, May 2001. [Online]. Available: http://www.saunalahti.fi/dncmrc1/lthesis.pdf.

[2] C. Gerekos, “The tesla coil”, M.S. thesis, Université Libre de Bruxelles, 2012. [Online]. Available: http://www.teslacoildesign.com/docs/TheTeslaCoil-Gerekos.pdf.