Simple low power Tesla coil

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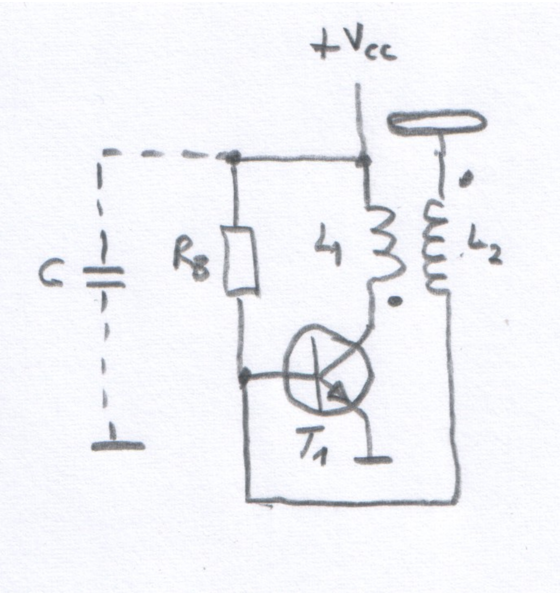
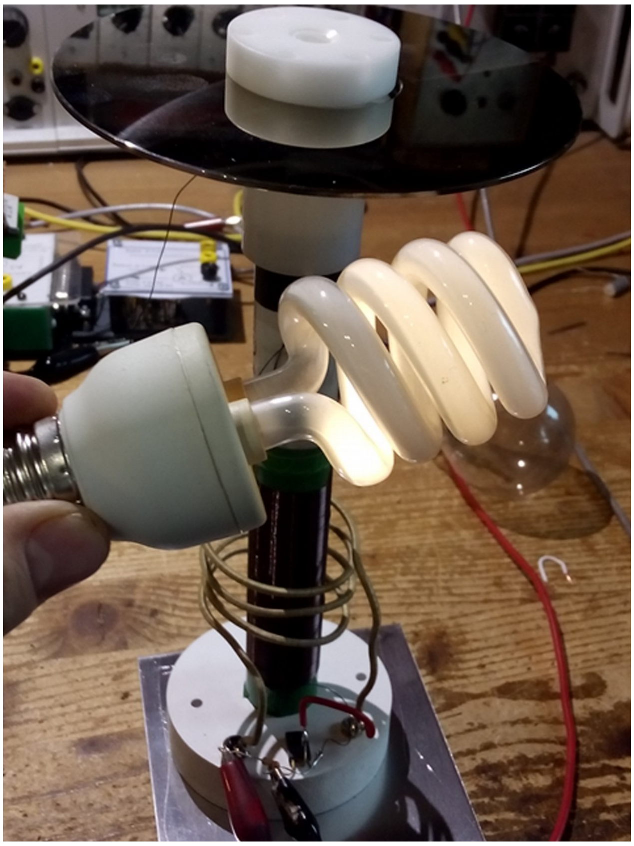
These days, one of the kids in our makerspace came up with the idea to build a Tesla coil.
We found a circuit that was simple enough for him and not dangerous.

The circuit



T1 = BD139 or similar
RB = 22KΩ
L1 = 3 windings 1mm CuL, D=5cm
L2 = 250 windings 0.3mm CuL D = 25mm
Vcc = 9...15V
C = 0.25µF (may be omitted)
Secondary plate made of hard disk plates, or simply aluminium foil



This circuit or a similar is found on Internet, and it works! (as seen in the photo above).
It produces no sparks, or only very small ones, but it can light up a fluorescent bulb (note that it works also with defectuous ones).

The function

Though the circuit could not be more simple, it‘s function is not so easy to explain.

There are two resonant LC circuits with a week coupling through the air.
A transistor amplifier compensates the losses that every resonant circuit has.
By positive feedback the circuit works as an oscillator. (The polarity of the coils is important to

have positive instead of negative feedback. If the circuit doesn‘t work, try to reverse polarity of the primary coil.)

The secondary coil has a terminator that works as a capacitor C2 (of only a few picofarads) to ground. So we have a secondary resonance at $f_2 = \frac{1}{2\pi\sqrt{L_2 C_2}}$

The primary coil L1 is obvious to see, but where is the corresponding capacitor C1 ?
There is no physical component in the circuit, so there are only two possibilities: either there is no C1 and the primary circuit is non resonant. In this case the power of the Tesla coil might be increased by providing a physical capacitor C1. Or C1 is invisible and provided by a component. A candidate for this might be the transistor T1.

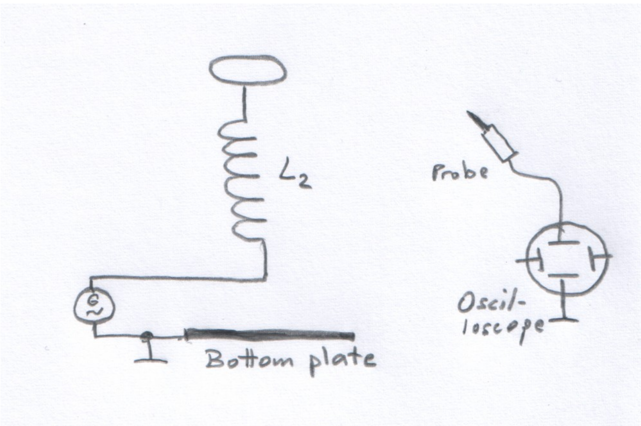
Every PN junction has a capacity, so have the junctions BE and BC of the transistor.

The exact description is complicated, as these capacities also vary with the applyed voltage.

To have an idea, I had a look at the SPICE model of the BD139 (see appendix). This model has capacities of about 10pF, which is a really small value.

All this means that the primary coil seems to work far out of resonance, as L and C have very small values. If this is true, the circuit could be optimized by adding a primary capacitor.

Measuring the secondary resonance



Günther Wahl proposes a method where a sine wave generator is connected between the bottom terminal of the coil and the bottom plate.

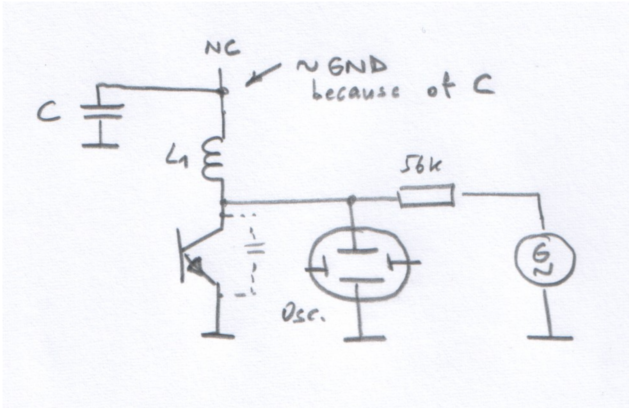
An oscilloscope probe is fixed in some distance to the upper terminal (20cm...1m).

As the frequency is swept, there is a clear resonance seen by an acreasing of the amplitude on the oscilloscope.

My circuit showed this resonance at 2.9MHz, a rather high value for a Tesla coil.

The resonance frequency displays a strong „hand effect“. This means that it changes very much when approaching a hand or other conducting things. This is due to the very small terminal capacity that is strongly changed by other conductors in the neighbourhood.

Measuring the primary resonance



The circuit is without supply voltage, but the transistor is included to include its parasitic capacities (though they may change with applied voltage!).
The upper terminal of the coil is set to AC ground by the capacitor C.

The secondary coil is present, but it‘s lower terminal is disconnected.

I measured a resonance at 18.6MHz.

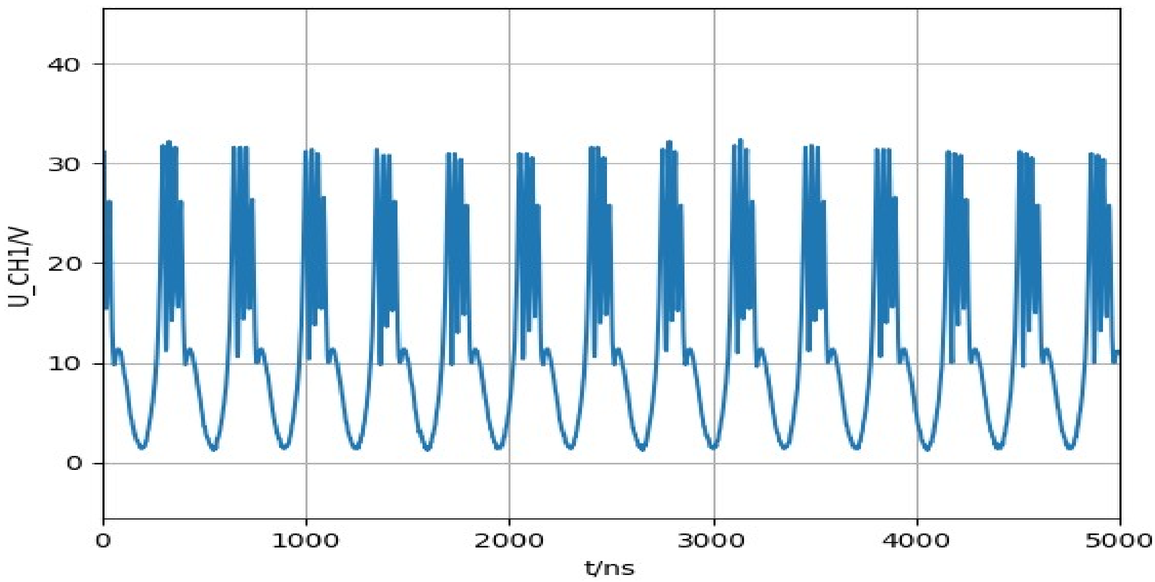
This means that the primary resonance is much higher than the secondary one.
So, it seems that it would be good to add an extra capacitor on the primary side to get the same resonance frequency for both LC circuits.

Measures for the original circuit

At 12V supply the circuit draws a current of about 100mA, this means a consumption of about 1.2W.

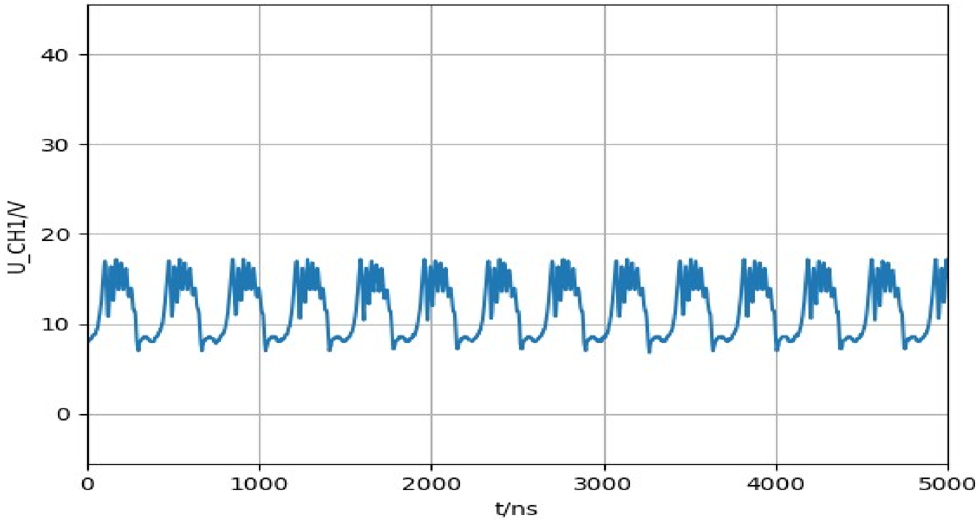
An oscilloscope probe in the neighbourhood (that means very loosely coupled) catches a 2.9MHz signal, this is the resonance frequency of the secondary winding.

By measuring directly the collector-emitter voltage (with a 10:1 probe) I got this:



The bigger peaks correspond to the 2.9MHz frequency, but there are strong harmonics at a higher frequency, namely 32.4MHz, of uncertain origin.

When lighting a fluorescent tube, the amplitude is considerably damped:



Improvements?

I tested some capacitors in the range 100pF … 4.7nF in parallel to the primary winding.
Astonishingly, with none of them there was a significantly better function.
On the contrary the amplitude was somewhat lower and a fluorescent bulb had more difficulty to ignit.

So it seems that this simple circuit works better with just one resonant circuit, in contrast to Tesla‘s two coupled LC circuits.

Appendix

SPICE Model BD139

```
element component template bd139 c b e
#**************************************
#     Model Generated by MODPEX     *
#Copyright(c) Symmetry Design Systems*
#        All Rights Reserved        *
#   UNPUBLISHED LICENSED SOFTWARE   *
#   Contains Proprietary Information *
#     Which is The Property of      *
#    SYMMETRY OR ITS LICENSORS      *
#   Modeling services provided by   *
# Interface Technologies www.i-t.com *
#**************************************
# MODPEX model for BJT transistor bd139
# Model generated on Feb 14, 2004
electrical c,b,e
{
# BODY_BEGIN
# Model format: Saber
spq..model qqbd139=(type=_n,
is=1e-09,bf=222.664,nf=0.85,vaf=36.4079,
ikf=0.166126,ise=5.03418e-09,ne=1.45313,br=1.35467,
nr=1.33751,var=142.931,ikr=1.66126,isc=5.02557e-09,
nc=3.10227,rb=26.9143,irb=0.1,rbm=0.1,
re=0.000472454,rc=1.04109,xtb=0.727762,xti=1.04311,
eg=1.05,cje=1e-11,vje=0.75,mje=0.33,
tf=1e-09,xtf=1,vtf=10,itf=0.01,
cjc=1e-11,vjc=0.75,mjc=0.33,xcjc=0.9,
fc=0.5,cjs=0,vjs=0.75,mjs=0.5,
tr=1e-07,ptf=0,kf=0,af=1)
spq.q c b e e=model=qqbd139
}
```