Free Energy Research Basics

or

what every FE researcher need to know

Revision 1

FE R&D group http://groups.yahoo.com/neo/groups/ferd041/info

2014

Chapter 1. Power measurements

***Hello**,*

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I am starting a series of posts about FE research basics.

As a start topic, let’s consider some typical mistakes when power
measurements performed.

Here an example of message from overunity.com (it is from 2007 but you still
can occasionally re-posted by somebody).
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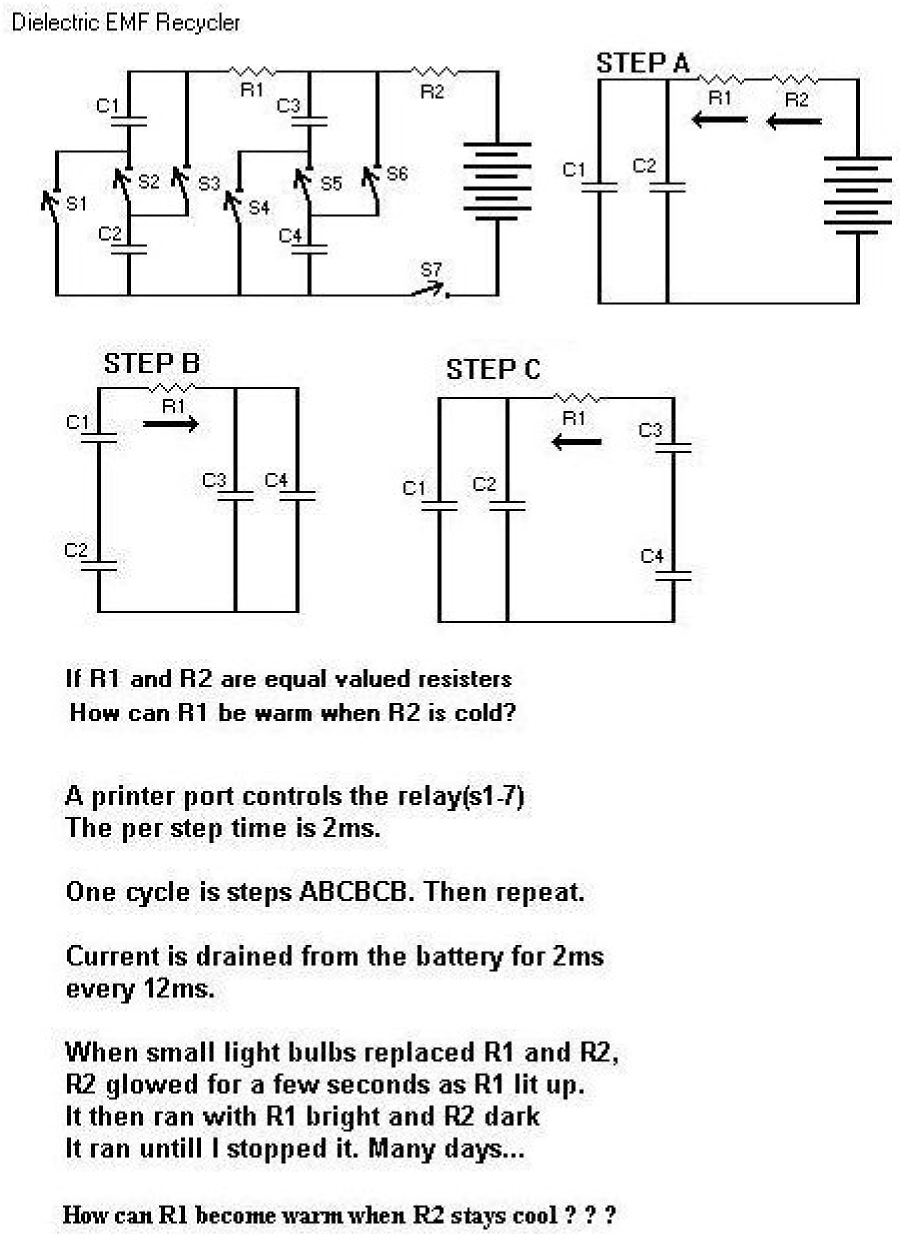
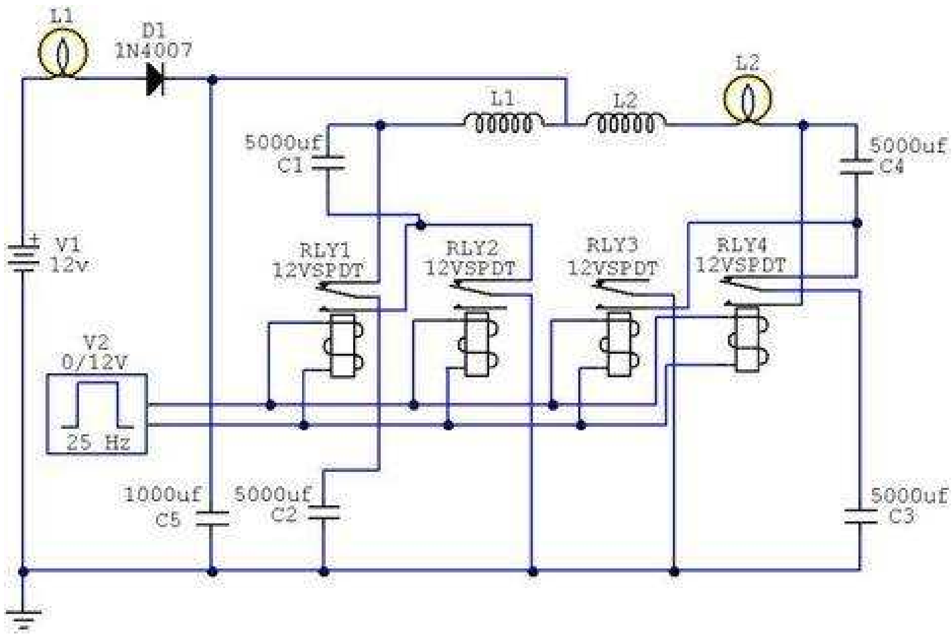
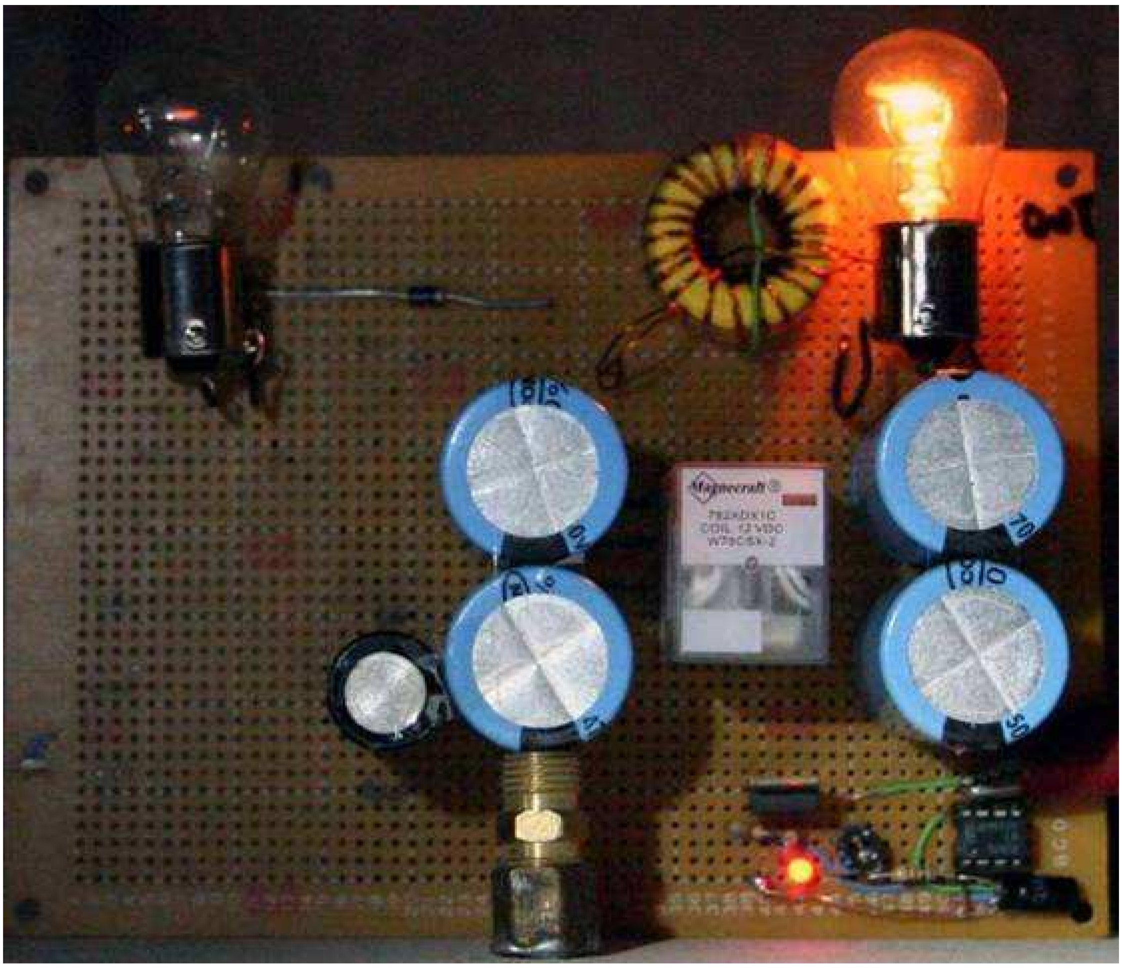
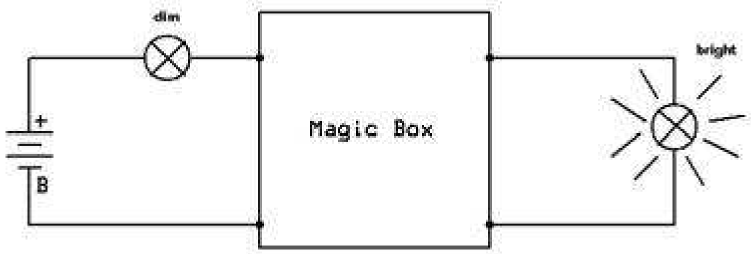




Another similar device, looks like Bedini’s Tesla switch.



Here a photo of working device ☺



In other words, author said “Hey, I have one bulb in series with power supply and one on the output of my magic box. See, first lamp is just glowing, and second one is shining bright. I got OU!”

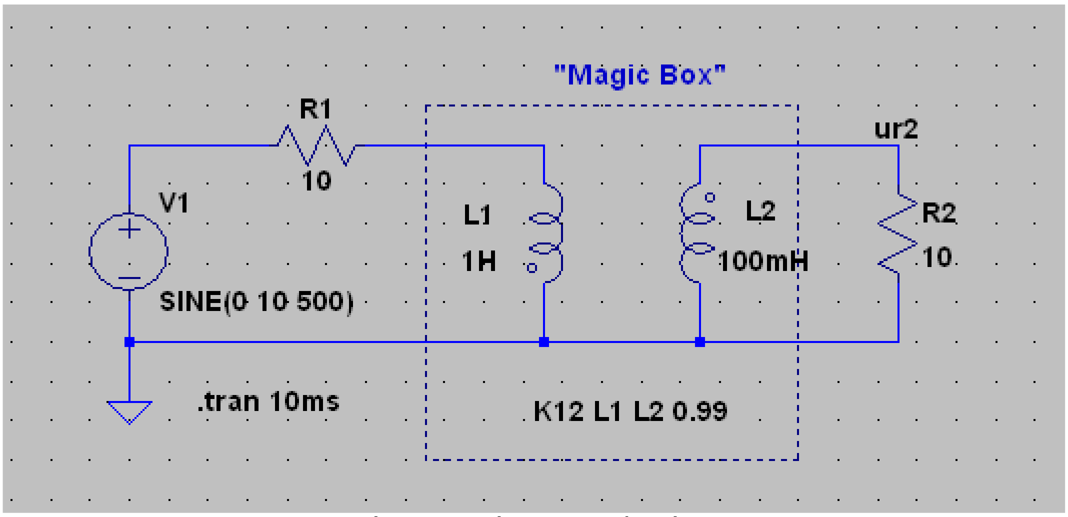
I am sure that everyone has seen such claims made by different people with different devices many many times.

Magic Box #1

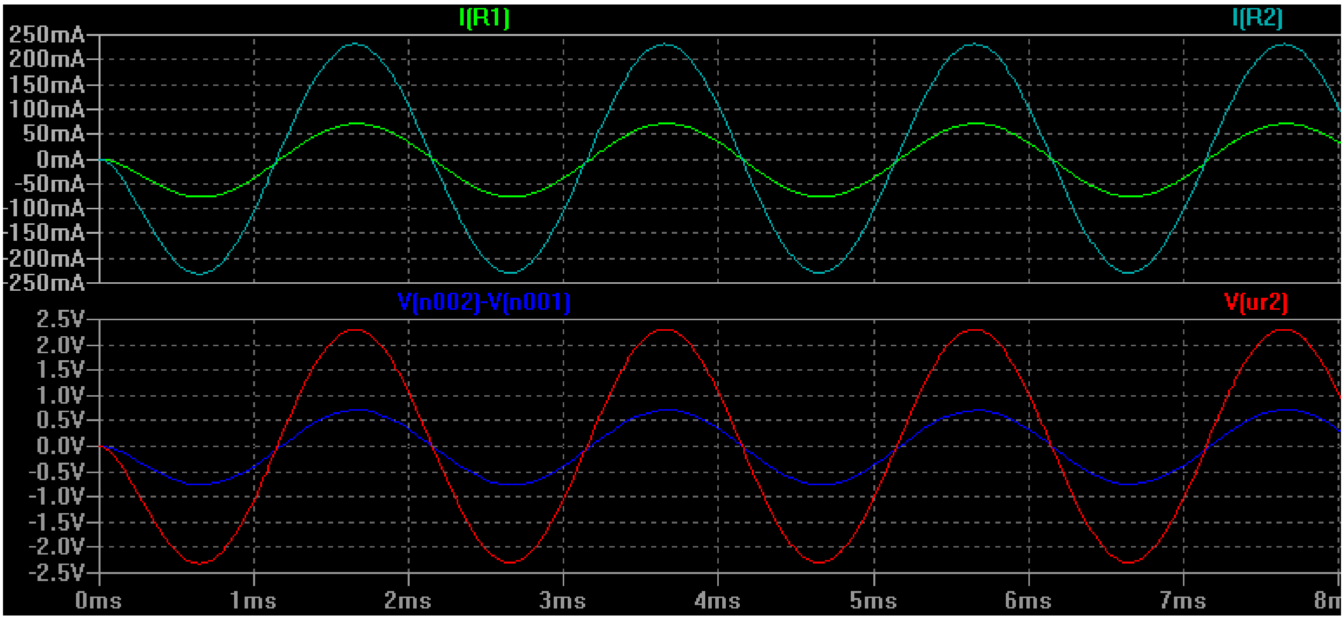
Let's take a look inside a "magic box" ;-)

To simplify simulation I am using alternative current and... just an regular step-down transformer (1:10) as a "magic box" ;-)

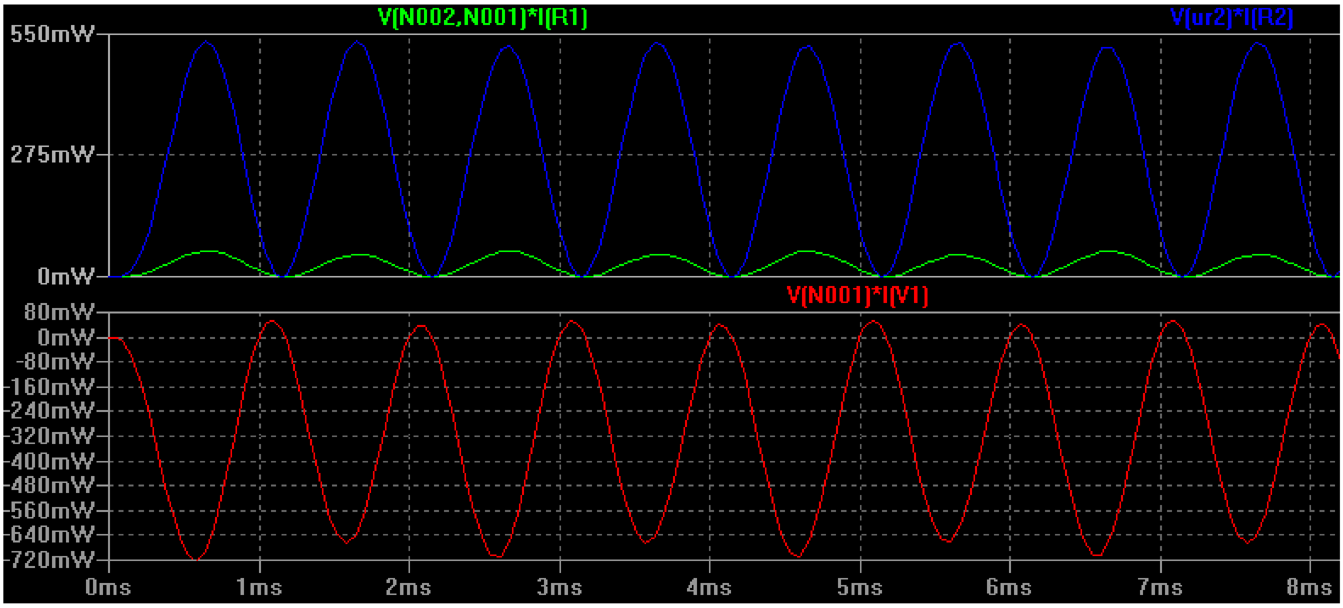
I am also using resistors instead of light bulbs.



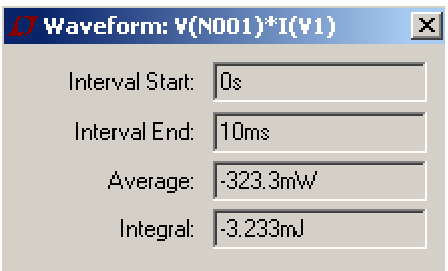
pic. Magic Box design

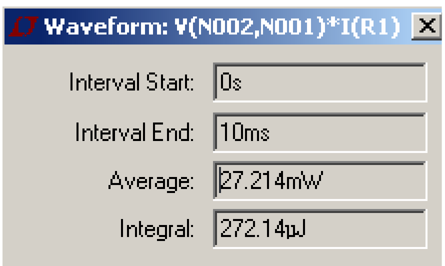


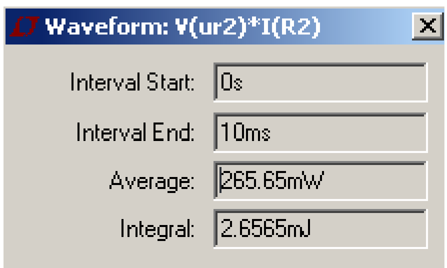
pic.1 You can see that both voltage and current are greater on R2 in comparison to R1



pic.2 So also power on R2 greater than on R1 (about 10 times in this example) and if there will be lamps one would glow and second one would be bright...







However there is a bad news :-) Power on R1 is not the same as power provided by power source V1. And original author's assumption that inserting

a light bulb in series with device could help comparing input vs. output power is obviously wrong.
As it was expected in this setup all power comes from V1 and it is equal to sum of power on R1 and R2 (not taking into account loses in the transformer).

I let you as an "exercise" to design a "magic box" which works similar way but with direct current :-)

Light bulbs

I used resistor in my previous post, now let's take a closer look on light bulb as a load.

Many people use light bulbs as a load and often trying to estimate output power based on bulb's brightness. You see it almost in every Youtube video where somebody showing its FE device.

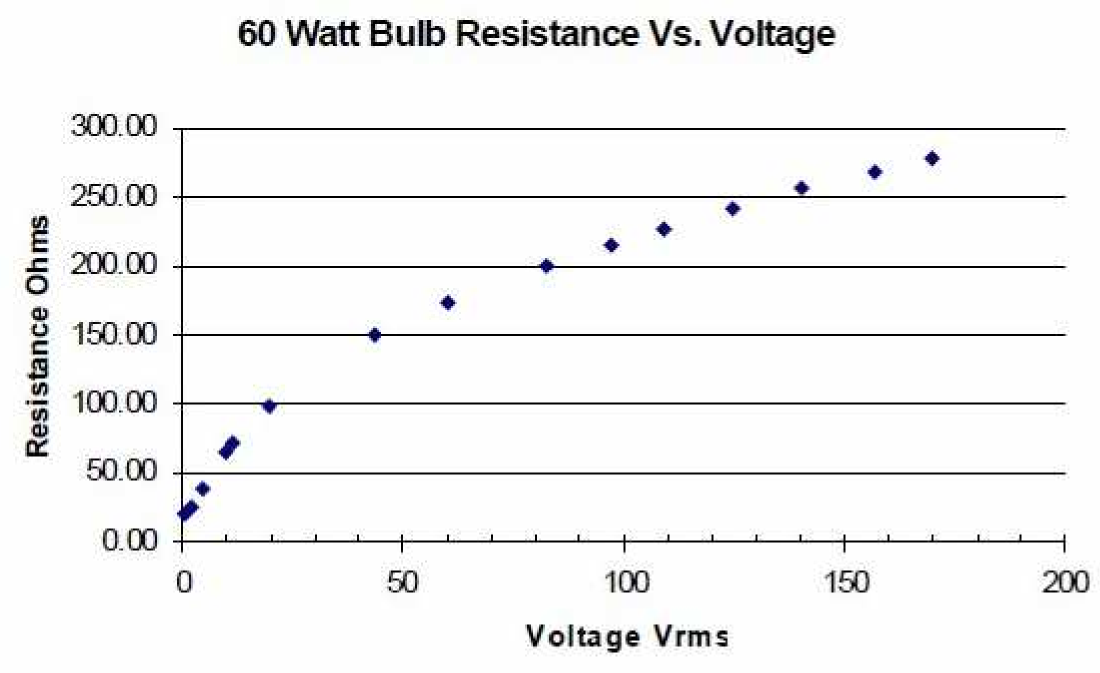
There are 3 things that one has to remember about light bulbs:

1. Bulbs have non-linear resistance; it depends on voltage applied to the bulb

See this:

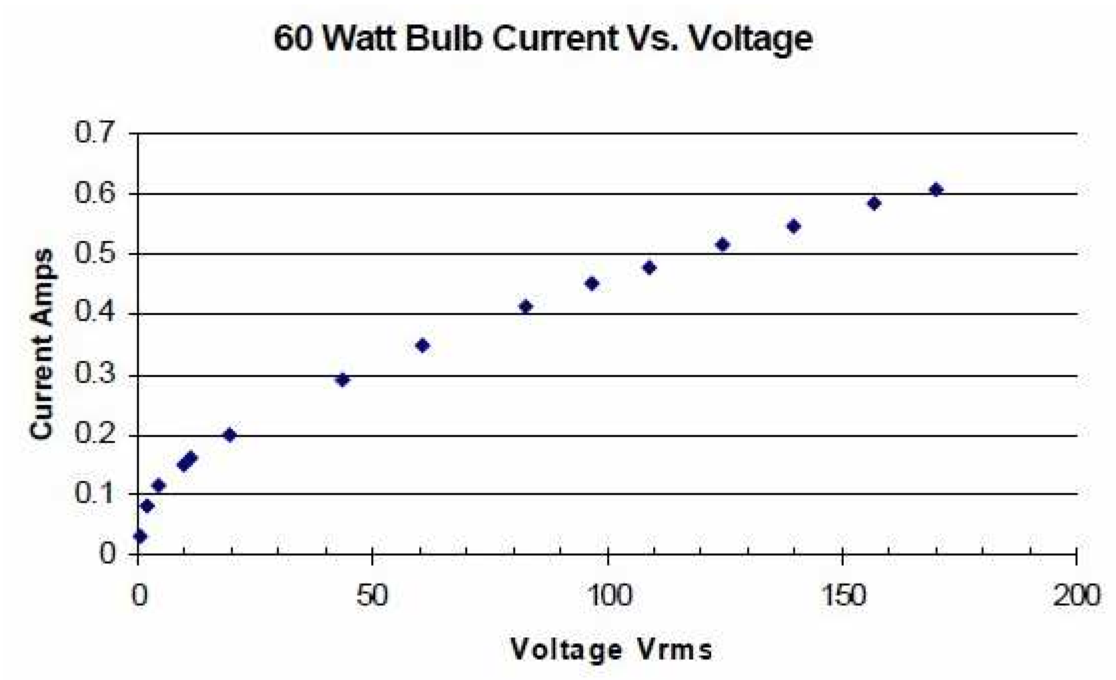
Vrms	Amps	Resistance	Power Watts
0.63	0.032	19.69	0.02016
2	0.079	25.32	0.158
4.5	0.115	39.13	0.5175
9.7	0.15	64.67	1.455
11.46	0.16	71.63	1.8336
19.7	0.2	98.50	3.94
43.7	0.29	150.69	12.673
60.4	0.35	172.57	21.14
82.7	0.414	199.76	34.2378
97	0.45	215.56	43.65
109	0.48	227.08	52.32
124.6	0.515	241.94	64.169
140	0.547	255.94	76.58
157	0.584	268.84	91.688
170	0.61	278.69	103.7

Tab.1 Bulb's resistance vs. voltage

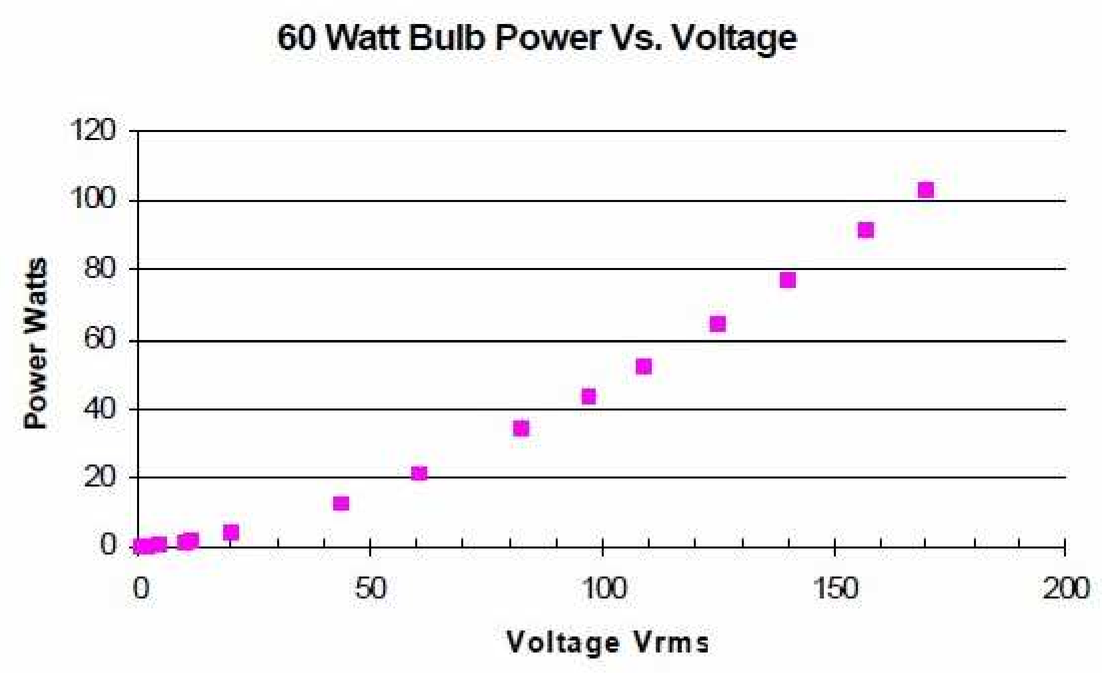


pic. 1 Bulb's resistance vs. voltage

and this



pic.2a Bulb's current vs. voltage



pic2b. Power vs. voltage

(original document can be found here http://site.devicecraft.com/ApplicationNotes/60_watt_Incandescent_Bulb_Characteristics.pdf)

2. Bulb's brightness also non-linearly depends on voltage (and frequency) and it also changing with the lamp's age.
See this <http://www.photometrictesting.co.uk/File/lamp_depreciation.php>

3. Bulbs have "inertia". This means that it takes milliseconds or seconds until current thru the lamp became stable when constant voltage applied.

All these properties make accurate power estimation based on light bulb's brightness very difficult.

Gustavo mentioned that bulb can be used as a current limiter. It's a quite common application but one always has to remember about bulbs "inertia". Many sensitive circuits can blow up completely while lamp is warming up :-)

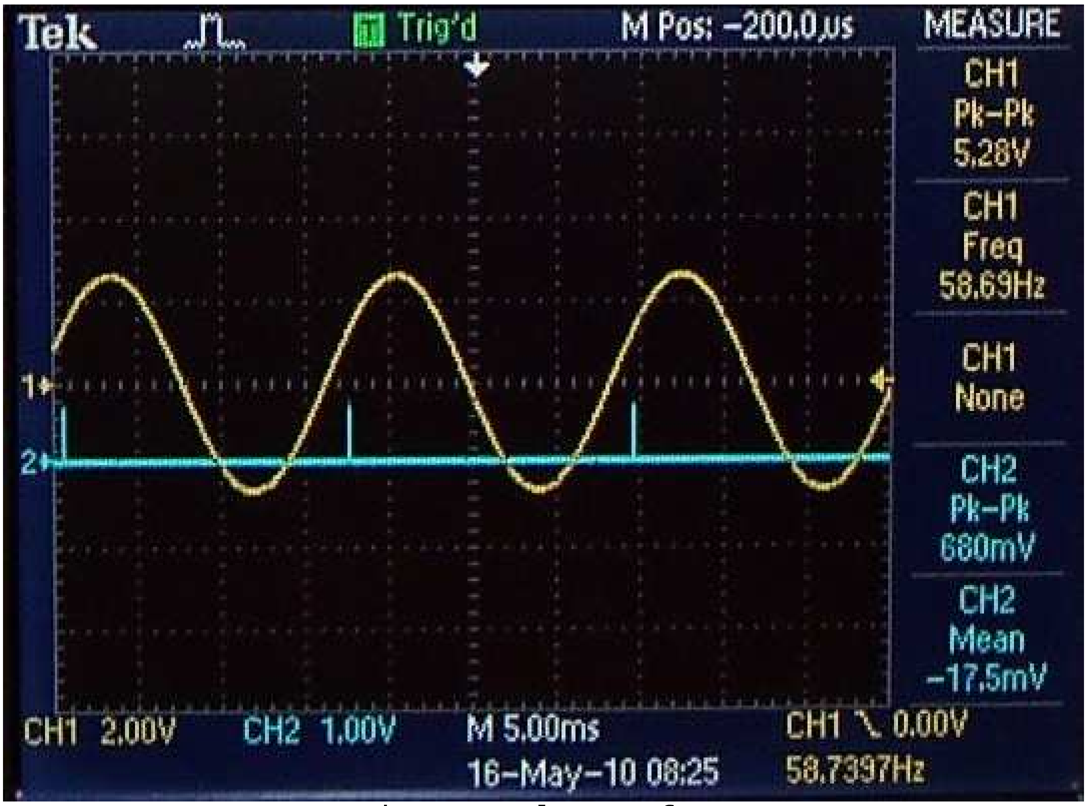
P.S. Perhaps it would be interesting to make experiment and study bulb's nonlinearities.

Measuring power in AC circuits

Another interesting topic is Measuring power in AC circuits.

Let's consider a practical example.
You have some circuit, it produce some power on the output. You put a load resistor and observing voltage on it with oscilloscope.

Here example picture (from my TV research)



pic.1 Sample waveform

Let's assume that load is 10 ohm resistor and peak-to-peak voltage on it 5.28v (channel one on the picture)

What is an output power here?

Let's use Ohm's law and calculate ;-)

$I = U / R$

$P = U * I = U^2 / R = 5.28 * 5.28 / 10 = 2.78$ W

Ok, did you get OU? Ha, ha, perhaps :-)

After thinking a while you remember that it was actually peak-to-peak voltage... so to get number comparable with DC you have to divide result by 2.... Oh no! Actually by 4 (because there is U * U in the formula)

So it will be P = 2.78 / 4 = 0.69 W (is it still OU? ;-)

After thinking one more moment, you probably remember that you also have to use RMS coefficient, so... again divide by two square root of 2, or

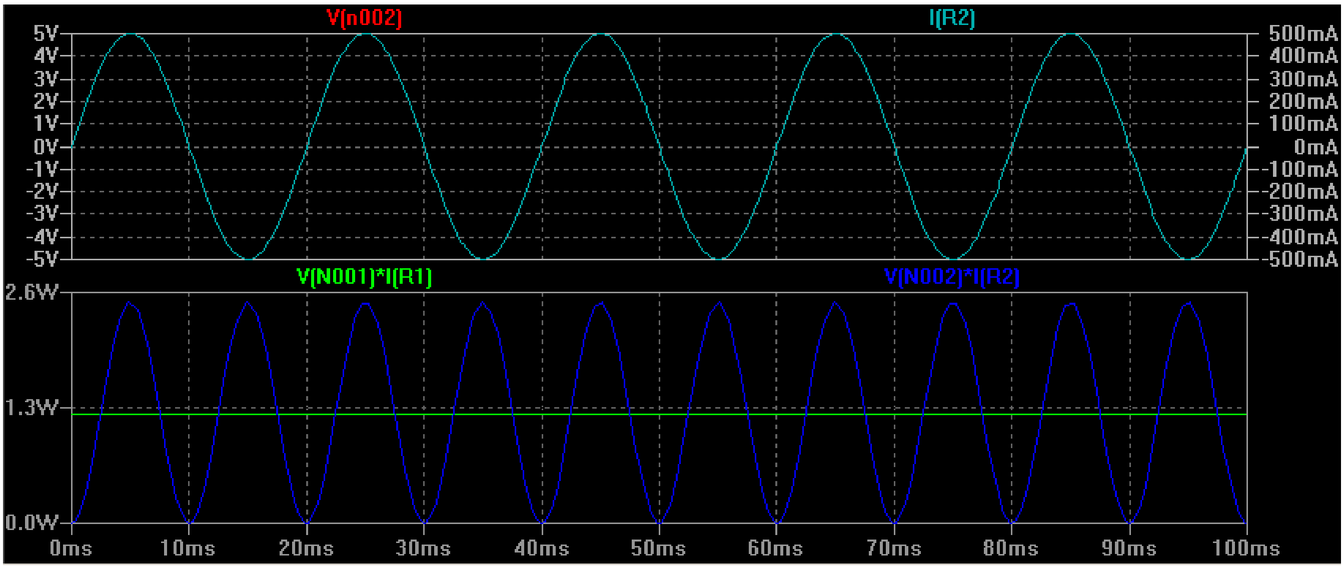
P = 0.69 / $\sqrt{2}$ / $\sqrt{2}$ = 0.34 W (what a disappointment! :-)

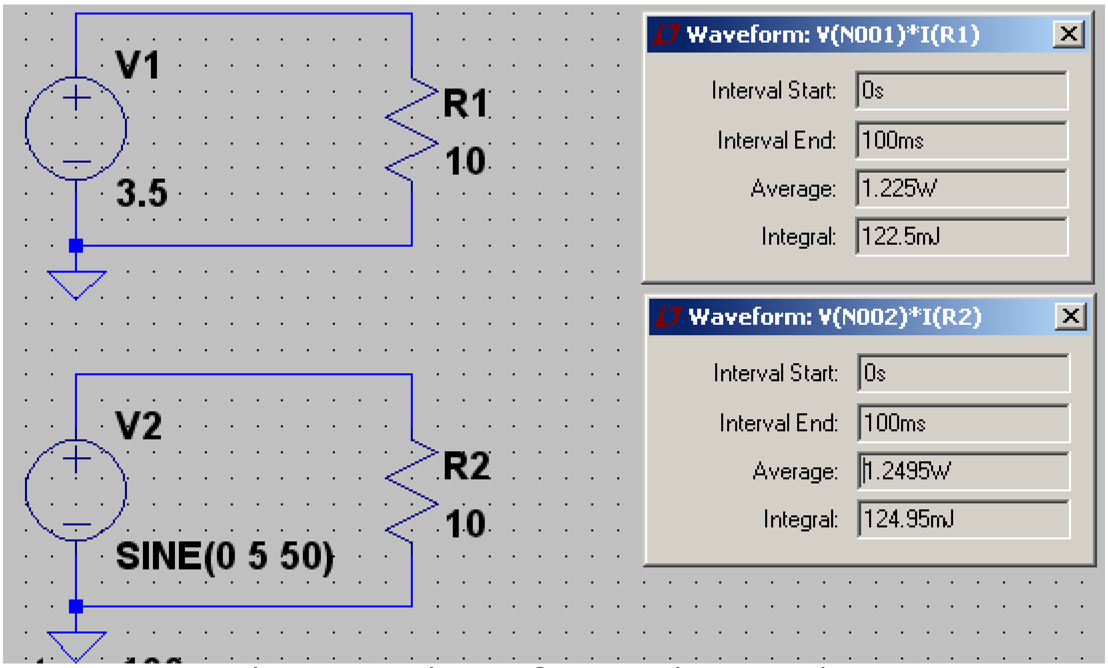
And if we collect everything in one formula we get P = Upk * Upk / R / 8.

This coefficient ($\sqrt{2}$) depends on signal shape.

Here some reading about RMS
https://en.wikipedia.org/wiki/Root_mean_square

and an example simulation to consider





pic. Comparison of power in DC and AC

Magic Box #2

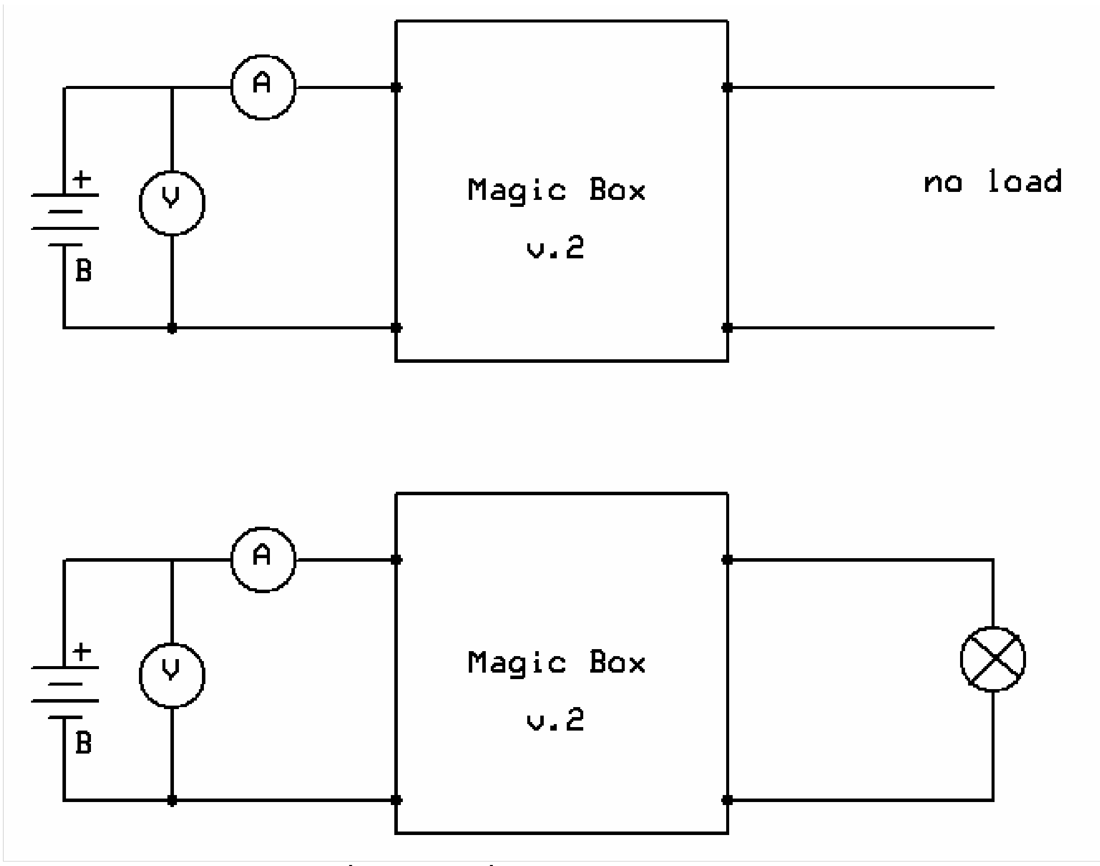
And last thing I can't leave without our attention in this thread - yet another "magic box" case :-)

a.k.a. Power consumption drop under load.

Have you ever met a person who claims: "Hey guys, I made amazing device. When I put load on it actual power consumption is dropped. This is a straight way to over unity!"

He, he... I have met many...

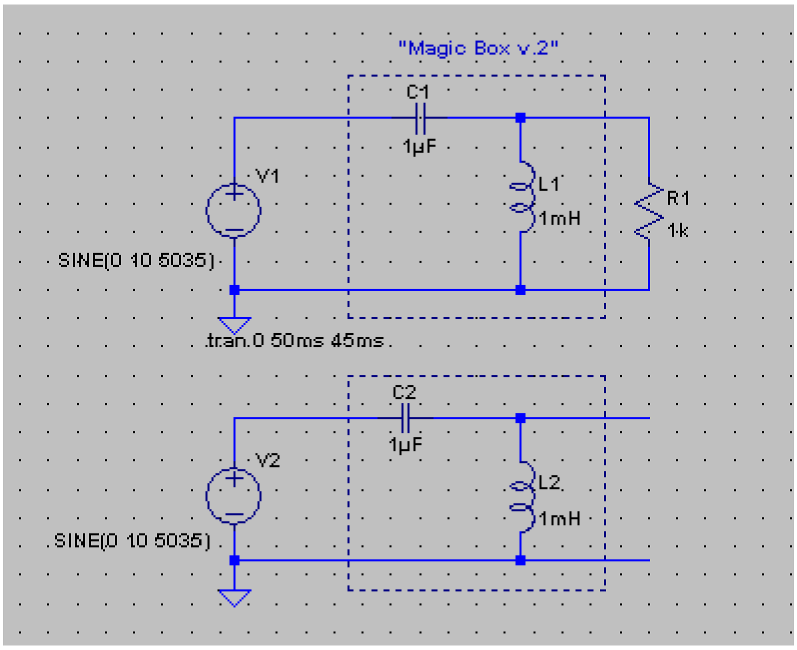
So let's consider another magic box (version 2)

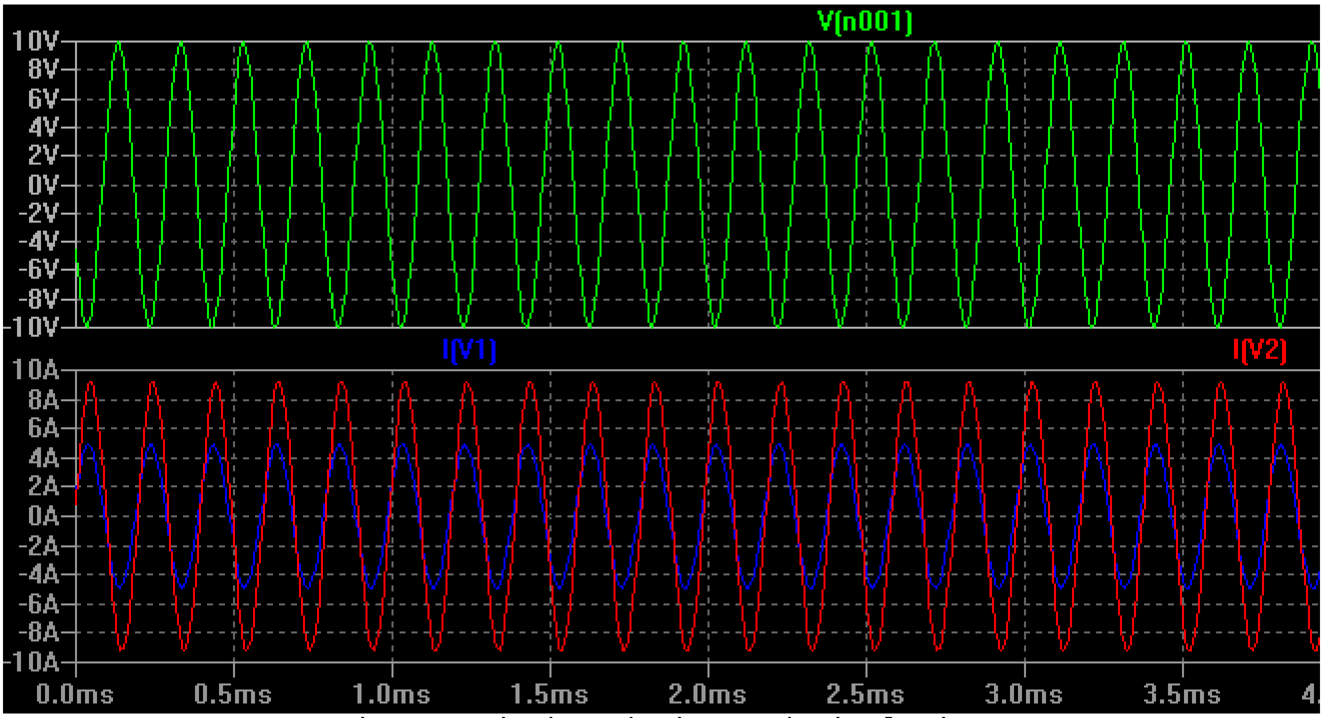


pic.1 Magic Box #2 concept

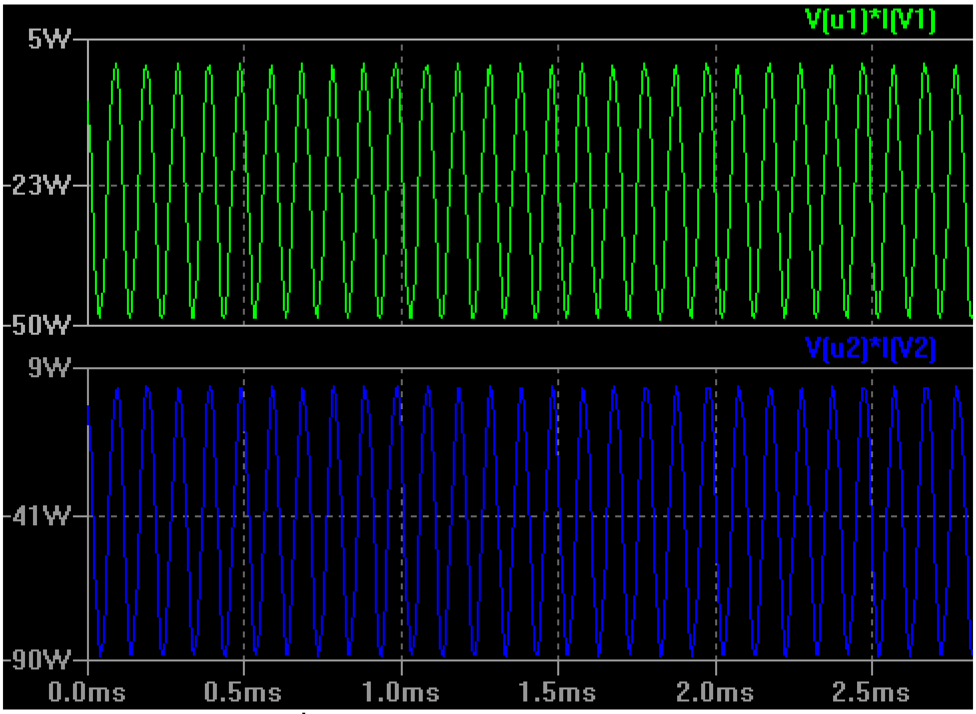
In first case (top picture), power source is driving only the Magic Box. When we attach some load (bottom picture), amazingly, power consumption decreases even some power goes into load.

Ok, can we make such "magic box"? Sure, we can :-) Here my design. I am again being lazy and do it for AC, you can build DC version yourself.

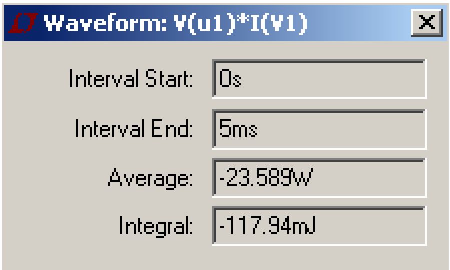


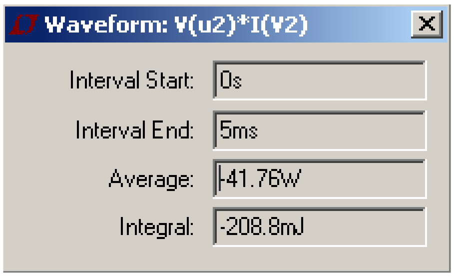


pic.2 Magic box design and simulation



pic.3 Power measurements





After all, do you think it was "wrong way"? ;-)

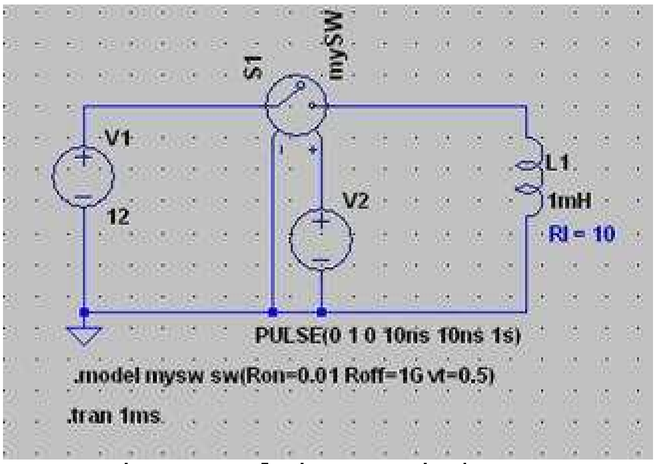
Chapter 2. Flyback

Hello,

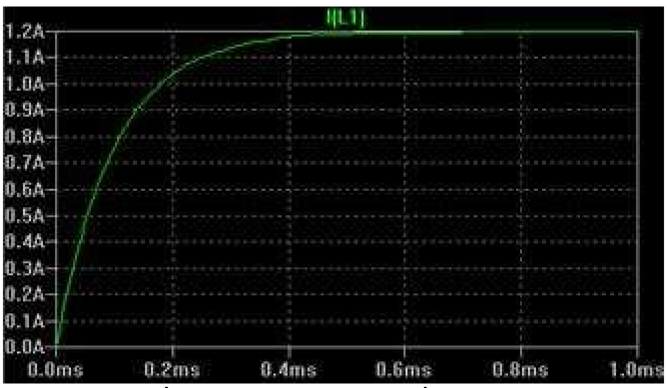
I am continuing the "entertainment" and starting new thread about Flyback circuit, its properties and applications.

A word before going into details...
After doing FE research for some time I realized that
- Mathematics don't care about reality
- Electronics don't care about anything, it just use ready available components with known properties
- Modern Physics unfortunately forget almost at the beginning about reality and goes deep into math and spend most of the time writing formulas :-)
And we have to bind all three together, fix when necessary and make serve our needs. While doing electronics we need perfect understanding of physics involved and we need math to do calculations. Sometimes it's a real challenge.

Flyback usually consists of two coils. Let’s start with one.



pic 1. Pulsing an inductor



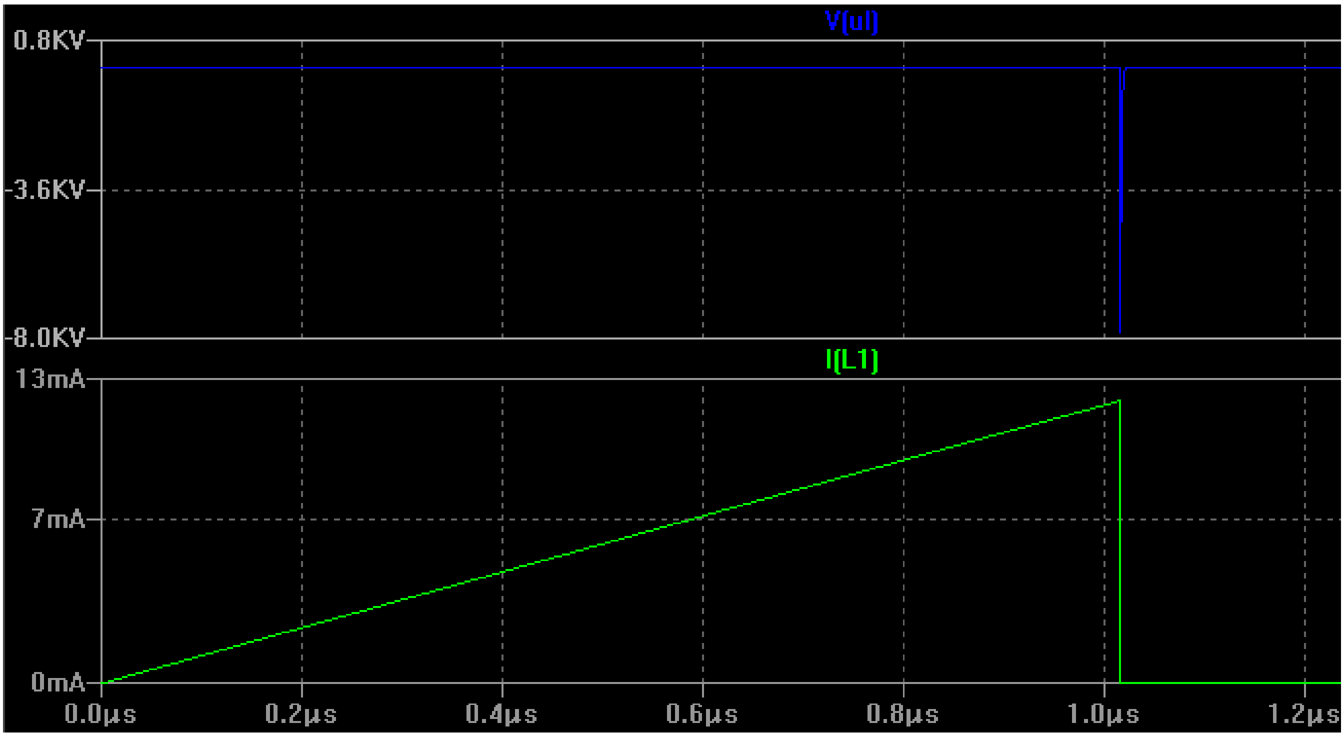
pic 2. Current thru L1

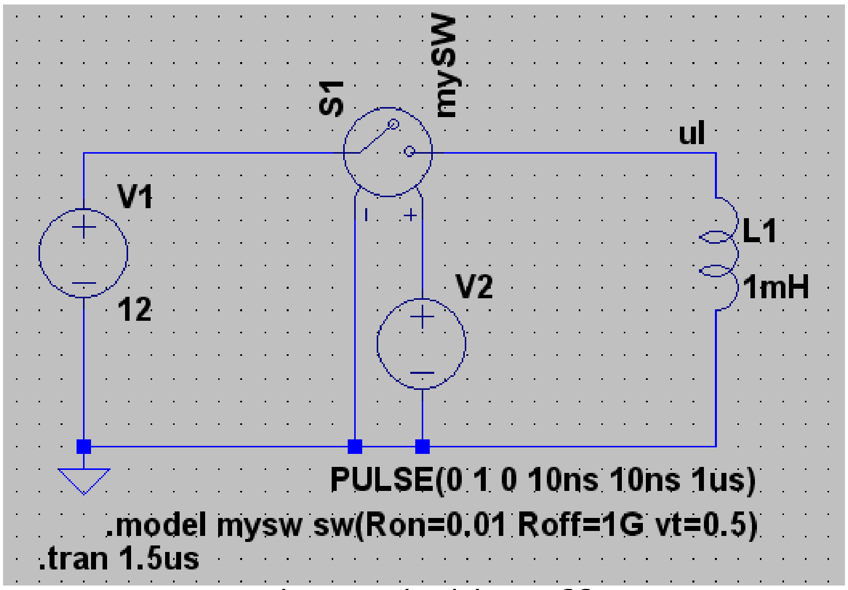
When we turn switch on current begin grow until it reach maximum value which depends on power supply voltage and coil’s internal resistance (Imax = U / Rcoil)

This “grow” is exponential as it shown on pic.2, however in practice usually we will be using only very beginning of the process so current grow will be almost linear (see region t < 0.1ms).

It is often said that current thru coil can’t change “fast” or “momentary”. This is not exactly true as we will see soon. While current grows magnetic field also “building up” and some energy being “stored” in magnetic field across the coil (E = L * I * I / 2)

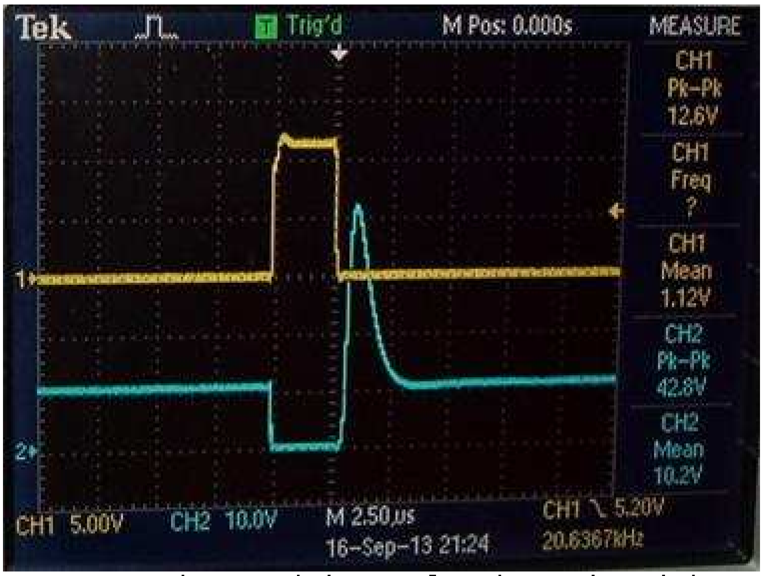
If we disconnect coil from power source, current thru coil stops abruptly, so magnet field collapse and big voltage spike appears across the coil (if no load connected).



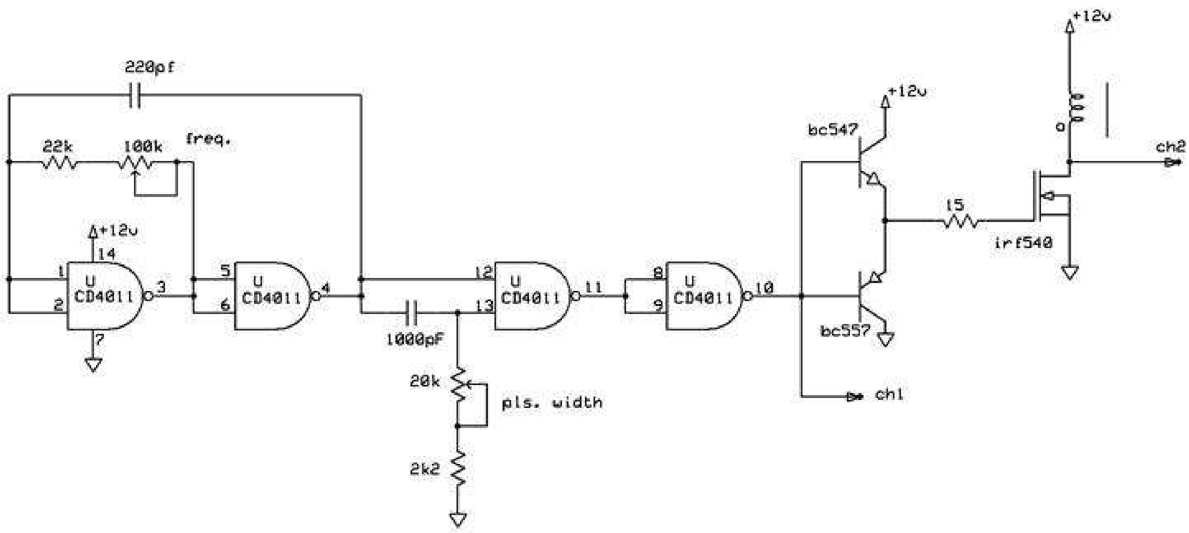


pic.3 Switching off

This process can be seen on pic.3, “size” of voltage spike across the coil depends on coils parameters (capacitance, internal resistance etc.)



pic.4 Same process observed in real schematic with oscilloscope

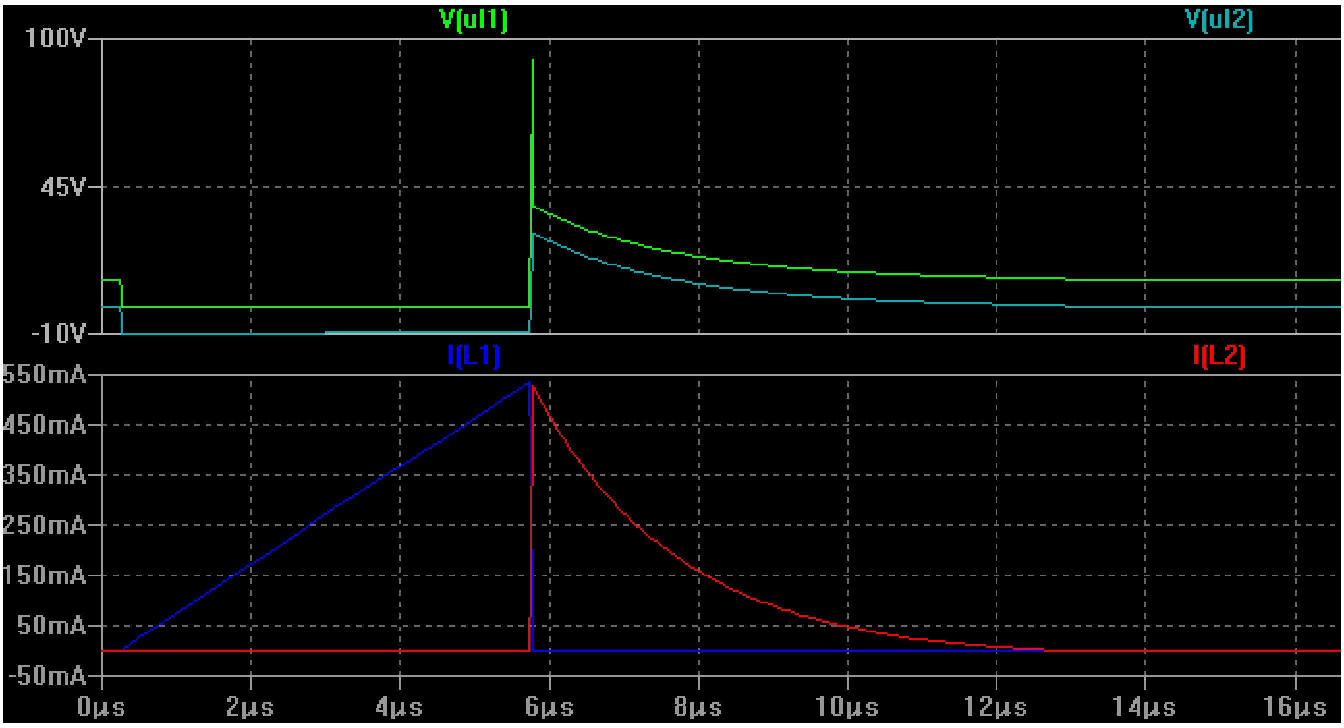


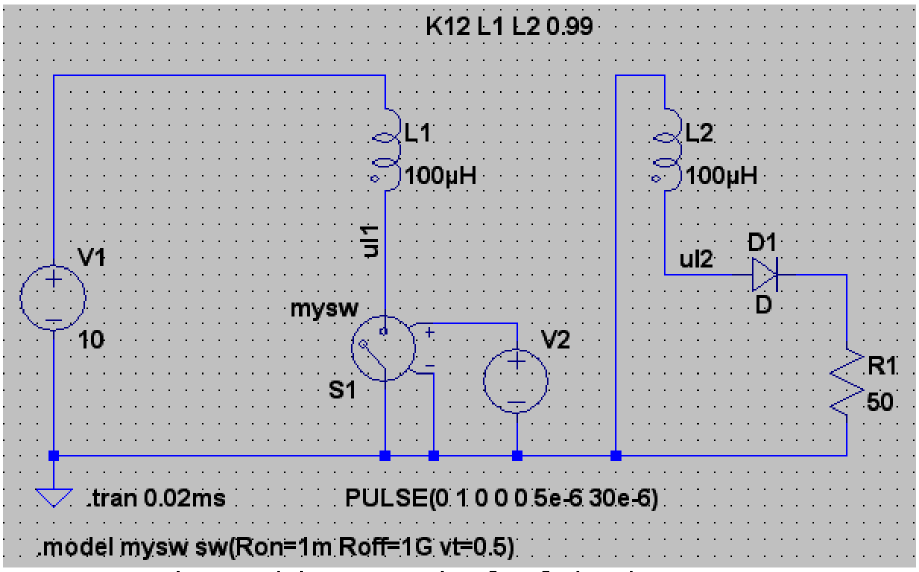
pic5. Here an example schematic which can be used for this experiment

And here some links with info to consider:
http://www.electronics-tutorials.ws/electromagnetism/magnetism.html
http://hyperphysics.phy-astr.gsu.edu/hbase/electric/indsol.html

Flyback circuit

As we saw in previous post, when we disconnect power supply energy stored in magnetic fields "disappears" (from our circuit). This is not very good, so let's add another coil and "capture" this energy back :-)





pic.1 This a typical Flyback setup.

Diode in the secondary needed to prevent current thru the load during first working phase when energy “stored” into magnetic field. In the second phase, collapsing magnetic field creates voltage on the secondary coil and if there is a load connected; current begins to flow (almost immediately). This current creates own magnetic field which oppose to original field. It is interesting that the lower load resistance the higher current will be in secondary and stronger field it creates, therefore the longer (wider) output pulse will be. Another interesting feature is that fly back always draws same power from power supply independently what load applied to secondary, it also does not “afraid” of shorting output.

This kind of setup used in many different variations in nowadays power supplies.

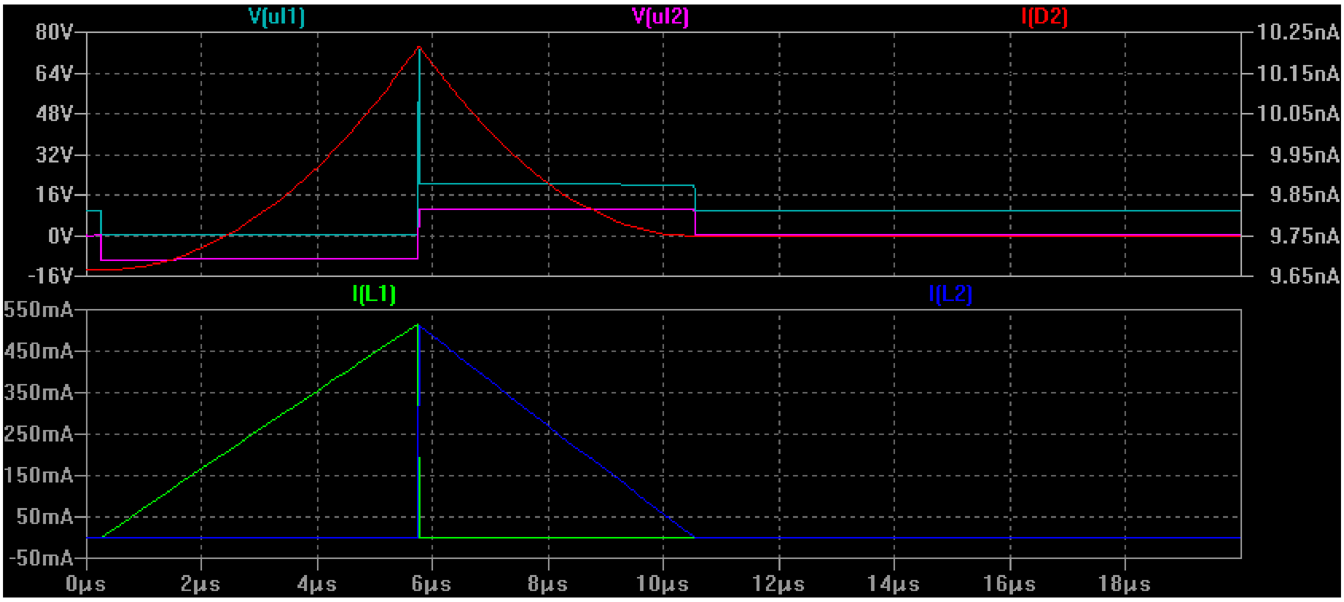
Here some interesting is reading about flyback:
http://www.dos4ever.com/flyback/flyback.html
http://www.ti.com/lit/ml/slup261/slup261.pdf

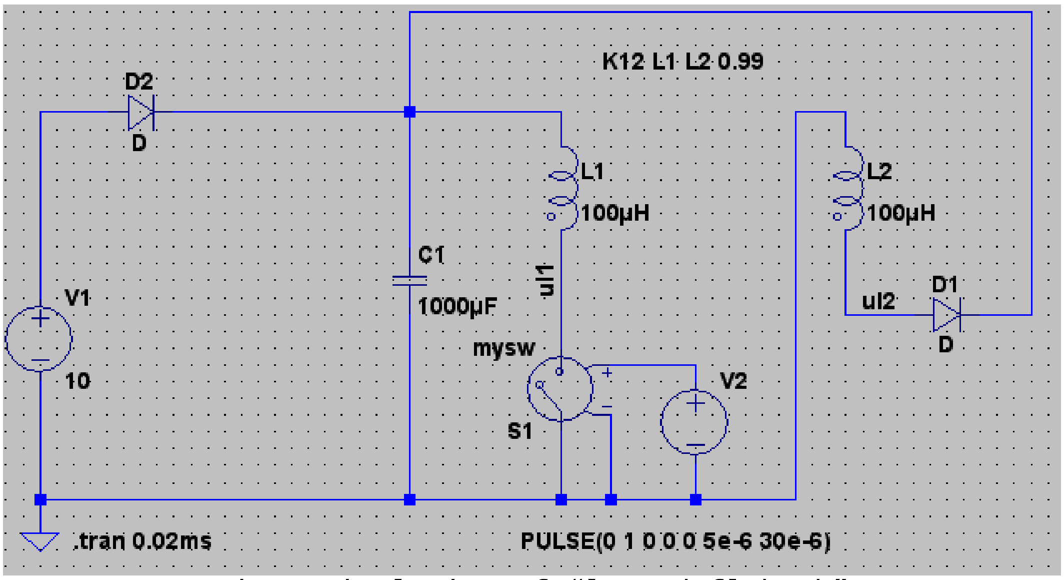
Looping flyback

As we discussed earlier, we “put” some energy into magnetic field with primary coil and then “collect” it back with secondary coil. By some reason people tend to think that we can get out here more than we put in.

Just imagine, you put some water in a cup and when you drink it appeared that there is more water than you put in.
Wouldn’t it be nice to have such magic cup ☺

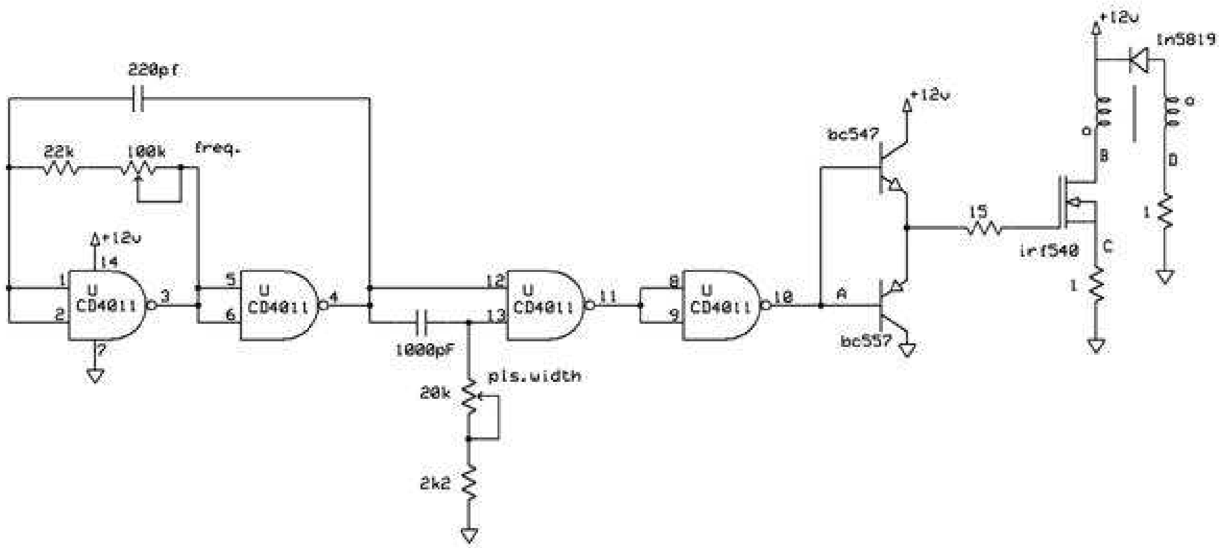
Ha, ha, anyway, people keep trying and I can’t resist give it a try as well…



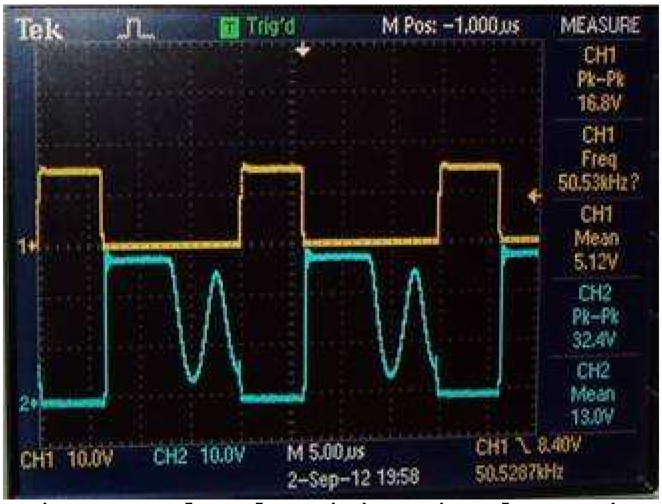


pic.1 Simulation of “looped flyback”

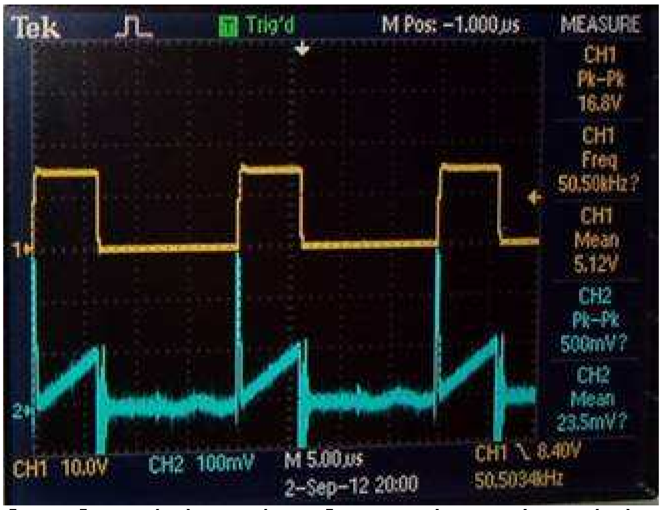
Notice power supply and coils current values ;-)



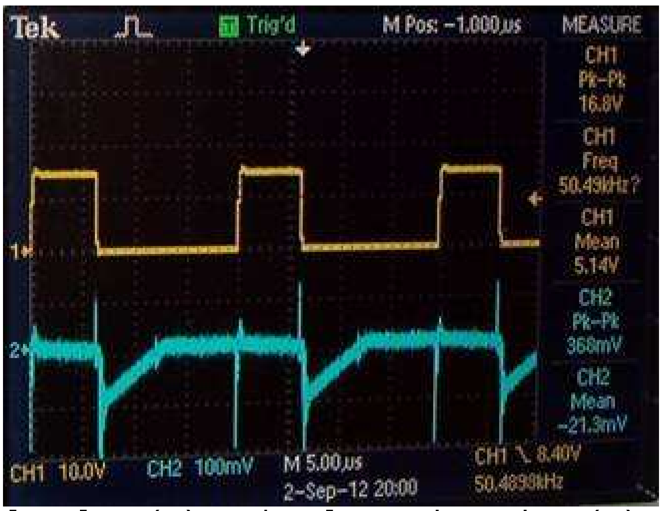
pic.2 Experiment’s schematic



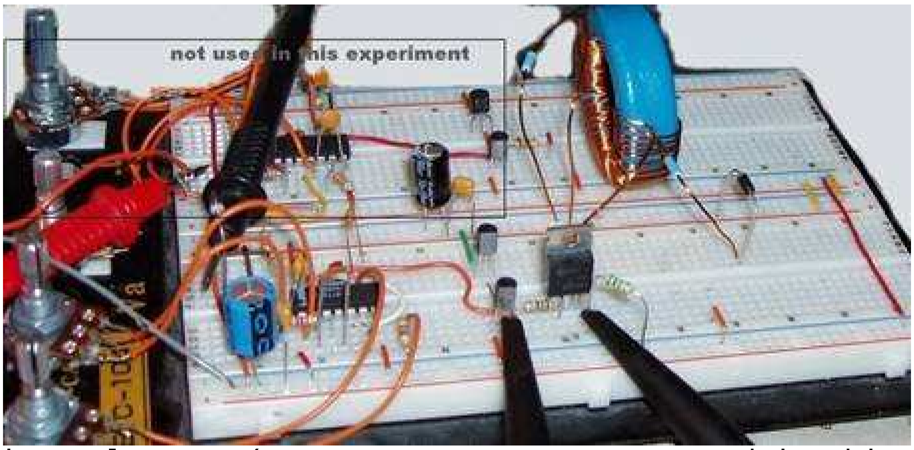
pic3. Switch control pulse (A) and voltage in point (B)



pic4. Switch control pulse (A) and voltage in point (C) = current thru coil L1 (Spikes at the beginning of the pulse caused by MOSFET gate charging process)



pic5. Switch control pulse (A) and voltage in point (D) = current thru coil L2



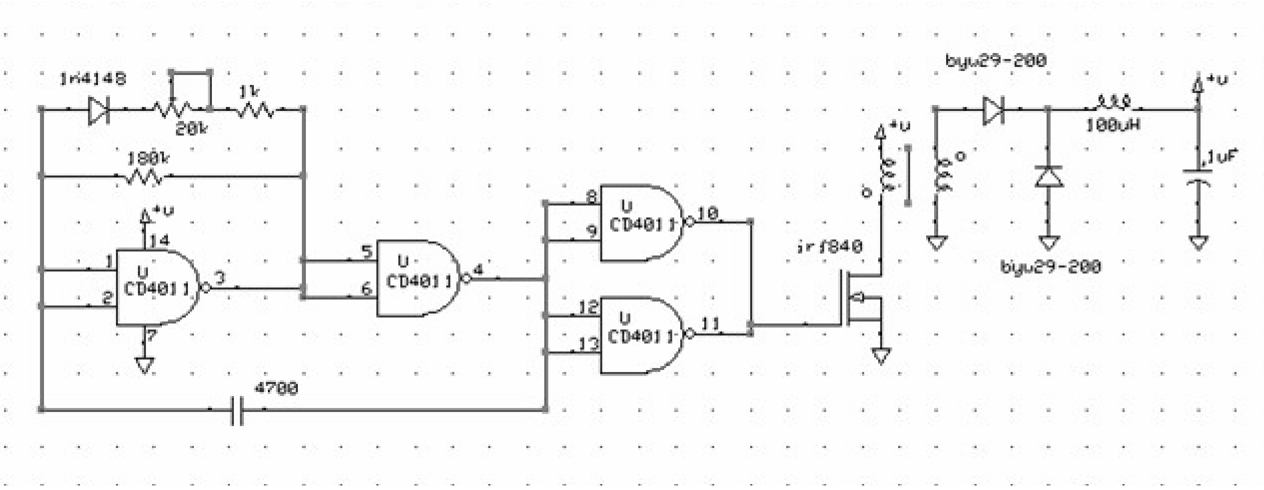
pic6. Experimental setup (some components are not used in this experiment)

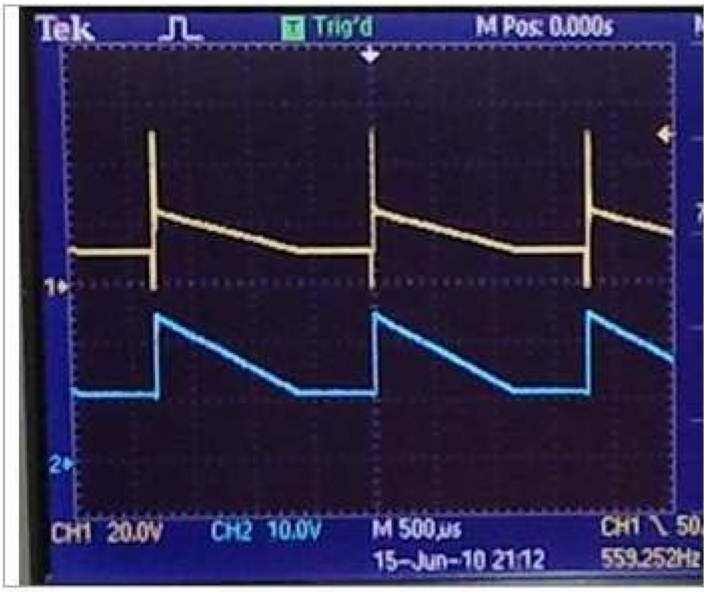
As simulation show, this setup consumes very small current 100uA – 5mA depends on pulse width and coils and can be used to measure loses in ferrite.

Trying harder…

Somebody probably say: "You not being serious and you not trying hard!" Ha! ha! Being serious will not help us ☺

Here similar “Flyback looped” setup I tried earlier



	one of earlier versions of "looped flyback" "yellow" channel = secondary "blue" channel is a power supply (+U) connected to lab power supply thru diode… Notice ground level on the picture ;-)

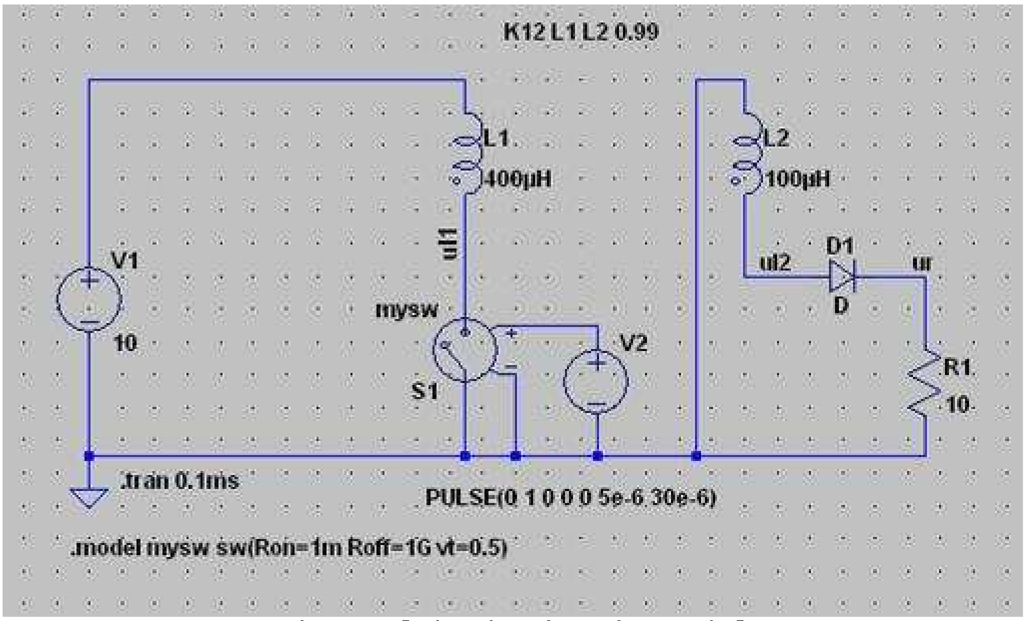
pic1. One of the earlier trials

The issue with flybacks is diode in secondary, voltage drop on it, internal capacitance and limited turn-on time (delay). Adding small inductor in series sometimes can help to “handle” current spikes.

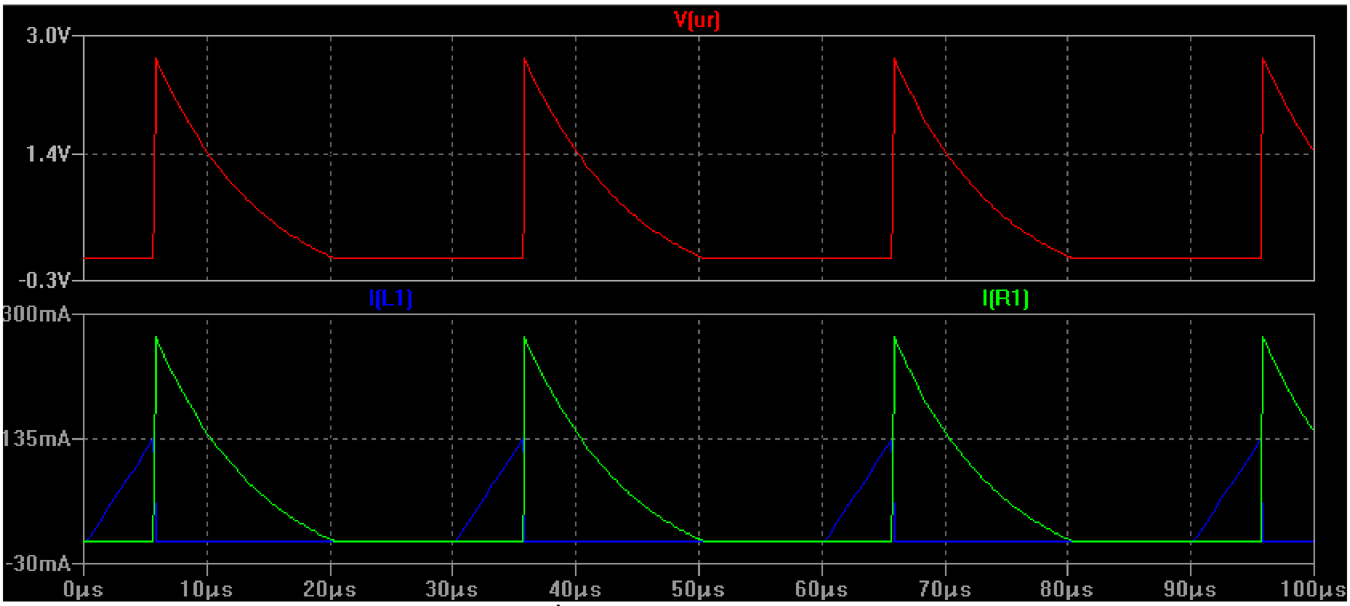
Decreasing capacitor connected to power gives possibility observe how power transferred from secondary.

Simulating flyback

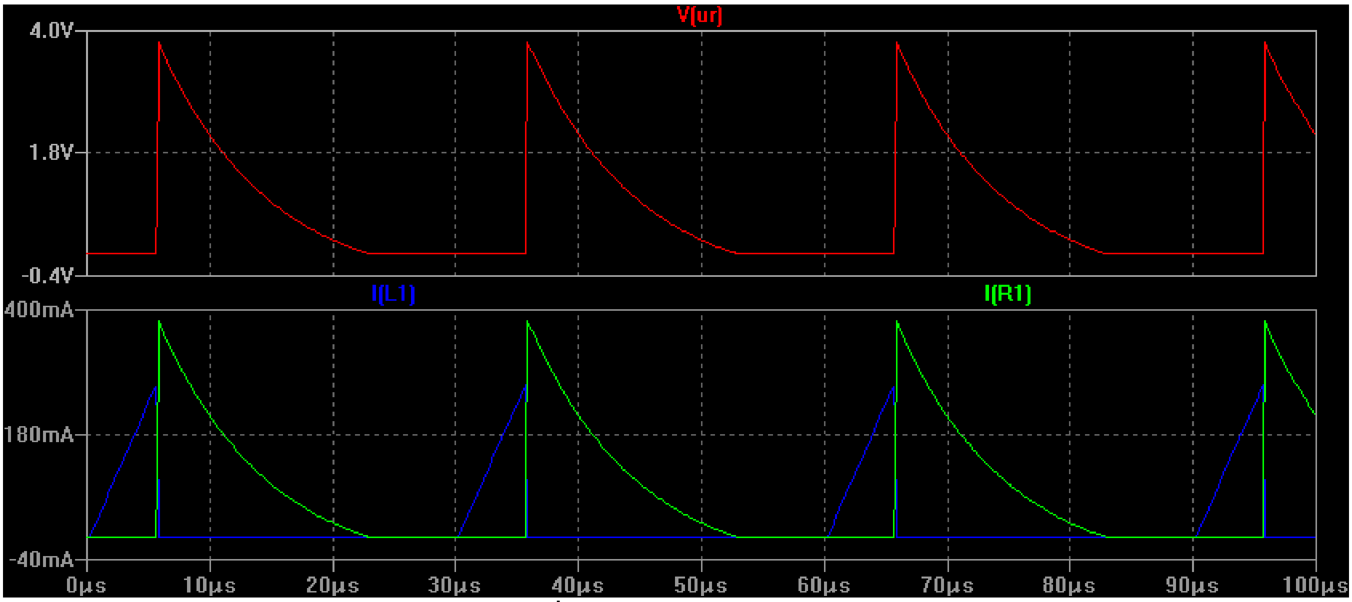
Despite that currents in primary and secondary winding never exists at the same time, if we start changing number of turns (and therefore inductance) of primary and secondary, Flyback will behave in a similar way as "regular" transformer. We can gain voltage or current but not both :-)



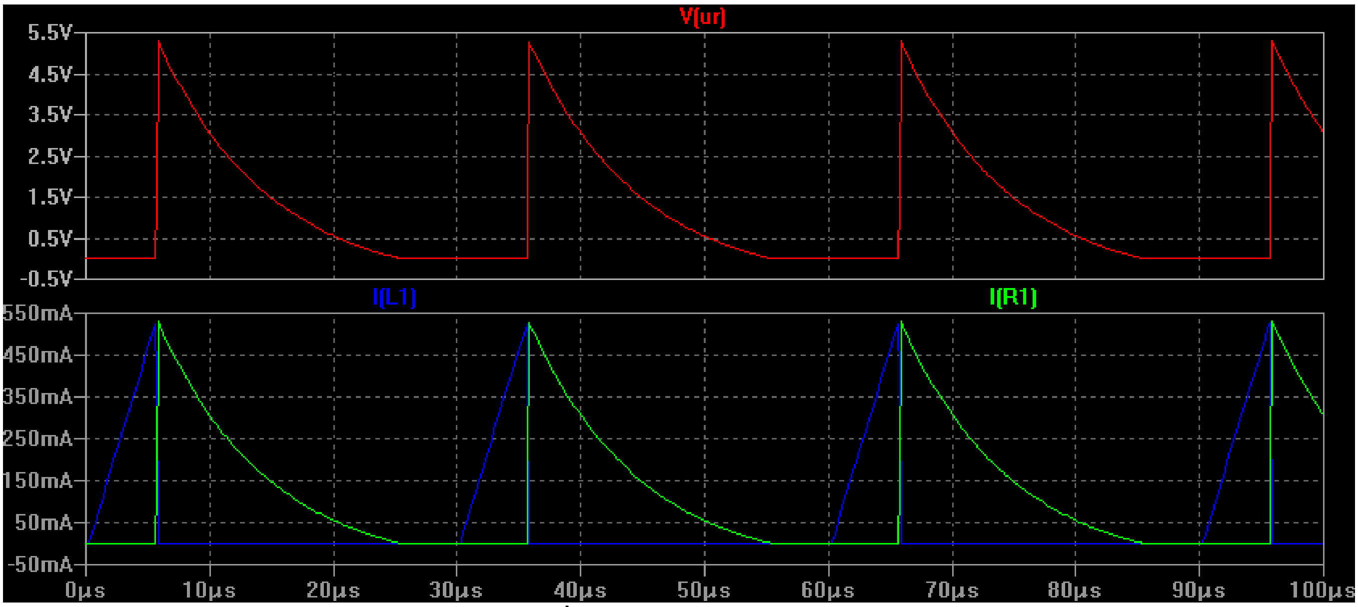
pic1. Flyback circuit model



pic2. L1 = 400uH



pic3. L1 = 200uH



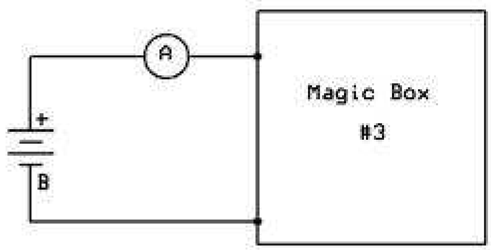
pic4.L1 = 100uH

I made this simulation to illustrate how change off L1/L2 ratio affects output voltage and current.

Magic Box #3

Let’s consider another “Magic Box”.

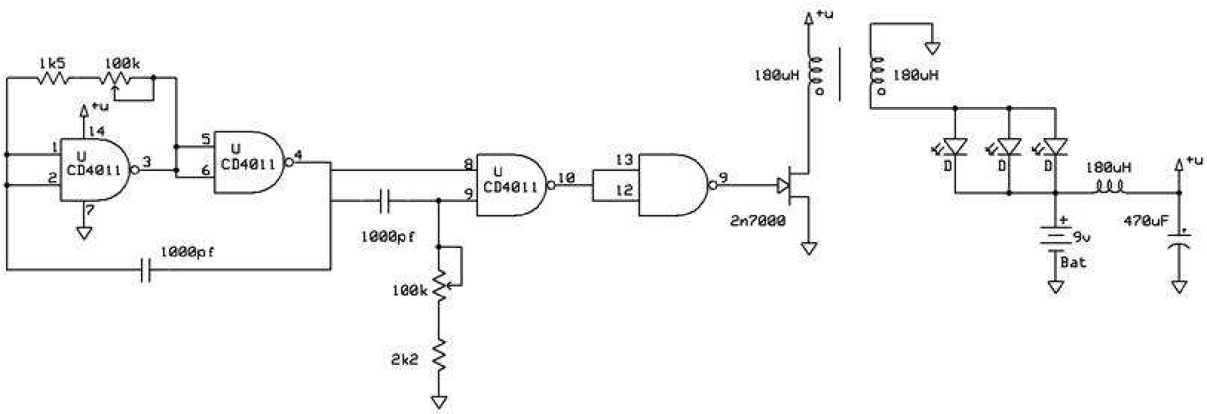
From time to time you see a video or post where some smart guy telling that he invented very advanced schematics which allow you to power some load from battery and charge the battery at the same time. Wouldn’t it be nice to have such circuit?



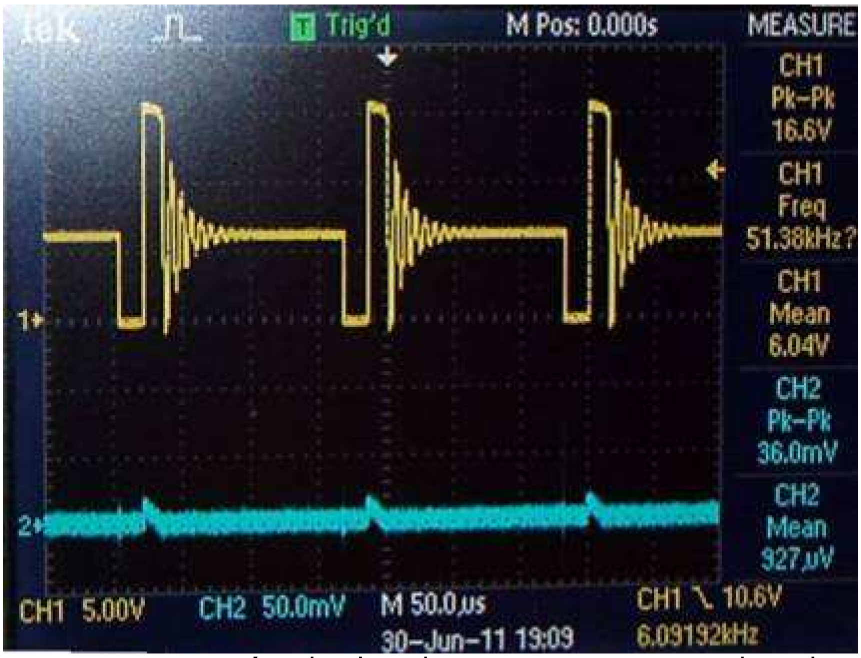
pic.1 Magic Box #3 concept – we attach something to the battery via current meter and… surprisingly it shows that current actually flowing into the battery...Does it charging the battery ?

Well, this magic box creates much more controversy rather than two previous.

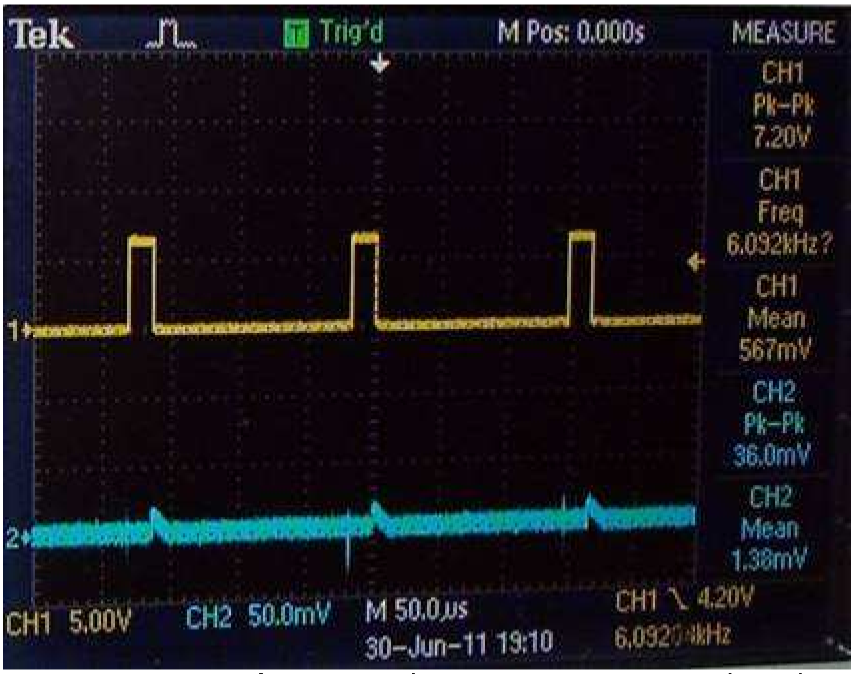
I would like to show two similar devices behaving like described “magic box”, both devices are based on flyback circuit.



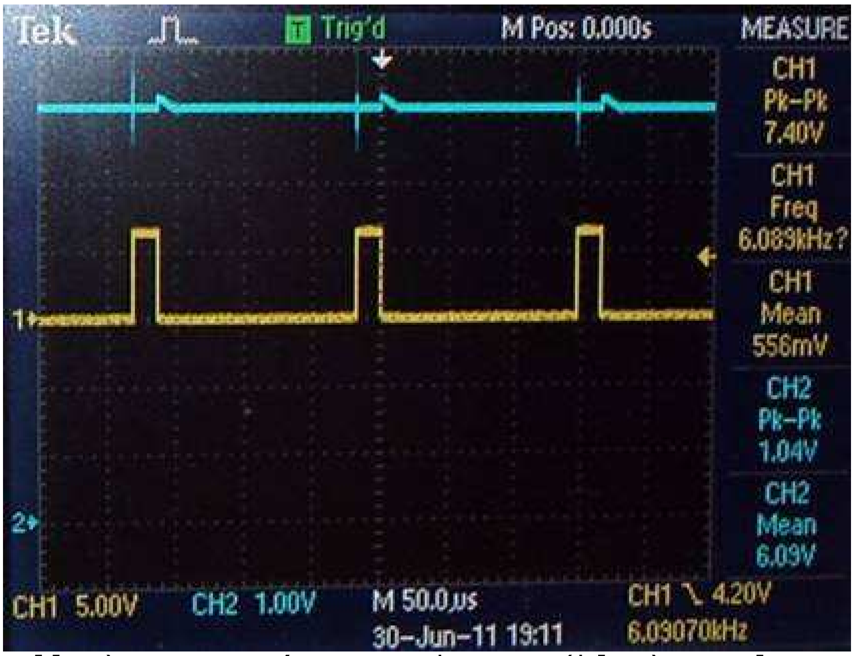
pic1. “Magic” LED light “charging” small NiMH battery



pic2. top – MOSFET's drain, bottom – current thru battery

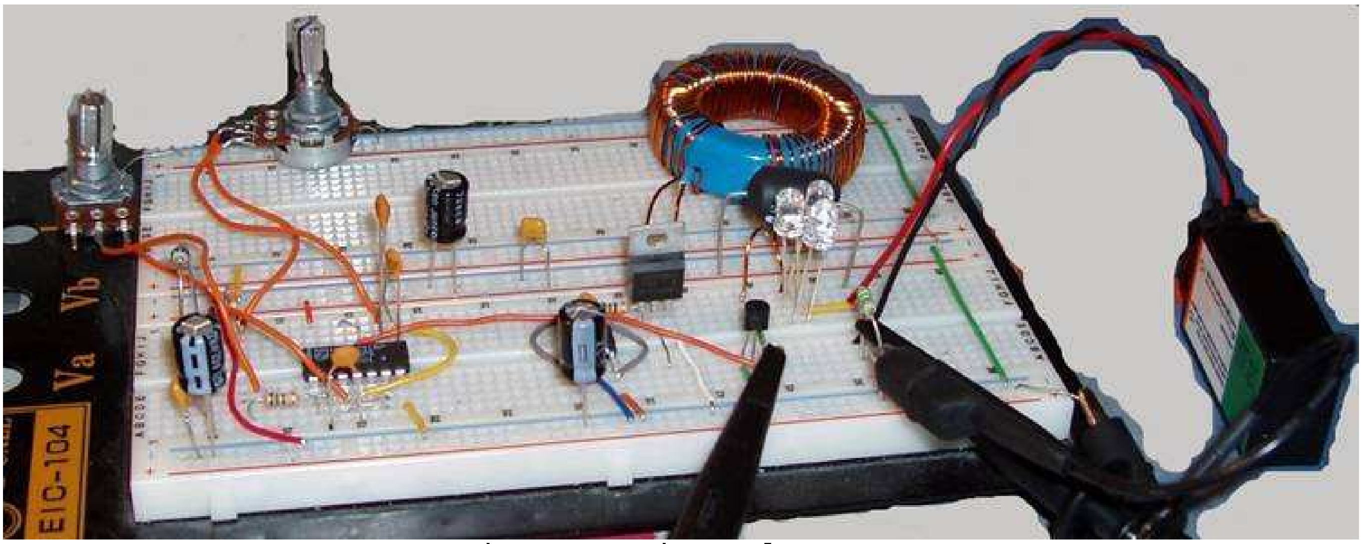


pic3. top – MOSFET's gate, bottom – current thru battery



pic4. top(yellow) – MOSFET's gate, bottom (blue) – voltage on battery

As you can see, circuit creates current pulses "into battery" ;-)



pic5. Experimental setup

I let you decide yourself what is "wrong" with this "magic box"…

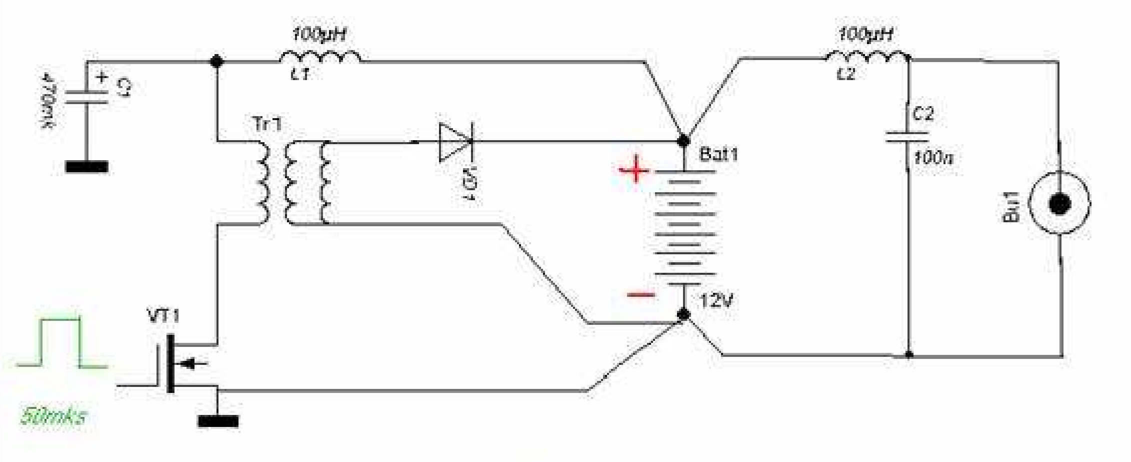


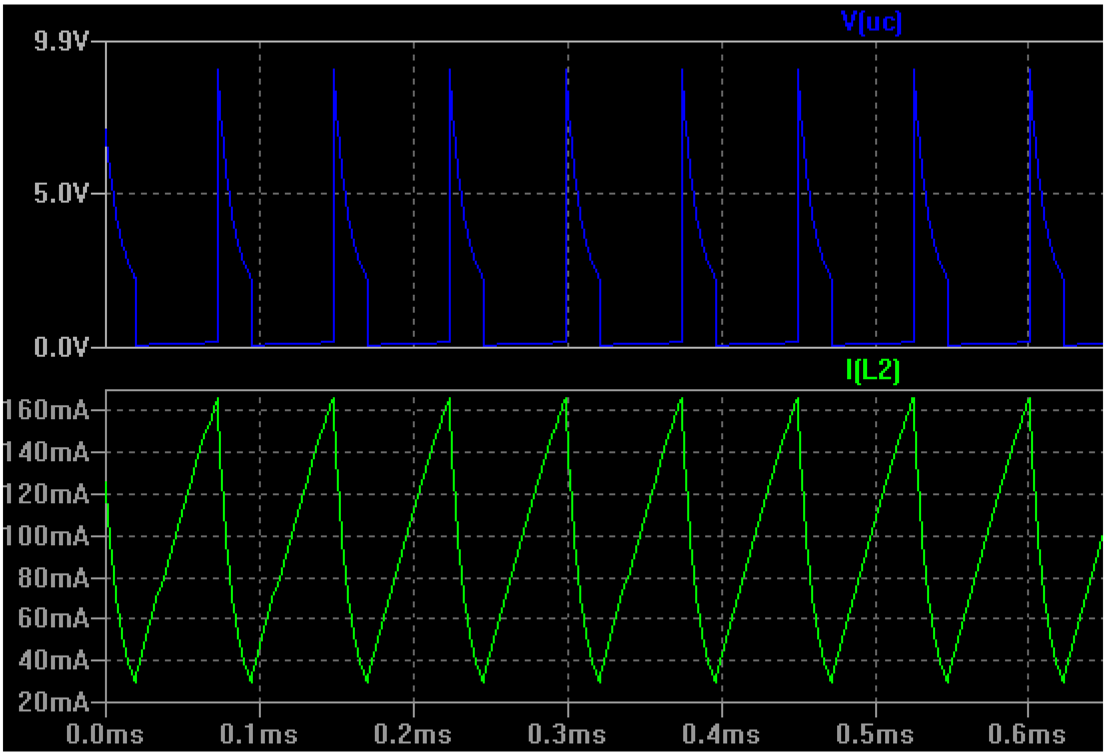
Fig. Self recharging batery

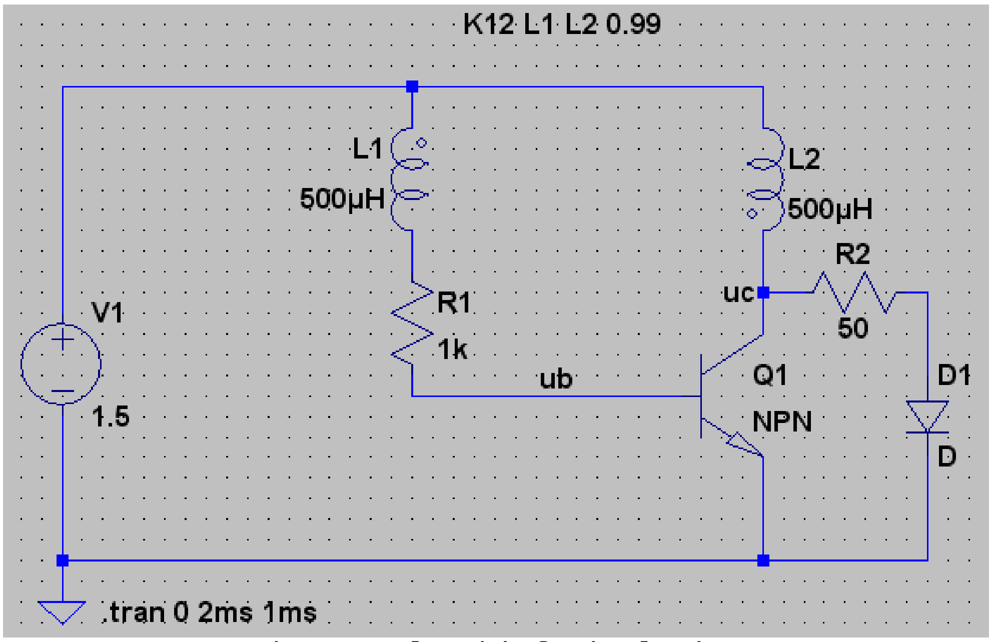
pic6. Another similar device

Author claims that this circuit allows power some small load from rechargeable battery for period about 2 years.
He also said that after that time battery's electrodes dissolved almost completely and he had to throw it away…

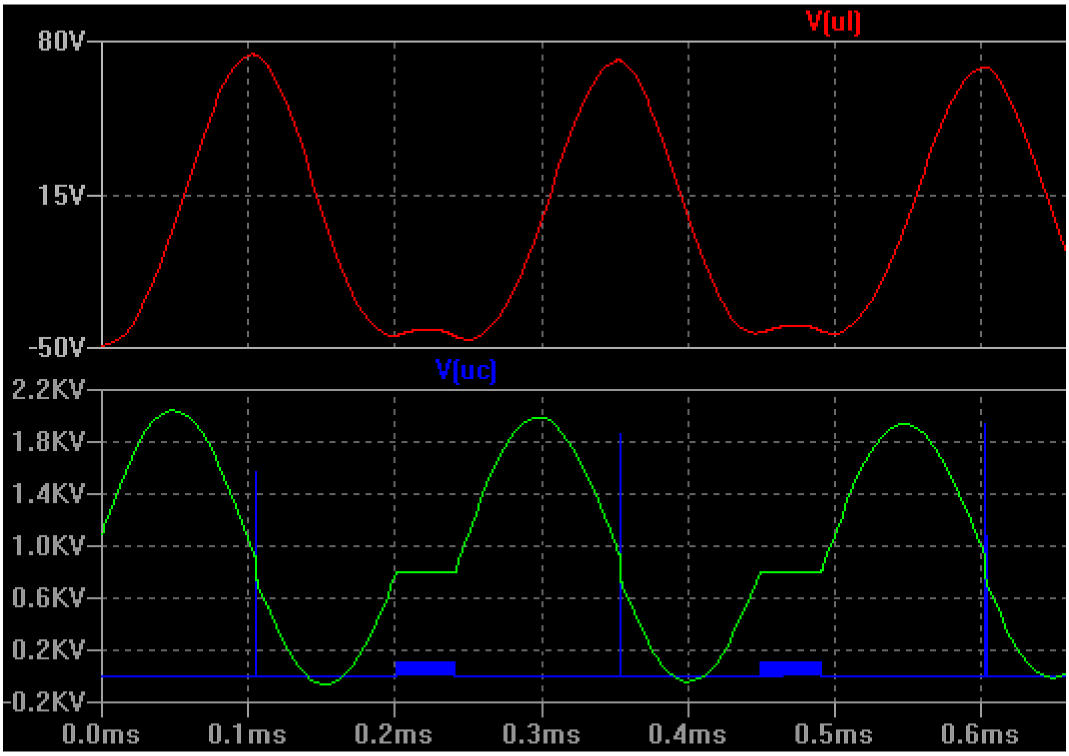
Joule Thief and LED lights

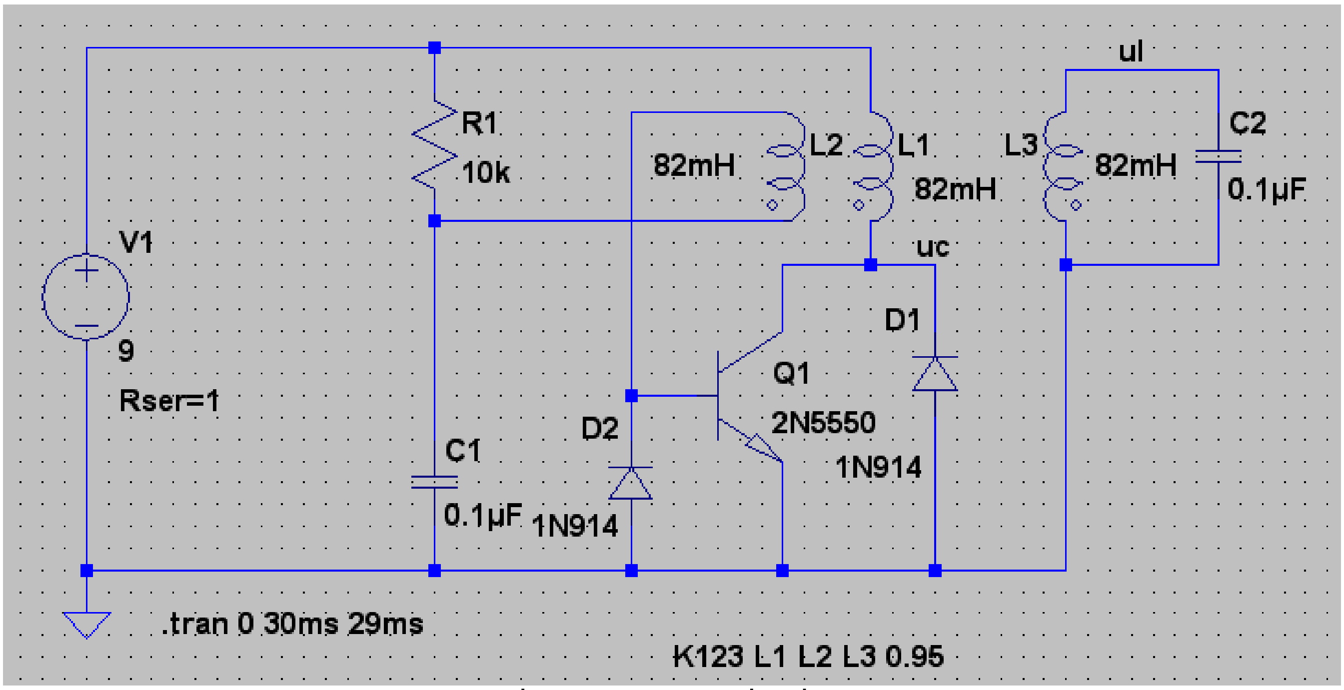
I think you agree that Joule Thief is one of most popular circuits on the web.
It is not a flyback but I think it is kind of related circuit and it would be interesting to mention it.



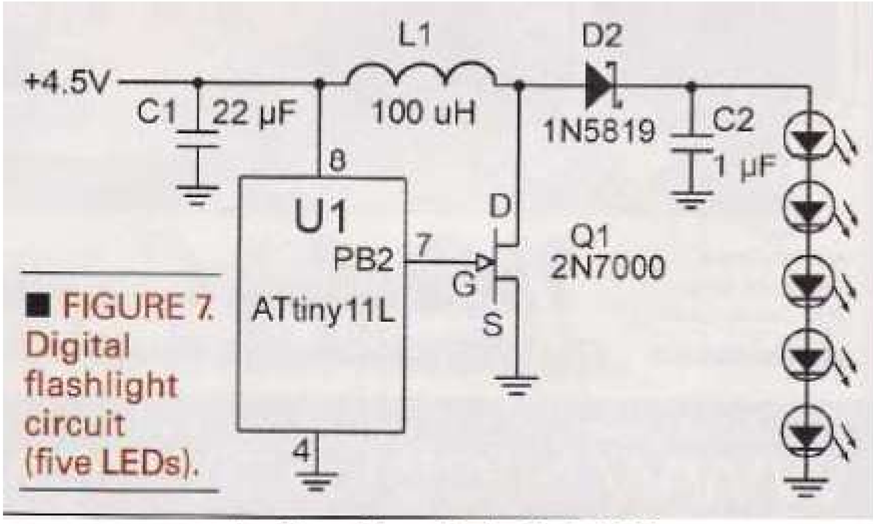


pic1. Joule Thief simulation





pic2. Some variation



pic. from Nuts Volts Feb 2008

pic3. MCU based flash light

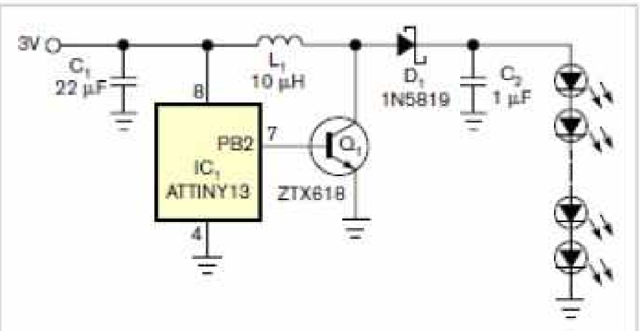


Figure 1 A charge-pump circuit creates the boosted voltage to light LEDs for a flashlight.

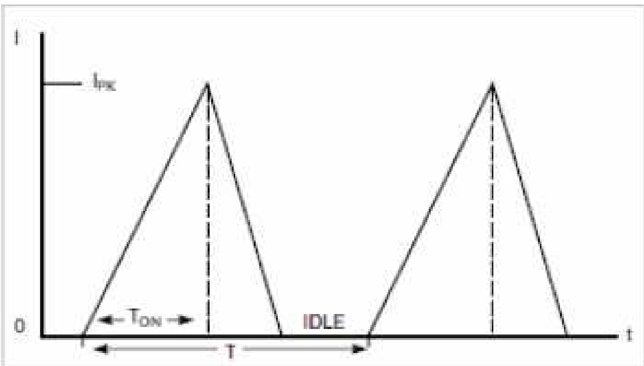
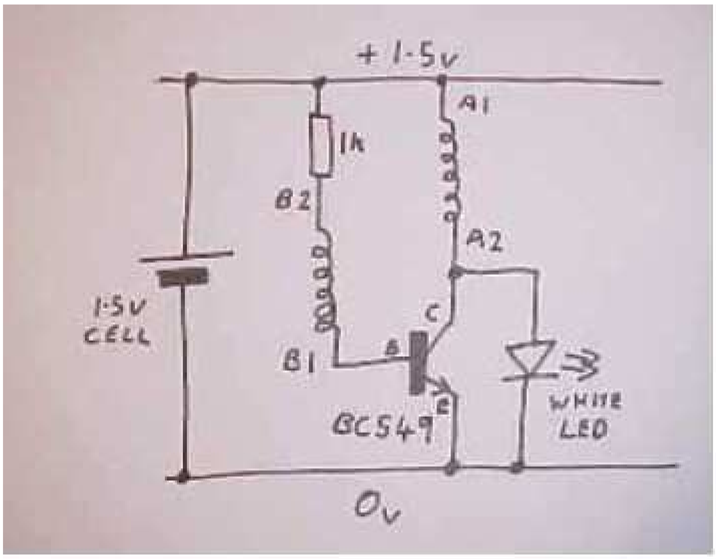


Figure 2 During the on time, current flows through the inductor and then charges the capacitor.

pic. same design from EDN Dec 2008

pic4. Slightly modified MCU based flash light



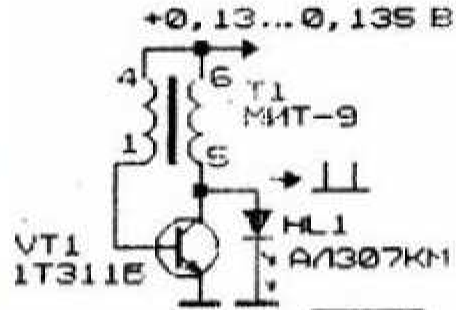


рис. 5

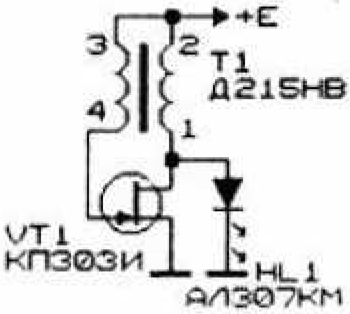


рис. 1

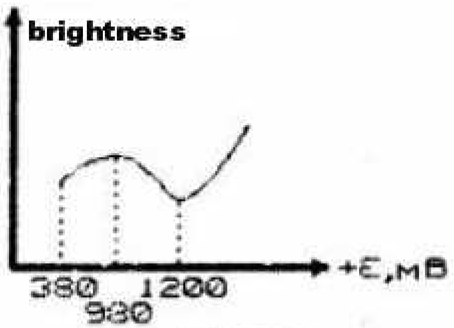


рис. 2

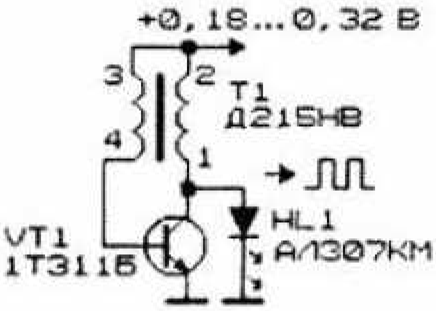


рис. 3

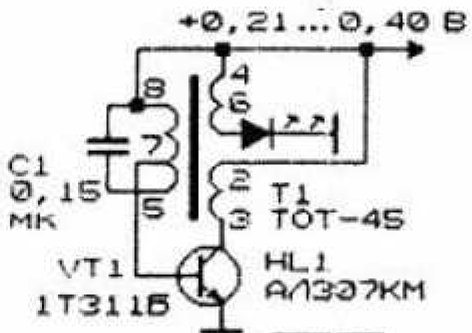
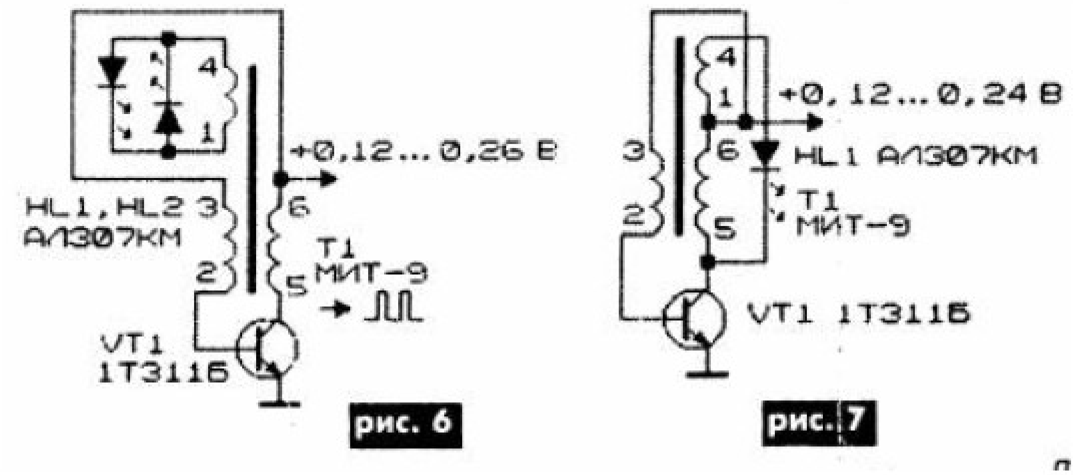
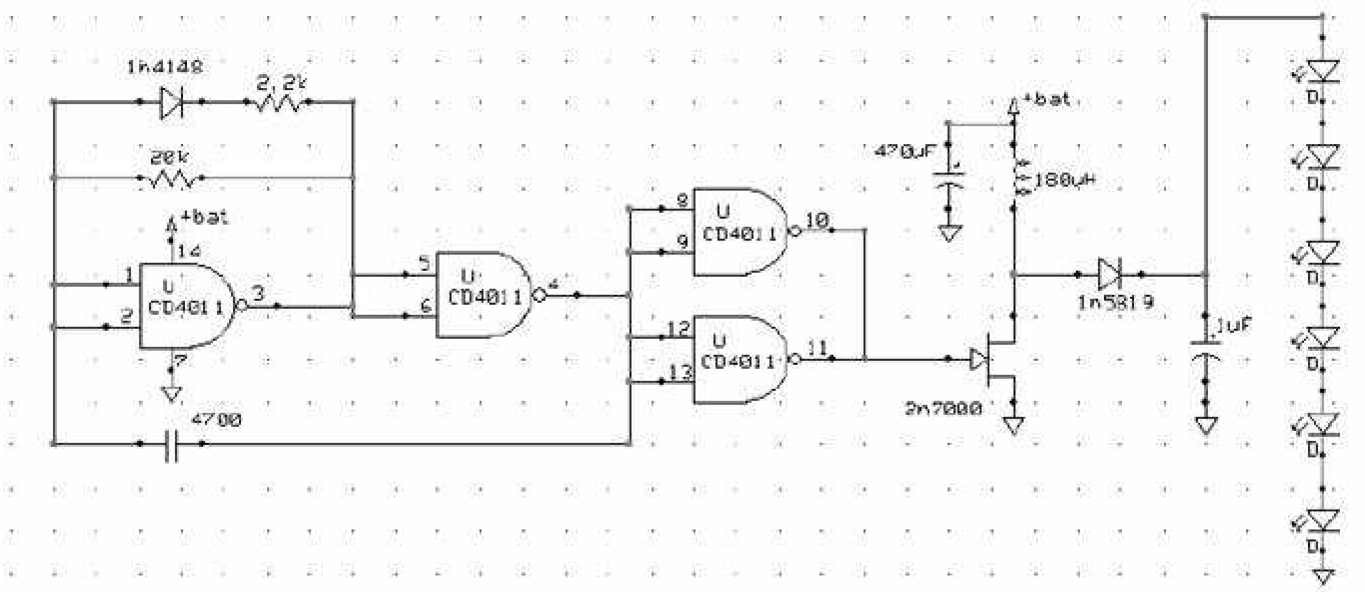


рис. 4



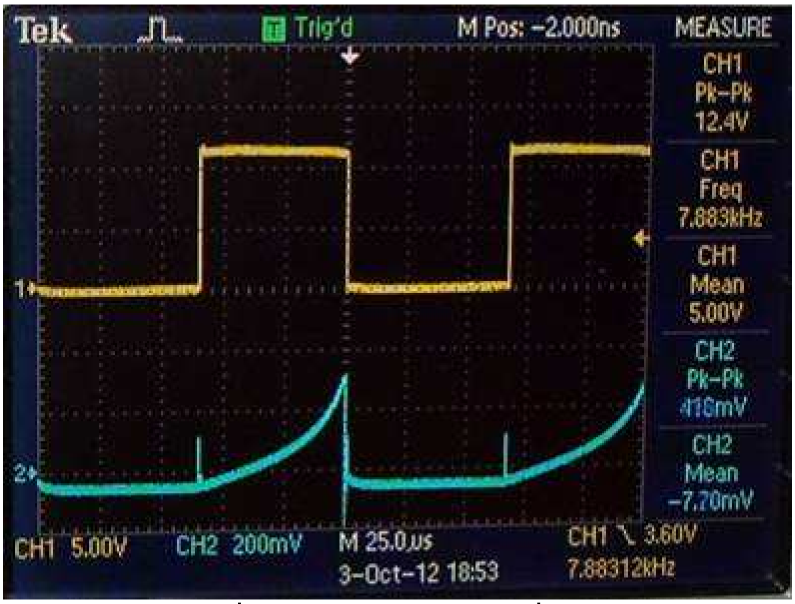
pic5. Different JT-like circuits



pic6. My version of LED flash light, I think more practical ☺

Suggested reading:
- SMPS http://en.wikipedia.org/wiki/Switched-mode_power_supply
- blocking oscillator http://mysite.du.edu/~etuttle/electron/elect37.htm

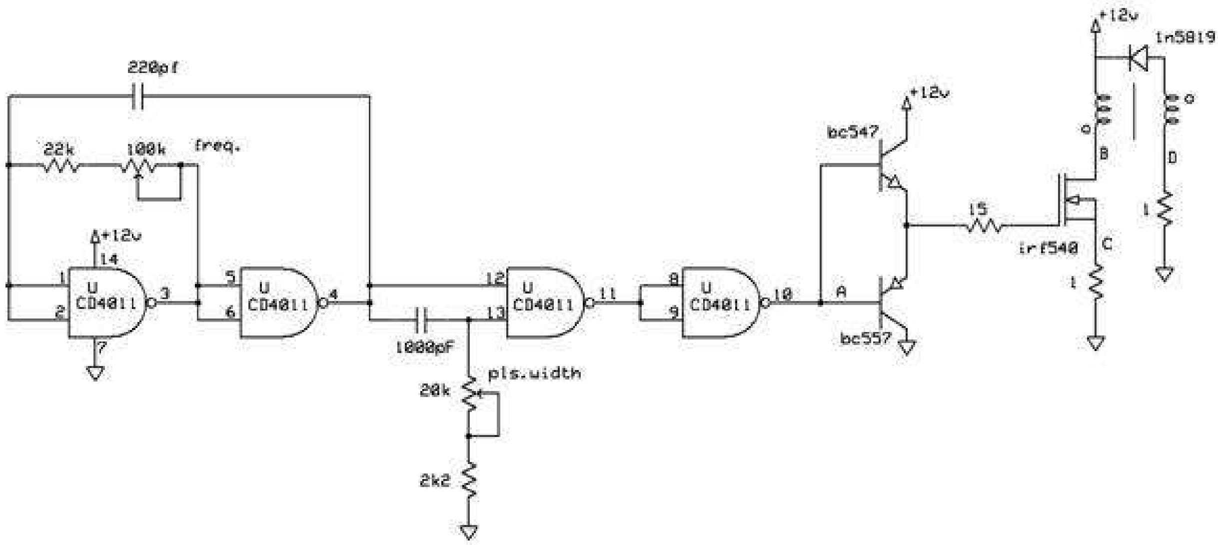
Observing core saturation



pic1. Core saturation

top – MOSFET control pulse; bottom – current in the primary coil (observed across resistor in MOSFET's source)

* Notice that after some time current start growing very fast (and non-linear)



pic2. Example circuit

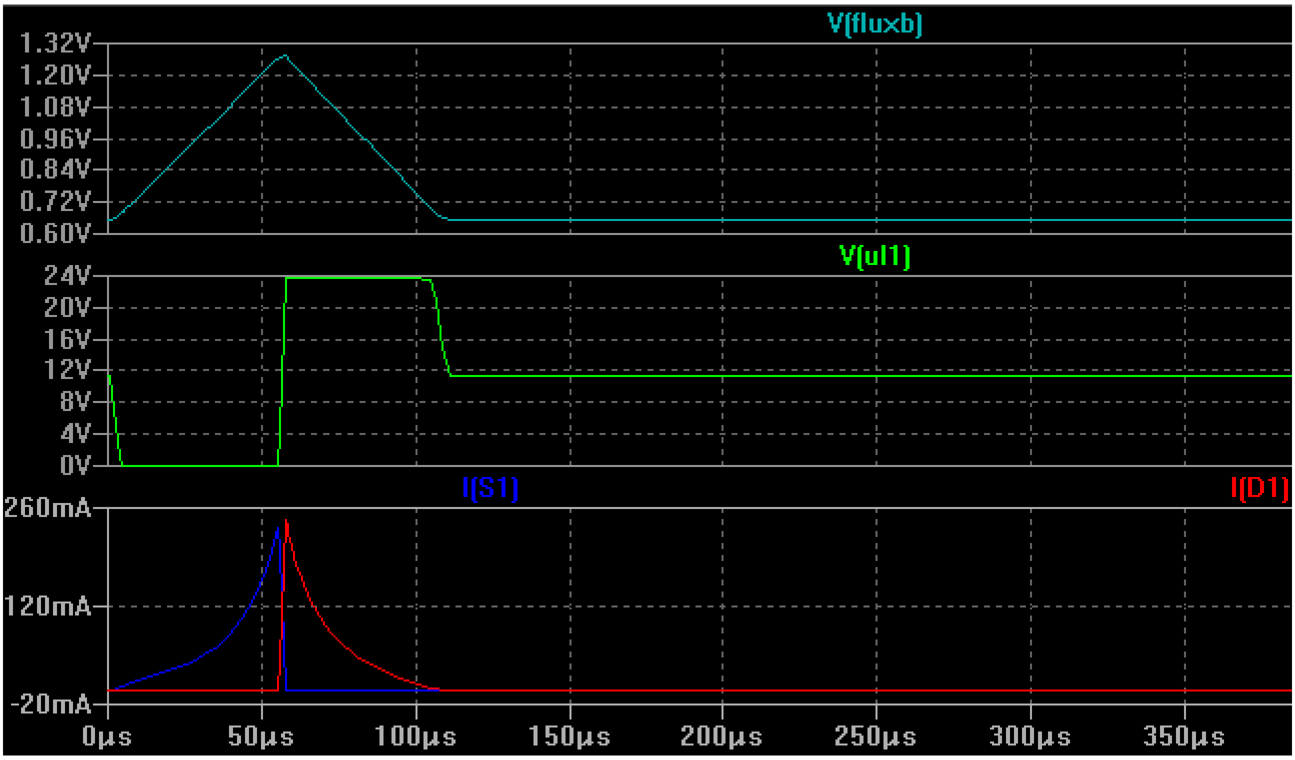
This is same "looped flyback" circuit I posted before.

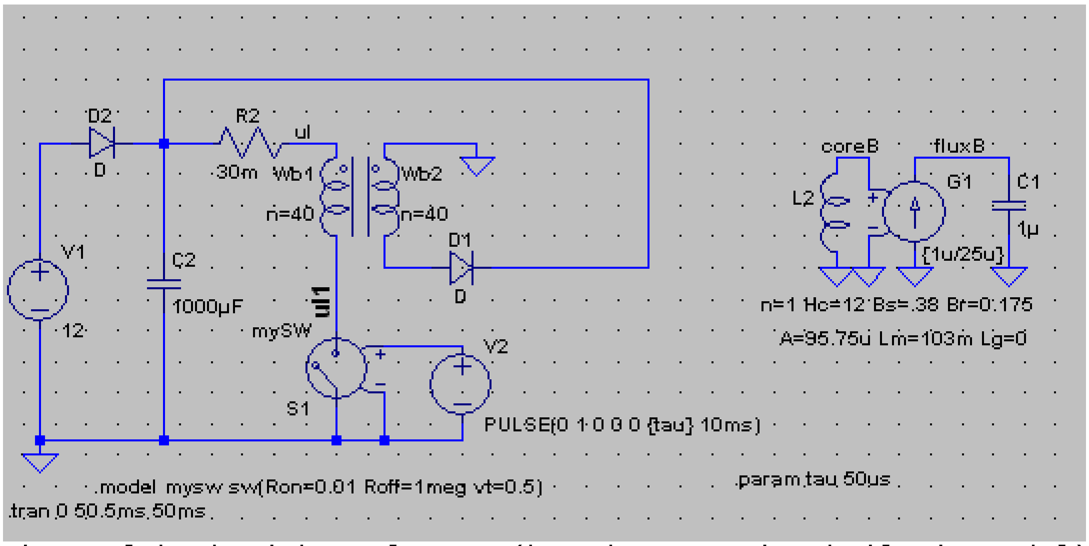
To observe saturation you just need gradually increase pulse width and observe current thru resistor in MOSFET's source (point C). When experimenting with saturation you should take care about MOSFET cooling because current grows very fast and transistor can became very hot. Transformer core saturation one of most common reasons of low efficiency in power supply circuits.

Some related links
http://en.wikipedia.org/wiki/Saturation_%28magnetic%29
(Surprisingly not much information on the topic on the web)

Simulation with "real" core and "real" diode

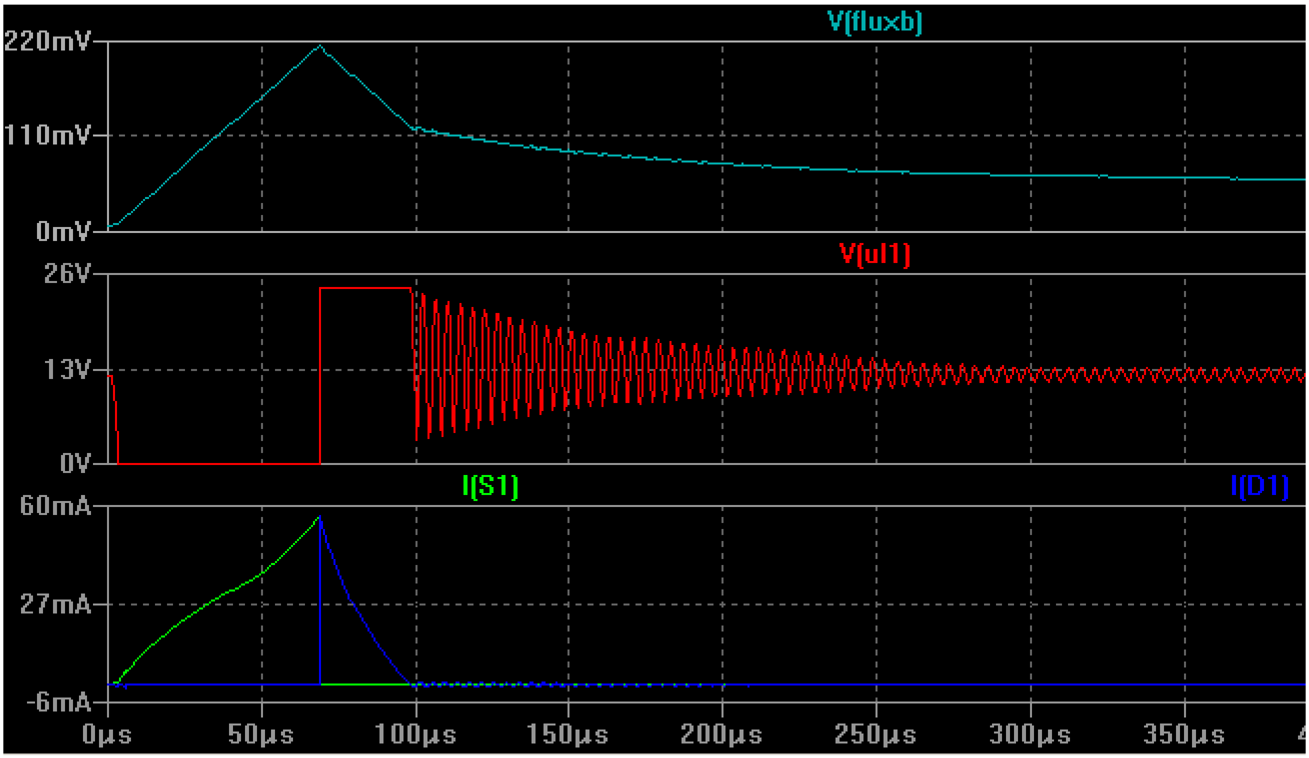
LTSpice gives some possibilities to simulate behaviour of real cores and other components like diodes.
I don't think that it is very practical but interesting to try ☺

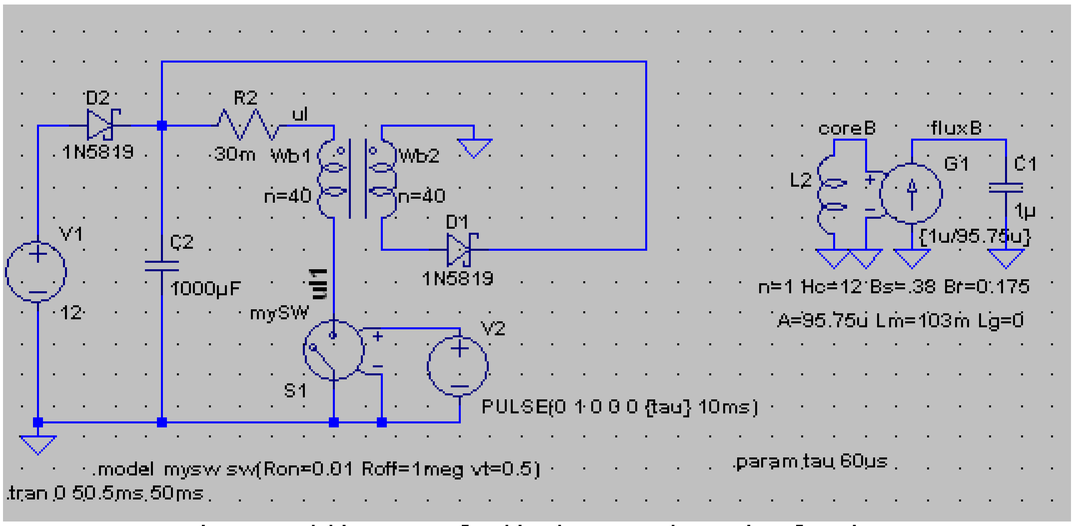




pic.1 Flyback with real core (based on LTSpice built-in model)

* notice shape of current in primary and secondary





pic2. Adding real diode to the simulation

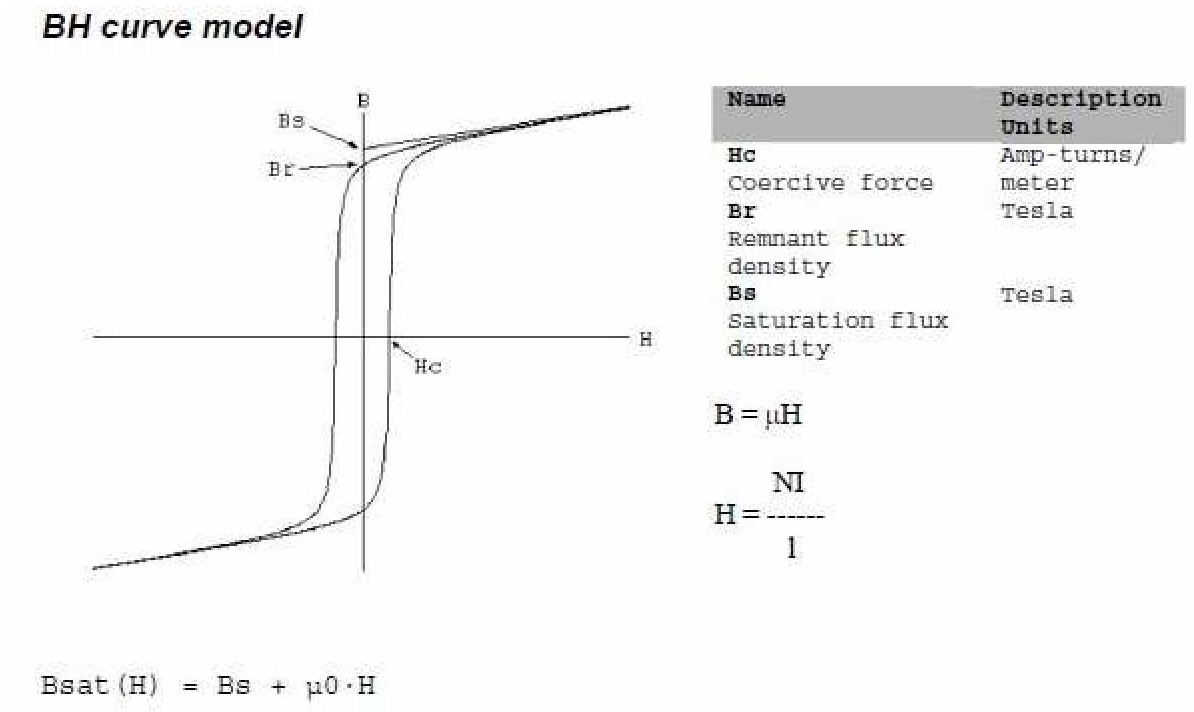
* notice oscillations on primary

So it’s looks quite similar to what real oscilloscope shows.

B-H curve model

As we saw "real" core in transformer brings non-linearity

Let's consider these effects in more details



BH curve model

Name	Description Units
Hc Coercive force	Amp-turns/ meter
Br Remnant flux density	Tesla
Bs Saturation flux density	Tesla

$$B = \mu H$$

$$H = \frac{NI}{l}$$

$$Bsat(H) = Bs + \mu 0 \cdot H$$

pic.1 A page from LTSpice manual about built-in core model

The upper and lower branches of the hysteresis major loop are given by

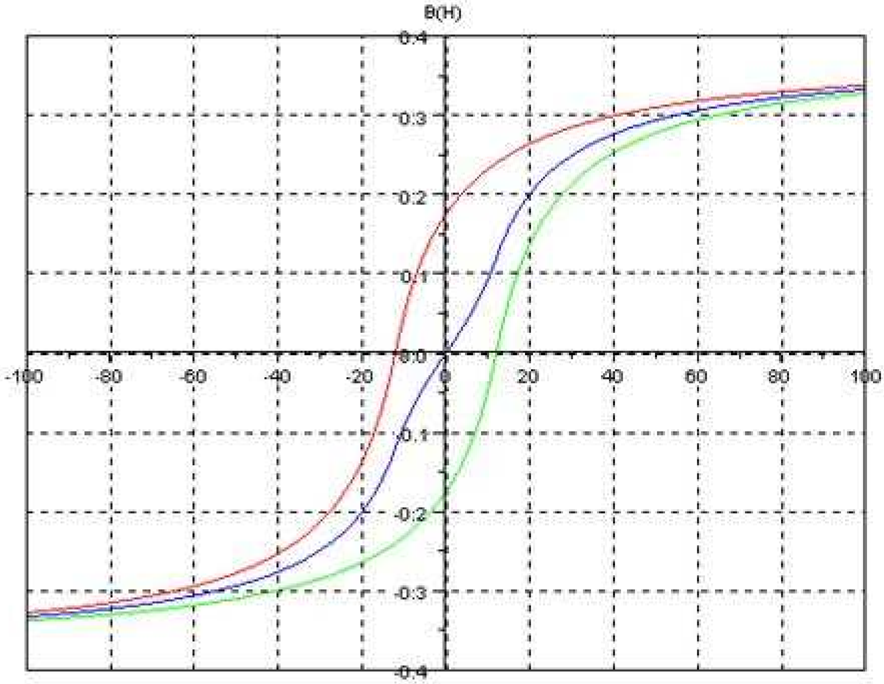
$$Bup(H) = Bs \cdot \frac{H + Hc}{|H+Hc| + Hc \cdot (Bs/Br-1)} + \mu 0 \cdot H$$

and

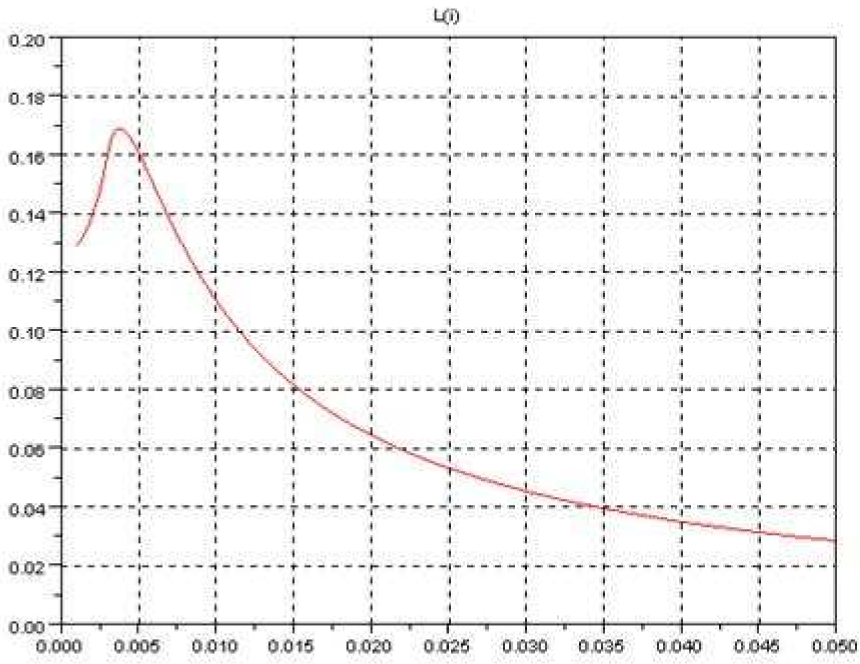
$$Bdn(H) = Bs \cdot \frac{H - Hc}{|H-Hc| + Hc \cdot (Bs/Br-1)} + \mu 0 \cdot H$$

$$Bmag(H) = .5 \cdot (Bup(H) + Bdn(H))$$

Name		Description Units
Lm	Magnetic Length(excl.gap)	meter
Lg	Length of gap meter	meter
A	Cross sectional area	meter**2
N	Number of turns	meter**2

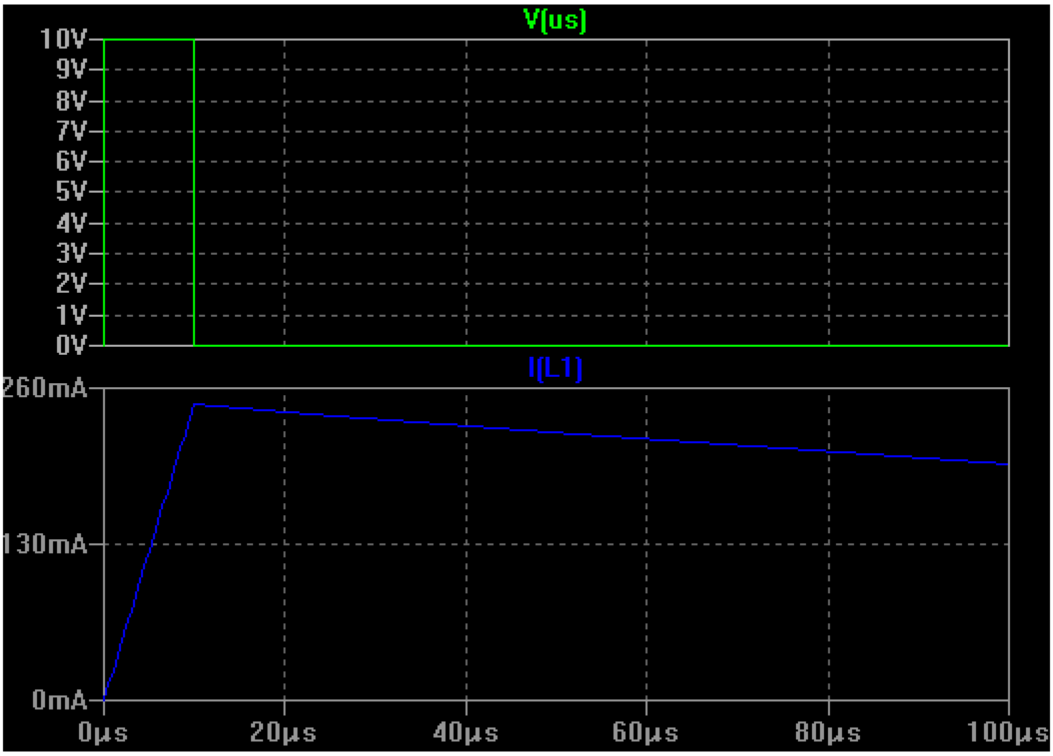


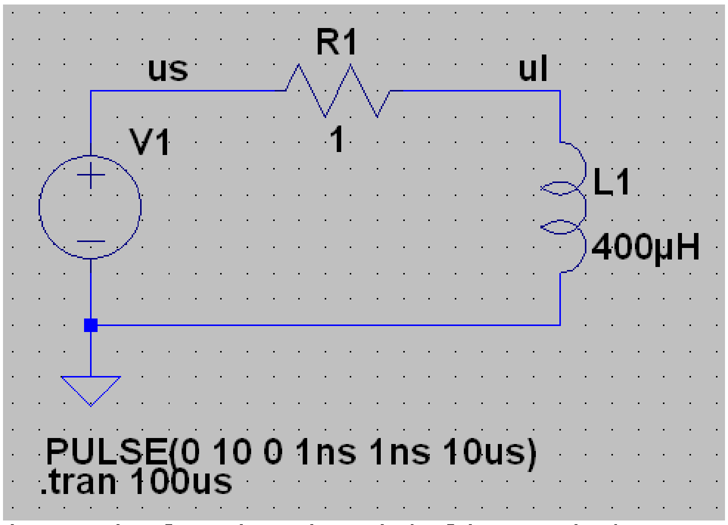
pic.2 BH curves drawn with above formulas



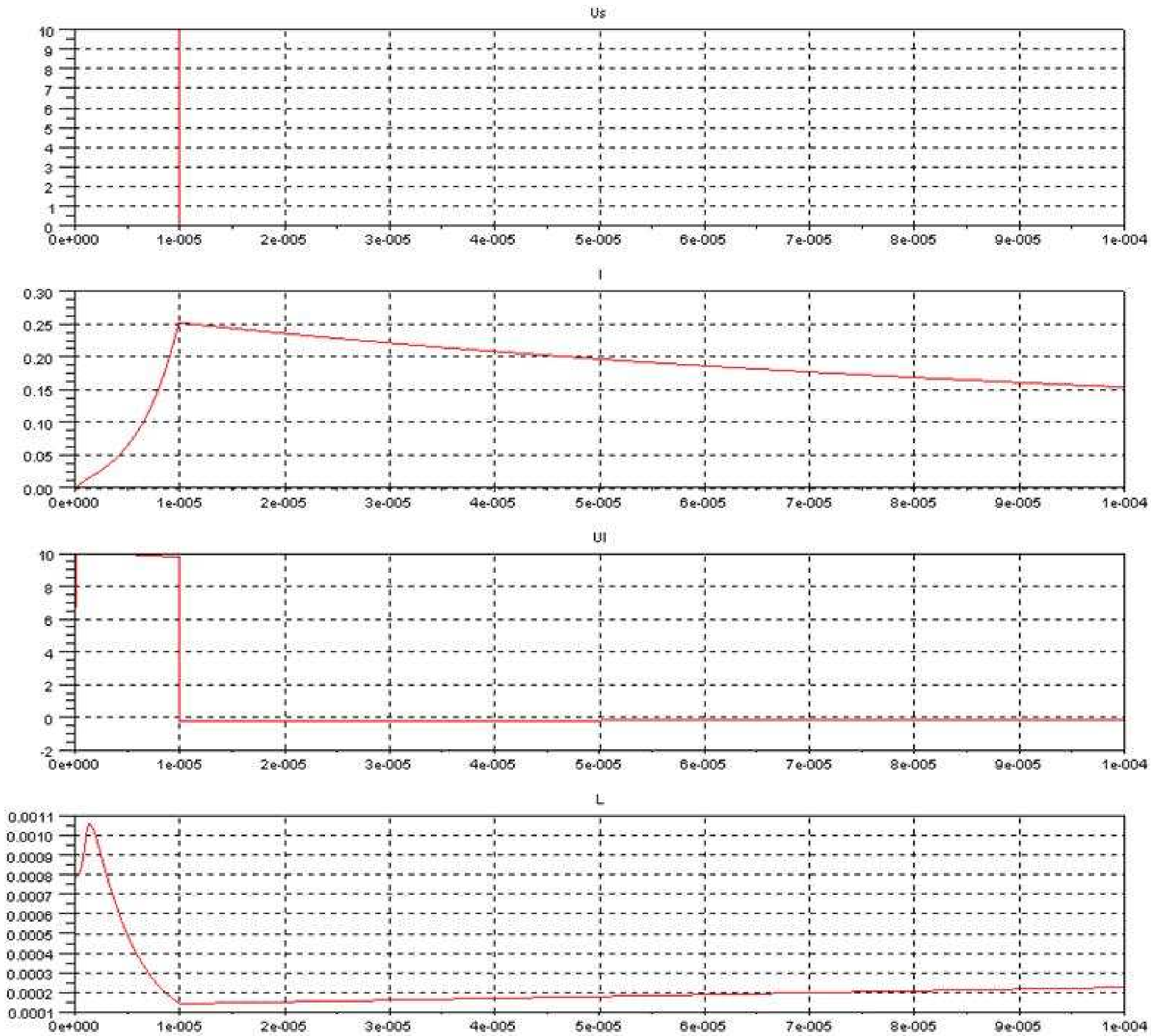
pic3. Inductance (H) vs. current (A) based on above BH curve

This result opens quite interesting possibility to model non-linear inductance ourselves.





pic4. Simple circuit with linear inductance



pic5. Simulation for above circuit made in SCI lab using model for non-linear core

Graphs from top to bottom:
- voltage on power source,
- current thru inductor,
- voltage on inductor,
- inductance of inductor vs. time

* Notice current and inductance variations

This simulation made using Finite difference method to solve differential equation

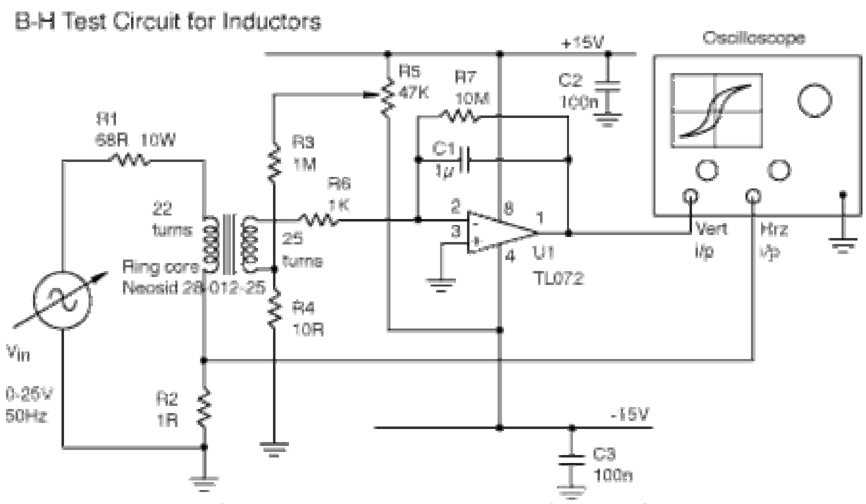
Us = IR + L dI / dt

It might be not very straight forward to perform (comparing to LTSpice simulation) but it gives us full control on the model.

Some links:
https://www.dropbox.com/s/lx23vkvjpsgi0hc/John%20Chan%20Nonlinear_Transformer_Model_for_Circuit_Simulation.pdf
http://en.wikipedia.org/wiki/Finite_difference_method

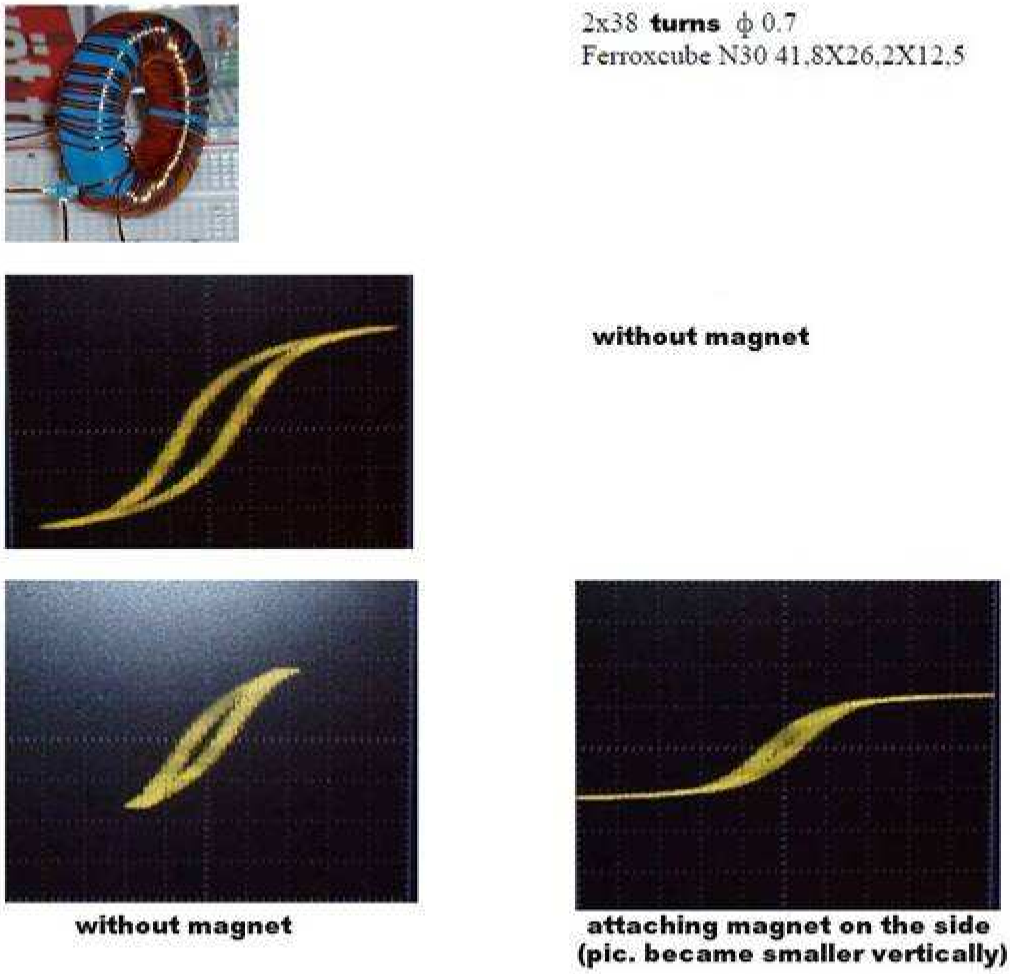
Plotting BH curves yourself

We saw quite a lot of theoretical staff about BH curve and core non-linearity.
Perhaps it would be interesting to do something practical about it.



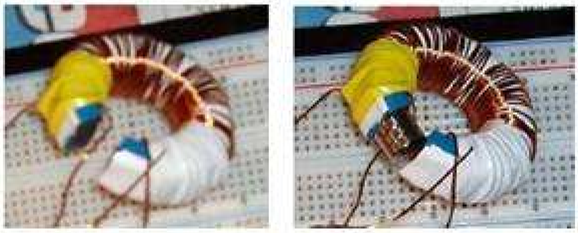
pic.1 Core tracer schematic

With this simple circuit and oscilloscope we can observe actual magnetization curves for different cores.
It is also interesting how magnet affects these curves.



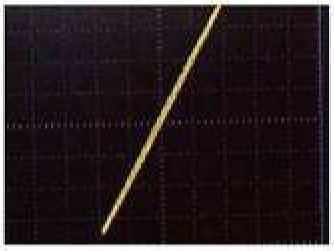
pic2. Effect of magnet attached to the core's side

Here some pictures of experimentally obtained BH curves for Ferroxcube N30 ring core.



Ferroxcube N30 41.8X26.2X12.5

gap about 8mm

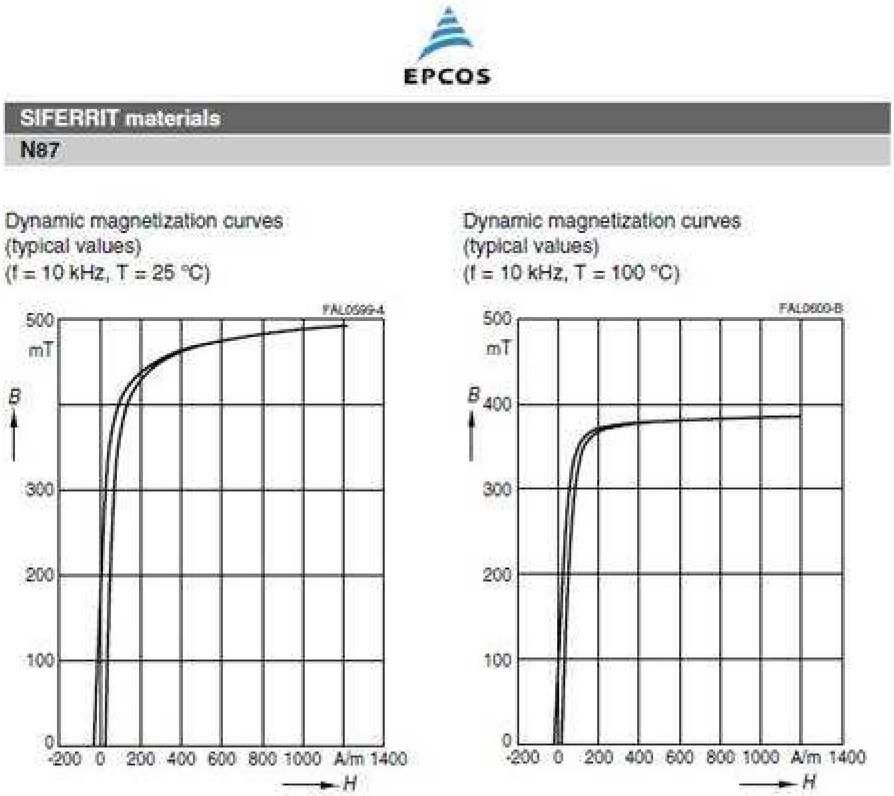


without magnet

magnet in the gap

magnet in the gap (reversed)

pic3. Effect of magnet inserted into core’s gap

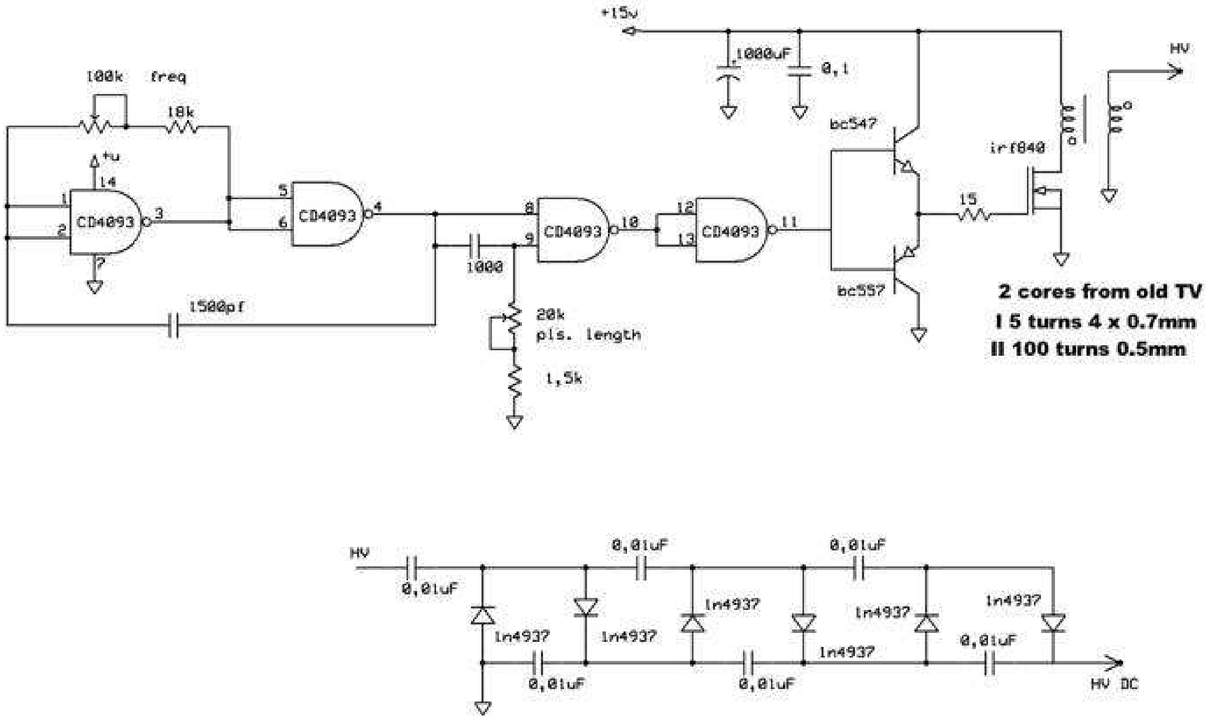


pic4. BH curve for N87 ferrite from datasheet - looks similar to what we see in experiment ☺

Plotting Magnetization Curves
http://info.ee.surrey.ac.uk/Workshop/advice/coils/BHCkt/index.html
http://www.cliftonlaboratories.com/type_43_ferrite_b-h_curve.htm

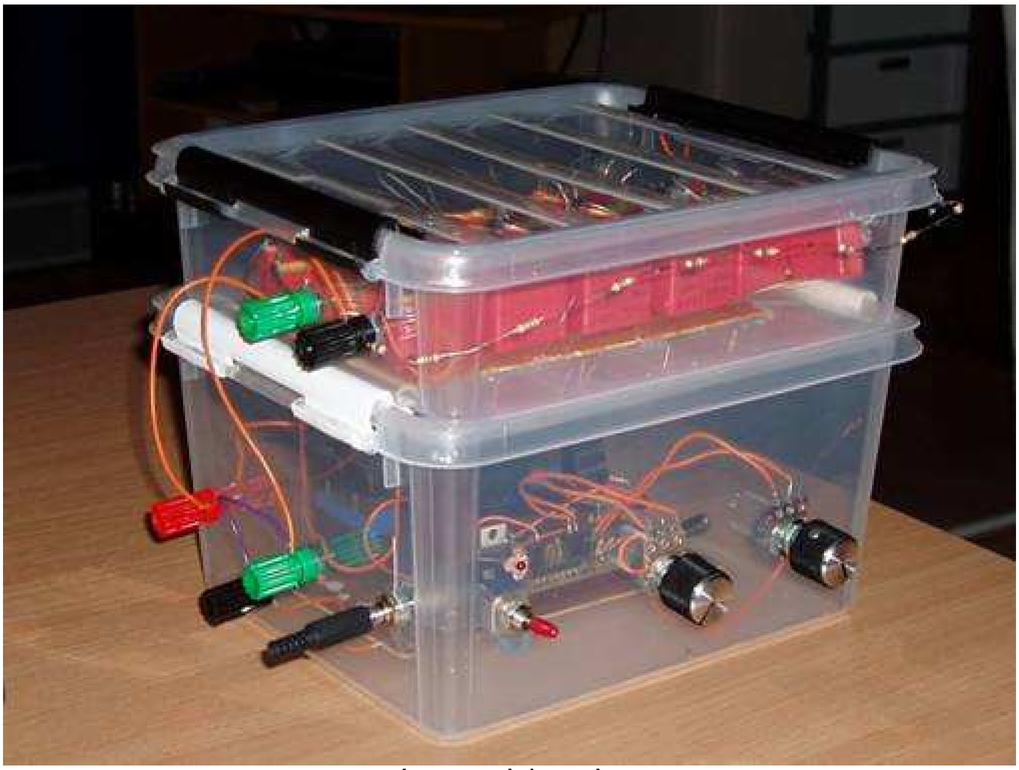
HV power source

We saw a step-down flyback application in MB3,
another very important application of step-up flyback is a spark gap drivers and HV DC power sources.

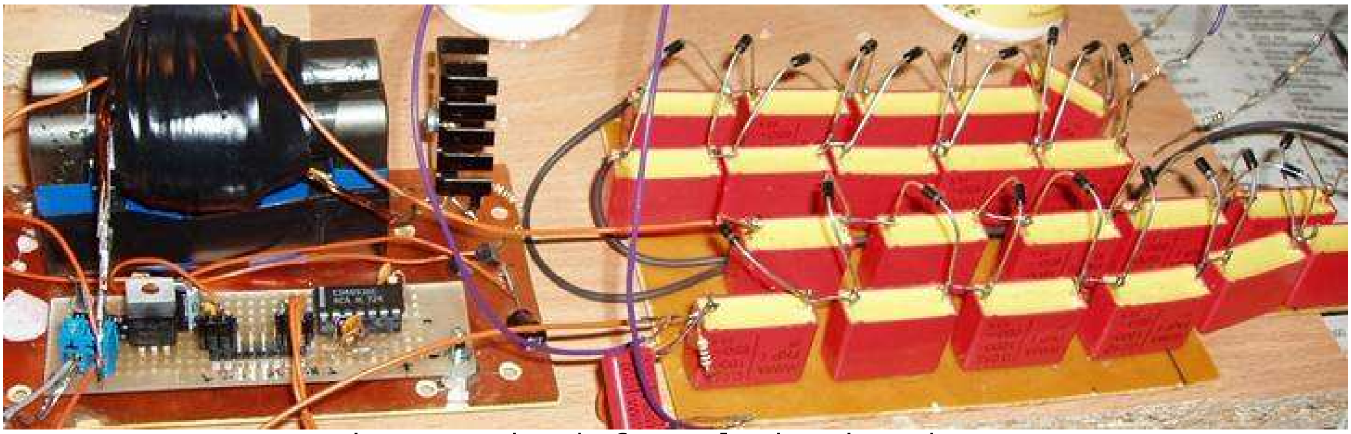


pic1. Schematic HV pulse generator and optional voltage multiplier

pic2. Pulse generator and multiplier assembled in plastic boxes



pic3. Side view



pic4. Testing before placing into boxes

This simple circuit produces short pulses up to 5KV (without multiplier) and capable to supply about 1ma current at 5KV with 10 stage multiplier. Output voltage can be adjusted in some range by changing pulse width (20k pot.).

Please be careful when working with high voltage!

Some related links:
10KV power source http://www.sentex.ca/~mec1995/circ/hv/hvdcgen/hvdcgen.html

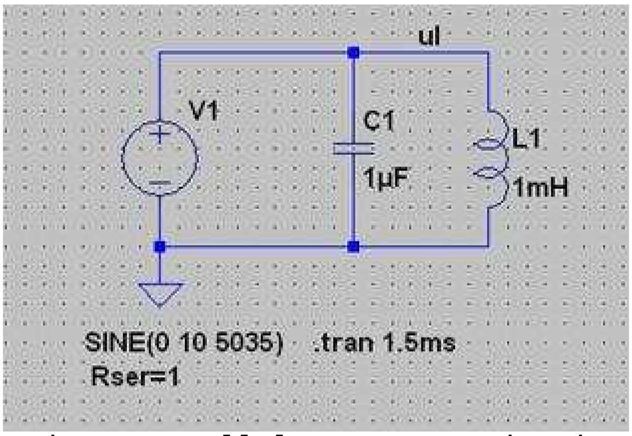
Chapter 3. Resonance

Resonance is next topic I would like to discuss.

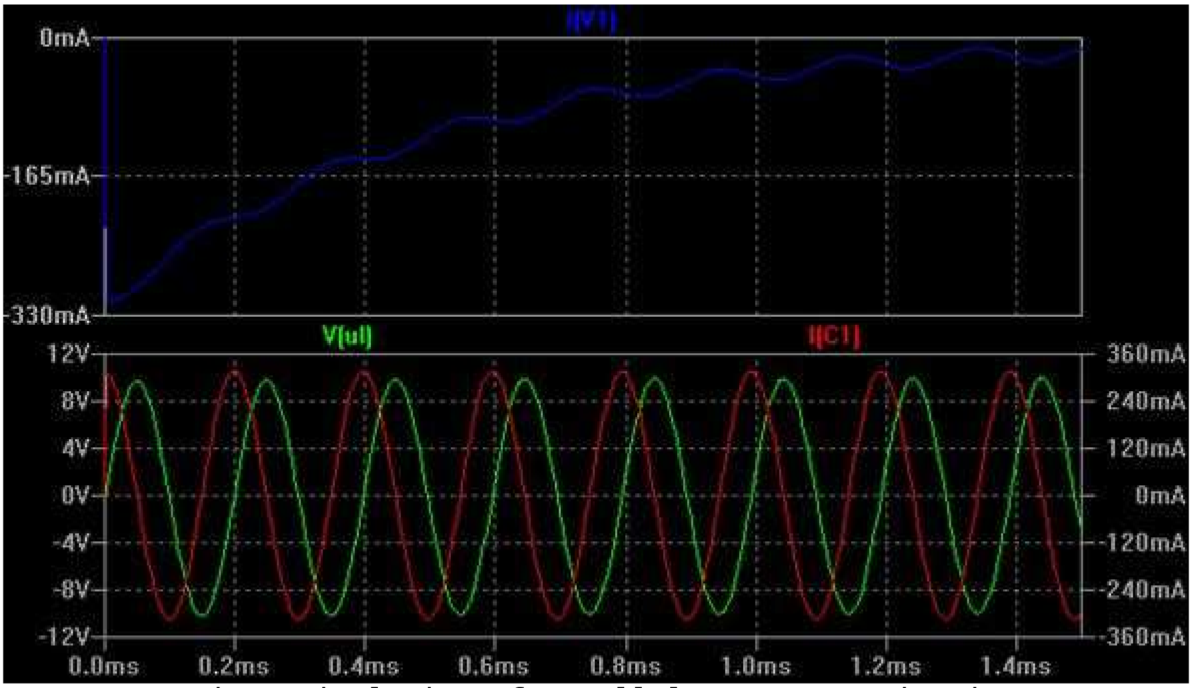
Let’s start with two most common setups –

Parallel and series resonance circuits

In these two setups energy from capacitor (C * U * U / 2) flow to inductor (L * I * I / 2) and back. “Originally” this energy comes from power supply (V1). Resonance circuit «accumulate» energy until power of source became equal to power of loses in the circuit. Or Pcirc = Psource * Q where Q is quality factor



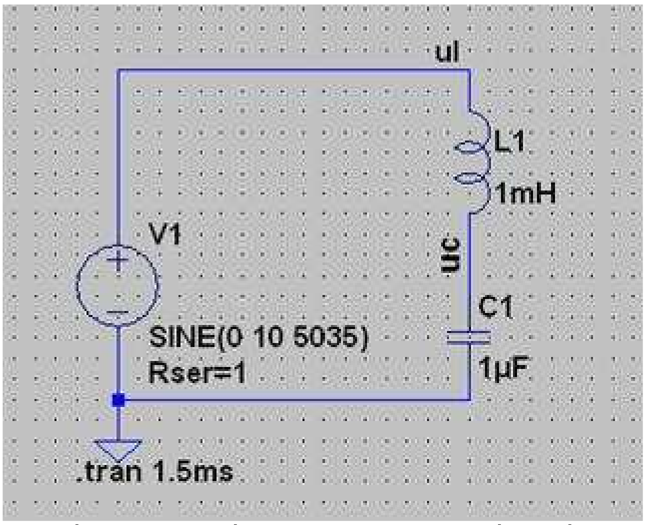
pic1. Parallel resonance circuit



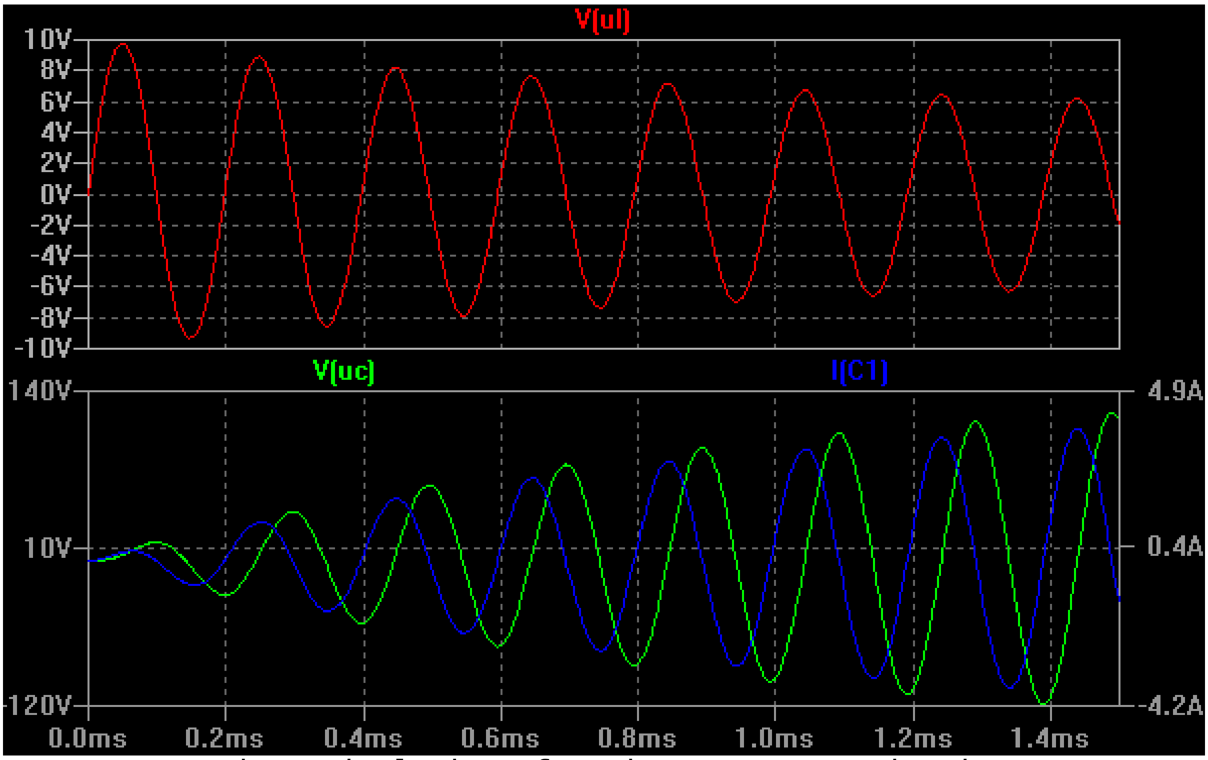
pic2. Simulation of parallel resonance circuit

In parallel resonance circuit we have circulating current Q times more than power source current

* notice current decreasing while oscillation settling down



pic3. Series resonance circuit



pic4. Simulation of series resonance circuit

In series resonance circuit voltage on capacitor (and inductor) Q times more than voltage on power source.

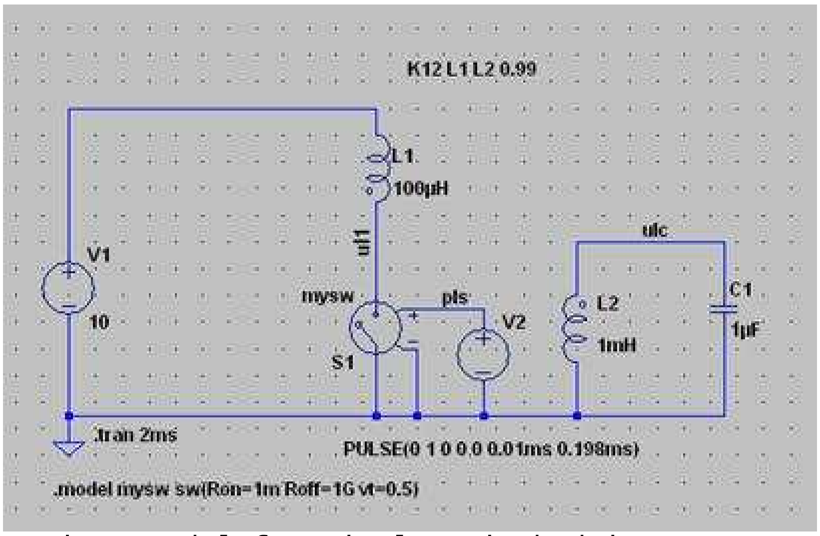
* notice voltage grow while oscillations settling down

We can “accumulate” some energy in resonance circuit, we can “extract” this energy back at any time and rate but…no more than we put there from power source.
By some reason people tend to believe that there is extra power in resonance circuit and we just need to find a way how to get it from there ;-)

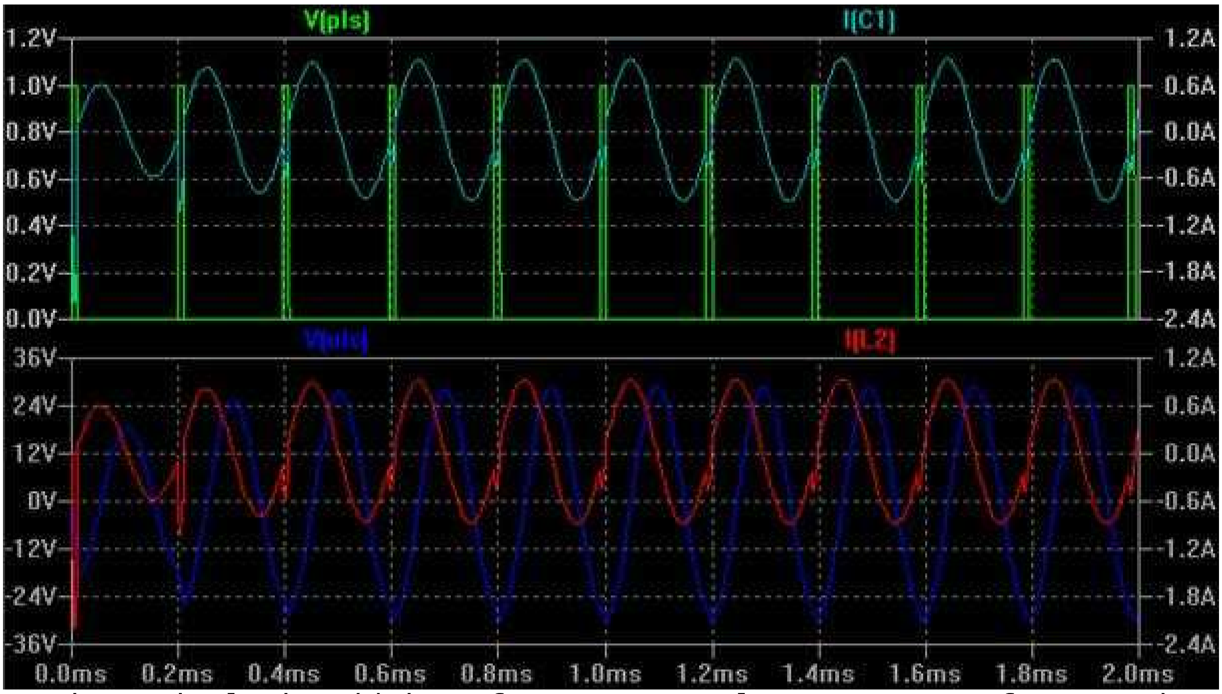
Some reading about resonance:
http://www.allaboutcircuits.com/vol_2/chpt_6/1.html
http://www.electronics-tutorials.ws/accircuits/series-resonance.html
http://www.electronics-tutorials.ws/accircuits/parallel-resonance.html
http://farside.ph.utexas.edu/teaching/315/Waves/node12.html

Single switch driver

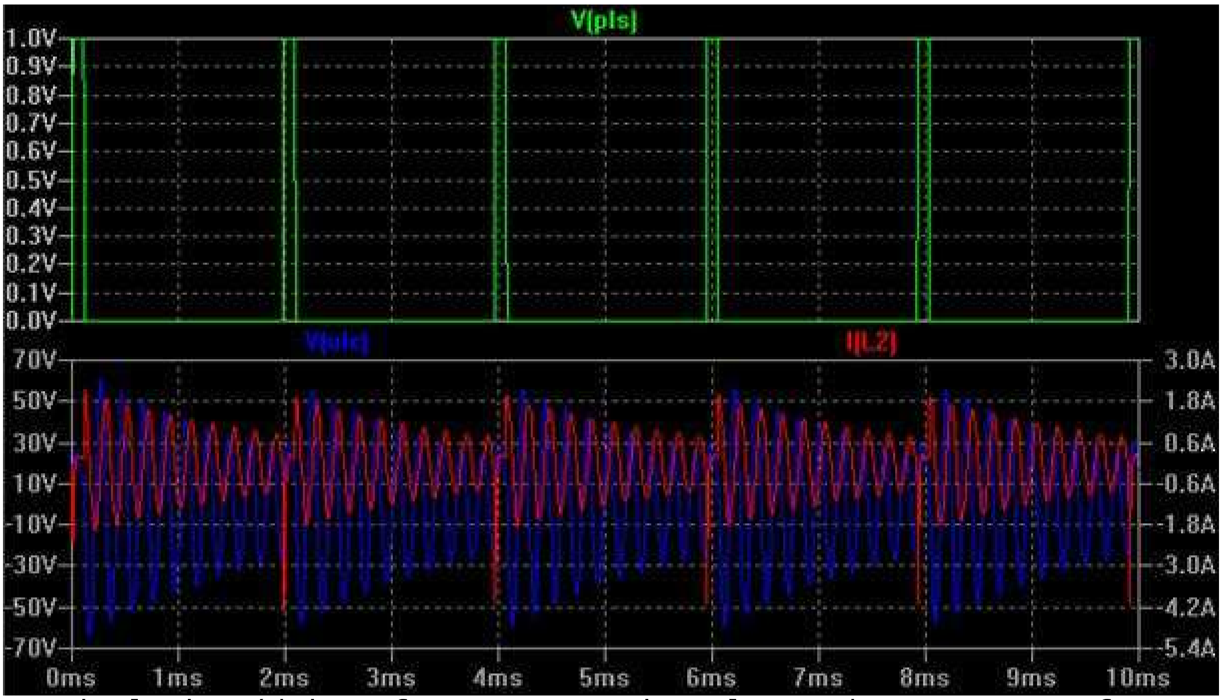
Let's review methods how we can power resonance circuit
and start with single switch driver



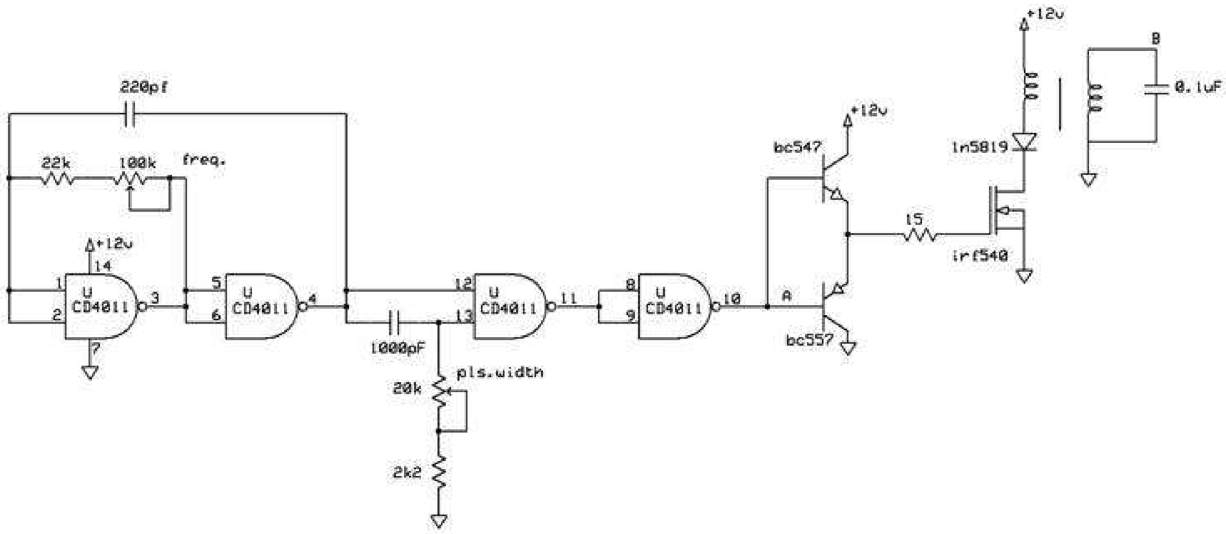
pic1. Model for single switch driver setup



pic2. Simulation (driver frequency equal to resonance frequency)

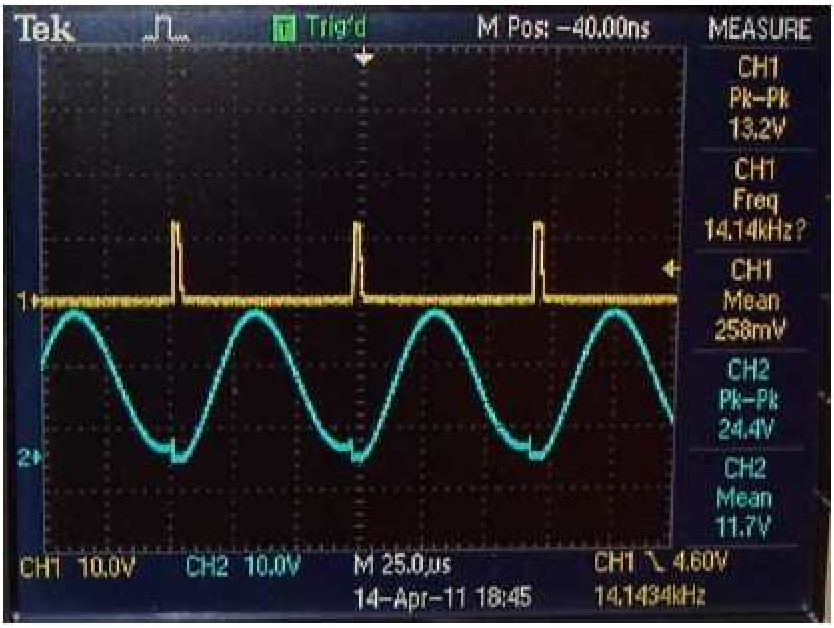


pic3. Simulation (driver frequency 10 times lower than resonance frequency)



pic4. Simple driver setup schematic

* notice diode in MOSFET’s drain to prevent built-in zener diode to interfere

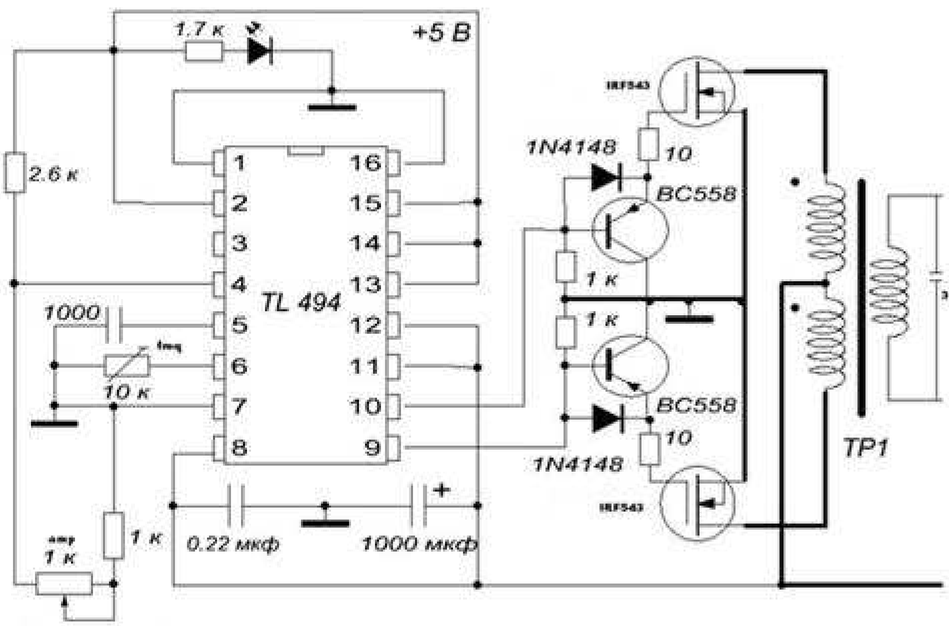


pic5. top – driver signal (point A), bottom – voltage on inductor and capacitor (point B)

This circuit quite simple and can be used for experiments on frequencies up to 100kHz. Two transistors can be replaced with integral MOSFET driver like TC4020…4029 (or similar) For higher frequencies cd4011 can be replaced with 74hc00 (requires 5v power supply and changes in MOSFET driver).

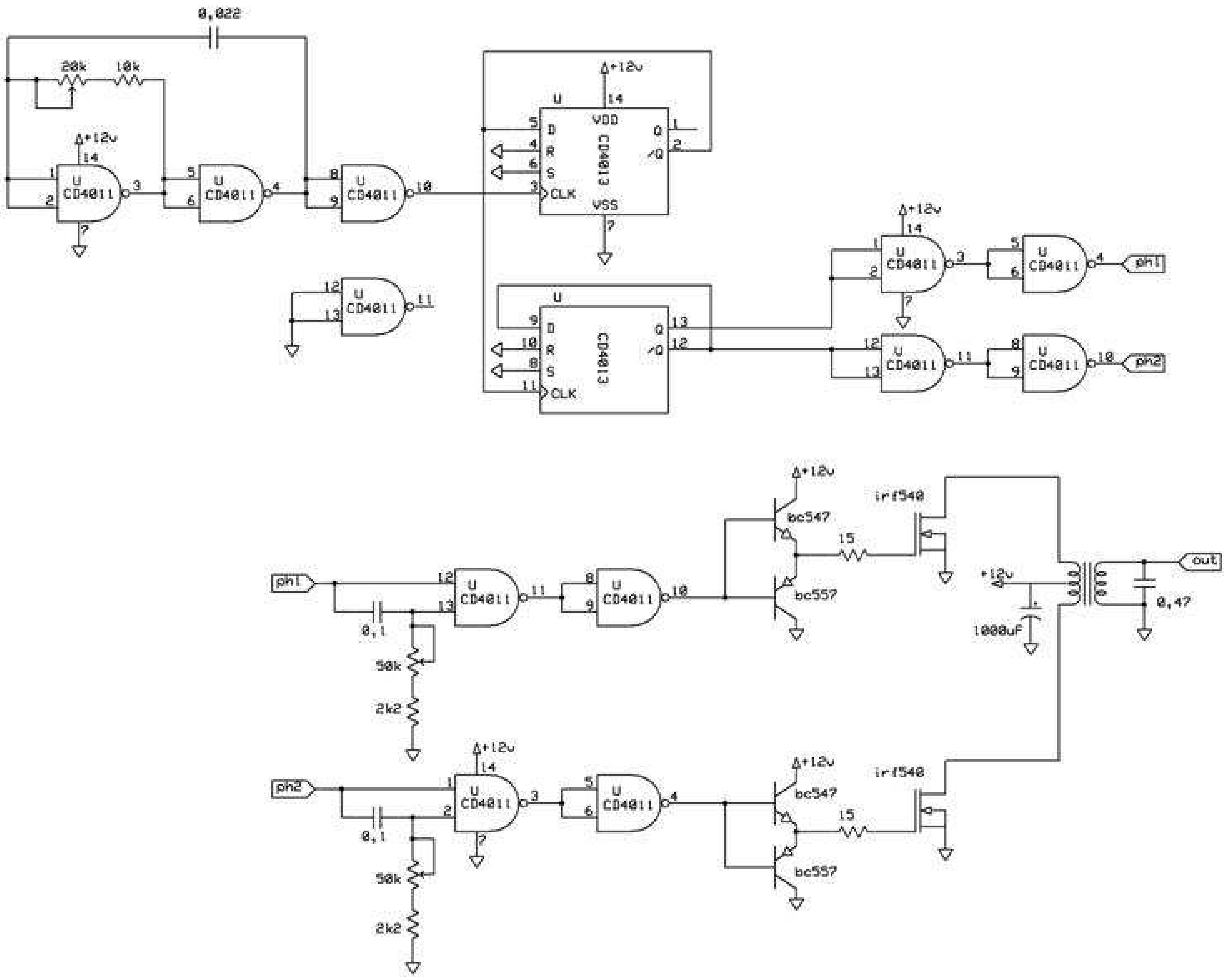
Push pull driver

– more powerful option



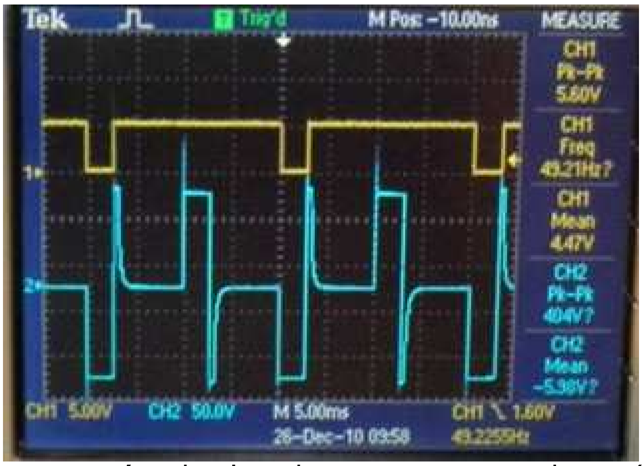
pic.1 Push-Pull driver with TL494

It appeared that TL494 does not work well on low frequencies so I made a simple substitution for it using CD4011 and CD4013. Other possibility is to use KA7500 (pin-to-pin replacement for TL494 which works ok on low frequencies) or some other PWM chip.

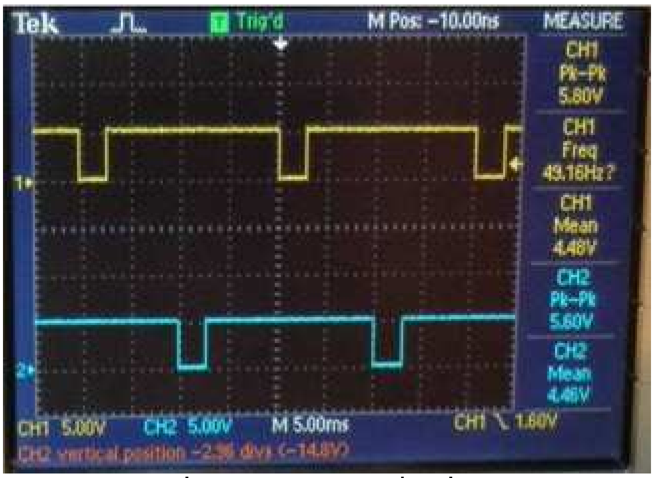


pic2. Push pull driver using CMOS logic

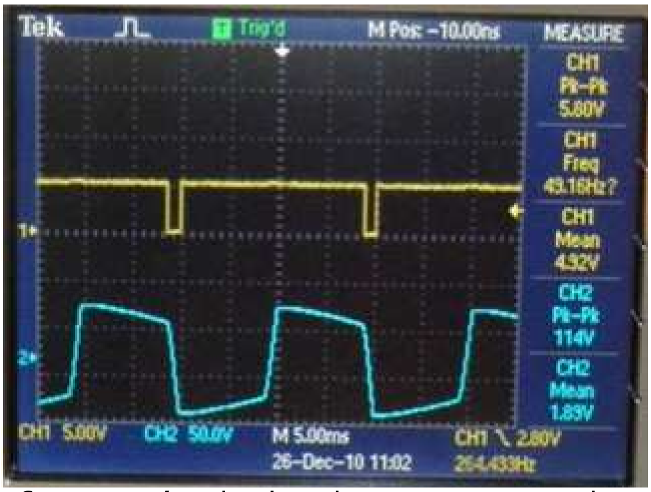
* 50k pots are mechanically connected so driver legs adjusted synchronously
** Additional 4011 elements after 4013 needed to avoid loading 4013 outputs by RC chains (number of elements can be reduced by using 4001 elements and rearranging the circuit)



pic3.top - one MOSFET's drain, bottom - secondary (w/o capacitor)



pic4. MOSFET drains

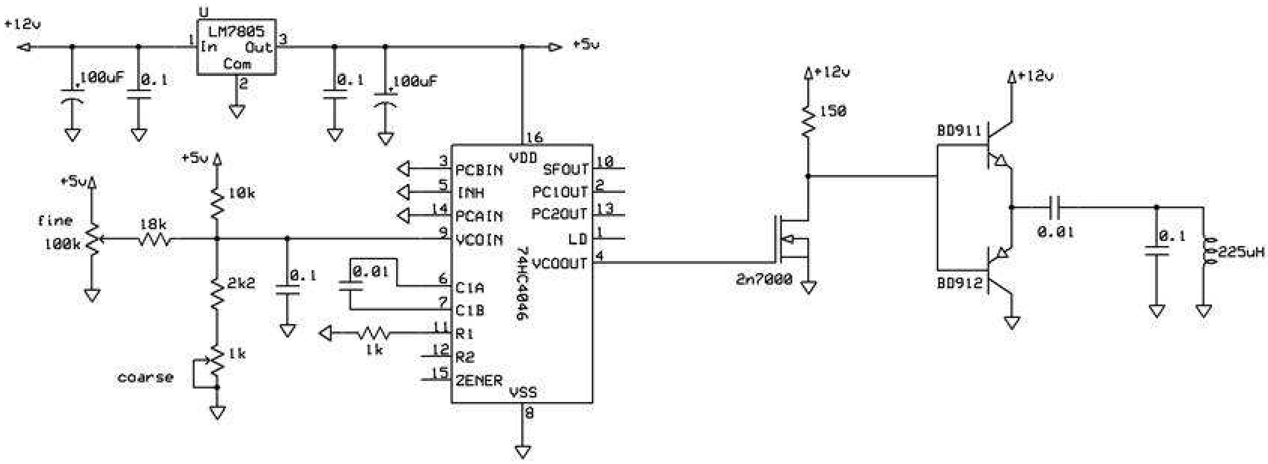


pic5. top – one of MOSFET's drain, bottom - secondary (with capacitor connected)

This circuit can also be used as an inverter to provide power to some appliances like led lamps etc.

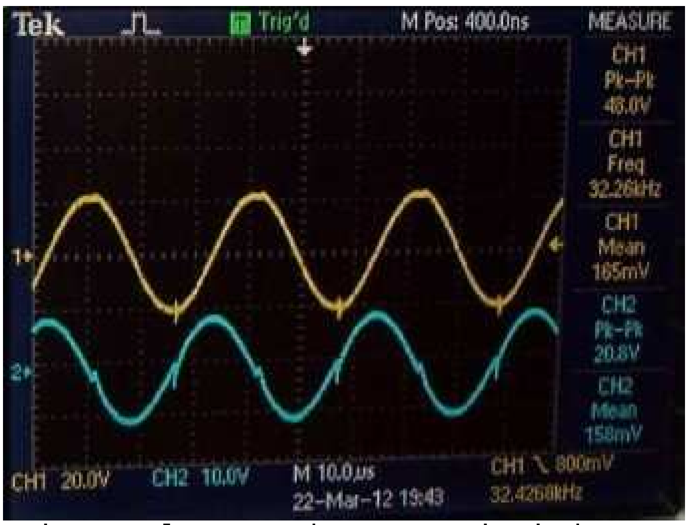
Links:
- Designing Switching Voltage Regulators With the TL494
http://www.ti.com/lit/an/slva001e/slva001e.pdf
- http://www.instructables.com/id/250-to-5000-watts-PWM-DCAC-220V-Power-Inverter/

Half bridge driver



pic1. Simple half-bridge driver based on 74HC4046 VCO.

* Power supply voltage can be increased up to 35v
** Value of resistor in 2n7000 drain may be need to be changed (depends on frequency and power supply voltage)

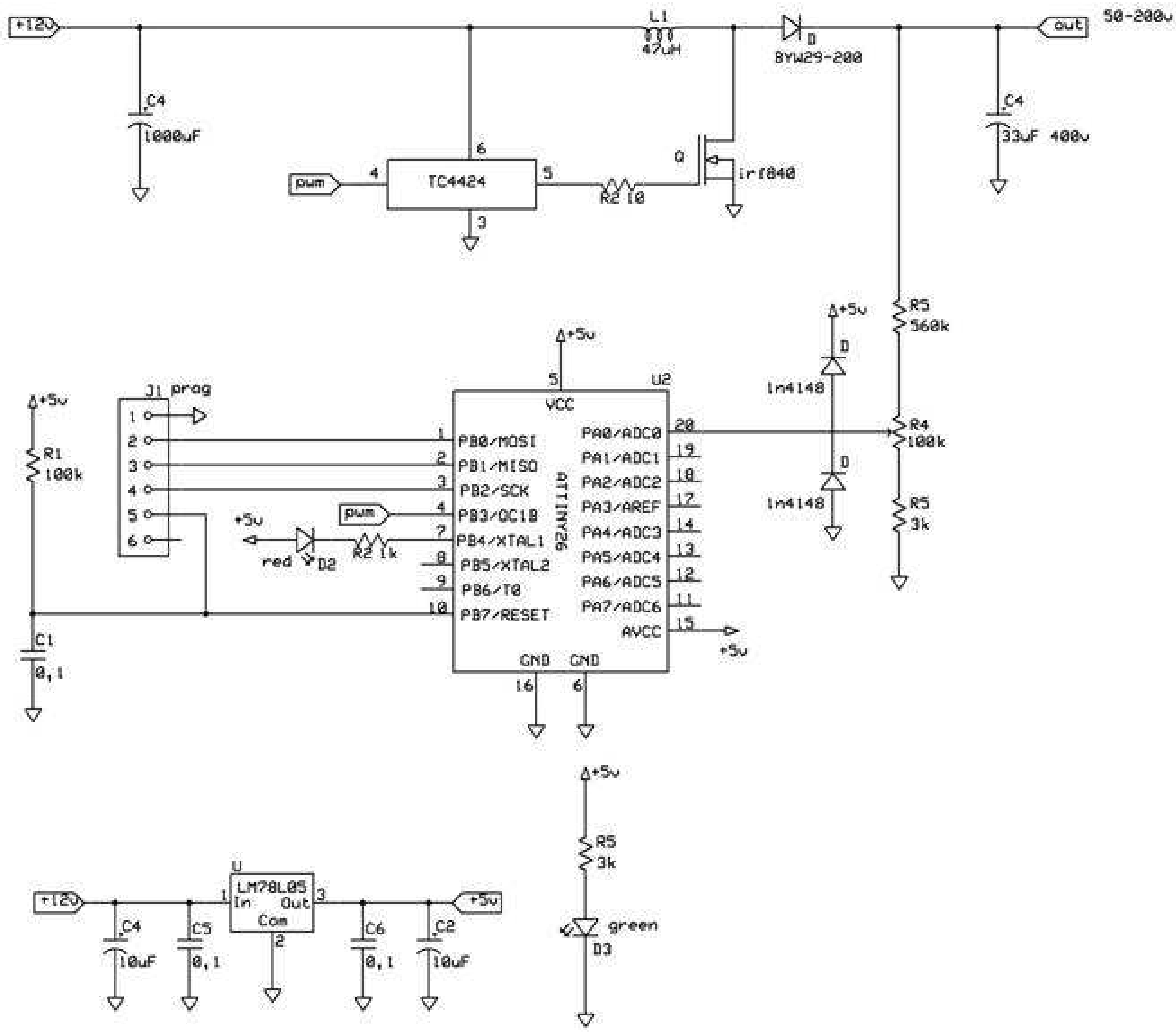


pic2. Voltage and current in inductor

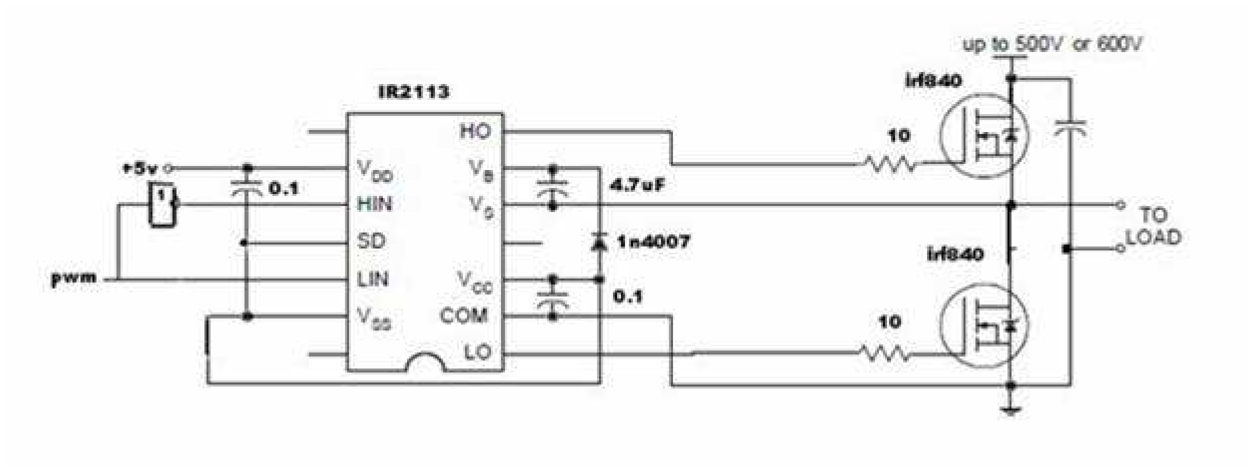
This driver works quite ok up to 200-300kHz

Bridge drivers

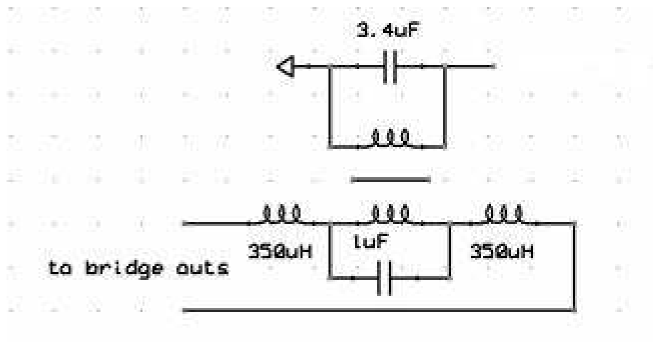
Let’s review one of possible MCU controlled HBridge setup



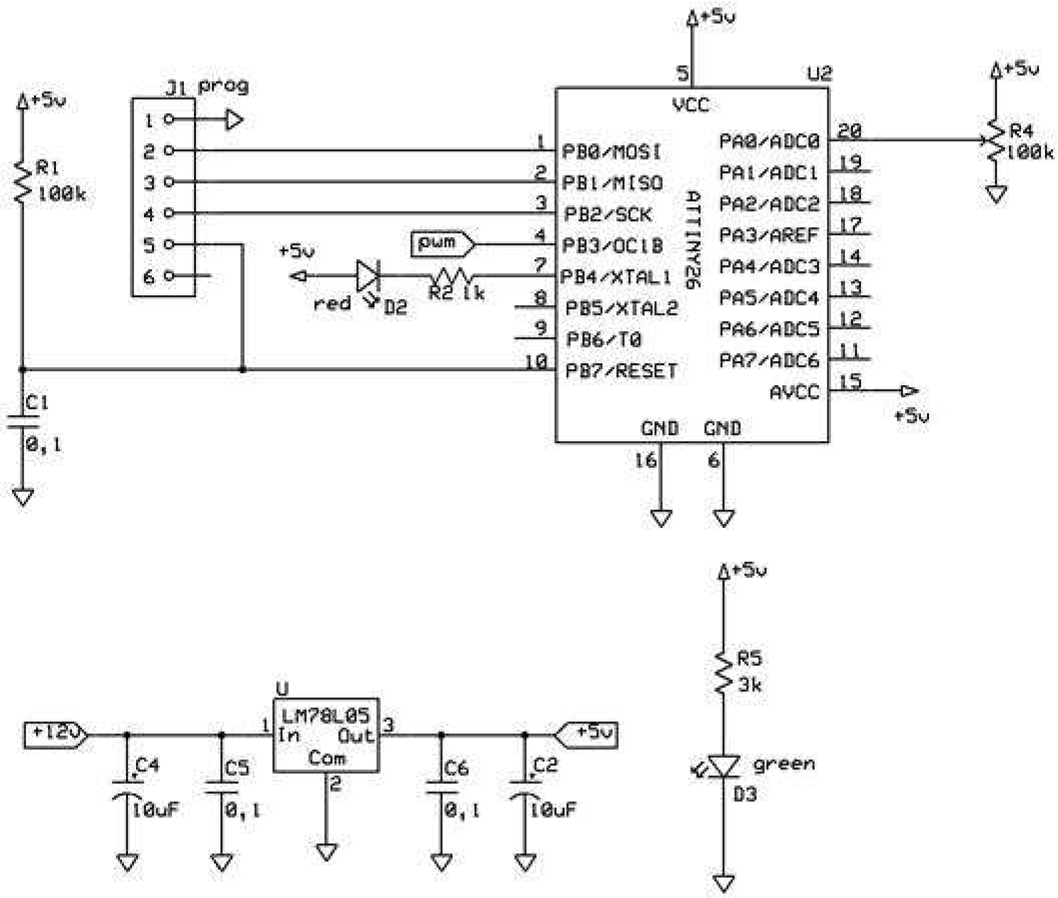
pic.1 Regulated DC-DC converter (output voltage can be adjusted 50-200v)



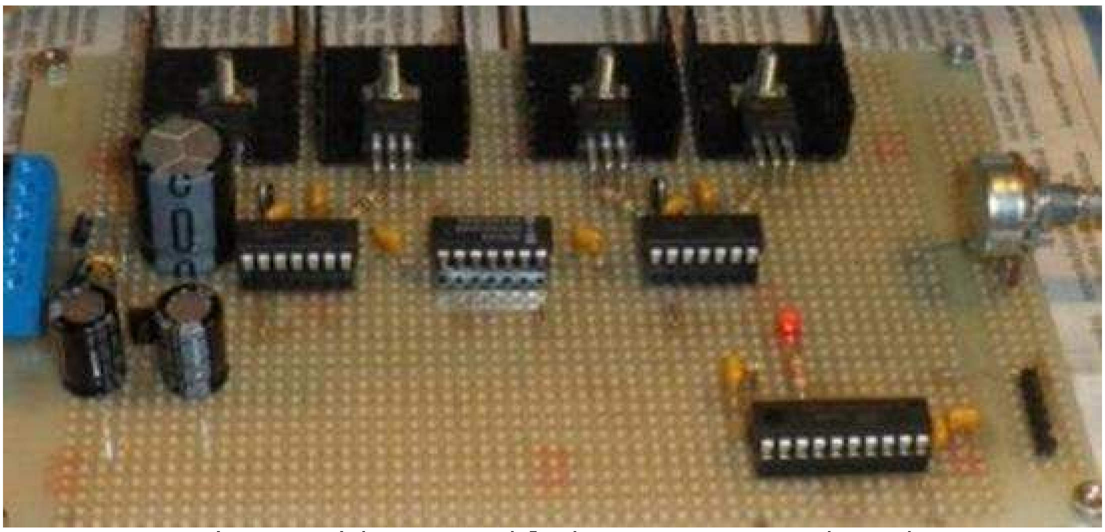
pic.2 One half of bridge driver



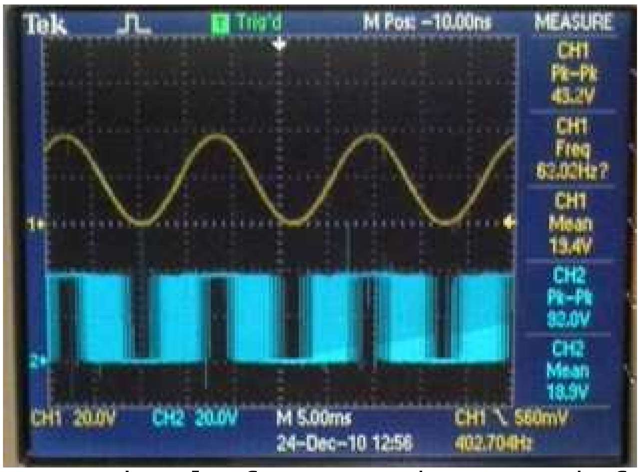
pic.3 LPF filter



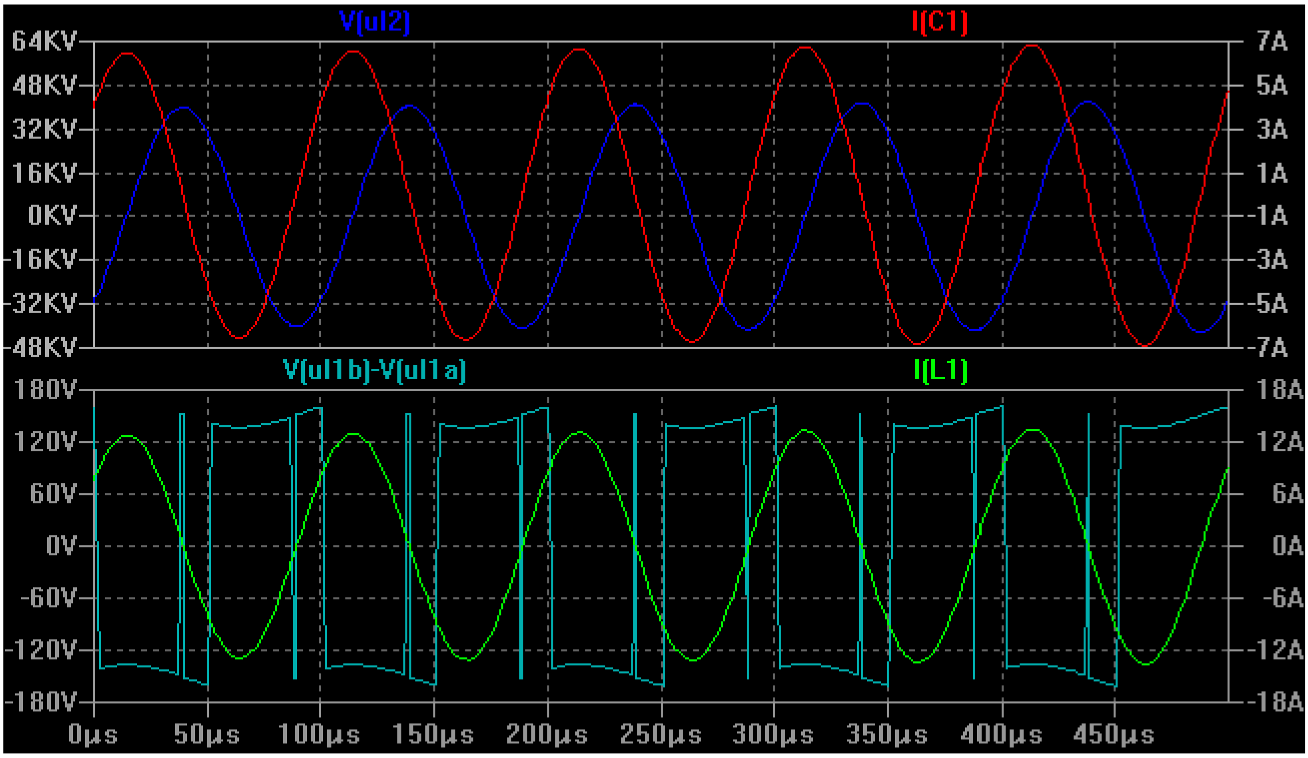
pic.4 PWM signal created with MCU

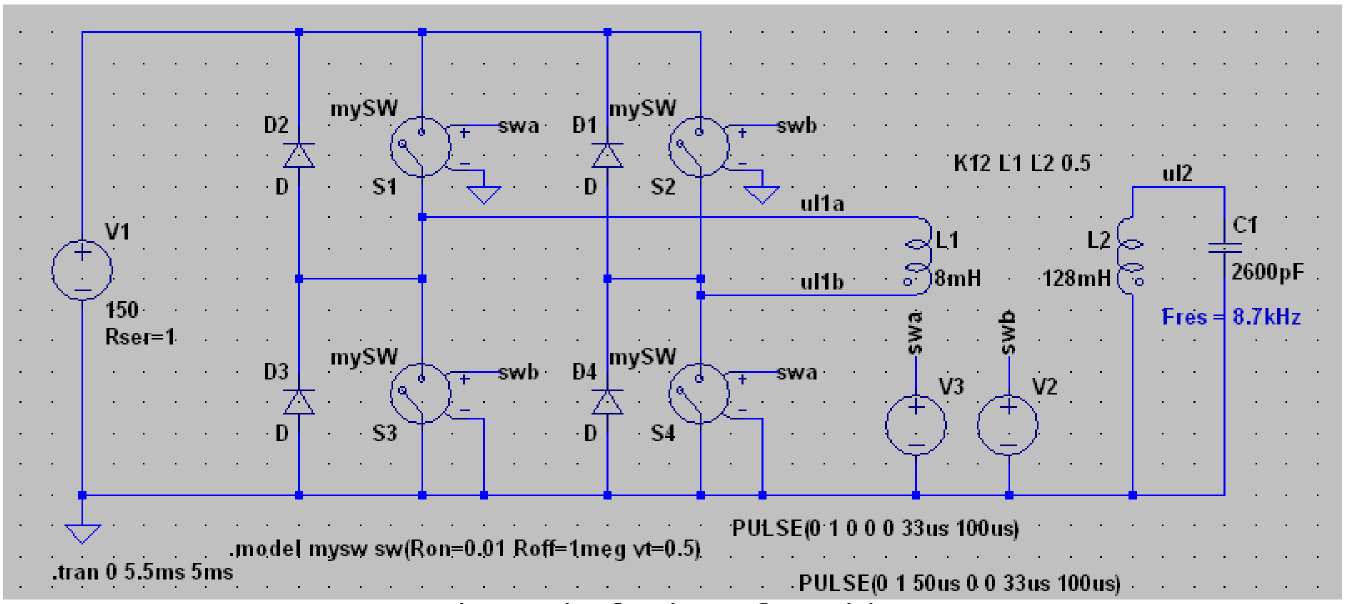


pic.5 Bridge assembled on prototype board



pic.6 top - signal after LPF, bottom - before LPF





pic.7 Simulation of HBridge

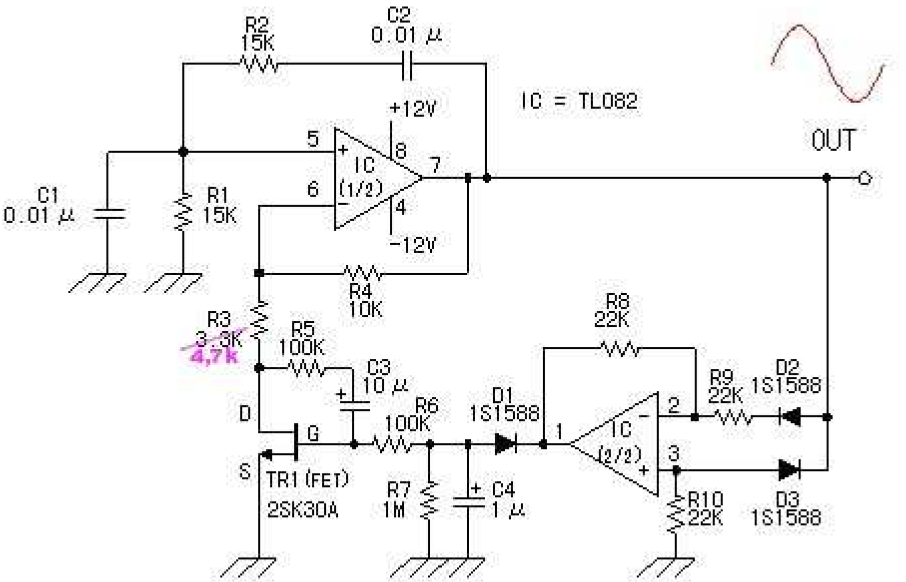
This is example of much more complicated setup. MCUs allow modify operation of the bridge without changing circuit. But it is also possible use “hardware” PWM like TL494 to produce PWM signal to control the bridge output.

Embedded software for MCUs created using Win AVR C compiler (see attached archives).

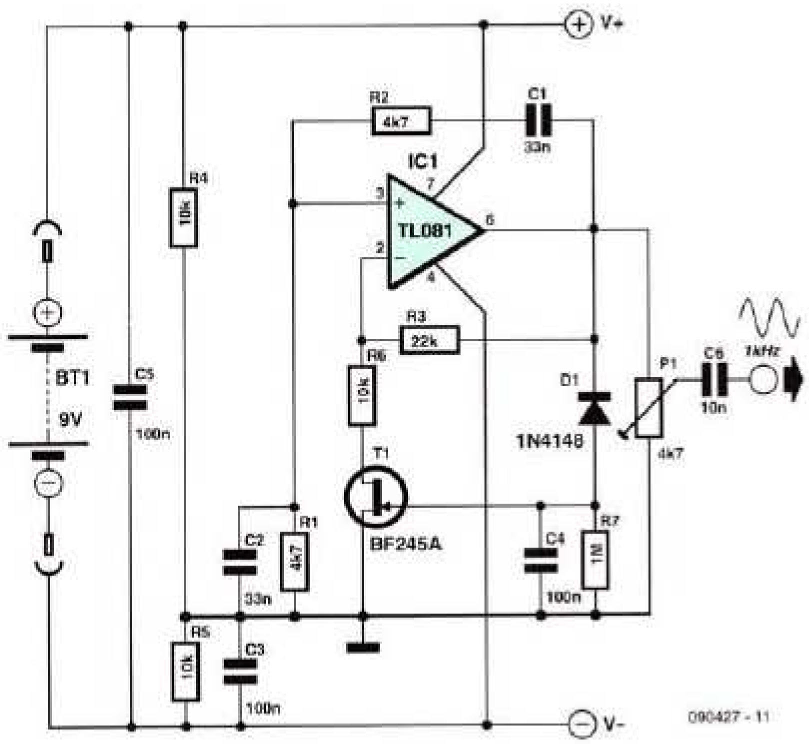
Some links:
- see page 40 for more advanced version of the bridge driver <https://04e8faec-a-62cb3a1a-s-sites.googlegroups.com/site/vasik041/homebrewtools.pdf?attachauth=ANoY7cqaamgaX-JXJRbIvErNtp4oVDipTLpw8NCUaF6guZH622pxRZFsEKfUf7rxr6RRJziZ2sa5h1sKsMRELqgyBKtBBHR4_hlT7884j9Mb9MEAX04mO1mauadYqHKhOUHz20_Gc0i1S0ABrvvWf6yZJEgyyCKNPGUOf79k6F3Ne7oiTyuFd6xwBFDyH8mYLfxfxfelQBj_Z741wnWr98H3bWy2nOJXpw%3D%3D&attredirects=0>
- http://www.tantratron.tk/index/tantratron.html
- http://winavr.sourceforge.net/
- http://www.wpi.edu/Pubs/E-project/Available/E-project-042711-190851/unrestricted/PWM_Techniques_final.pdf
- http://uzzors2k.4hv.org/index.php?page=ihpll1
- http://webpages.charter.net/dawill/tmoranwms/Elec_IndHeat1.html
- https://www.fairchildsemi.com/an/AN/AN-9012.pdf

Analogue approach

We saw variety of digital drivers, but it is also possible to do it in a "pure analogue" way. This is more (or less) conventional electronics, so I will just list circuits which I tried.

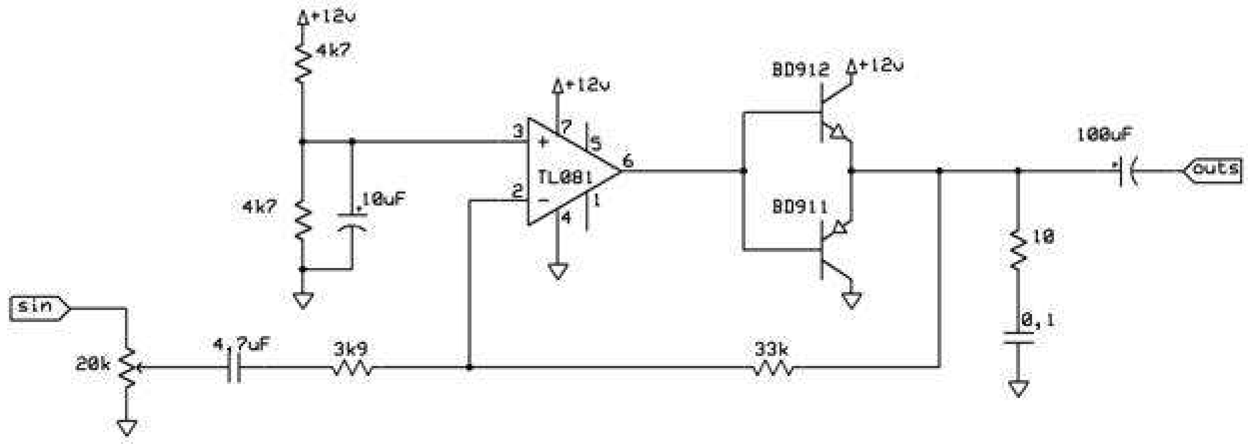


pic.1 Sin wave generator



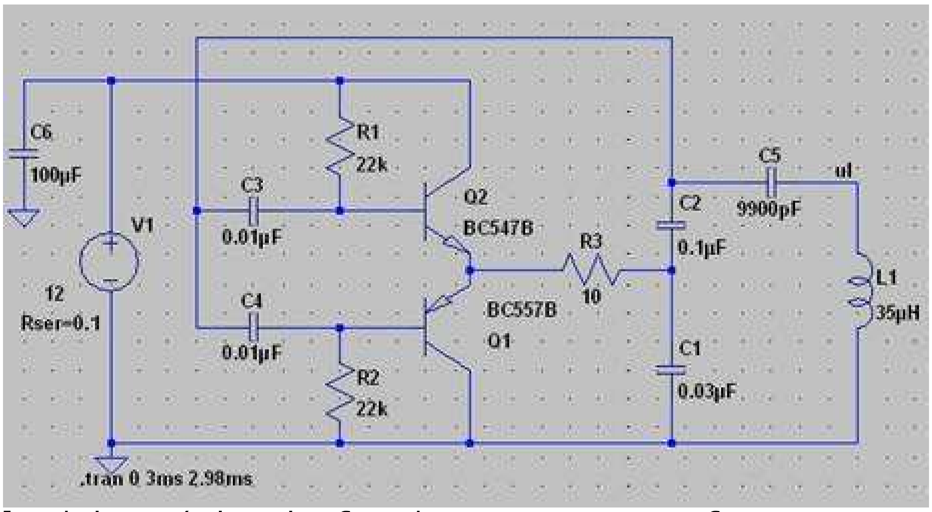
pic2. Simple sin wave generator which require with one power supply voltage

* Disadvantage of both generators is that FET transistor and precise selection of components needed



pic3. Simple power amplifier

* Perhaps too simple, it has big crossover distortion



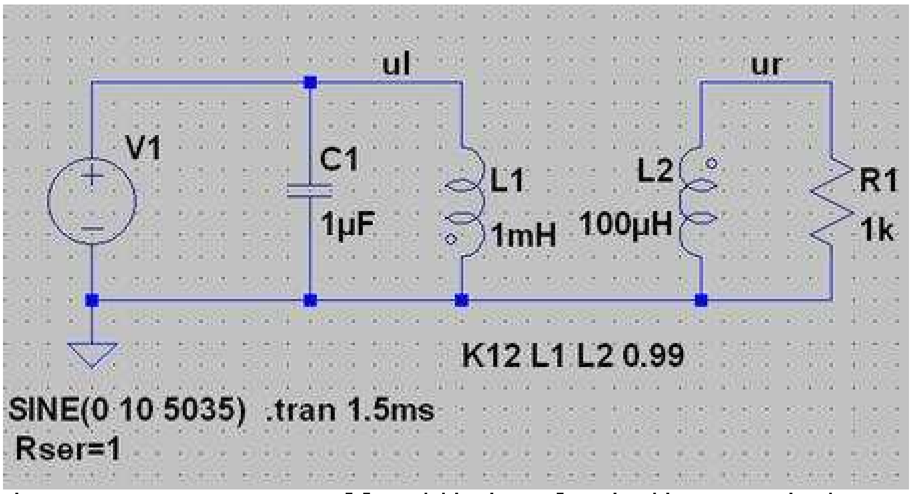
pic4. Simple driver (circuit found as a generator for tape recorder erase head)

* Despite simplicity it works very nice, it tunes resonance automatically if L or C changes

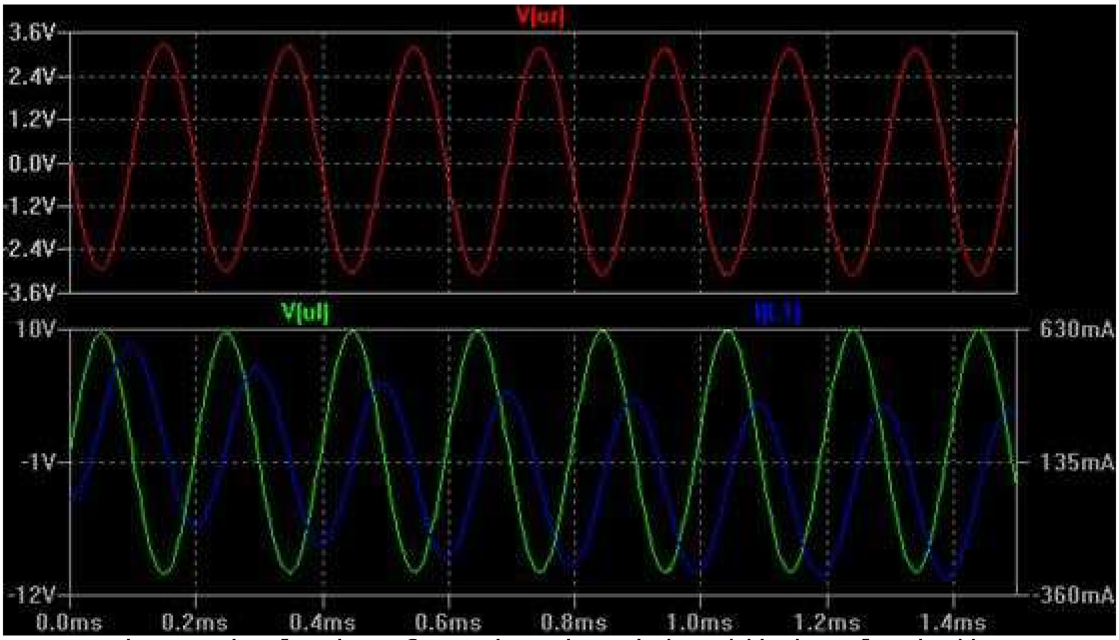
Links:
http://sound.westhost.com/articles.htm

Extracting power

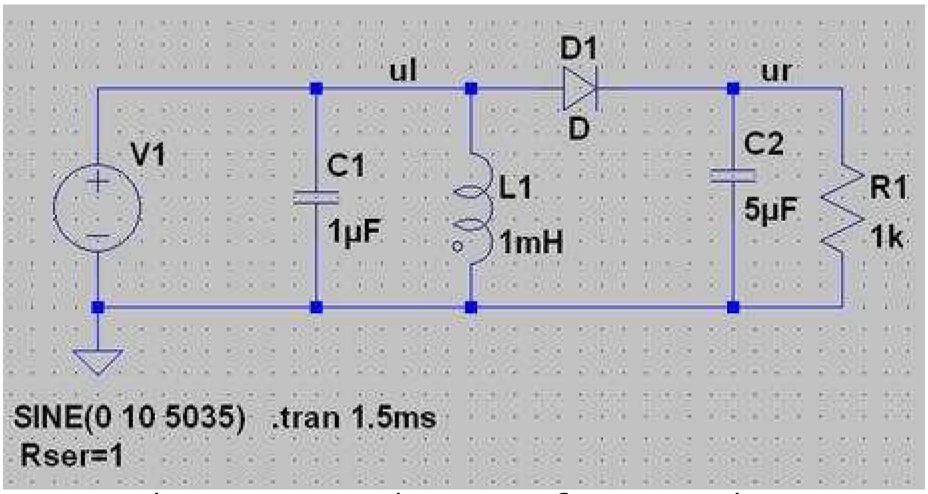
We saw many different driver setups; all of them allow us "put" some power into resonance circuit and create some oscillations. Now let's consider ways how we can extract power back.



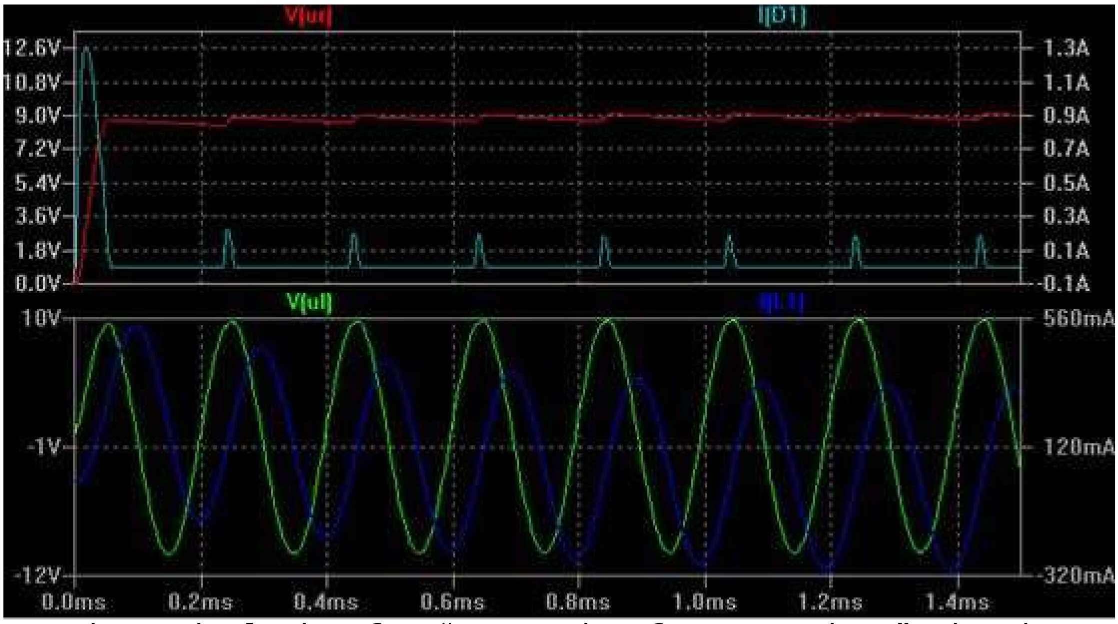
pic1. We can use small additional winding on inductor



pic2. Simulation for circuit with additional winding

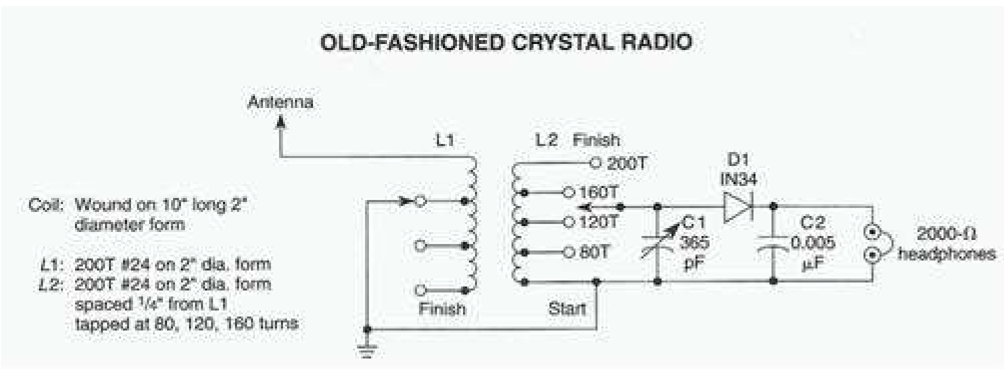


pic3. We can take power from capacitor



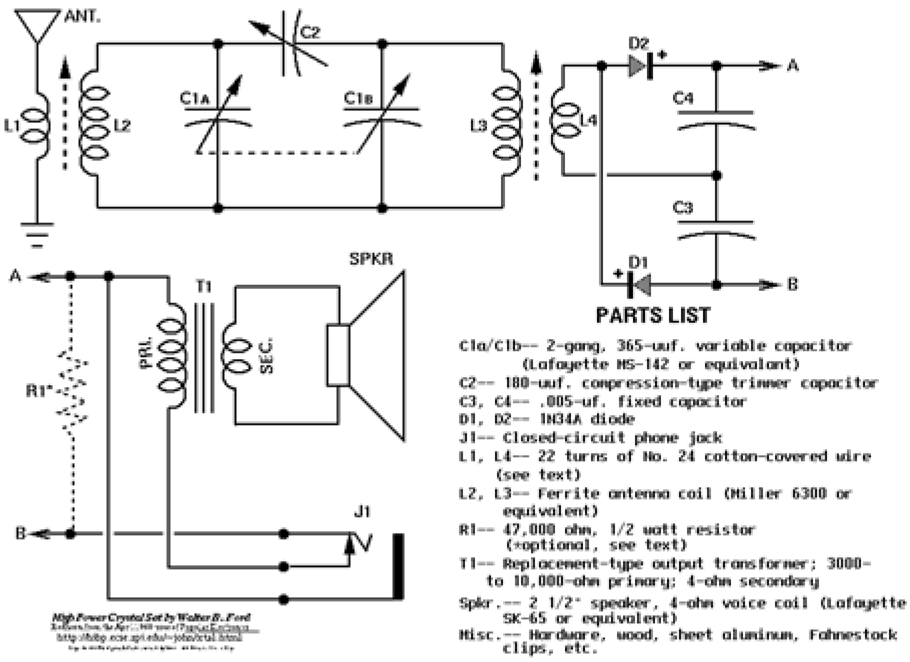
pic4. Simulation for “extracting from capacitor” circuit

Some people are claiming that they “just invented” new and very advanced concept of extracting power from resonance circuit. Well, for me it sounds naive. It all was invented about 100 years ago, we just got better components (e.g. diodes) but ideas are the same.



L1 and L2 are wound on 4" diameter 10" form and are 200 turns of #24 wire. PVC pipe can be used.

pic5. Crystal radio as an example of power extraction circuit



pic6. More powerful setup

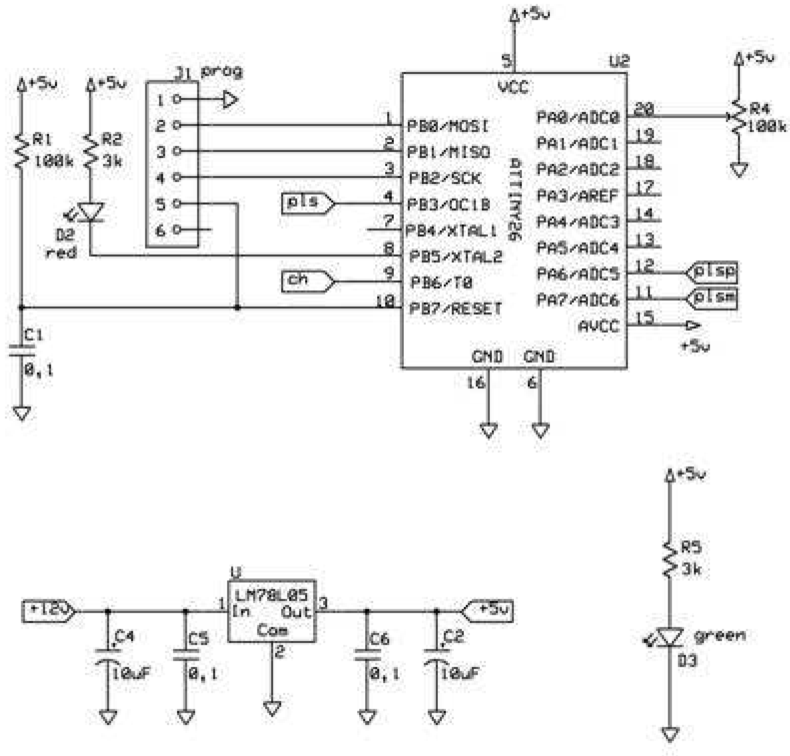
We cam use different setups, with diodes or switches but at the end load (or extracted power) always “work” as Q factor loss in resonant circuit. (This claim easy to prove using electrical circuits theory by drawing equivalent schematics).

Links:
High Power Crystal Set http://hibp.ecse.rpi.edu/~john/xtal.html
http://www.crystalradio.net/crystalplans/
http://www.makearadio.com/
http://www.radiosparks.com/schematics.asp?UID=Crystal+Radio
http://en.wikipedia.org/wiki/Mihajlo_Pupin
http://en.wikipedia.org/wiki/Loading_coil

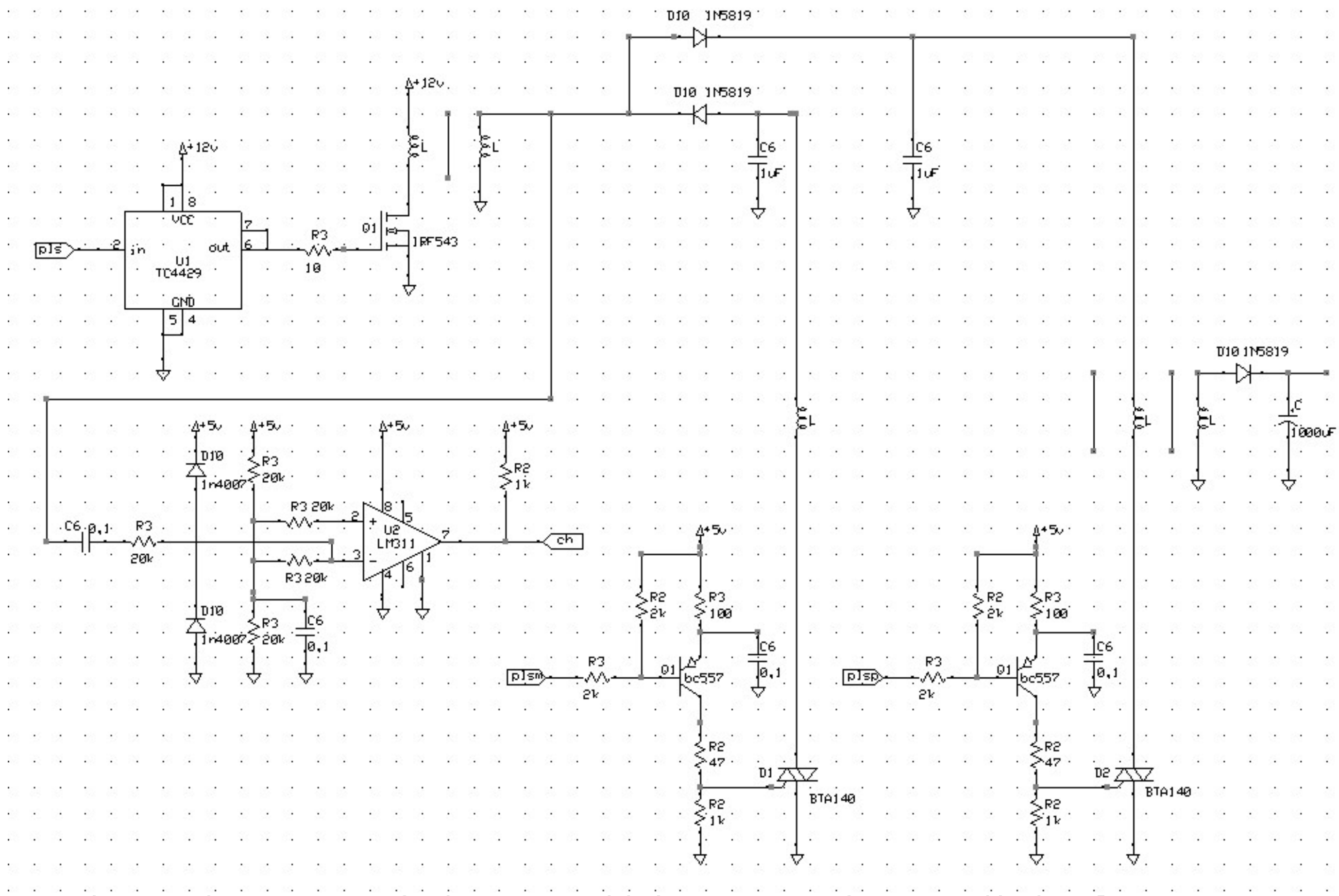
More examples of power extracting circuits

These two circuits are my implementation of Hector's transverter (TV) which is often discussed on EVGRAY group.
It could be a nice tool to learn about resonance, drivers and power extracting circuits… However, I see these circuits as an "over complication" in a hunt for "magic" resonance or frequency. If there would be a real "extra" power no such complex setup would be needed, just a regular diode bridge work fine ;-)

First setup is MCU based, MCU control driver and diode plug switches.

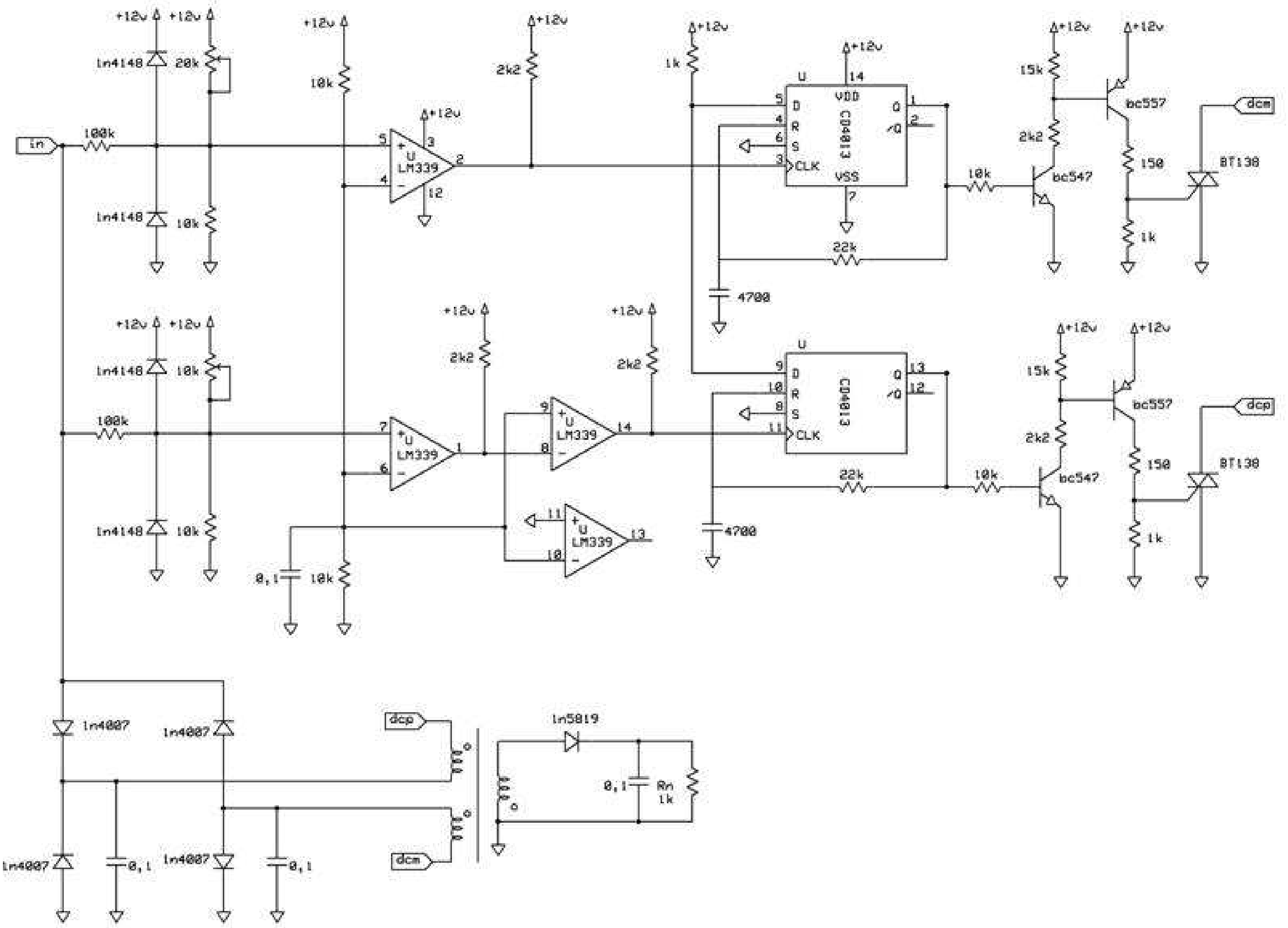


pic1. MCU used to control the setup



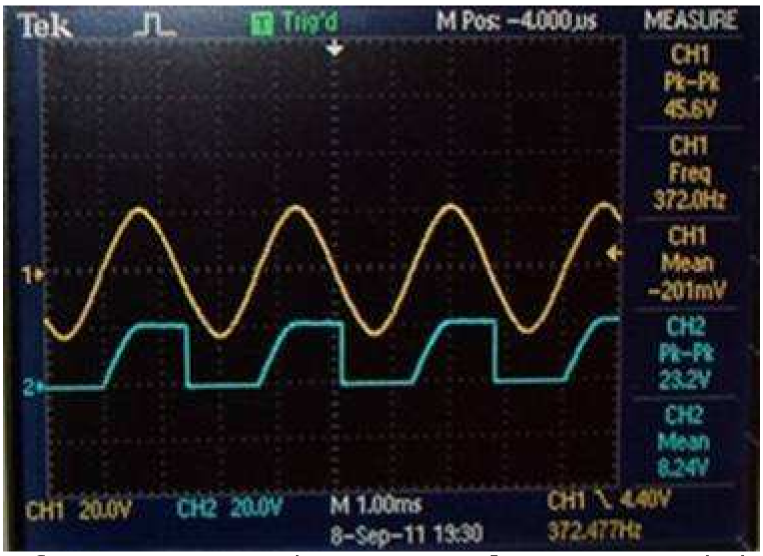
pic2. Other parts of the setup (driver, transformer, diode plug, zero crossing detector and discharge switches)

Below shown less complicated setup, without MCU.

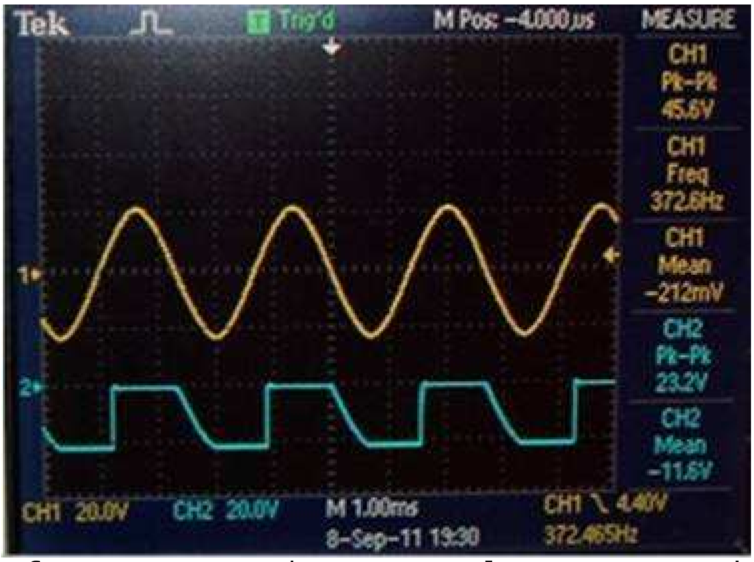


pic3. Simple “diode plug” (two zero-crossing detectors and triac drivers)

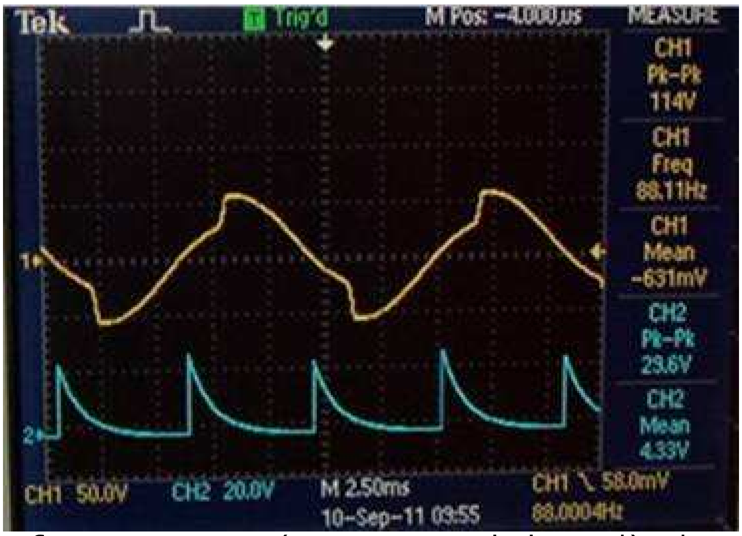
Here some diagrams from important points in the circuit



pic4. top – transformer output, bottom - voltage on positive leg capacitor

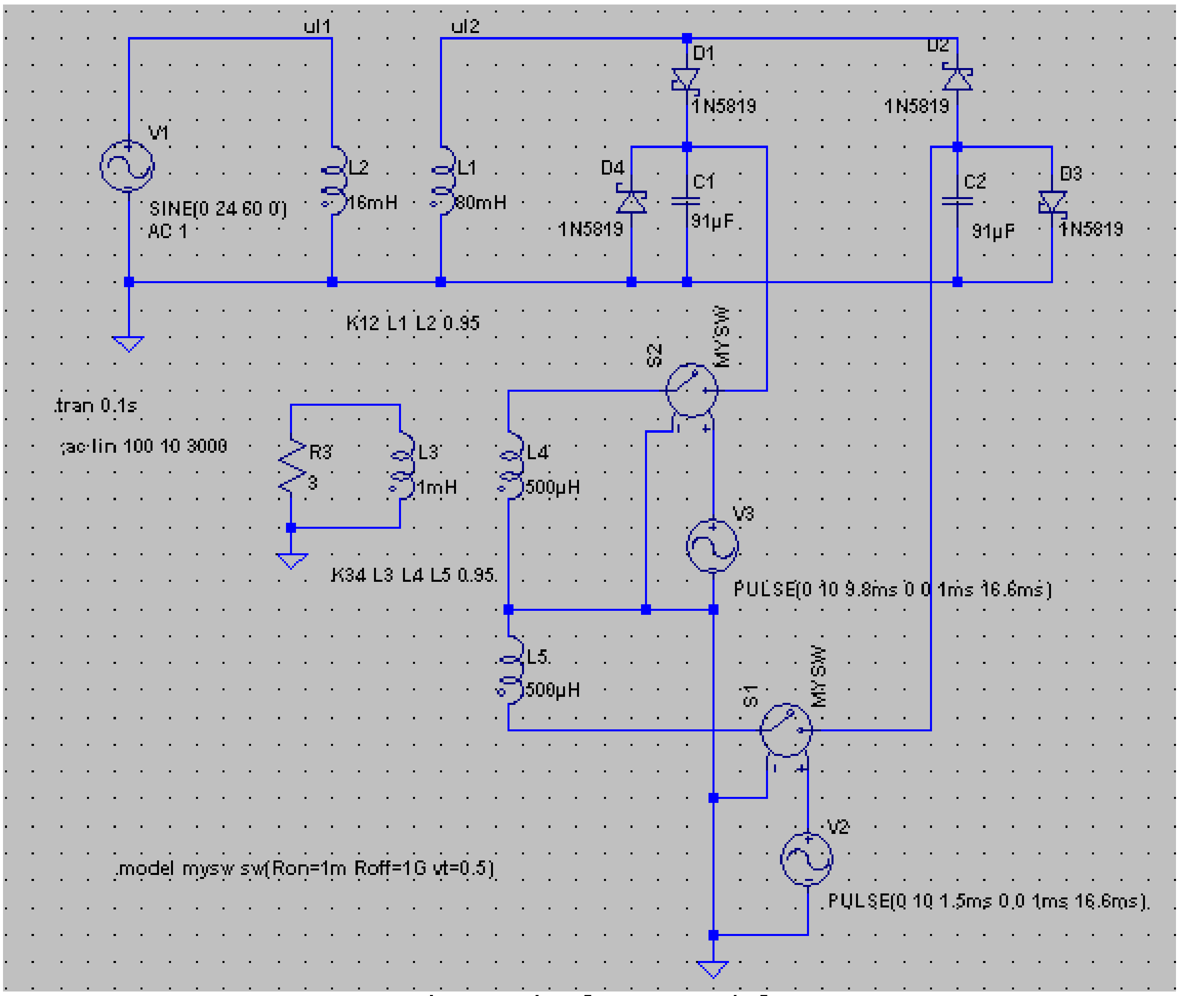


pic5. top – transformer output, bottom - voltage on negative leg capacitor

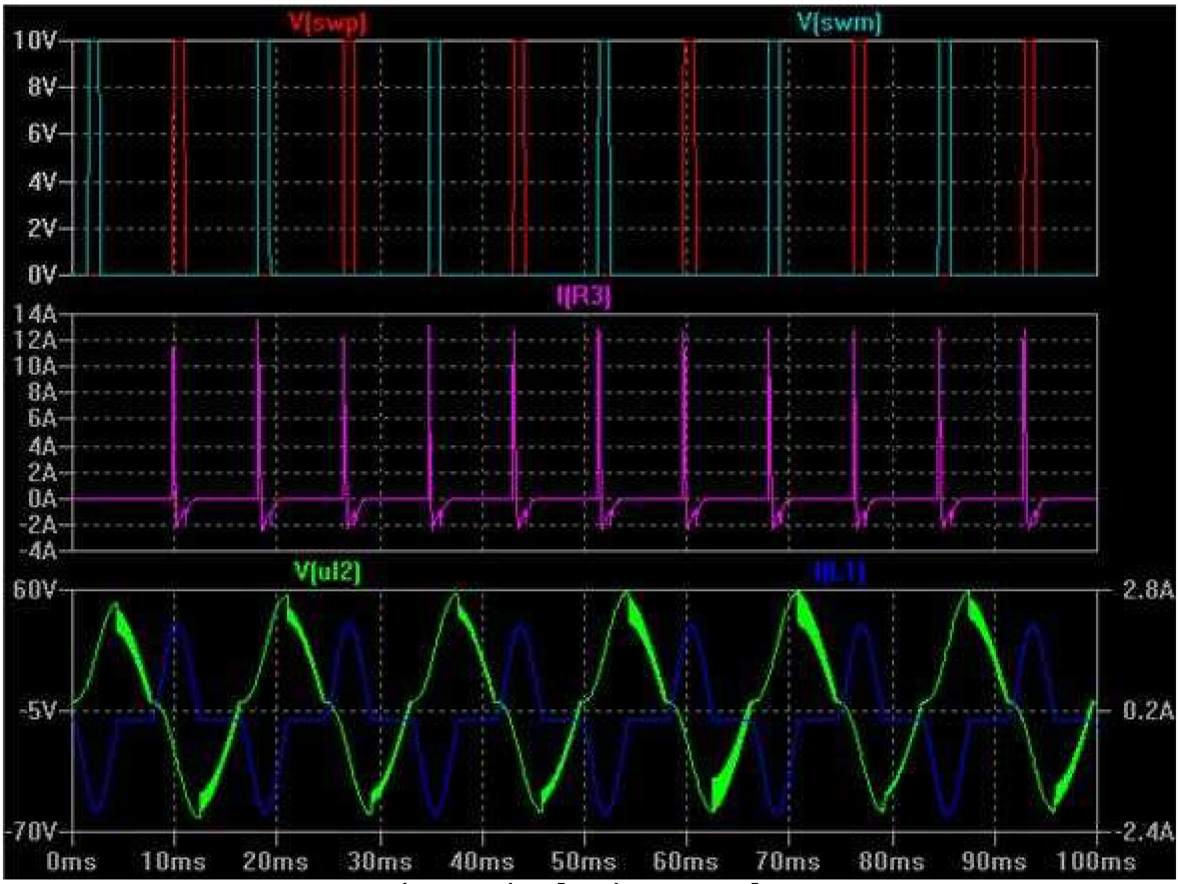


pic6. top – transformer output (more power injected), bottom - voltage on the output (Rn)

I made this simulation to illustrate the idea of TV setup. Transformer core is linear in this simulation.



pic7. Simple TV model



pic8. Simulation results

After all I still think that no mater what driver we use and how complicated extracting circuit, energy stored in LC circuit comes from power source… unless some real magic happen ;-).

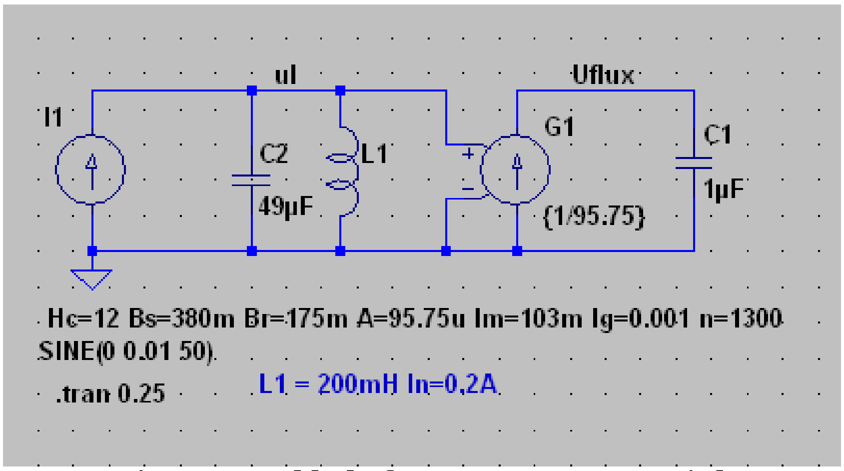
Ferroresonance

What would happen if we "put" too much power into LC resonance circuit?

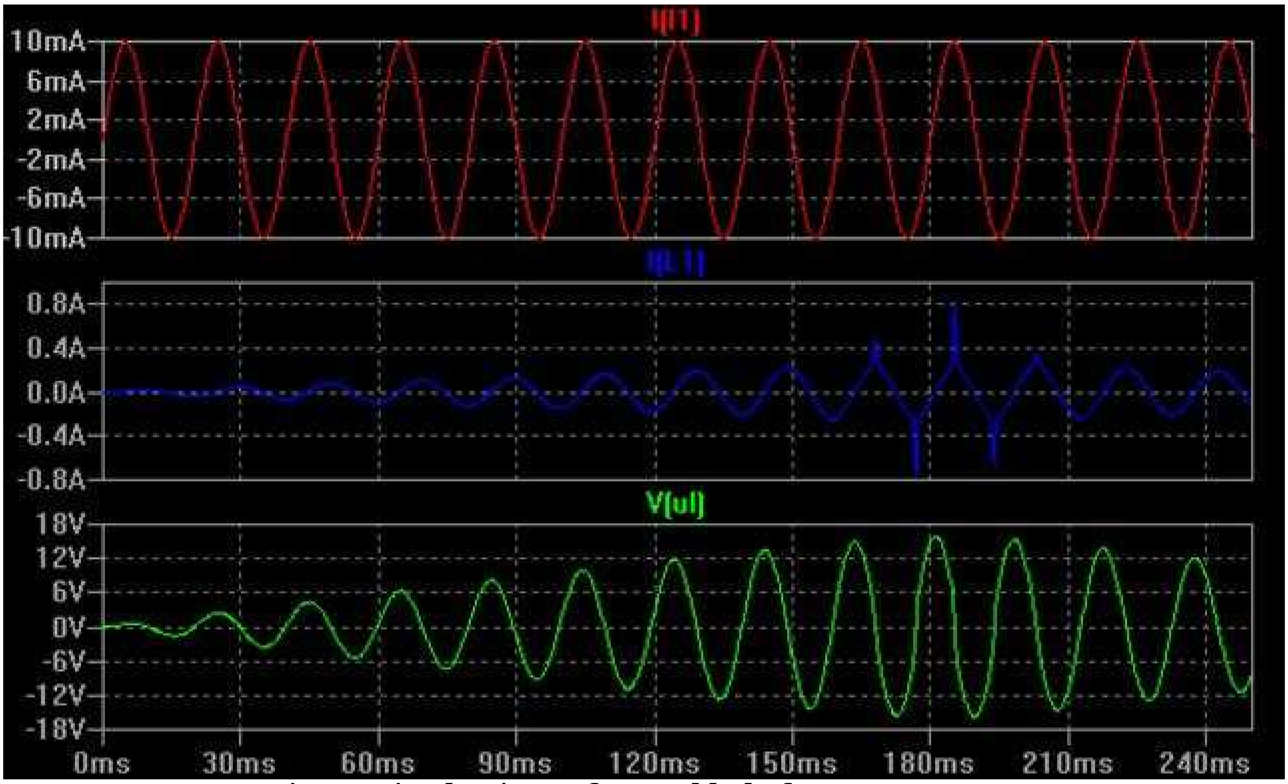
If there is a core in inductor, occasionally it get saturated and ferroresonance occurs.

As you remember saturation causes non-linear change of inductance. This non-linearity in combination with oscillations produces many interesting effects.

Let's take a closer look on ferroresonance.

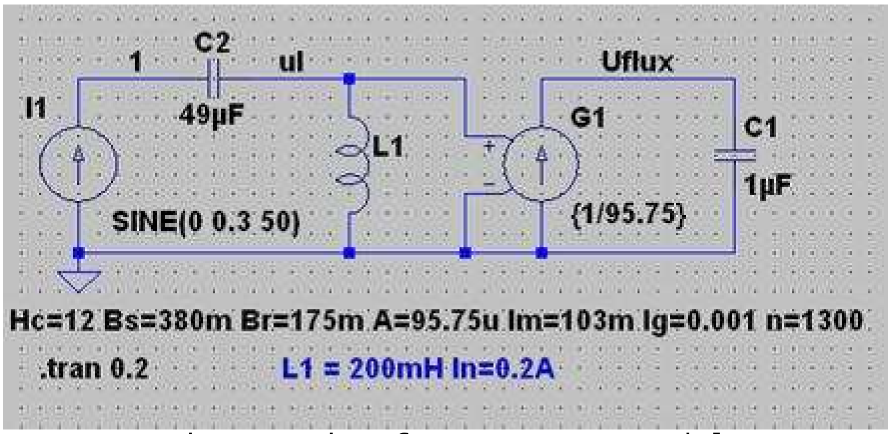


pic1. Parallel ferroresonance model

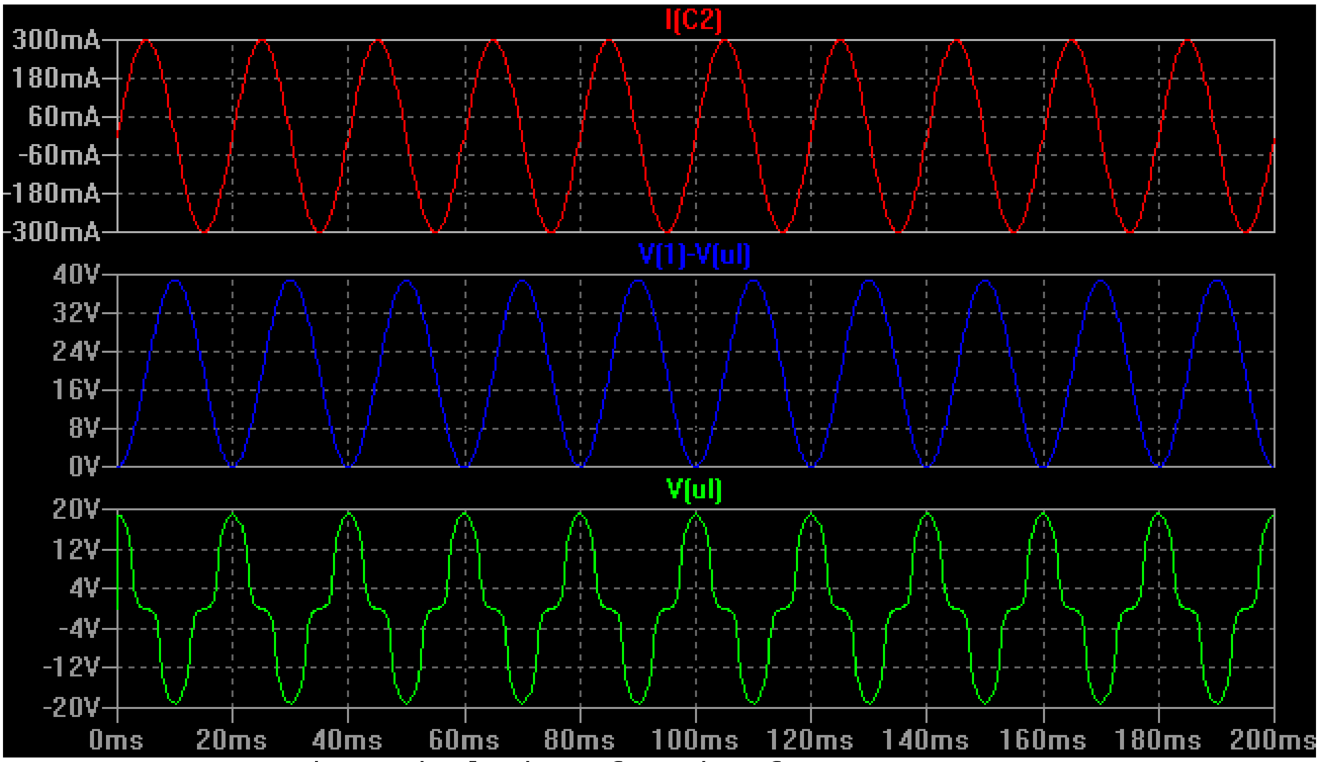


pic2. Simulation of parallel ferroresonance

* notice frequency variations and current shape



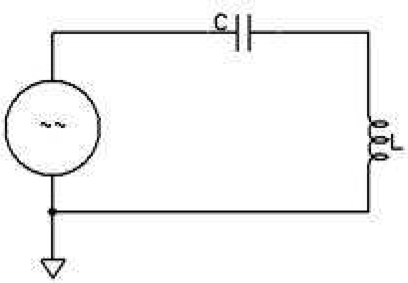
pic3. Series ferroresonace model



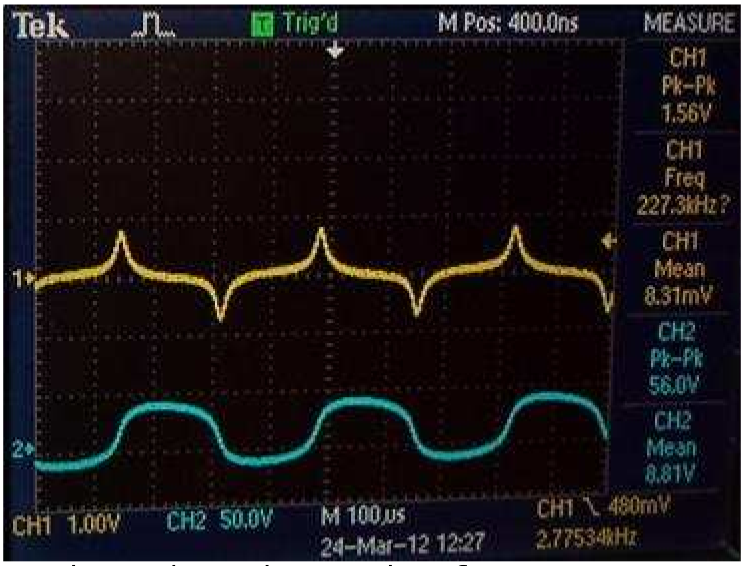
pic4. Simulation of series frerroresonance

* notice voltage on the inductor

Here a simple setup to observe a ferroresonance



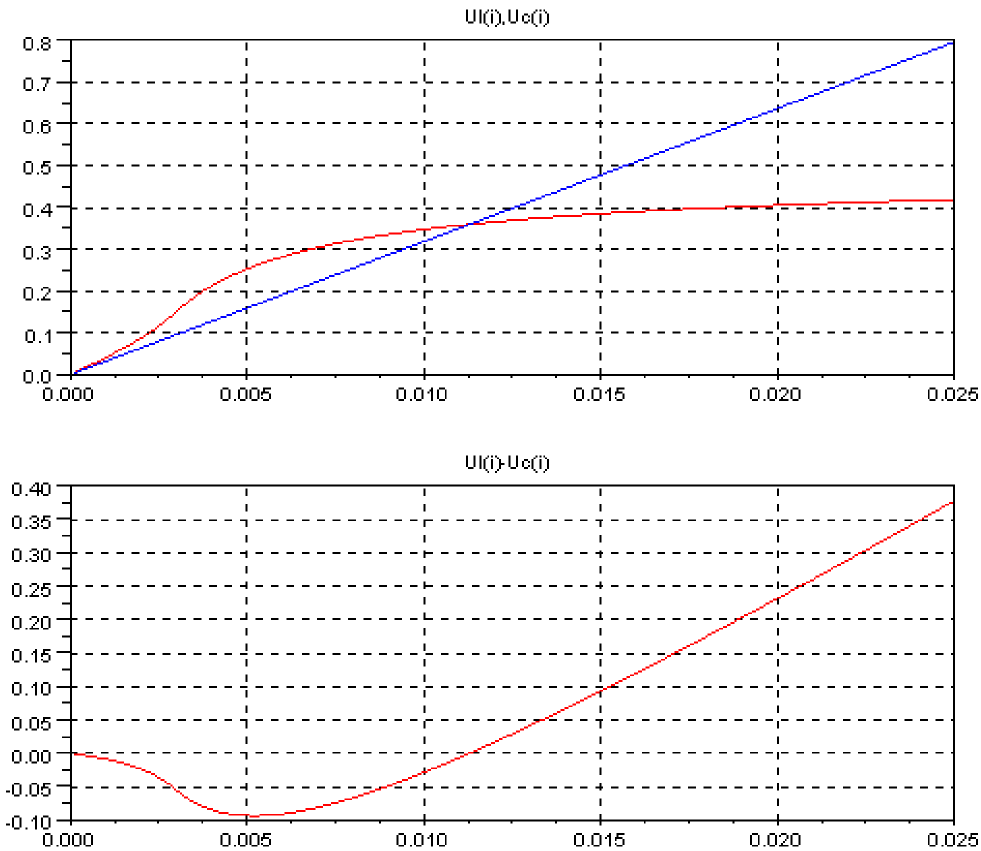
I used 4,7uF capacitor and 20 turns coil on 35mm N30 ferrite ring, signal generator and audio amplifier as a signal source. Below waveforms I got after tuning resonance:



pic5. Observing series ferroresonance

In simple words, when current increase core saturating and inductance decrease, this cause current increase even more.

When studding non-linear inductance we managed to get a formula how inductance depends on current, now we can use this to draw a resistance of LC circuit witch take into account inductance variations.



pic6. Drawing reactance (reactive resistance) for LC circuit with saturating inductor (voltage vs. current)

Formulas used to draw above graphs:

$$X_L = \omega L = 2\pi f L$$

$$X_C = \frac{1}{\omega C} = \frac{1}{2\pi f C}$$

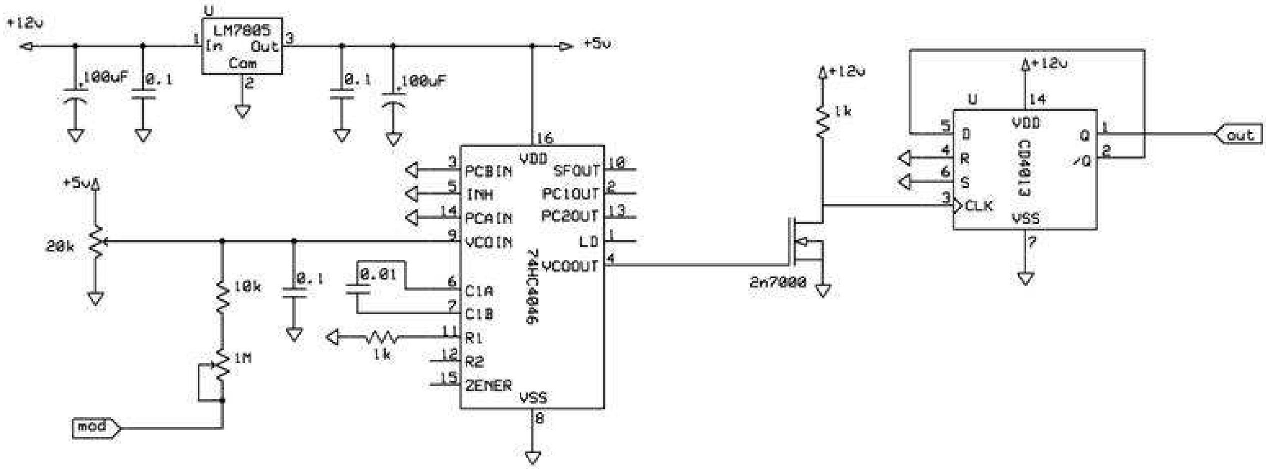
$$X = X_L - X_C = \omega L - \frac{1}{\omega C}$$

Does it look interesting?
(yes, it is negative differential resistance, I am going to discuss it later in more details)

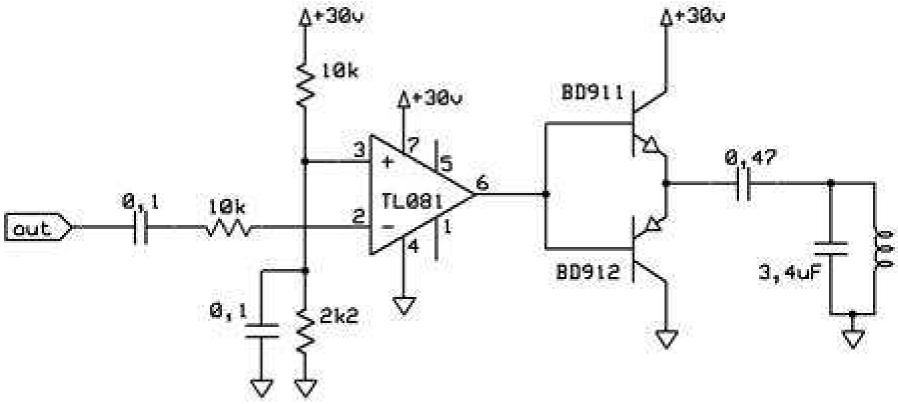
Some links:
http://en.wikipedia.org/wiki/Electrical_reactance
http://www05.abb.com/global/scot/scot235.nsf/veritydisplay/2e4528a2d55c5414c12572dd00247313/$file/vt%20guard_presentation-ferrores_sales_version_eng.pdf
http://www.kau.edu.sa/Files/320/Researches/52676_22982.pdf

Properties of ferroresonance

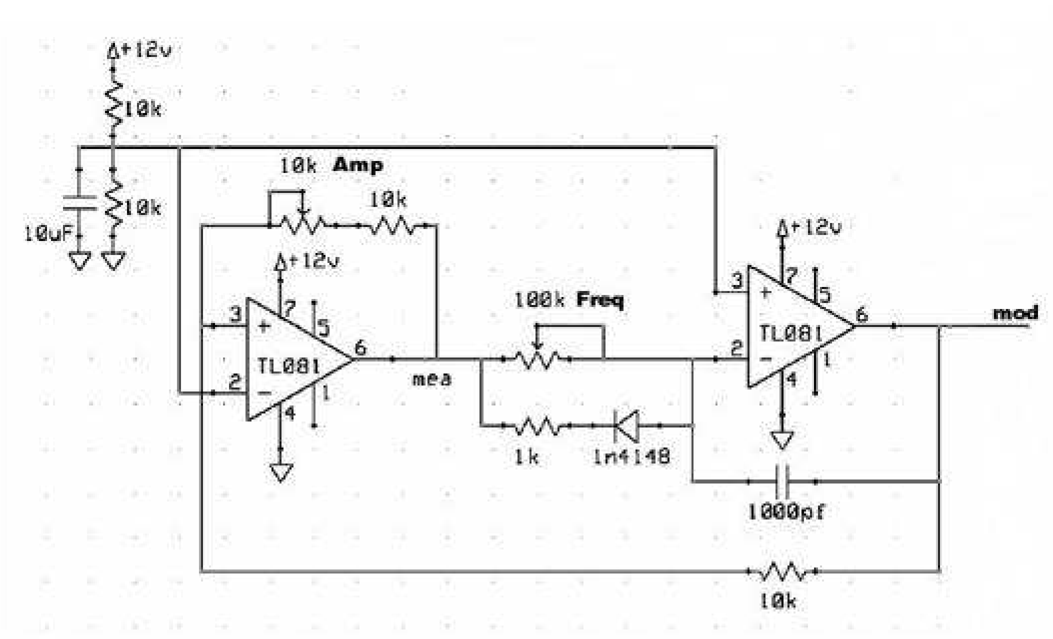
To observe interesting properties of ferroresonance circuits I made a simple sweep generator and loaded it with parallel LC circuit.



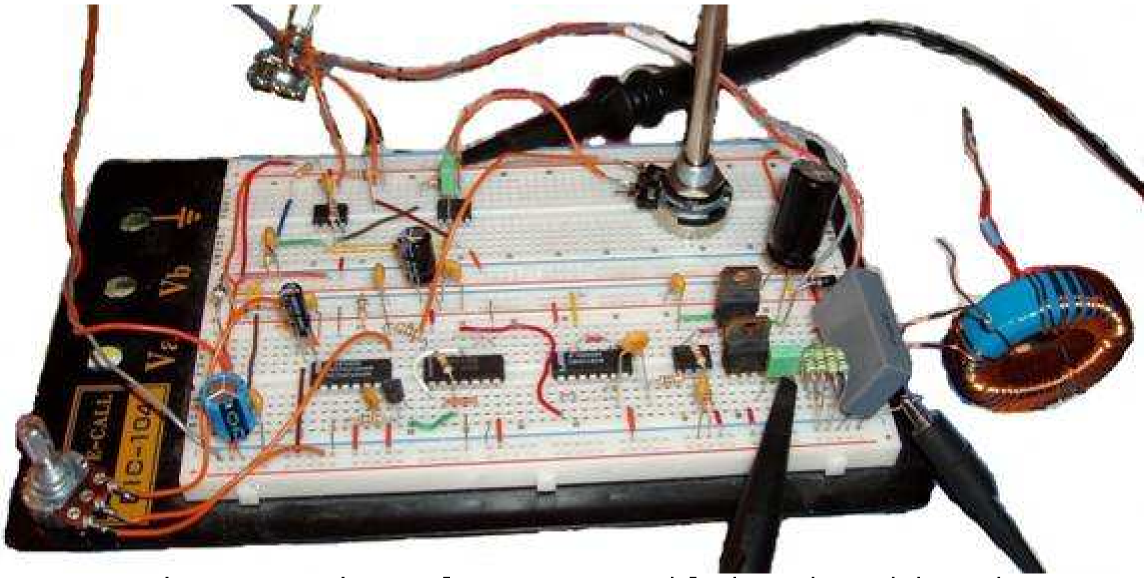
pic.1 VCO generator



pic.2 Driver



pic3. Triangle generator (I will use it as a modulator to control VCO frequency)



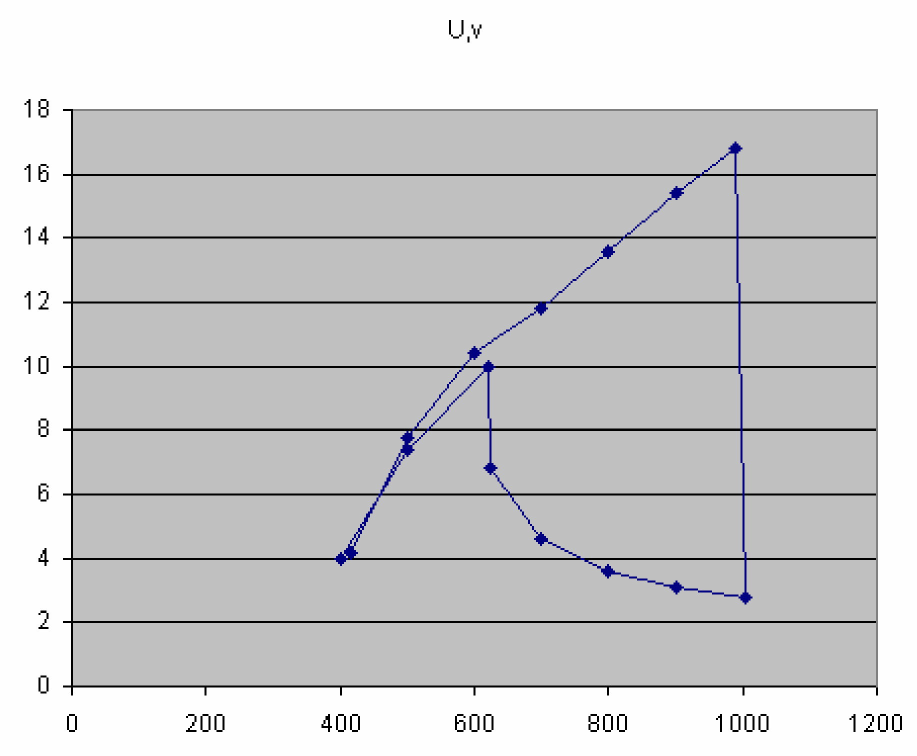
pic4. Experimental setup assembled on bread board

In first experiment I didn’t use modulation but slowly adjusted frequency manually. I measured voltage and current on inductor, here results

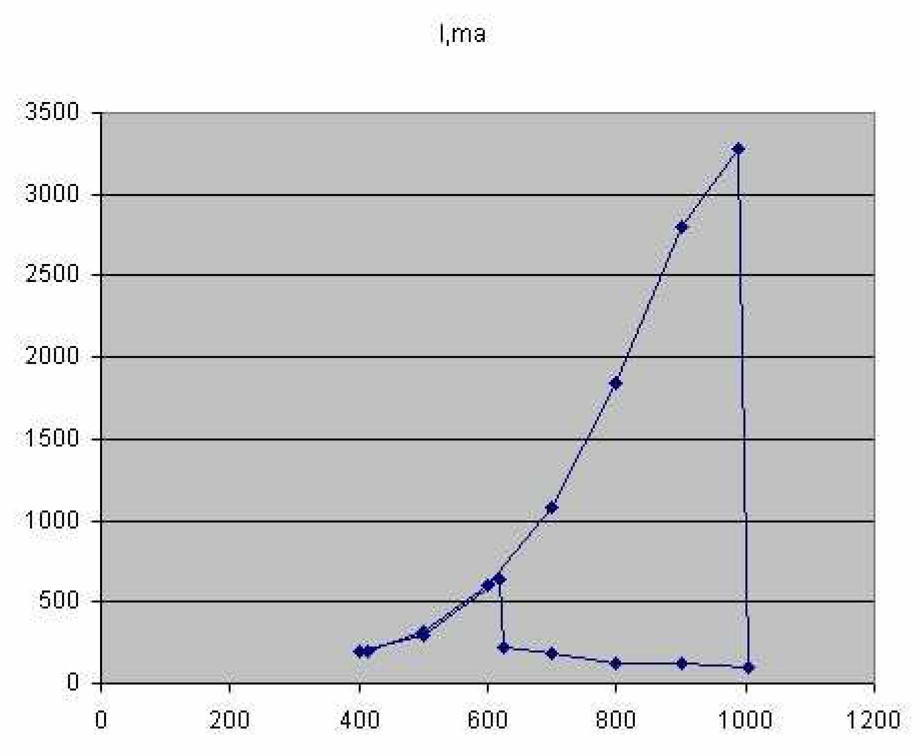
Ri=0.25

f,hz	415	500	600	700	800	900	990	1005	900	800	700	625	620	500	400
U,v	4,2	7,8	10,4	11,8	13,6	15,4	16,8	2,8	3,1	3,6	4,6	6,8	10	7,4	4
I,mv	50	80	150	270	460	700	820	25	30	30	45	55	160	75	50
I,ma	200	320	600	1080	1840	2800	3280	100	120	120	180	220	640	300	200

and graphs drawn based on the data



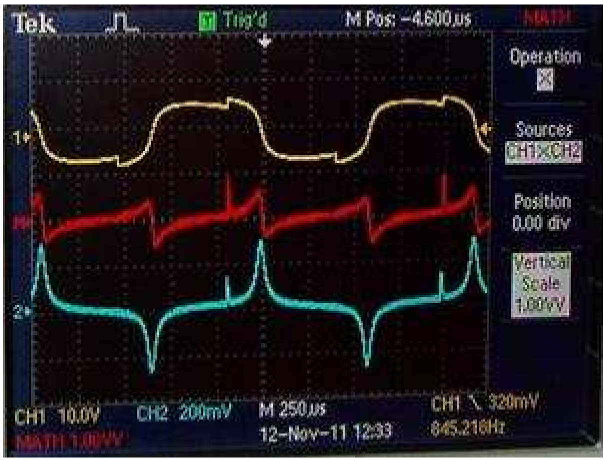
pic5. Voltage on inductor vs. frequency



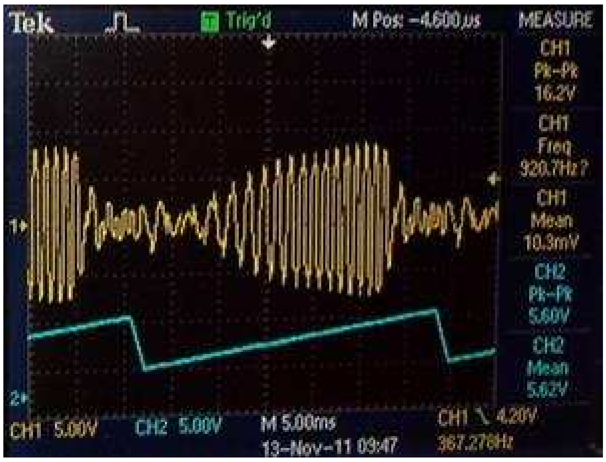
pic5a. Inductor's current vs. frequency

You can see interesting effect - sometimes it called “trigger effect”. When frequency slowly increased voltage and current also increasing until some point and then amplitude drop sharply. Frequency need to be decreased significantly first to repeat this effect.

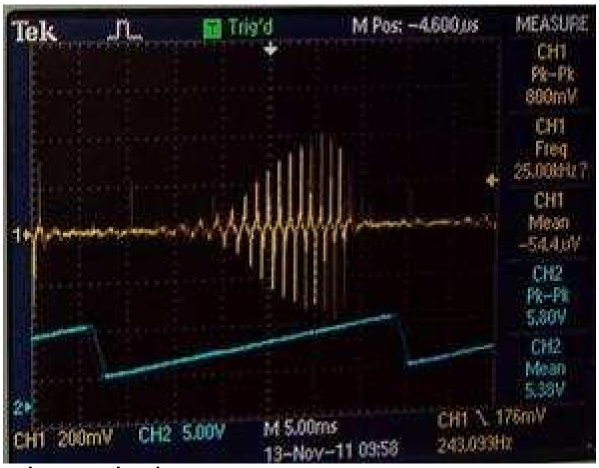
Below pictures obtained with modulation generator, circuit tuned so that we can continuously observe trigger effect.



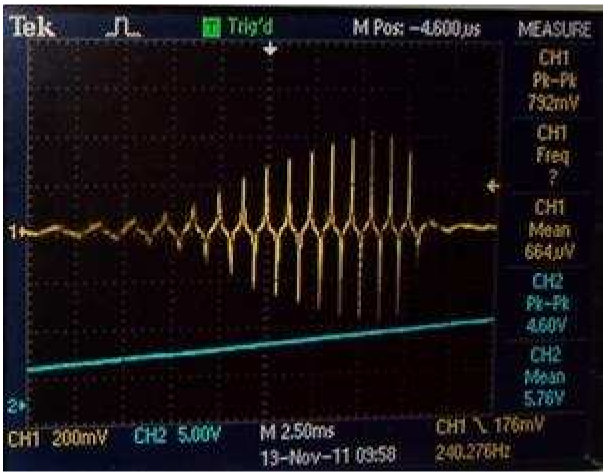
pic6. yellow - voltage on inductor U, blue – inductor current I, red - U * I



pic7. voltage on inductor



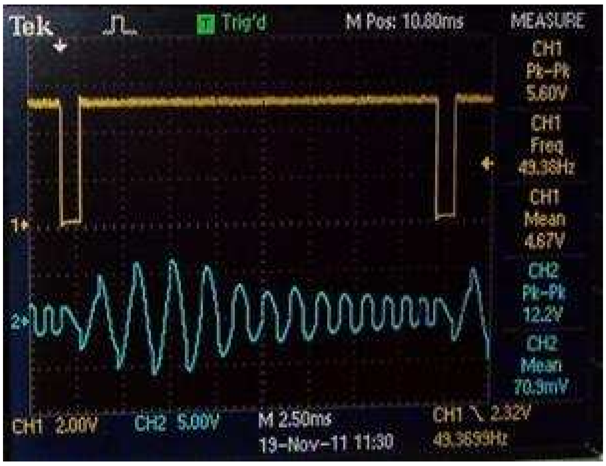
pic8. inductor current



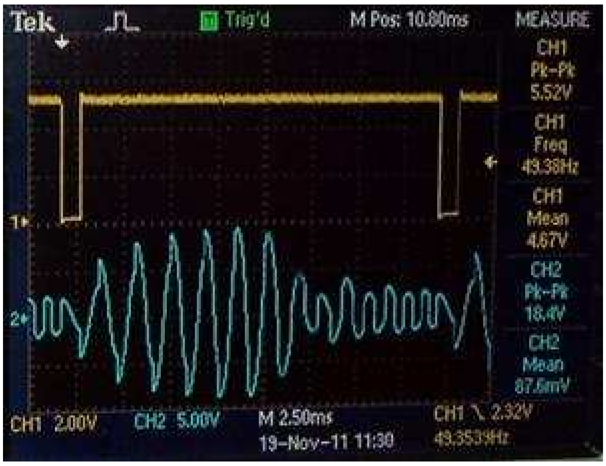
pic9. inductor’s current (bigger scale)

In resonance energy is «accumulated» in LC tank, but after some point it "does not fit" into the coil anymore because inductance decrease due to saturation, this cause non-linear oscillations and trigger effect.

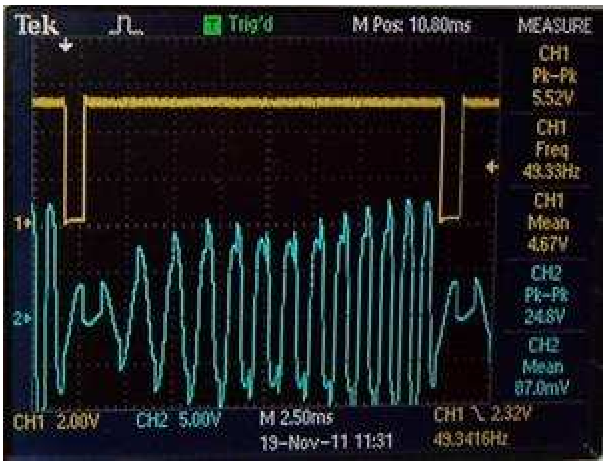
I also tried to adjust power supply voltage and see how it affects oscillations.
Below pictures obtained for different power supply voltage



pic.10 Ups=20v



pic.11 Ups=25v



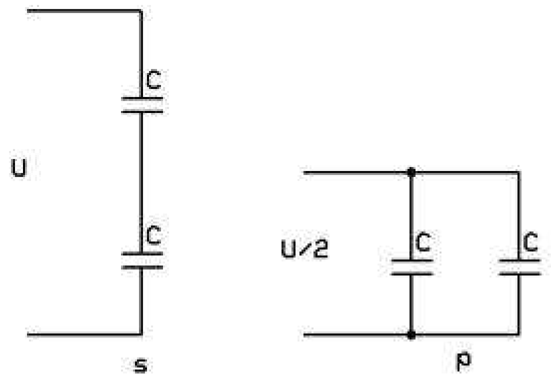
pic.12 Ups=30v

The higher the power supply voltage the greater frequency up to which the ferroresonance occurs. So in this mode of operation to achieve more current and voltage we have to “apply” more energy from power source (again).

Tesla switch and Co.

We saw a "natural" non-linearity caused by saturatiton, but what if we want create non-linearity ourselves? One interesting approach is to change inductance and capacitance in LC circuit “on-the-fly”.

Let's consider first “switching capacitors”.



pic1. Two capacitors in series and in parallel

Often people confused with capacitance, charge and stored energy when rearranging capacitors. This confusion cause some “interesting” claims about extra energy etc. Let’s remember what we learned in school and calculate capacitance, charge and stored energy for these two cases shown on pic1.

For series connection:

Cs = C/2
Qs = C/2 * U = C * U / 2
Es = C/2 * U * U / 2 = C * U * U / 4

For parallel connection:

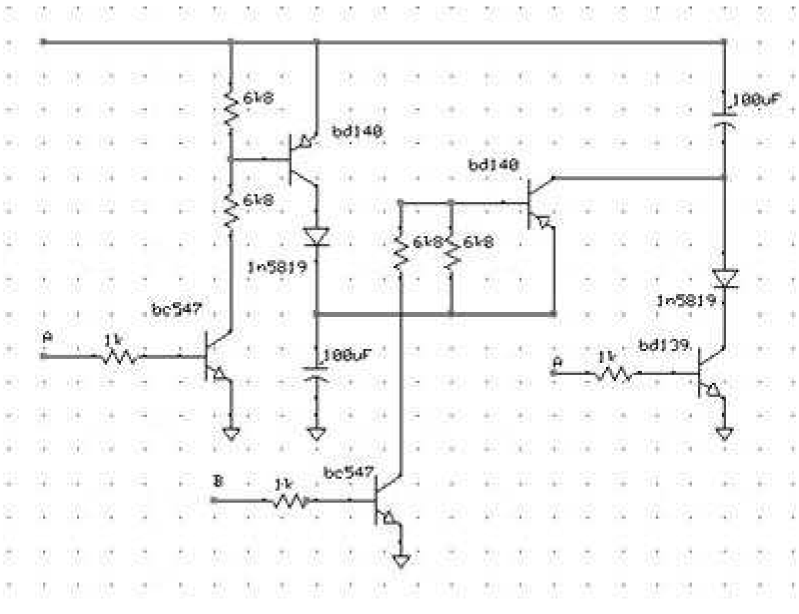
Cp = 2*C
Qp = 2*C * U/2 = C * U
Ep = 2*C * U/2 * U/2 / 2 = C * U * U / 4

These are interesting results; we see that stored energy does not change if we re-connect capacitors, but charge change.
Perhaps we can use this somehow…

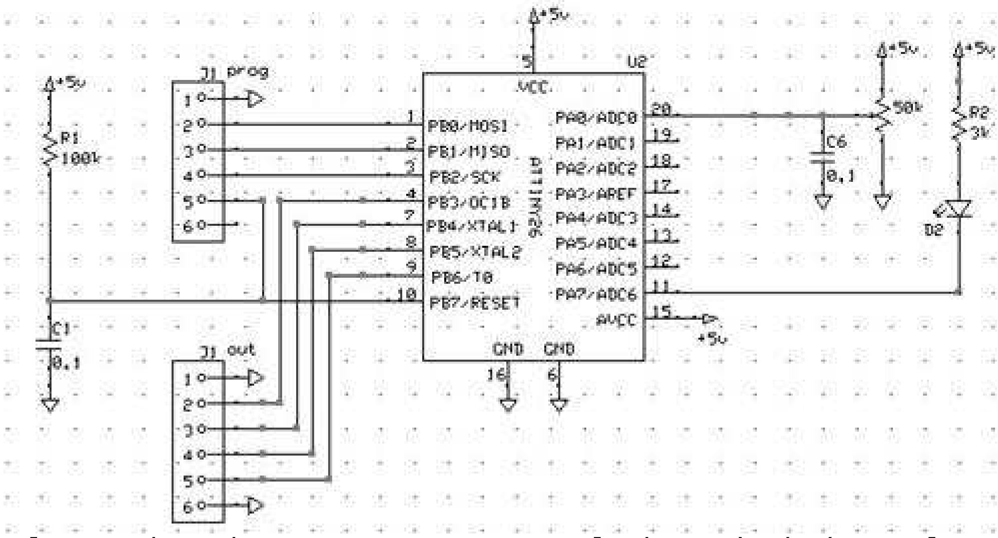
Some links:
http://en.wikipedia.org/wiki/Capacitor

Switching coils and caps

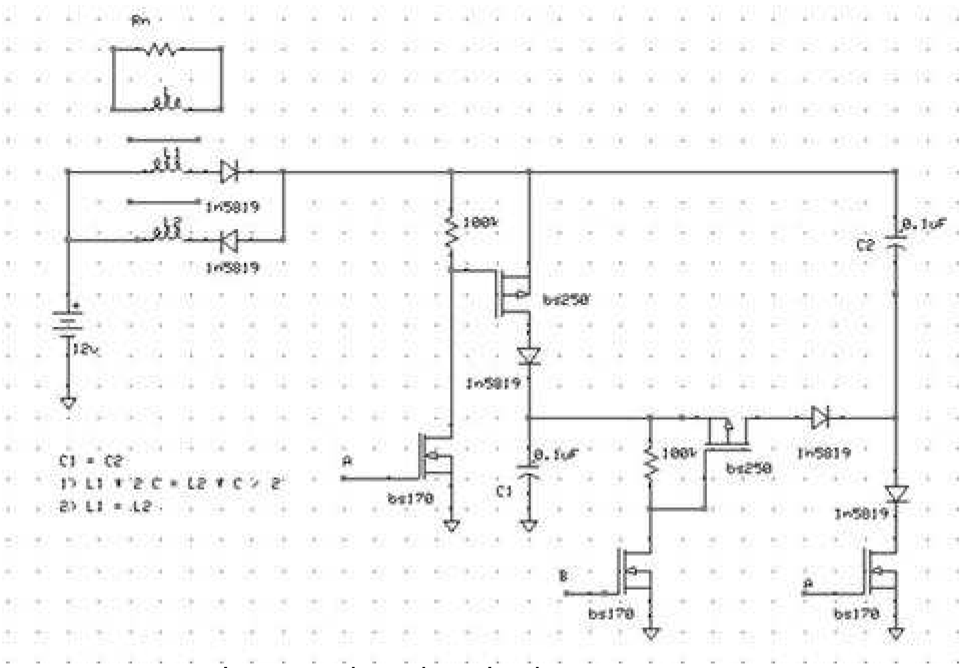
Let’s try switching something ☺



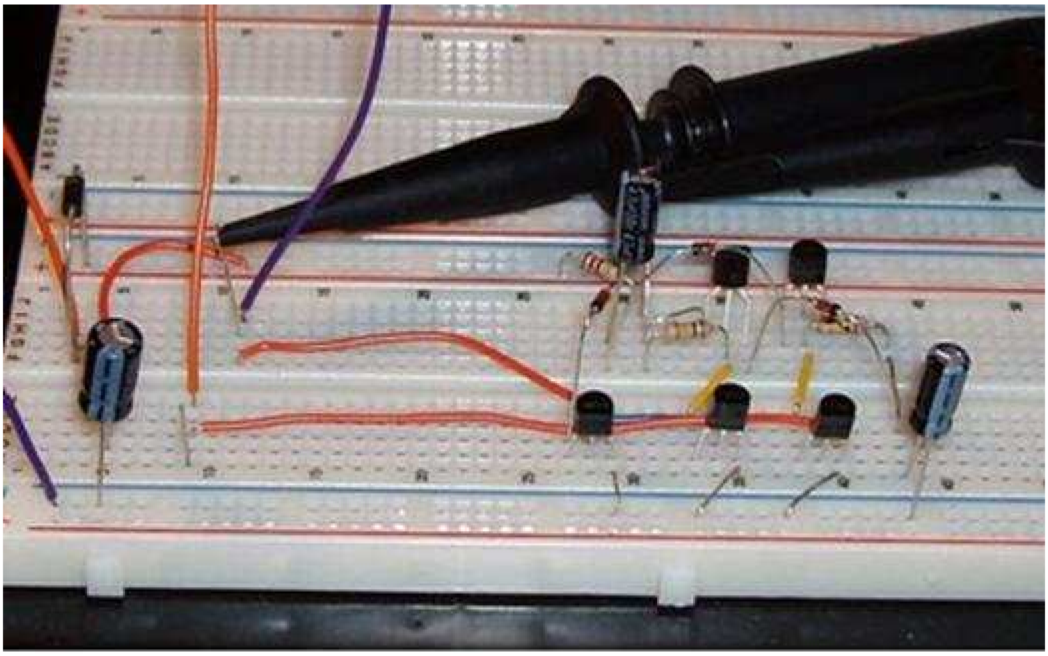
pic1. My variant of switching capacitors



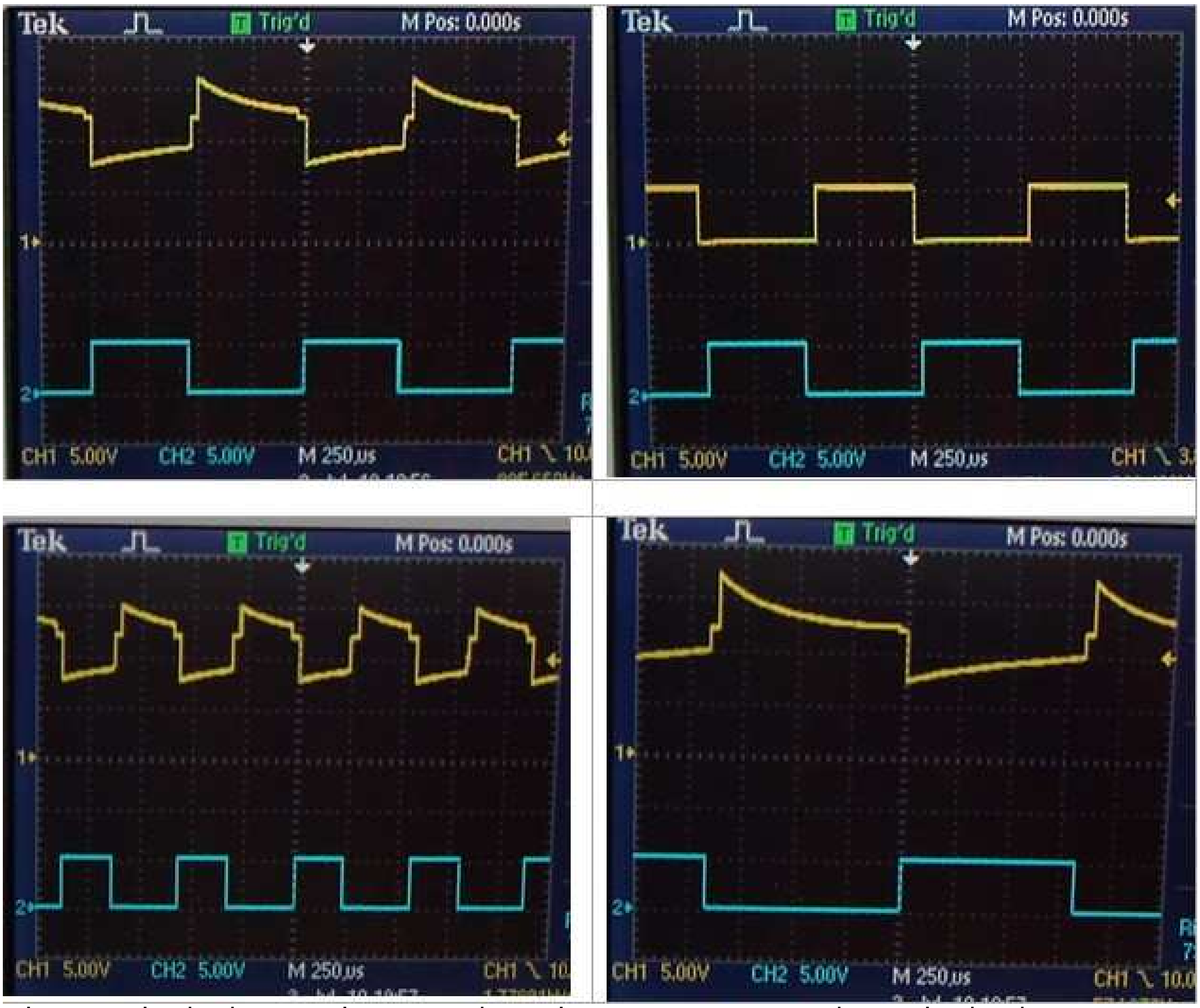
pic2. Simple MCU based generator to control the switch (see plsgen.rar for source code)



pic3. Updated switch use MOSFETs

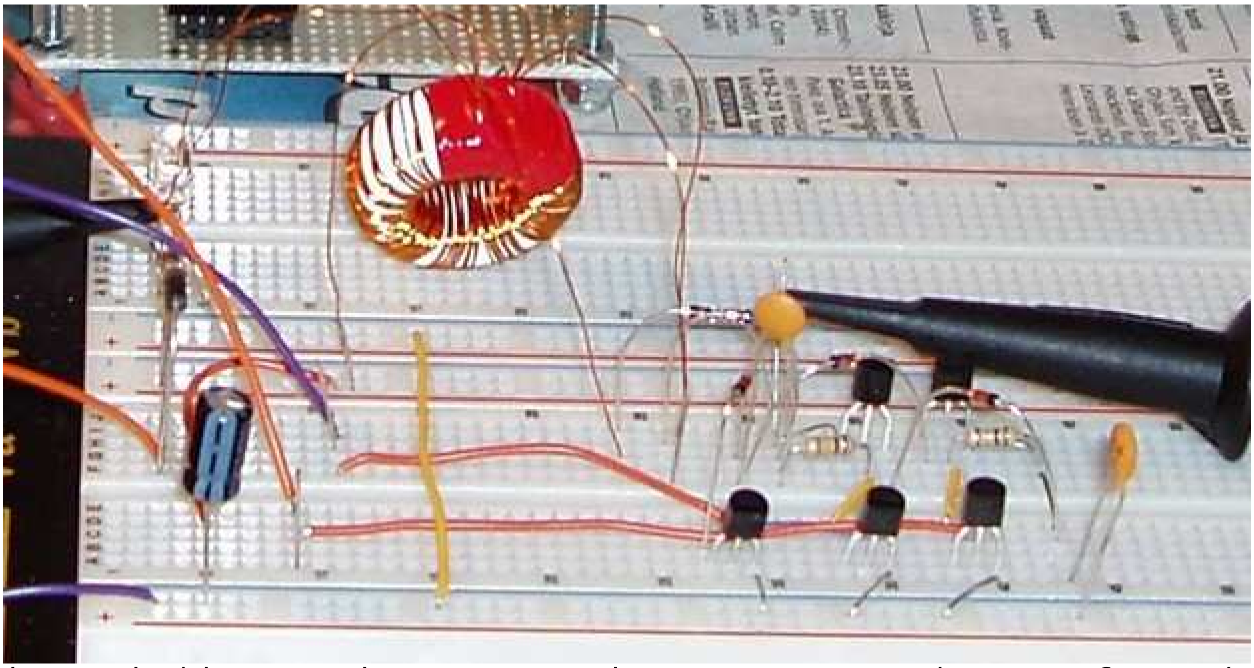

pic4. Experimental setup assembled on bread board

Below some oscilloscope traces for the switch connected to 12v power source thru resistor C1 = C2 = 4.7uF



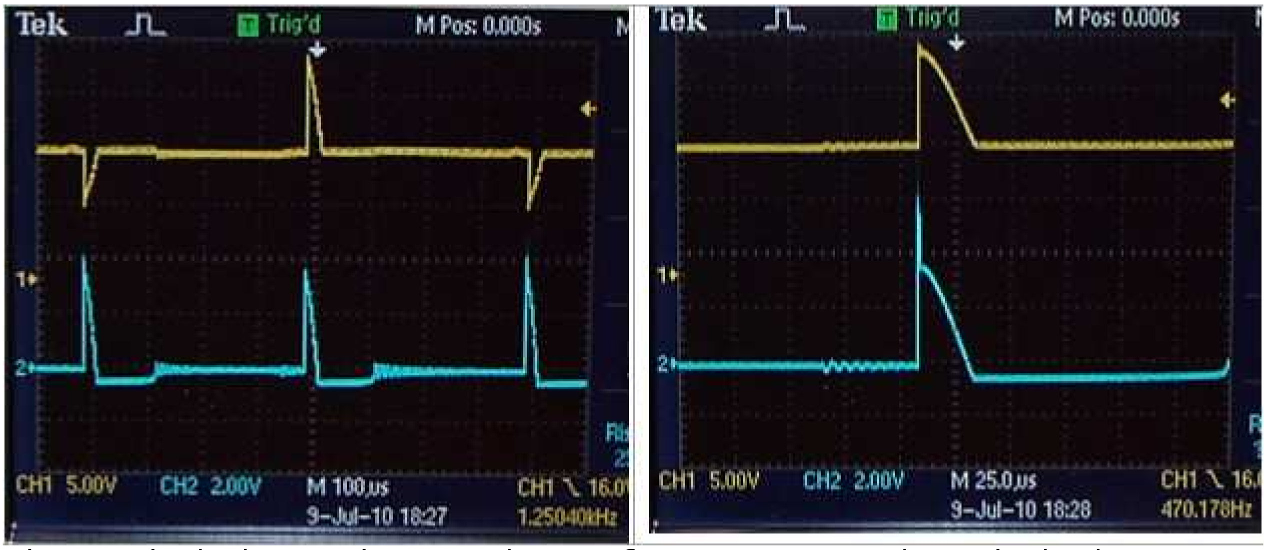
pic5. Switched capacitors and resistor; top – on the switch, bottom one of switch control signals

* notice that half of time current flowing back to battery (or power source), however this does not mean that we got FE device here ;-)



pic6. Switching capacitors connected to power source thru transformer (as shown on pic3)

In this setup C1 = C2 = 0.1uF

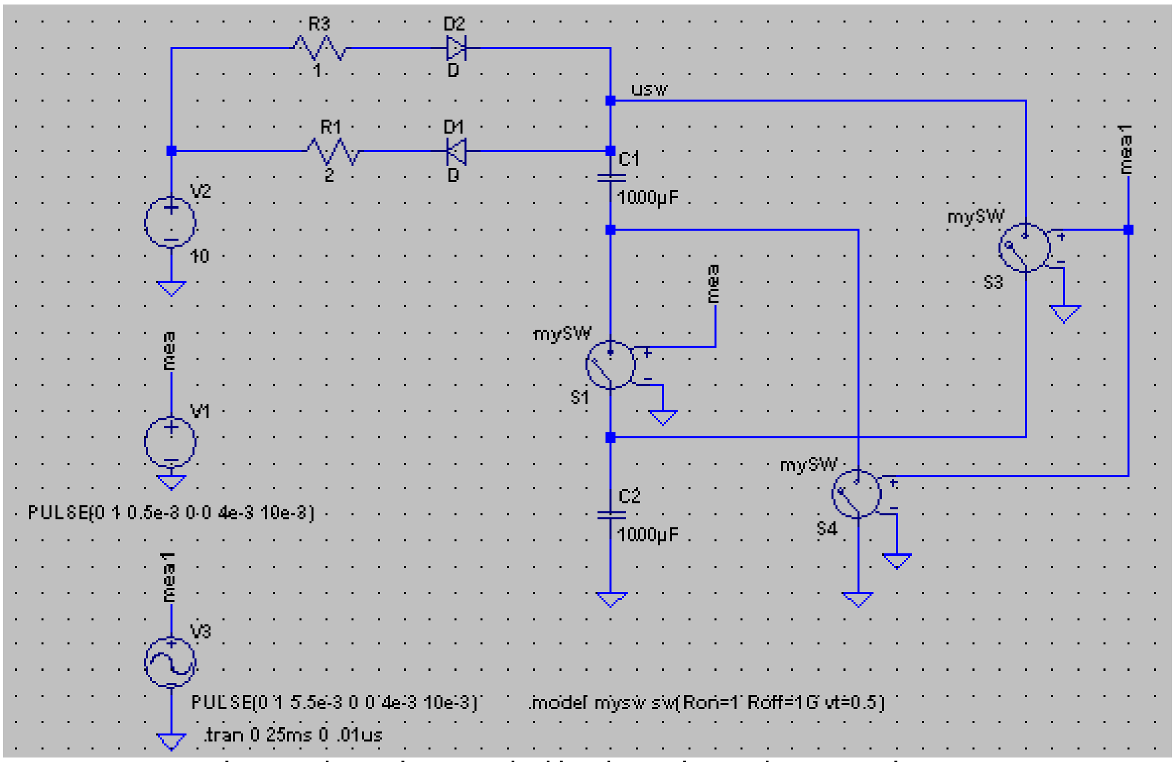


pic7. Switched capacitors and transformer; top-on the switch, bottom-on of the load (third coil) Both are same picture, but the right is bigger scale.

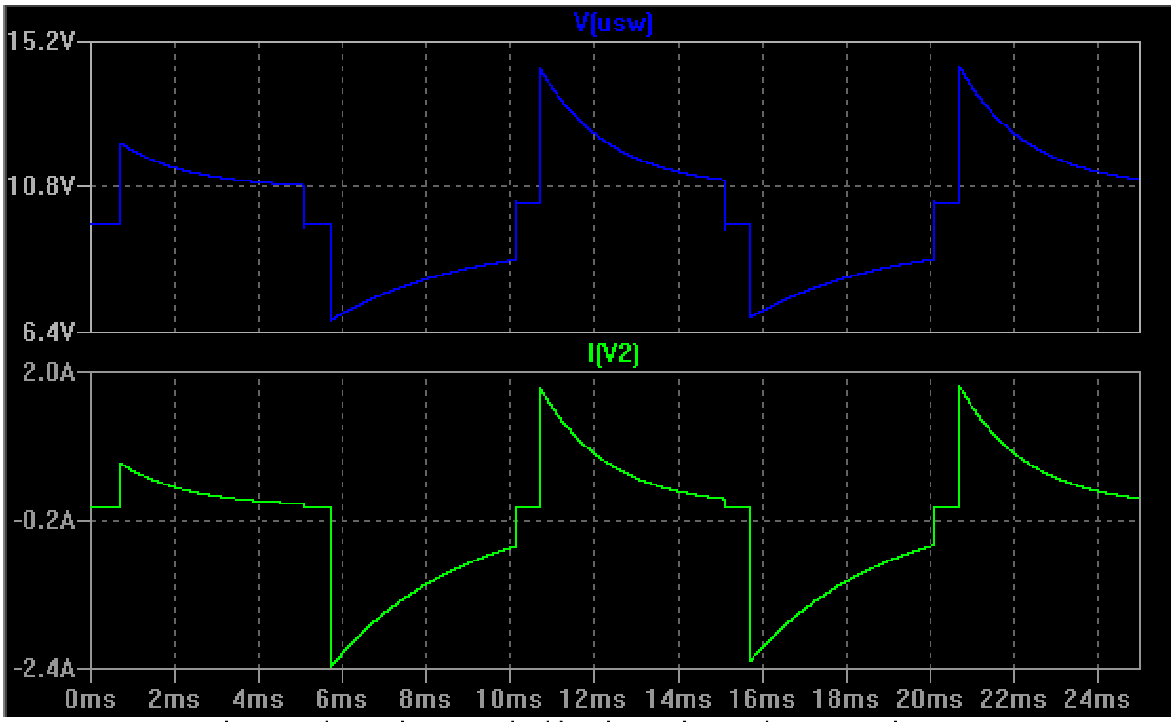
Link:
http://web.archive.org/web/20120826225130/http://www.energenx.com/john34/tesla.html

Simulating switched capacitors

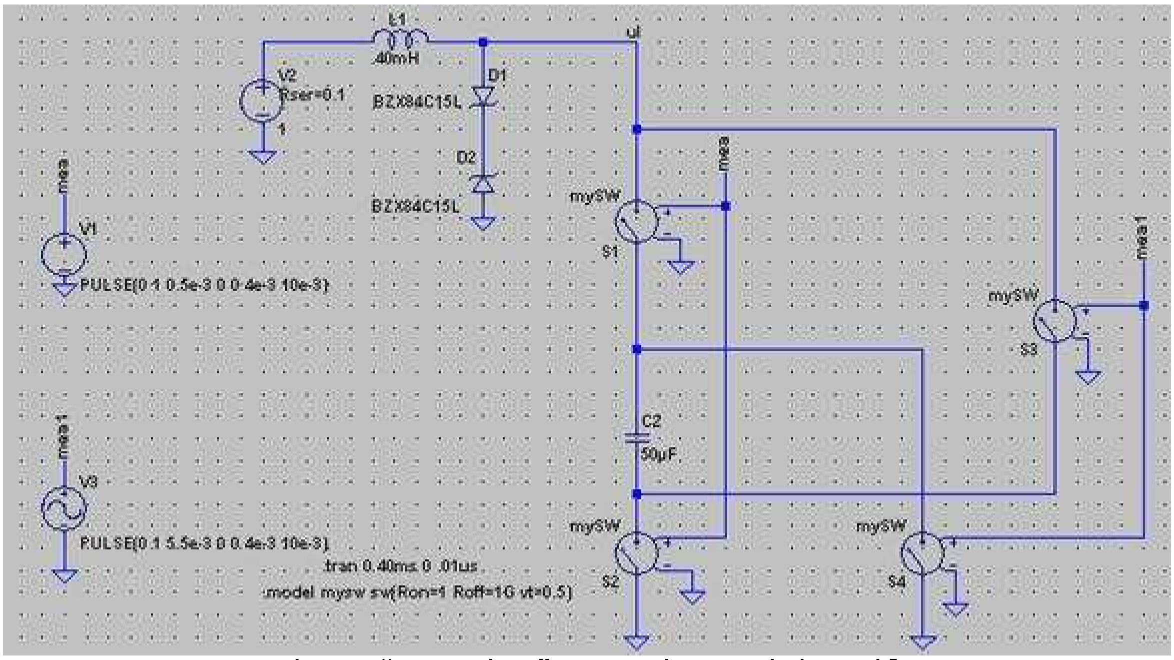
I made also some simulations about switched capacitors



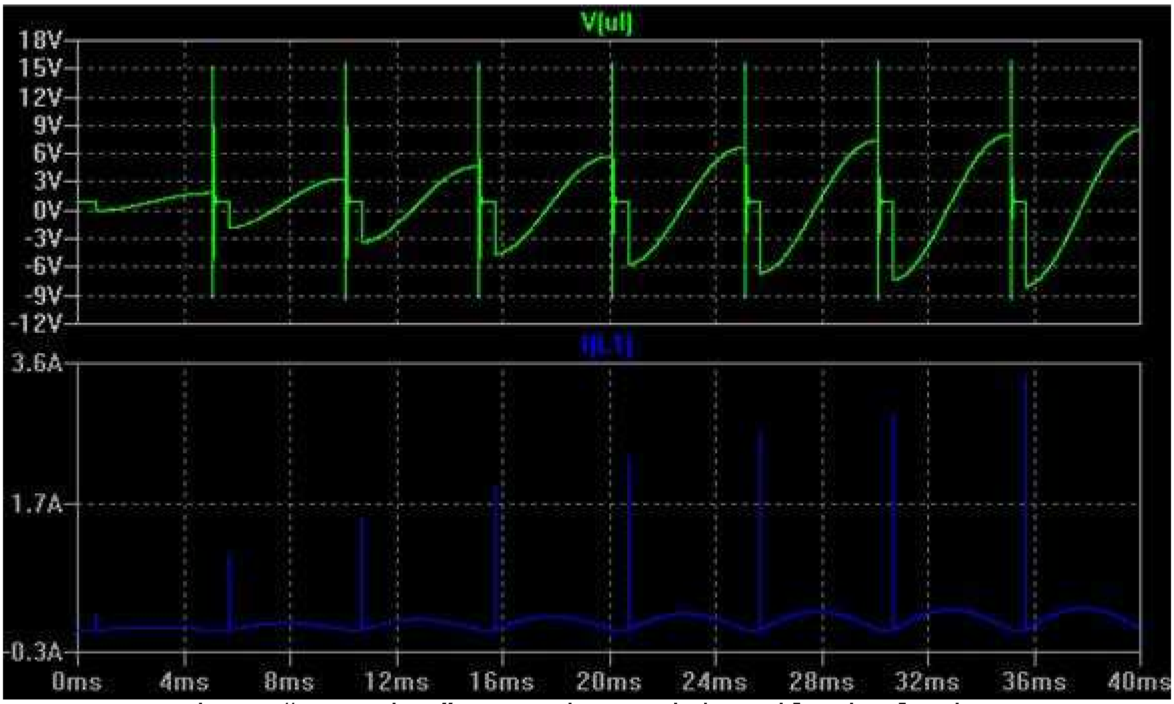
pic1. Charging and discharging thru resistor



pic2. Charging and discharging thru resistor

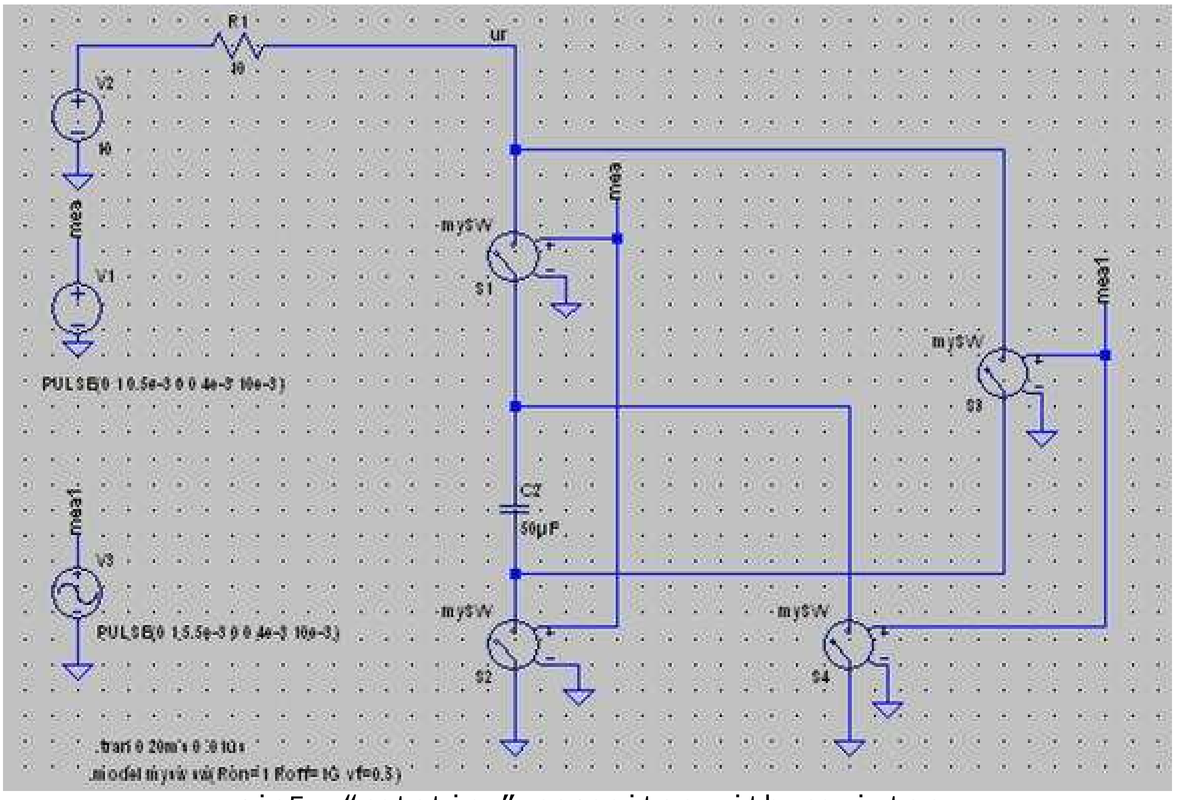


pic3. “rotating” capacitor with coil

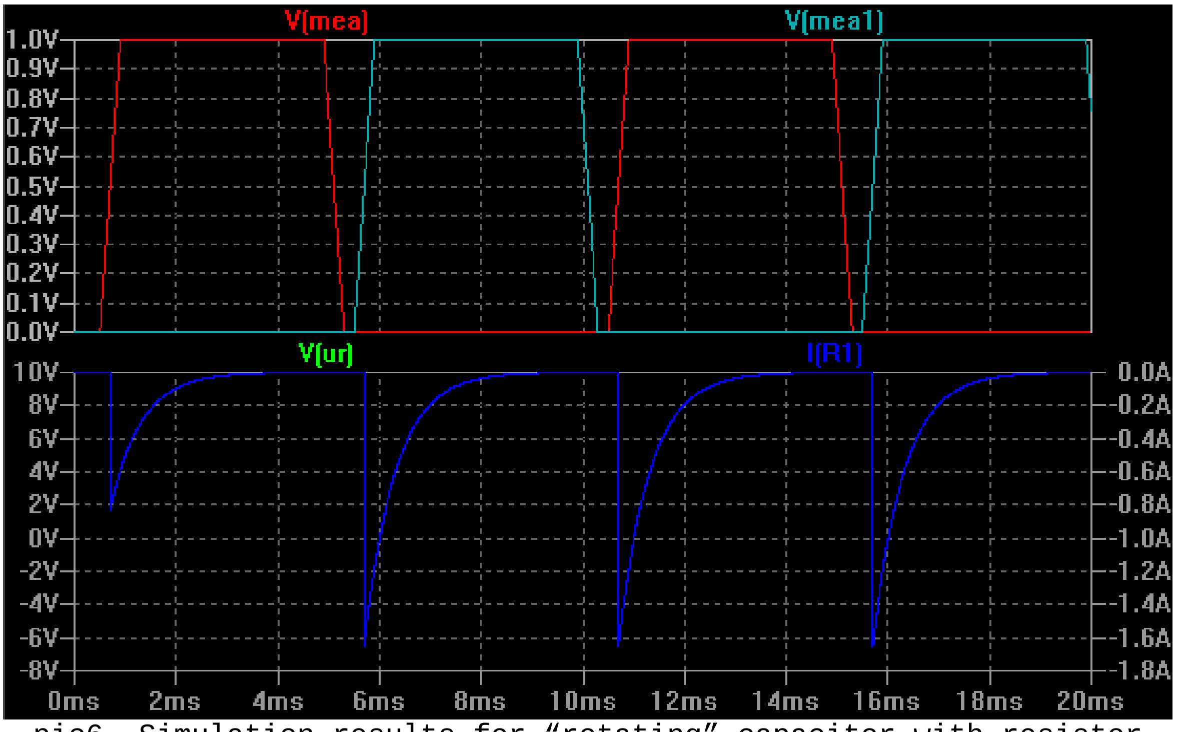


pic4. “rotating” capacitor with coil simulation

* this setup somehow similar to synchronous rectifier



pic5. “rotating” capacitor with resistor



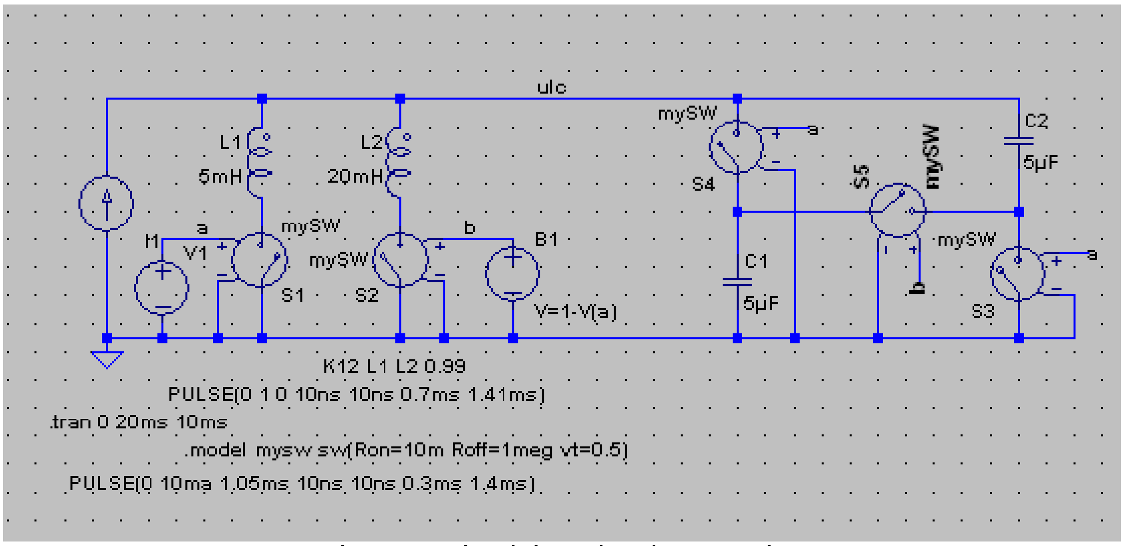
pic6. Simulation results for “rotating” capacitor with resistor

Links:
http://scholar.lib.vt.edu/theses/available/etd-173510281975580/unrestricted/chapter2.pdf
http://www.irf.com/product-info/fact_sheet/farnell/10142.pdf
http://www.ti.com/lit/an/snva595/snva595.pdf

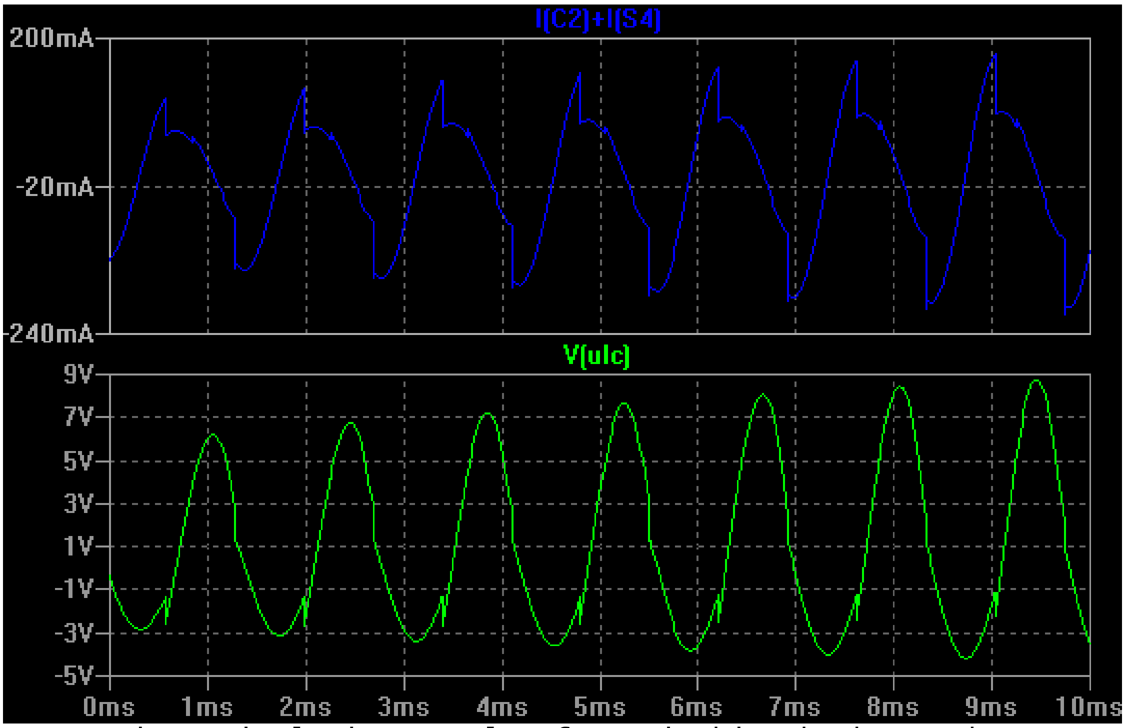
Switching coils and caps

We tried switching caps, coils (in flyback), now we can try switching both caps and coils.

Here a model for L/4L – 2C/0.5C switch. Such combination of switched L and C keeps resonance frequency the same.
However frequency can also be adjusted as we will see soon.



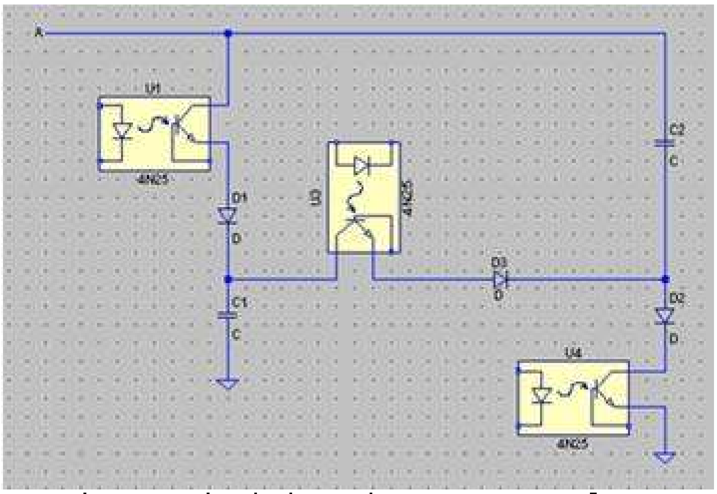
pic1. Switching both L and C



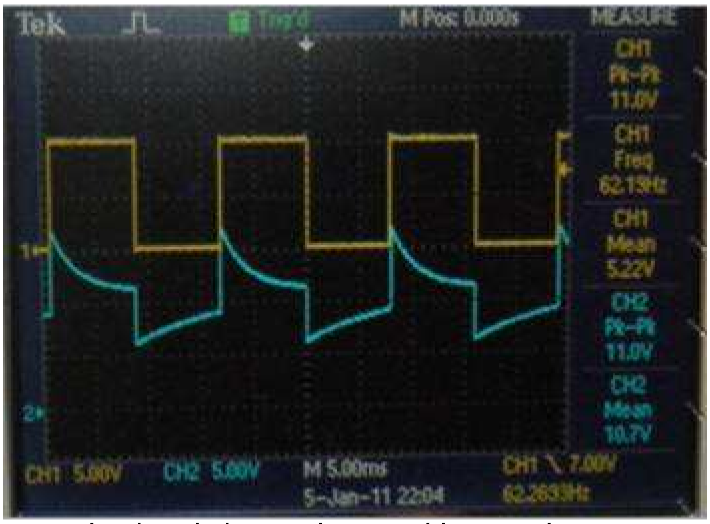
pic2. Simulation results for switching both L and C

* notice that waveforms have offset ;-)
** coils can also be switched using diodes.

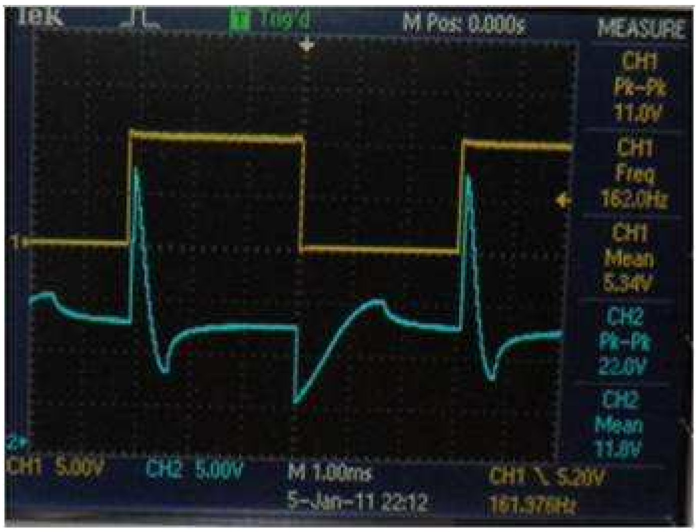
Real implementation of switches is difficult. I tried several different setups before I got something working ok.
Here one of setups which works. I use optocouplers to avoid any interference between control circuit and LC circuit.



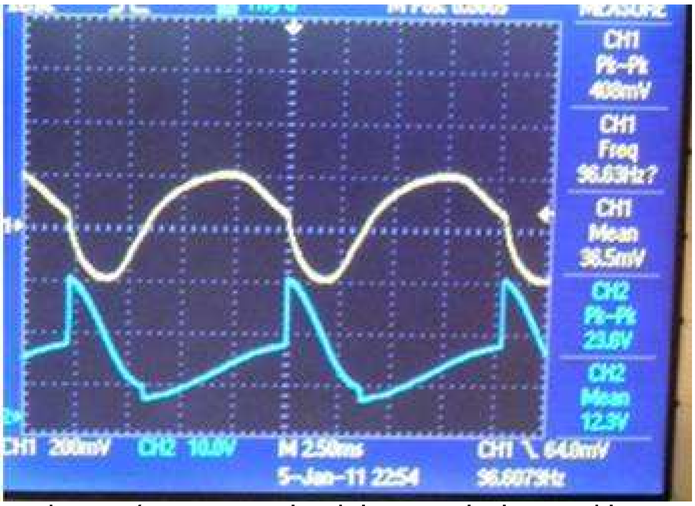
pic3. Switch based on optocouplers



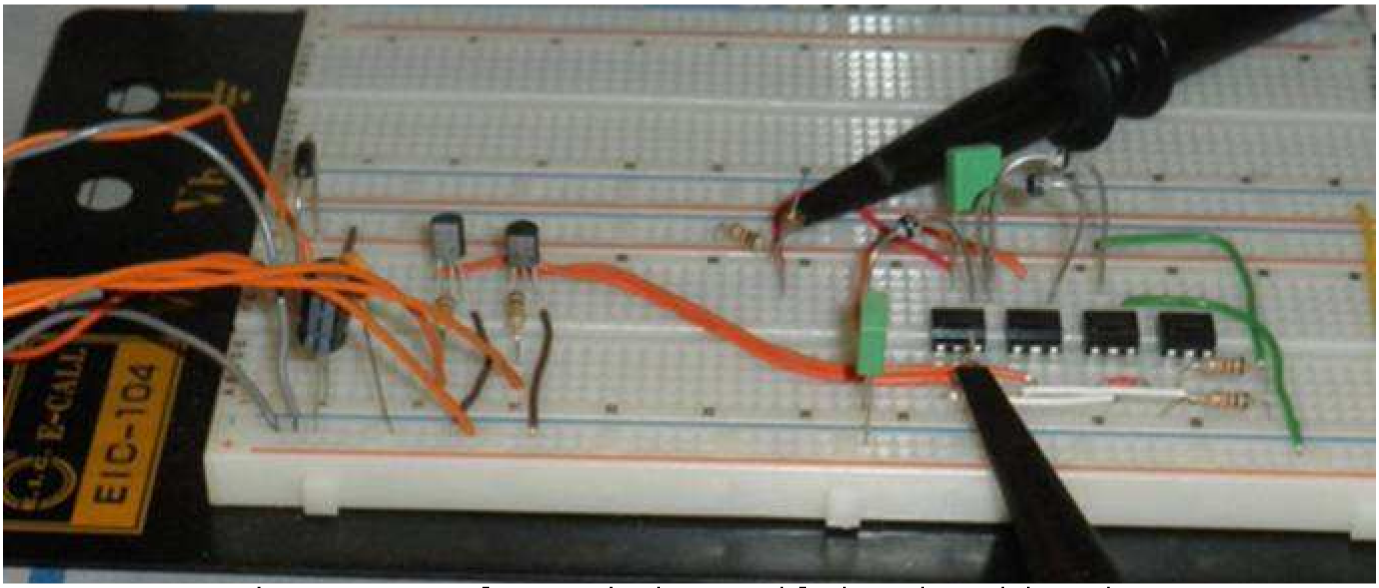
pic4. Trying switch with resistor (in series to power supply)
top – switch control, bottom - current



pic5. Trying switch with inductor (in series to power supply)
top – switch control, bottom - current



pic6. Inductor and 2C / 0.5C switching, timing adjusted for resonance
top – voltage, bottom - current



pic7. Optocouplers switch assembled on bread board

This experiment shows quite well that energy stored in LC tank does not change when we re-arranging capacitors or coils.

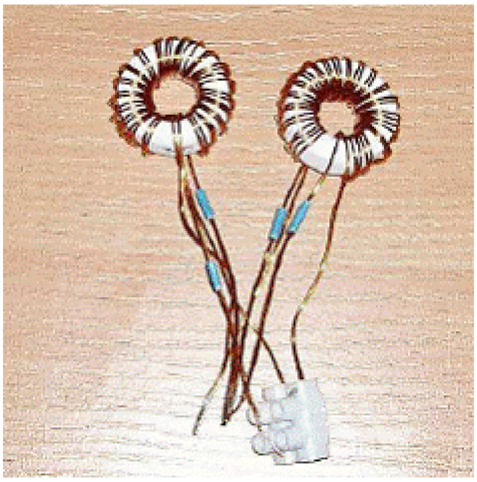
Follow my analogy with water I can say that the amount of water does not change if you pour it in different size cup ☺

Links:
http://en.wikipedia.org/wiki/Opto-isolator

Variable Inductor

We already saw non-linearity and inductance variations due to saturation. This effect can be used to create a variable inductor, electrically controlled variable inductor.

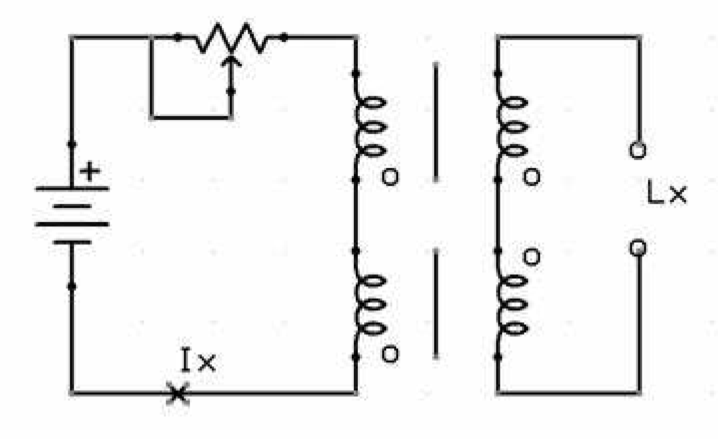
Below shown one of the simplest setups which allow create variable inductor. We need two identical ring cores with two identical coils on each inductor. One pair of coils connected “co-directional” and second pair connected “in opposite” direction. One pair will be used to control inductance and other will be “variable” inductor.



pic.1 Two ring cores
Ferroxcube FE25 3E25 25/14/10

2x18 turns on each

L1 = 2080uH
L1 + L2 = 4186 uH



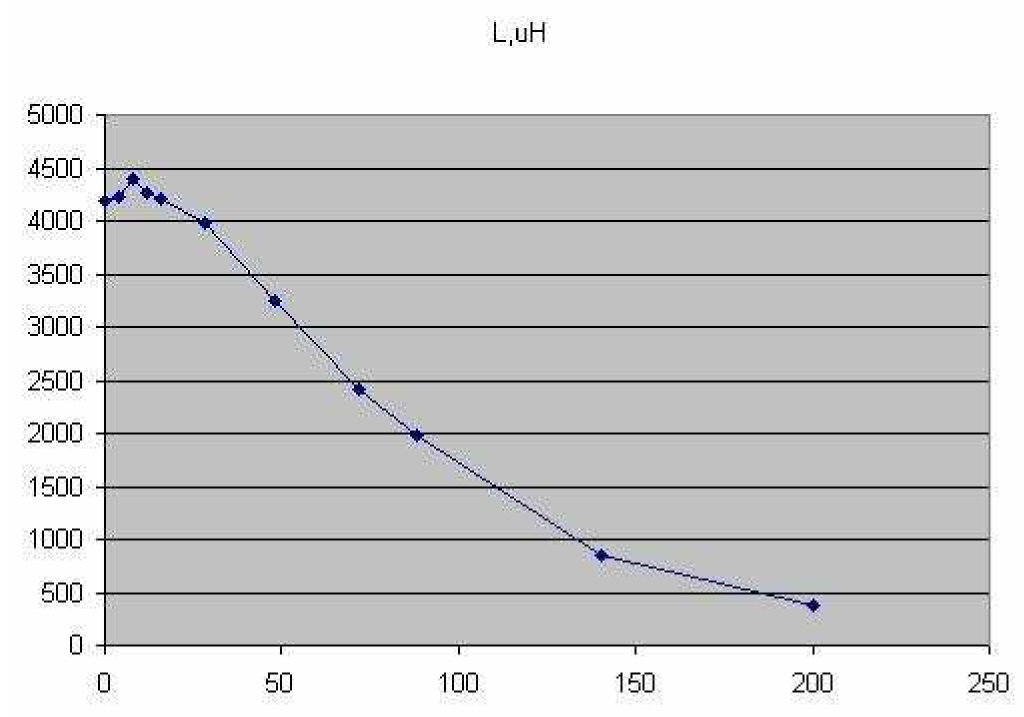
pic.2 experimental setup

current adjusted with potentiometer

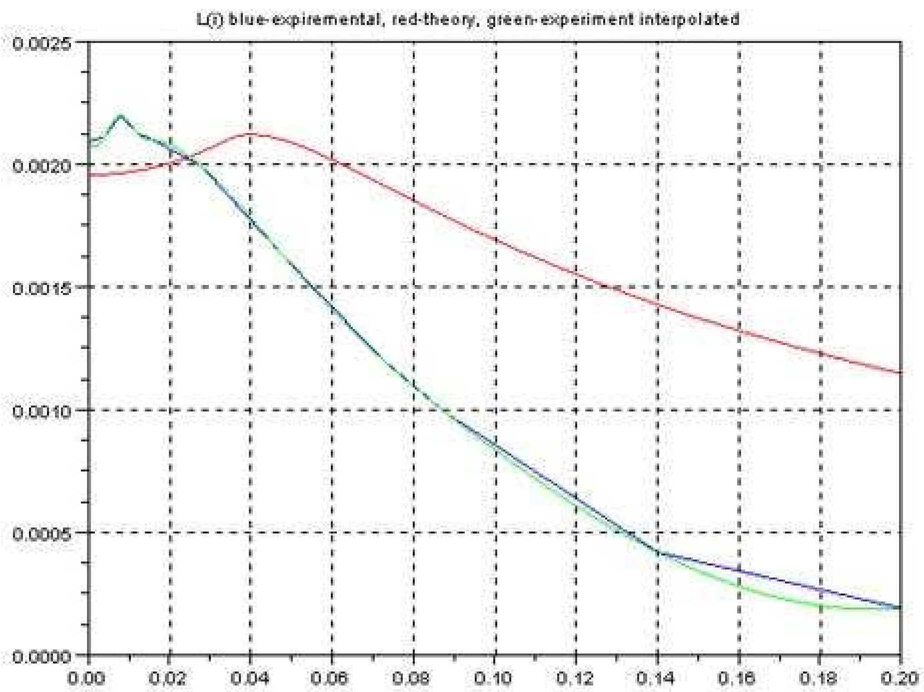
inductance measured with L – meter

I,ma	0	4	8	12	16	28	48	72	88	140	200
L,uH	4186	4228	4400	4255	4200	3980	3253	2424	1978	840	383

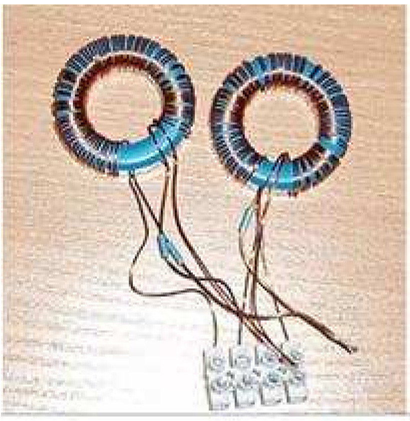
tab1. Inductance vs. control current



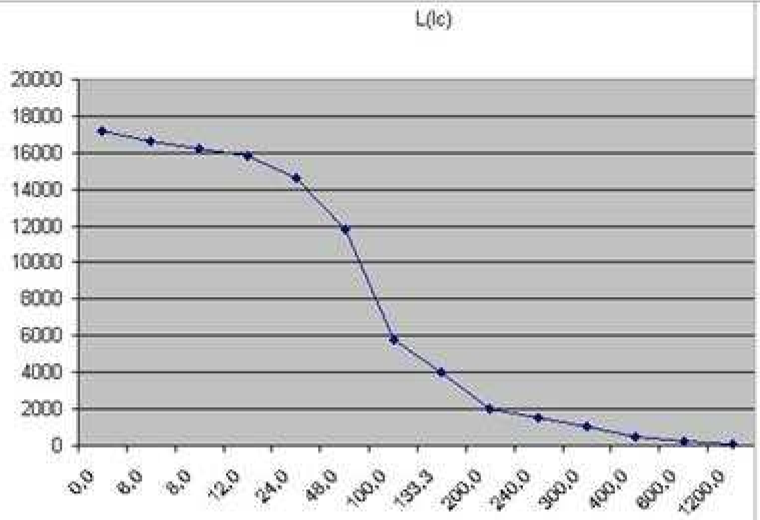
pic.3 inductance (L,uH) vs control current (I,ma)



pic4. Comparison of measured inductance with theoretically calculated based on formula used for non-linear inductance. blue – experimental; red - theoretical

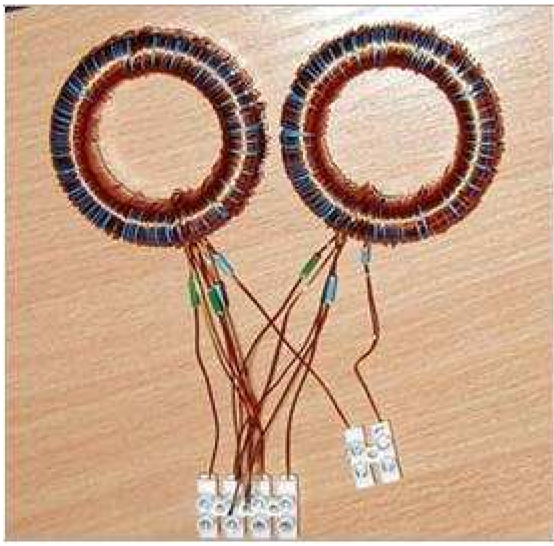


2x38 turns 0.7mm
N30 41,8X26,2X12,5



в	ом	ма	ма (расч.)	L,мкгн
12		0	0,0	17200
12	2000	12	6,0	16627
12	1500	12	8,0	16220
12	1000	16	12,0	15819
12	500	28	24,0	14644
12	250	52	48,0	11801
12	120	100	100,0	5773
12	90	200	133,3	4018
12	60	200	200,0	2048
12	50	240	240,0	1506
12	40	292	300,0	1047
12	30	404	400,0	518
12	20	592	600,0	238
12	10	1224	1200,0	76

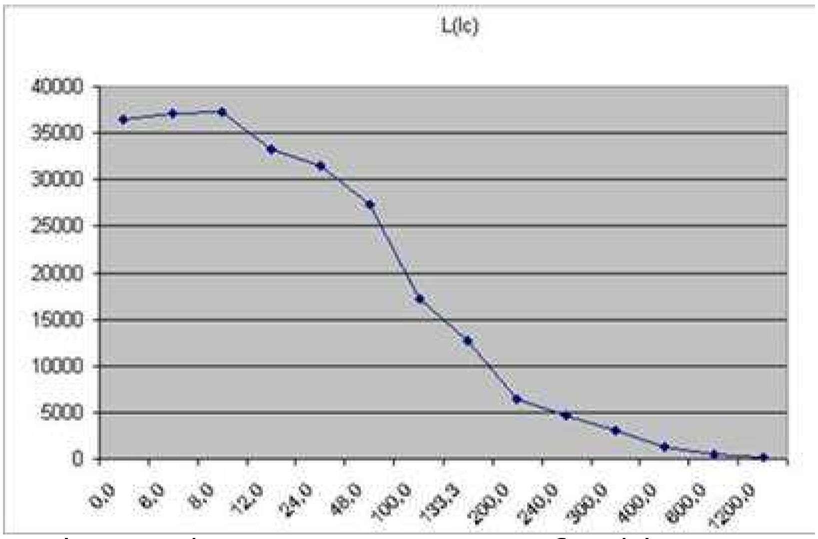
pic5. Same setup but bigger cores used



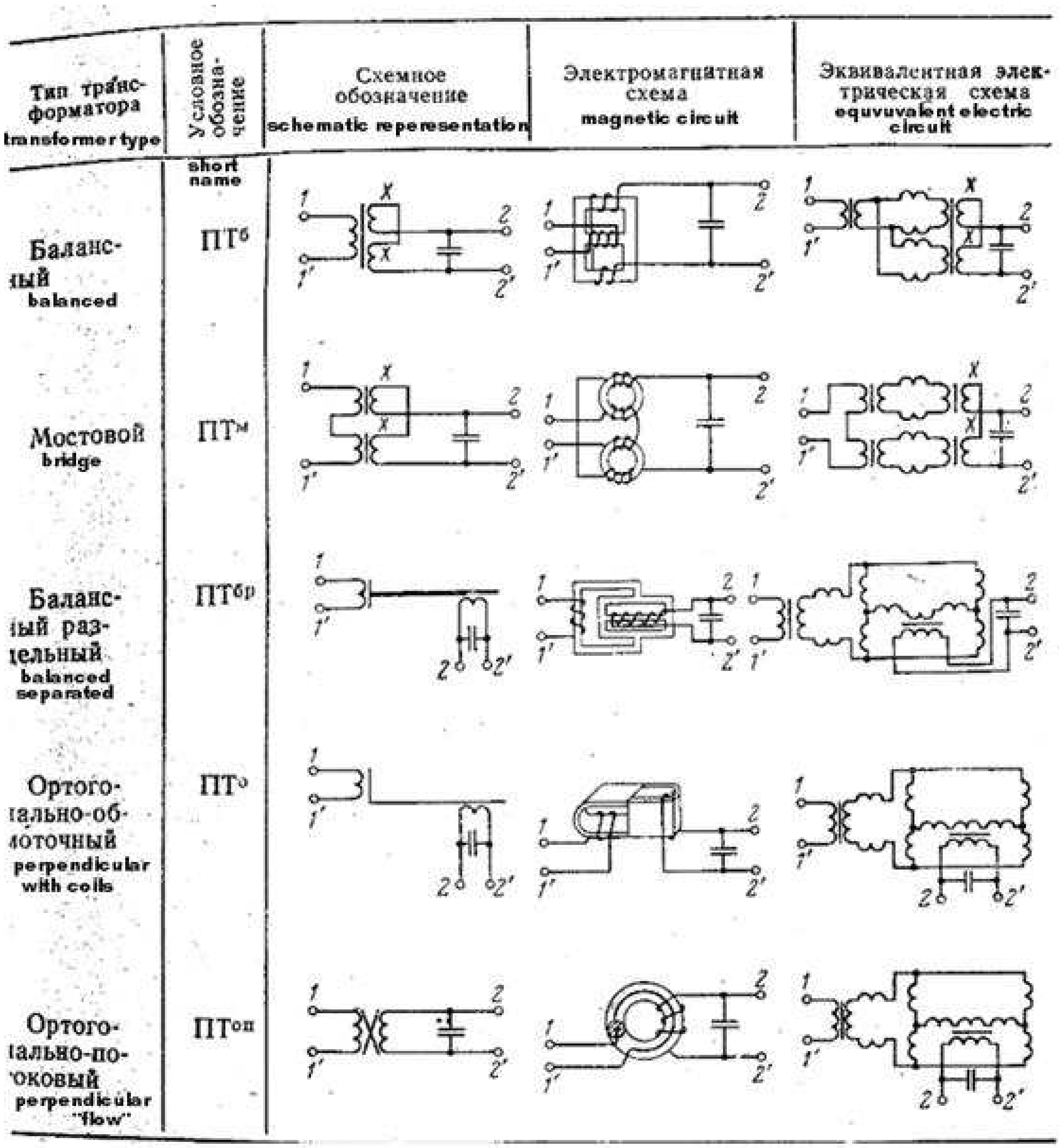
2x90 turns 0.7mm
Epcos B64290L40x830 R58 N30

pic6. Even bigger cores

в	ом	ма	ма (расч.)	L,мкгн
12		0	0,0	36500
12	2000	12	6,0	37109
12	1500	12	8,0	37231
12	1000	16	12,0	33307
12	500	28	24,0	31483
12	250	52	48,0	27251
12	120	100	100,0	17121
12	90	128	133,3	12643
12	60	192	200,0	6471
12	50	224	240,0	4718
12	40	272	300,0	3132
12	30	400	400,0	1235
12	20	588	600,0	529
12	10	1116	1200,0	159



pic7. Inductance vs. current for big cores



pic8. This a page from old russian book with different variable inductors setups shown

Some links:
http://translate.google.com/translate?sl=auto&tl=en&js=n&prev=_t&hl=en&ie=UTF-8&u=http%3A%2F%2Fwww.hcrs.at%2FPARAMET.HTM
http://jnaudin.free.fr/html/paraconv.htm

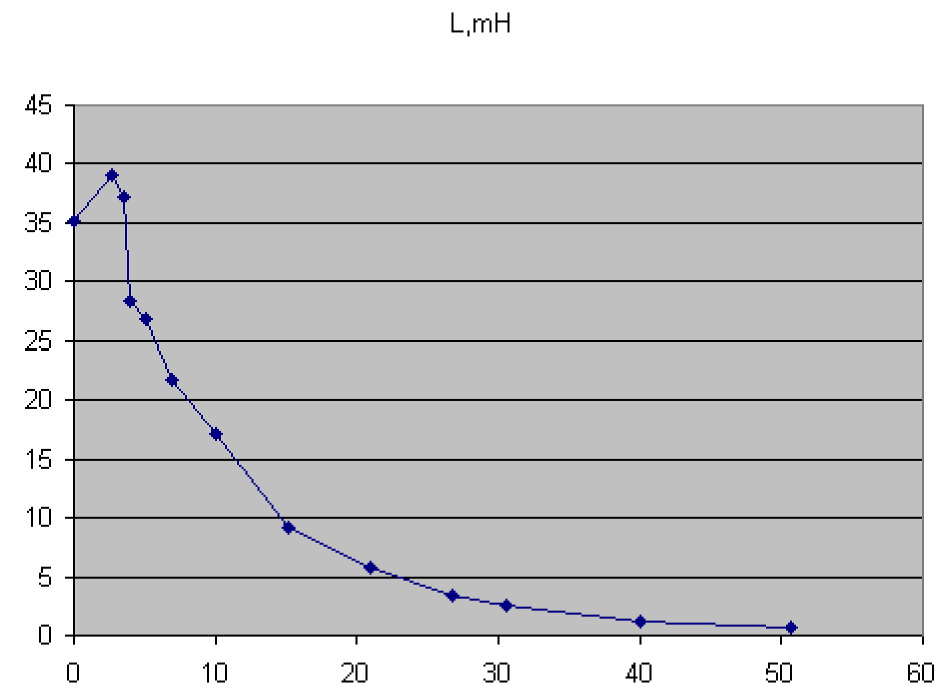
Magnetic amplifiers

Let's consider one of traditional application of variable inductor – magnetic amplifier.
If we make "primary" coils in variable inductor with many turns and "secondary" coils with small number of turns we can control our variable inductor with small current and build an amplifier out of it.

Below measured inductance vs. current for coils shown on pic.2

I,ma	0	2,7	3,6	4	5,1	7	10	15,2	21	26,7	30,5	40	50,7
L,mH	35,1	39	37,2	28,4	26,9	21,8	17,2	9,1	5,7	3,4	2,47	1,26	0,75

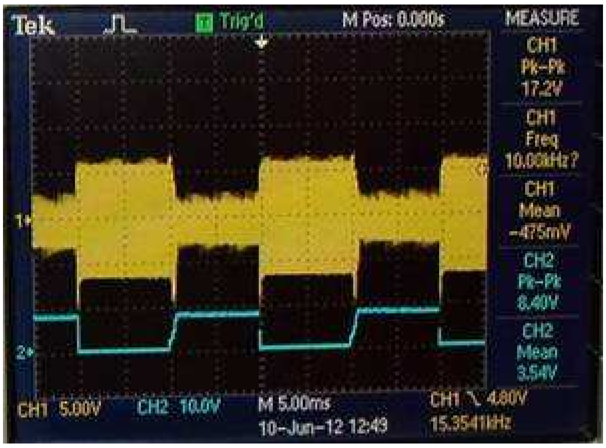
tab1. Measuring Inductance vs. control current



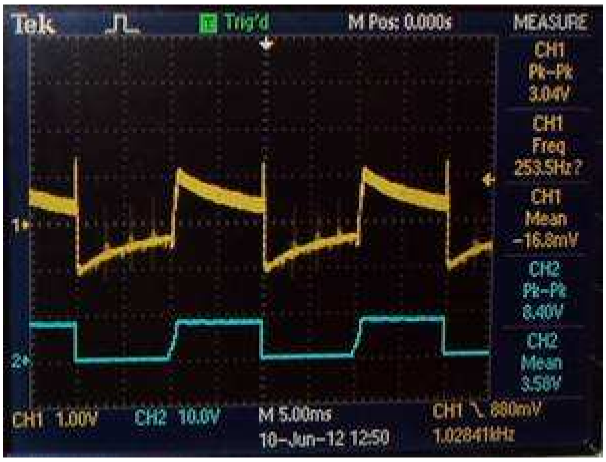
pic1. Inductance vs. control current (ma)

pic2. coils
two ring cores Ferroxcube FE25-3F3
I 11m -> 250t ϕ0.35
II 1.5m -> 25t ϕ0.5

Now we can try building simple magnetic amplifier



pic3. top – on one leg of output transformer; bottom - control

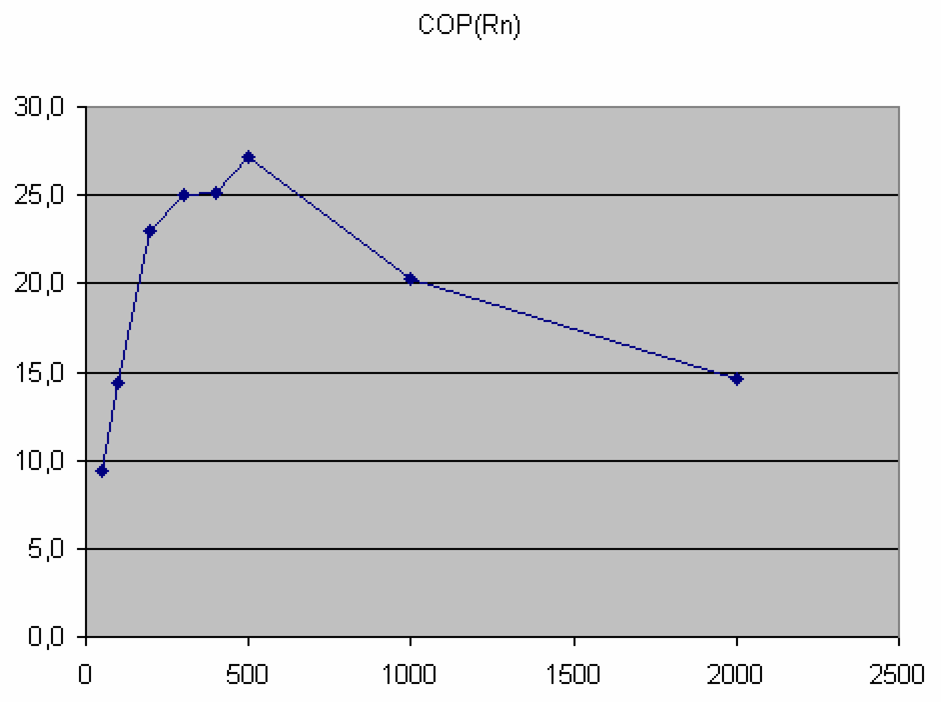


pic4. top – output; bottom – control

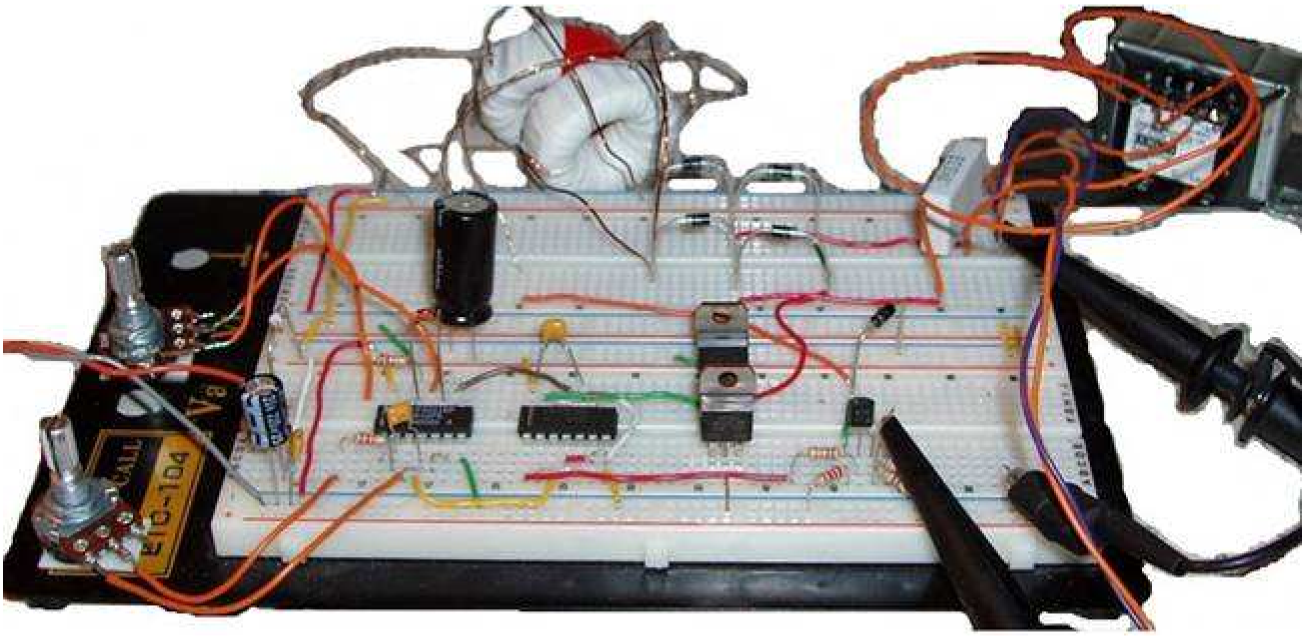
It would be interesting estimate efficiency of my amplifier

R,ohm	2000	1000	500	400	300	200	100	50
U,v	25,2	21	17,2	14,8	12,8	10	5,6	3,2
P,w	0,159	0,221	0,296	0,274	0,273	0,25	0,157	0,102
COP	14,6	20,2	27,1	25,1	25,1	22,9	14,4	9,4

Power consumption Up = 11,5V; Ip = 0,095A; Pp = 1,0925W

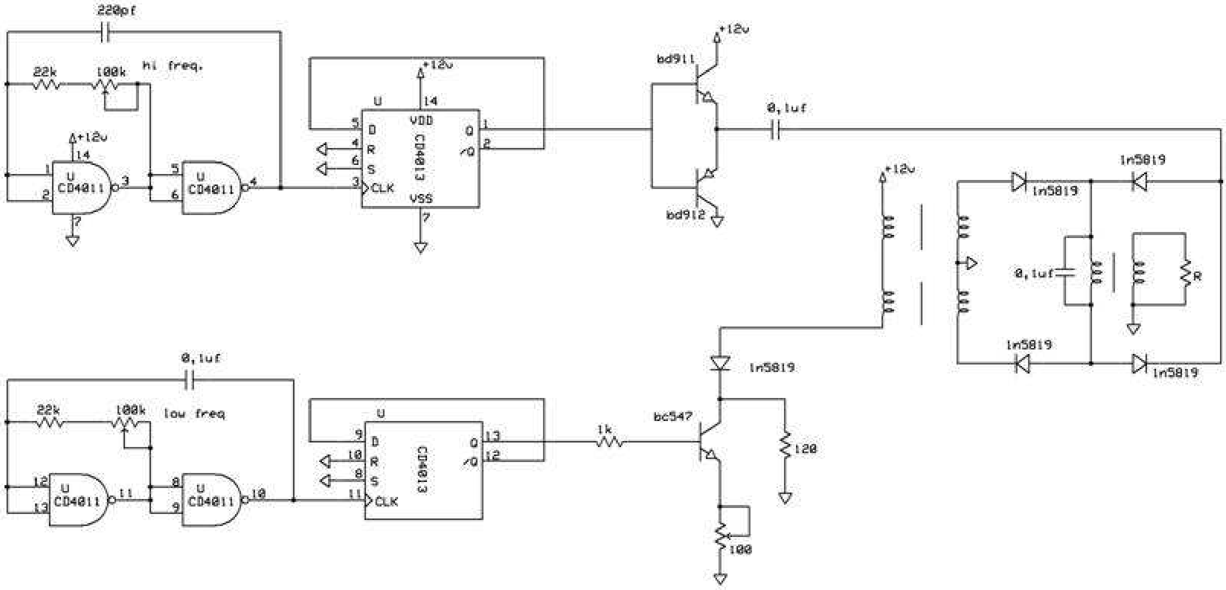


pic5. Trying measure COP of my magnetic amplifier (COP in percents vs R load in ohms)



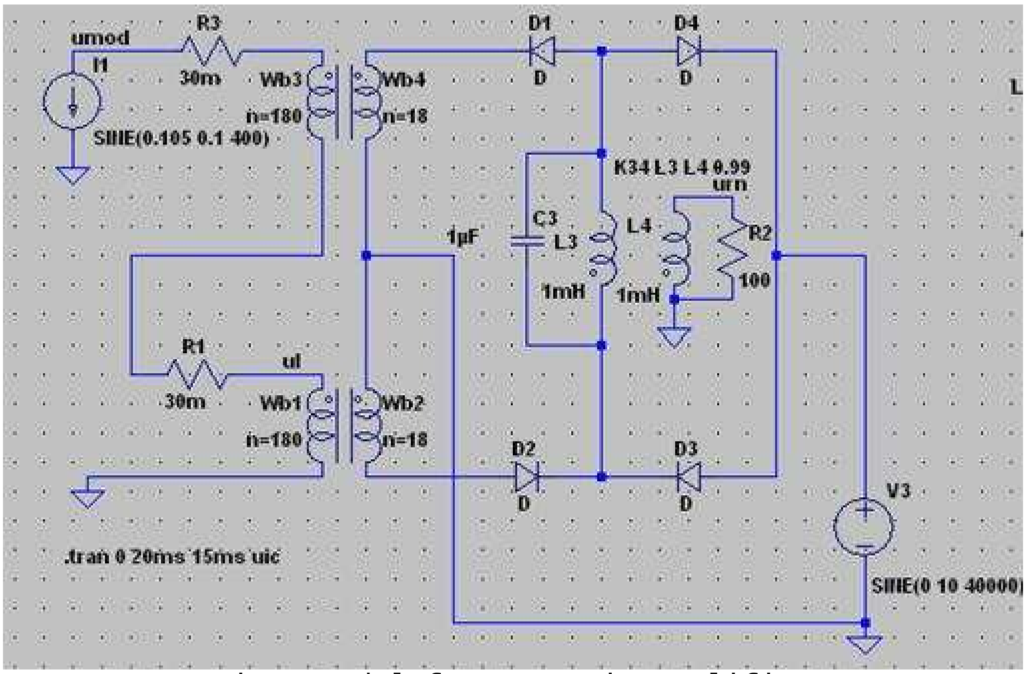
pic6. Experimental setup

* two secondary winding 24v from small power transformer used as output transformer

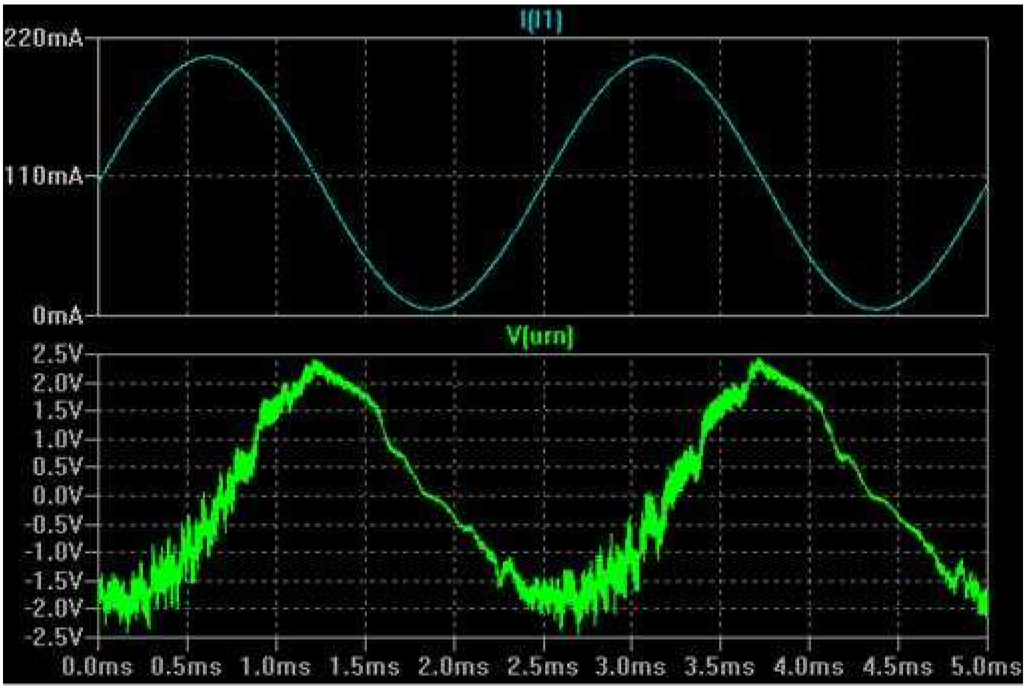


pic7. Experiment schematic (hi frequency about 15 KHz, low frequency about 1 KHz)

It’s probably not very useful model but it is interesting if we can simulate magnetic amplifier.



pic8. Model for magnetic amplifier



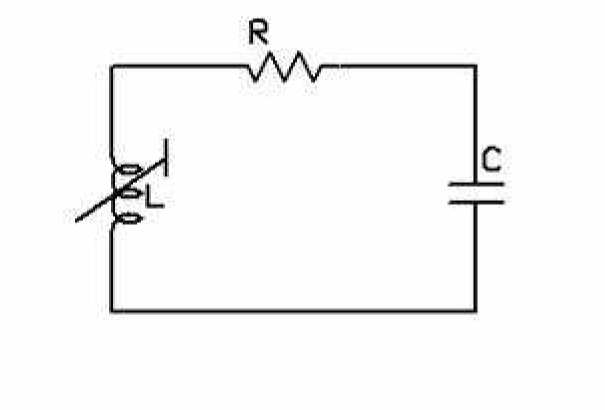
pic9. Simulation of magnetic amplifier

It is interesting why some people tend to believe that magnetic amplifiers have some “magic” properties e.g. can have COP more than 100%. What is actually different from a “regular” amplifier which uses transistors? (Power for output signal coming from power source in both cases)

Links:
http://sparkbangbuzz.com/mag-audio-amp/mag-audio-amp.htm
http://www.rfcafe.com/references/popular-electronics/magnetic-amplifiers-jul-1960-popular-electronics.htm
http://www.themeasuringsystemofthegods.com/magnetic%20amplifiers.pdf
http://www.grimeton.info/long_wave_transmitter.html
http://earlyradiohistory.us/1920alt.htm

Parametric resonance

- other interesting type of resonance I would like to mention



$$U_L = L\frac{dI}{dt} + I\frac{dL}{dt} = L\frac{d^2Q}{dt^2} + \frac{dQ}{dt}\frac{dL}{dt}$$

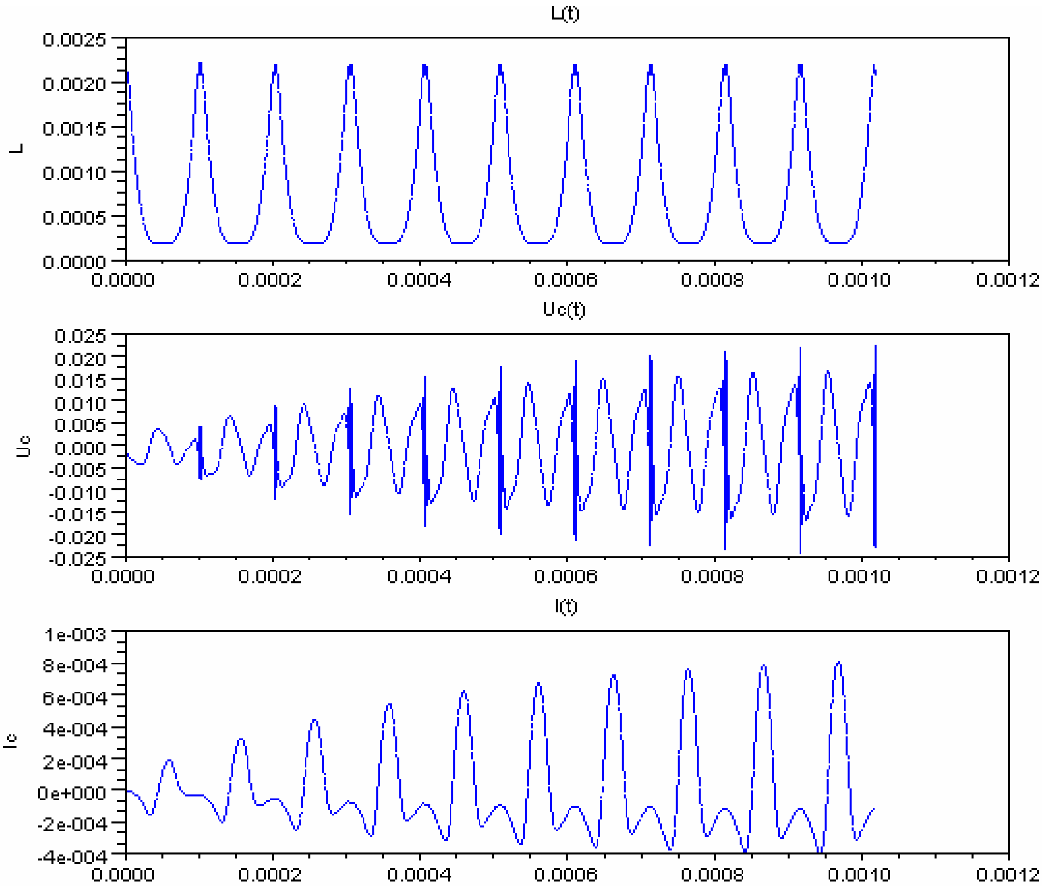
$$U_R = IR = R\frac{dQ}{dt}$$

$$U_C = \frac{Q}{C}$$

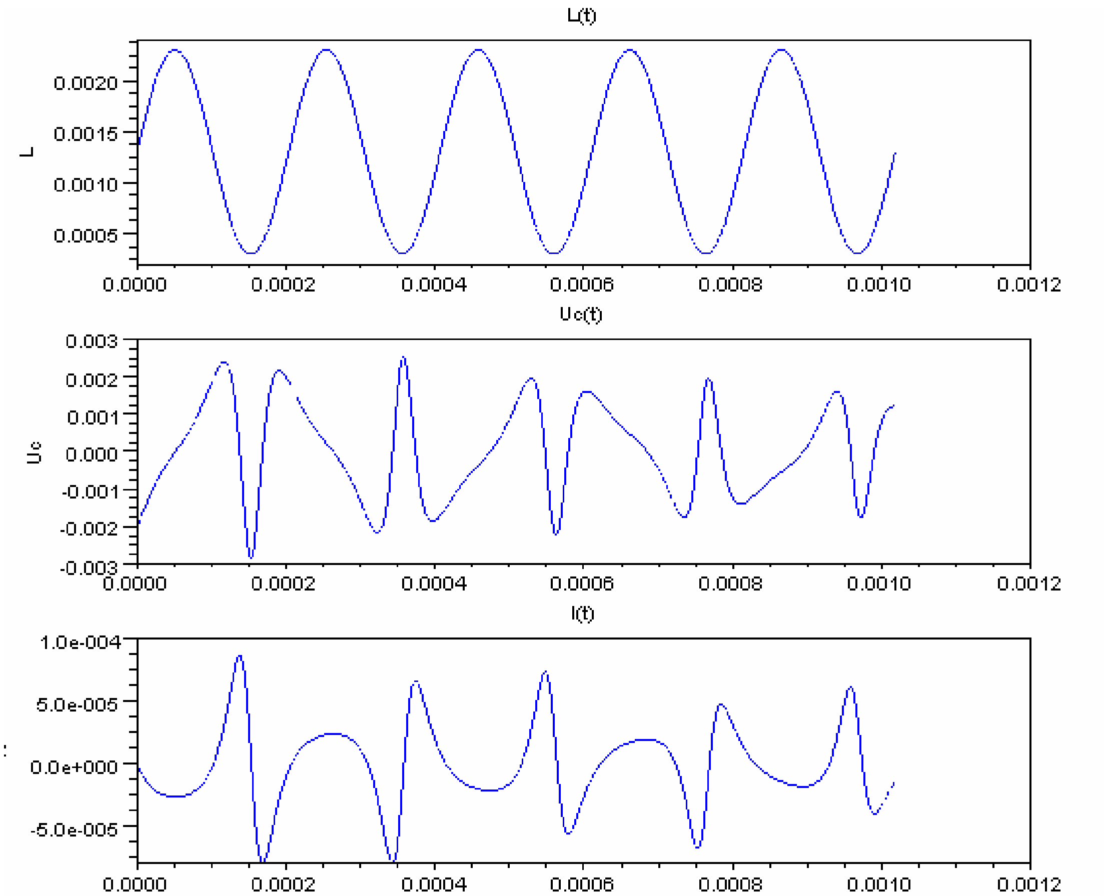
$$L\frac{d^2Q}{dt^2} + \left|R + \frac{dL}{dt}\right|\frac{dQ}{dt} + \frac{Q}{C} = 0$$

pic1. Parametric resonator with variable inductor and a bit of theory

We can see that not only current variation but also inductance variation affects voltage on the inductor (usually inductance is constant, so second term is zero).



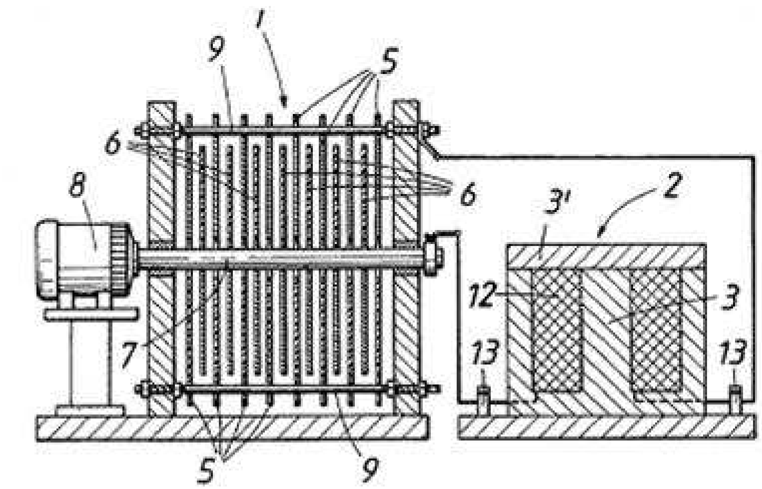
pic2. Simulation for sinusoidal control current



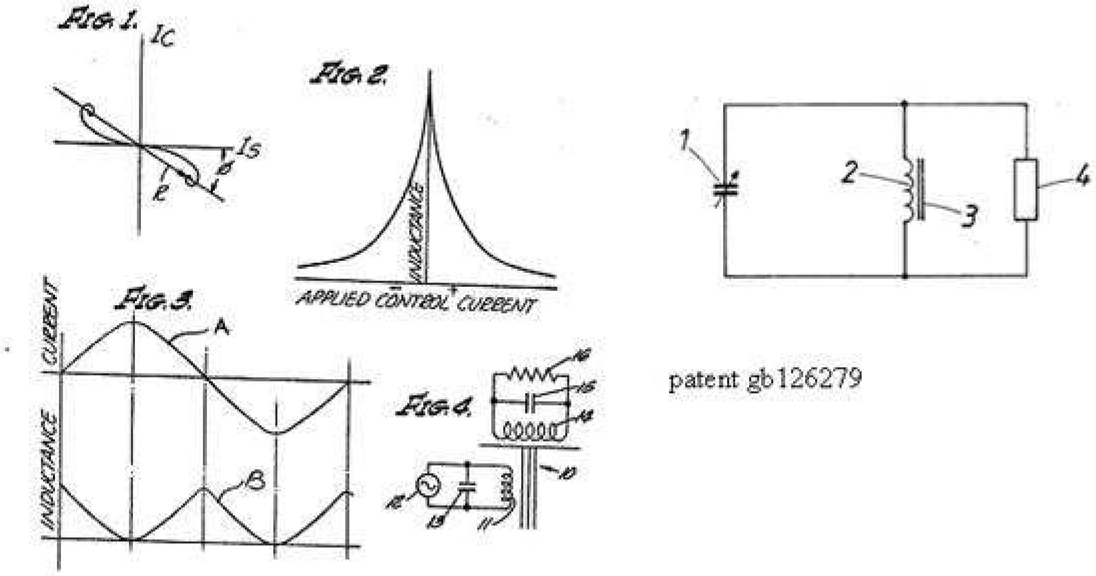
pic3. Simulation for sinusoidal control current with offset

Simulation made using finite difference method to solve differential equation shown above.

Below two examples of parametric resonators from patents

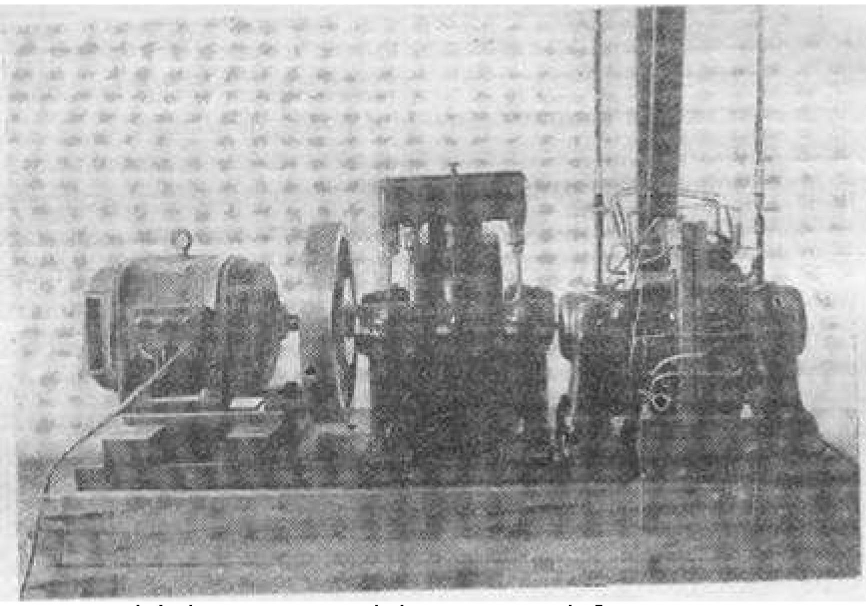


pic4. Mechanical parametric resonator with variable capacitor (see patent 4522510)



pic5. Parametric resonator with electrically controlled inductor

Mechanically controlled inductance is also possible, inductance can be changed e.g. by changing coils relative position or orientation.

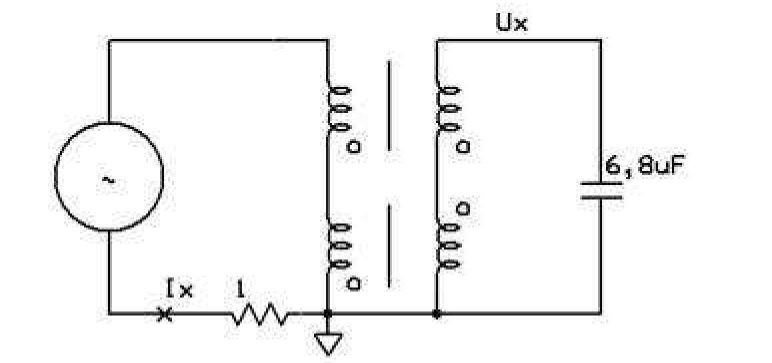


pic6. One of setups which were used by L. Mandelstam.
Inductance controlled by changing distance between coil and aluminum plate.

Links:
http://www.tuks.nl/pdf/Reference_Material/Mandelstam_Papalexi/Concerning%20the%20Excitation%20of%20Electrical%20Waves%20Through%20Parameter%20Changes%20English%20translation%201934.pdf
http://www.tuks.nl/pdf/Reference_Material/Mandelstam_Papalexi/
http://www.animations.physics.unsw.edu.au/jw/AC.html
http://aa1tj.blogspot.fi/2012/02/dl3pbs-all-tunnel-diode-parametric.html

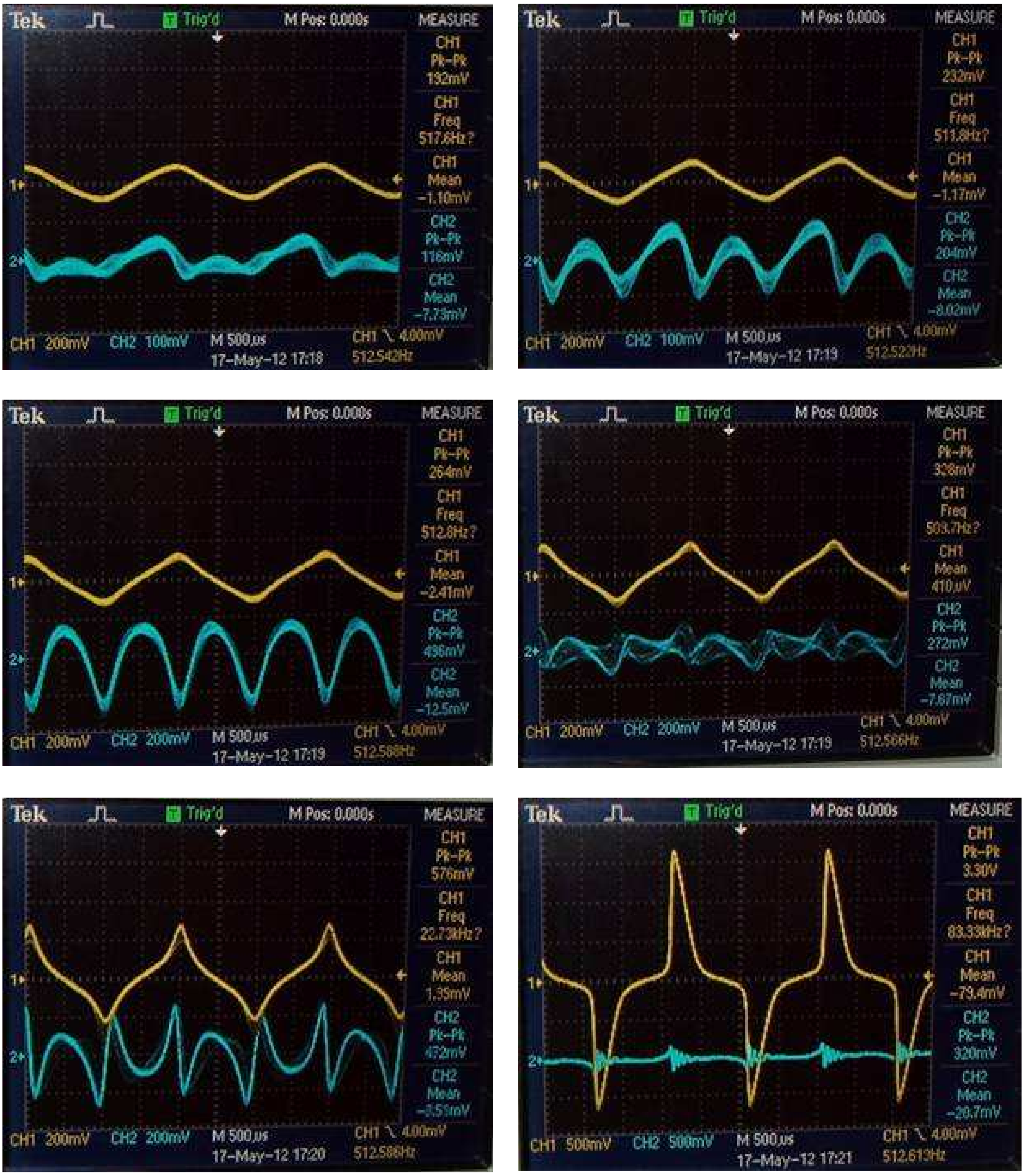
Building parametric resonator

Let’s try building parametric resonator ourselves.
We can use variable inductor from our previous experiments.



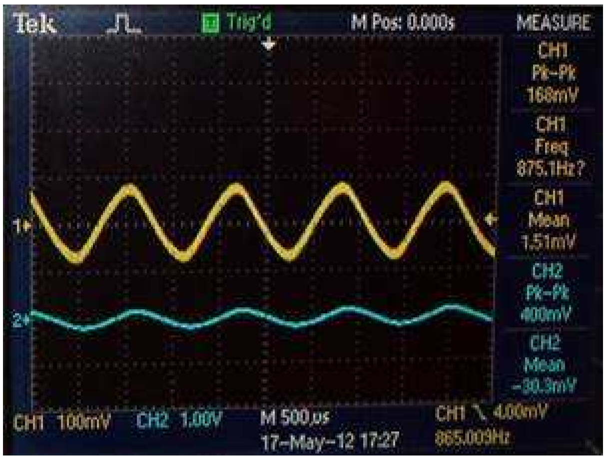
pic1. Parametric resonator experiment

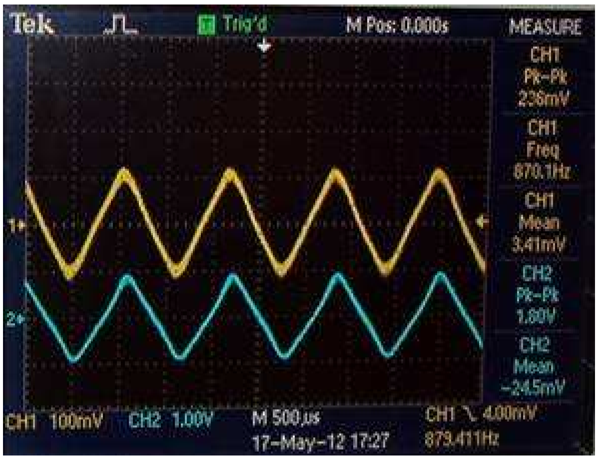
I use signal generator and audio amplifier to control variable inductor.
Below shown waveforms for different modes of oscillations in parametric resonator.

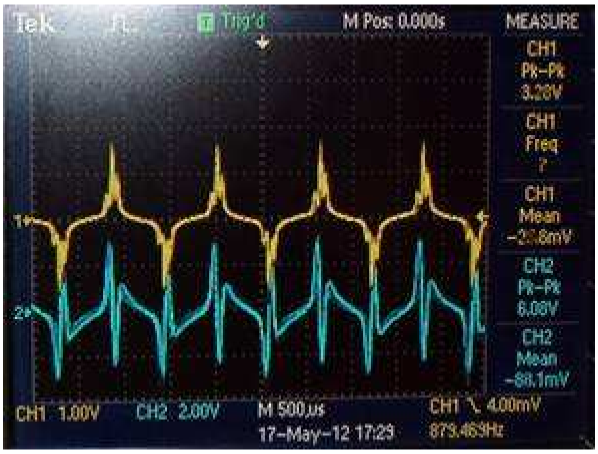


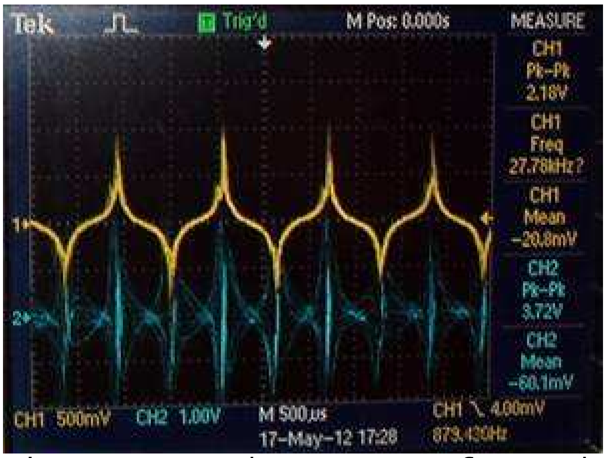
pic2. top- I_x, bottom- U_x,
f = 511hz

Same circuit but 2x control frequency







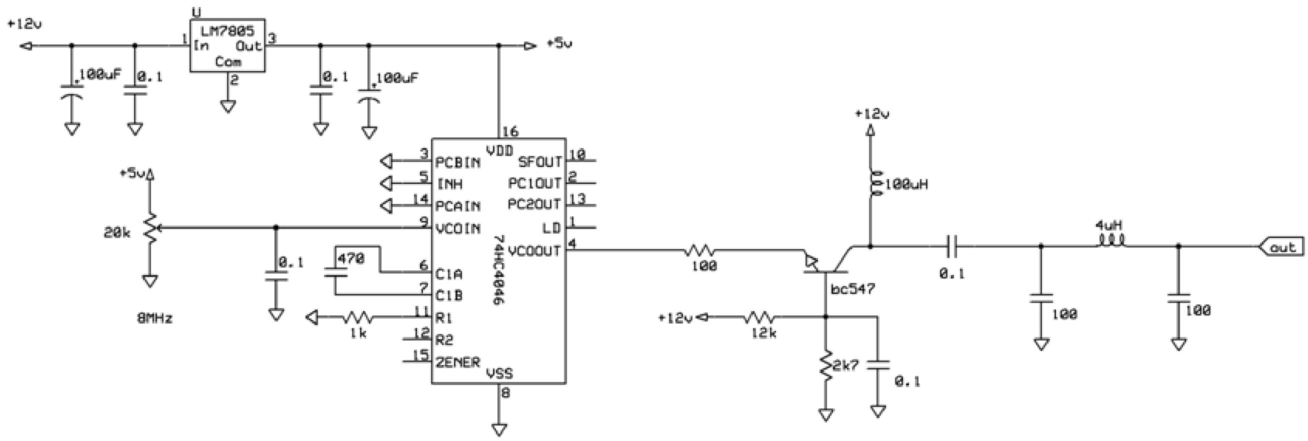


pic3. top- $I_{x,}$ bottom - $U_{x,}$ f = 911hz

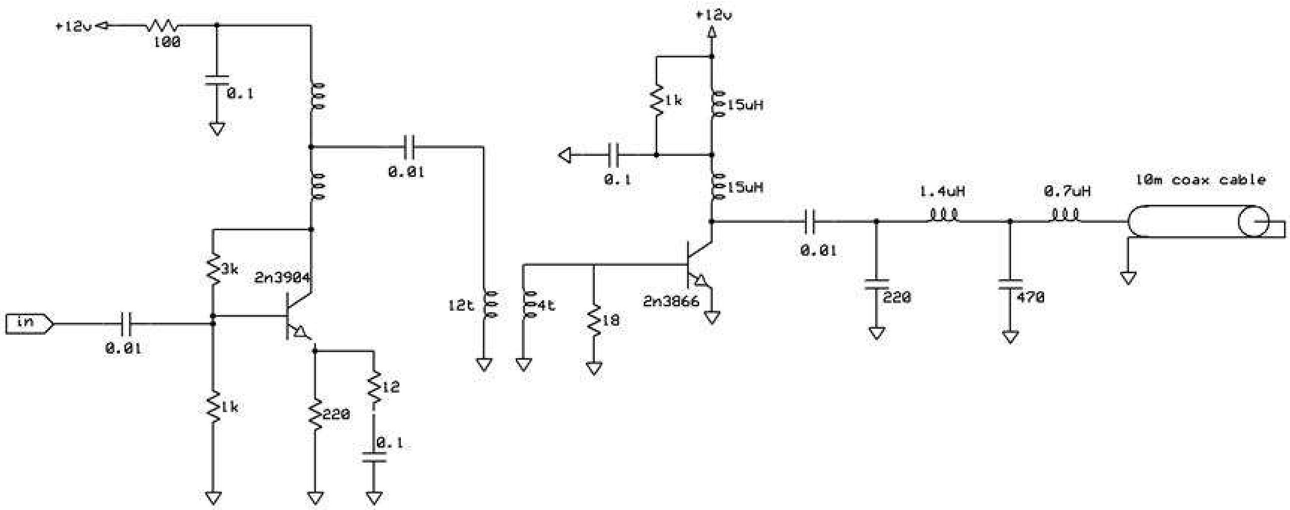
This is very interesting setup, our variable inductor has “inductive” input reactance, so theoretically we can have “normal” resonance in a control circuit and parametric resonance on the output ;-)

Standing waves or resonance in a media

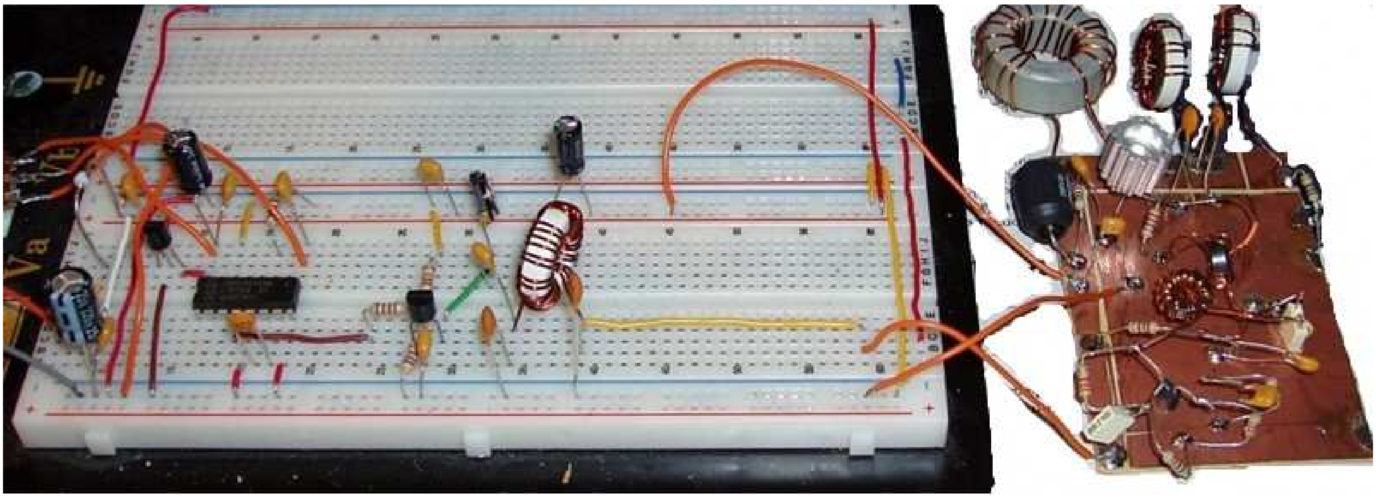
So far we observed resonance which was ”localized” in components or circuit but it is possible to have a dimensional resonance when oscillations occurs e.g. due to limited propagation velocity and reflections.
As first example let’s see a resonance in 10m long coaxial cable shorted at one end (1/4 wave resonance, frequency near 8 MHz).



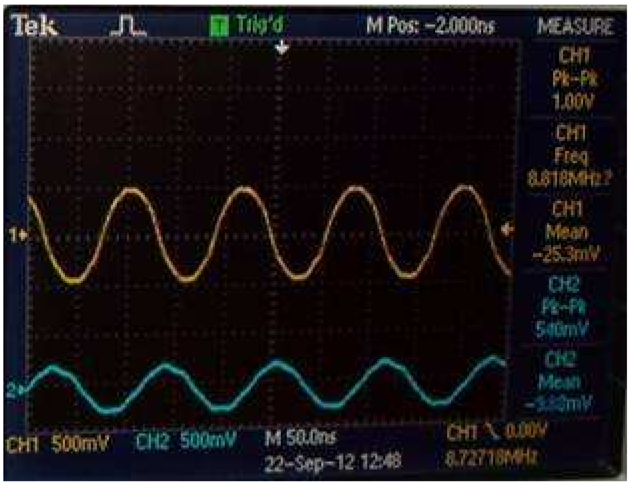
pic1. Generator I used for this experiment



pic2. Power amplifier

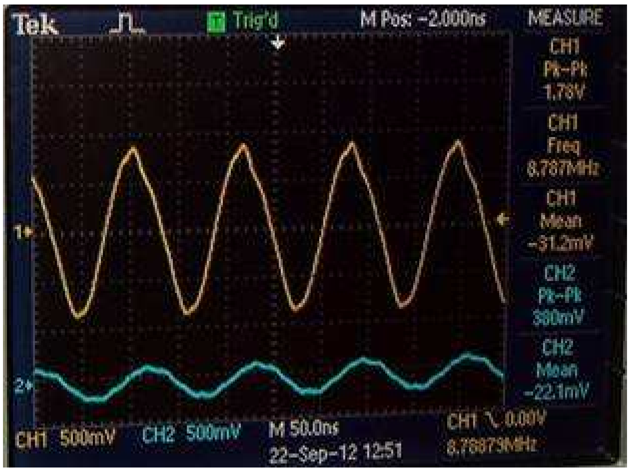


pic3. Experimental setup



pic4. Resonance in coaxial cable

top – voltage on the amplifier output, bottom – on the end of the line



pic5. Same but frequency adjusted a little

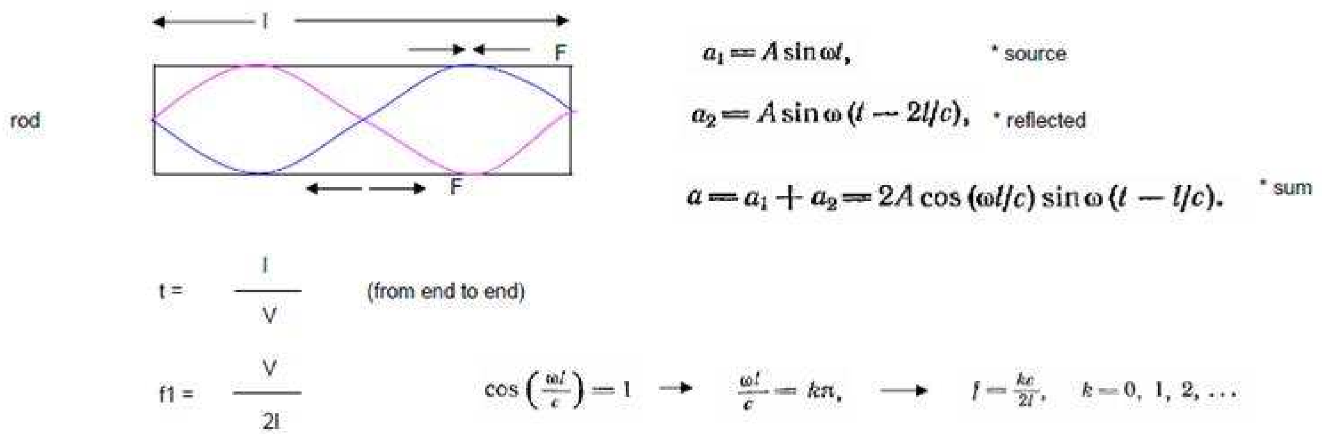
Links:
http://physics.info/waves-standing/
http://en.wikipedia.org/wiki/Reflections_of_signals_on_conducting_lines
http://www.youtube.com/watch?v=Il_eju4D_TM

Waves in ferrite core

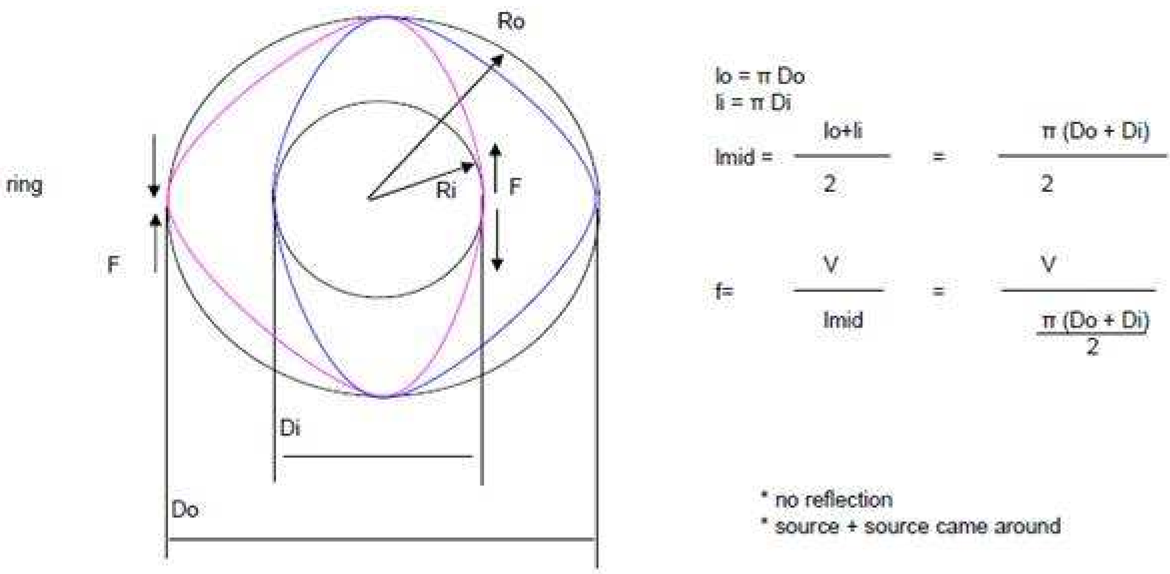
There can be different type of media where resonance occur, sound waves inside some objects can produce very powerful resonance.

See this for example http://www.youtube.com/watch?v=17tqXgvCN0E ☺

Similar effects can be created in ferrite cores. Conventional use of this effect is ultrasonic sound sources
but perhaps, one day we can find some other interesting applications.



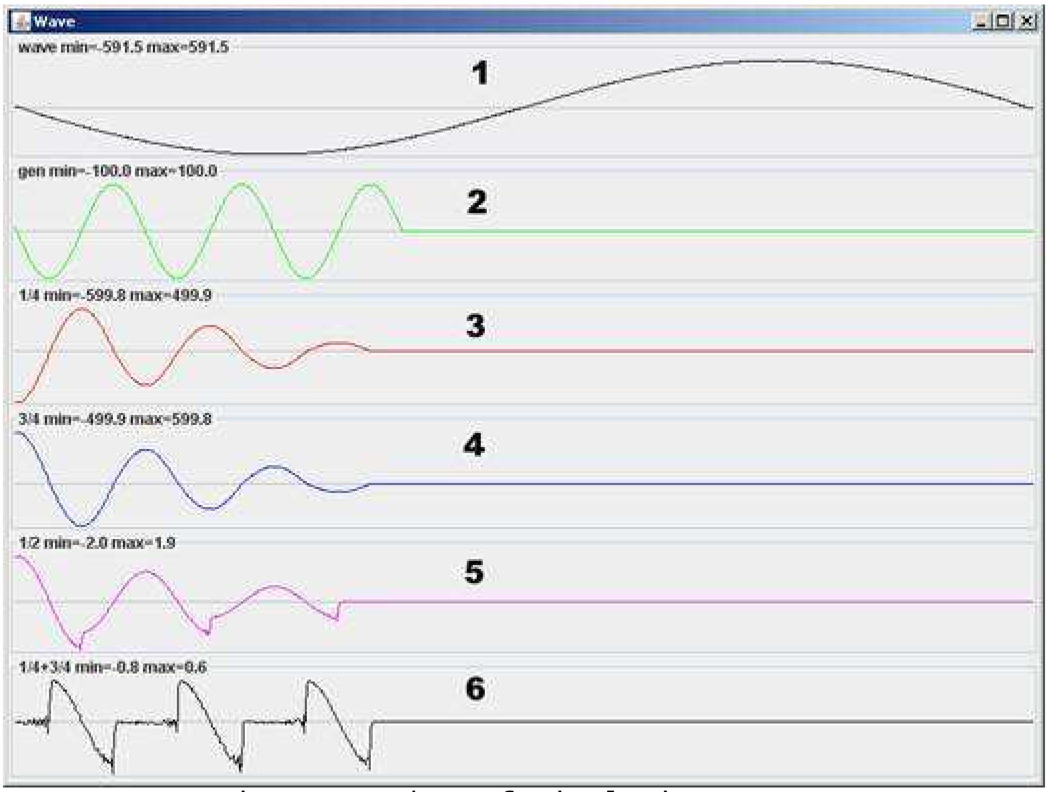
pic1. How oscillations occur in a rod



pic2. How oscillations occur in a ring core

I made a small Java program which simulate waves (based on wave equation)
Here a video with results captured
https://www.dropbox.com/s/annxxvnmh8chq9v/wave.flv
and here Java application itself
https://www.dropbox.com/s/4dmte1747d4lbe9/wave.jar (source code included)
It is easy to modify the program to simulate different setups.

In this particular simulation two sources (with same amplitude and phase) “connected” to the left and to the right ends of the “media”.



pic3. Snapshot of simulation screen

panel 1 "snapshot of the wave"
panel 2 generator 1 (most left point, 0)
panel 3 oscilations in point L/4
panel 4 oscilations in point 3*L/4
panel 5 oscilations in point L/2
panel 6 = 3 + 4

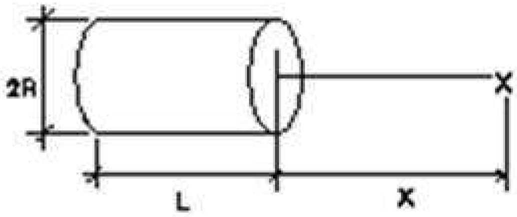
Panels 2-6 are “oscilloscope like” views (amplitude vs time) and panel 1 show media “state” in different locations (amplitude vs position).

Links:
http://en.wikipedia.org/wiki/Standing_wave
http://en.wikipedia.org/wiki/Magnetostriction
https://www.dropbox.com/s/sbeoh5y185xe9h1/How%20oscillations%20occur.pdf
http://mathworld.wolfram.com/WaveEquation.html
http://www.physicsclassroom.com/class/waves/

Chapter 4. Bifilar coils

Permanent magnets

and magnetic fields of different coils is a next topic I would like to discuss.

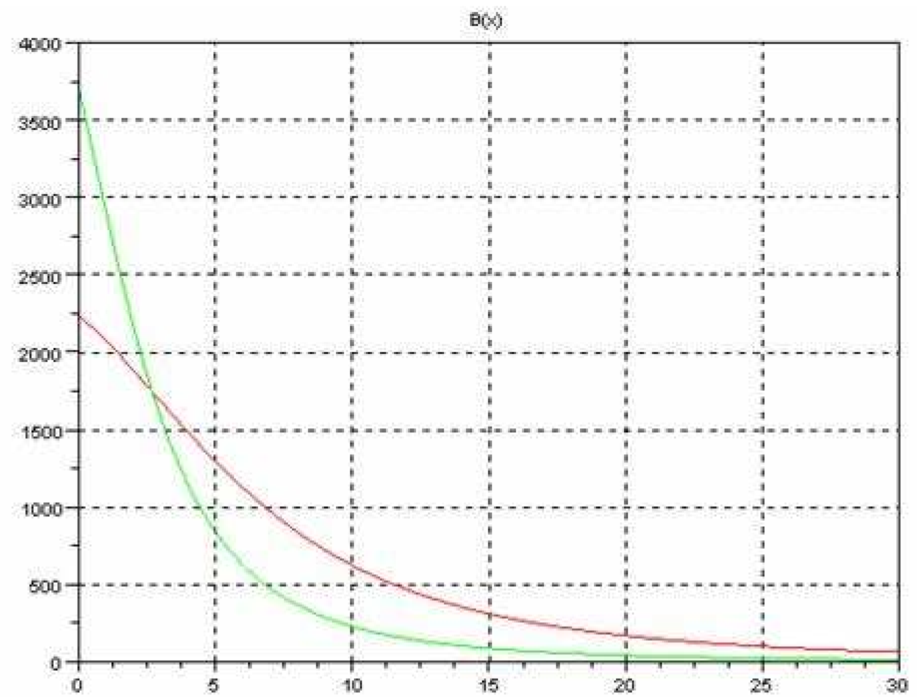


$$B_x = \frac{B_r}{2}\left(\frac{(L+X)}{\sqrt{R^2+(L+X)^2}} - \frac{X}{\sqrt{R^2+X^2}}\right)$$

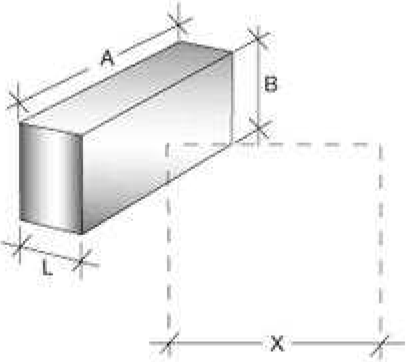
20x5 magnet – NdFeb (red)

9x5 magnet – NdFeb (green)

pic1. Ring magnets



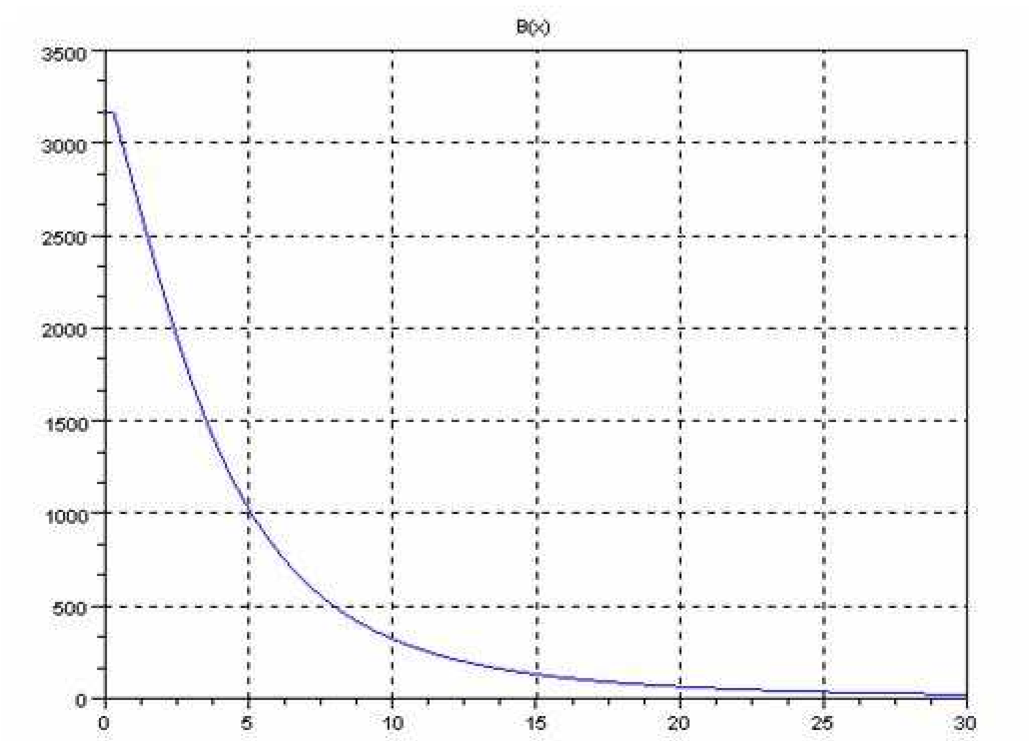
pic2. Magnetic flux density vs distance from magnet for ring magnet



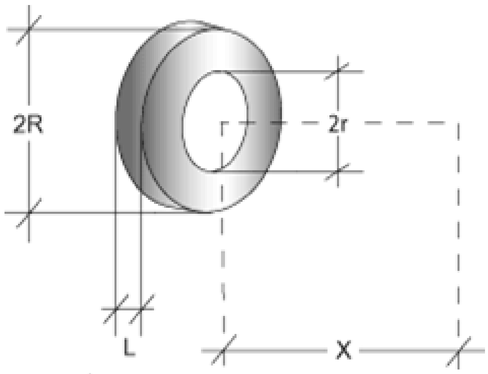
50x20x10mm NdFeb Magnets - SuperMagnet

$$B_x = \frac{B_r}{\pi}\left(\tan^{-1}\frac{AB}{2X\sqrt{4X^2 + A^2 + B^2}} - \tan^{-1}\frac{AB}{2(L+X)\sqrt{4(L+X)^2 + A^2 + B^2}}\right)$$

pic3. Rectangular magnets

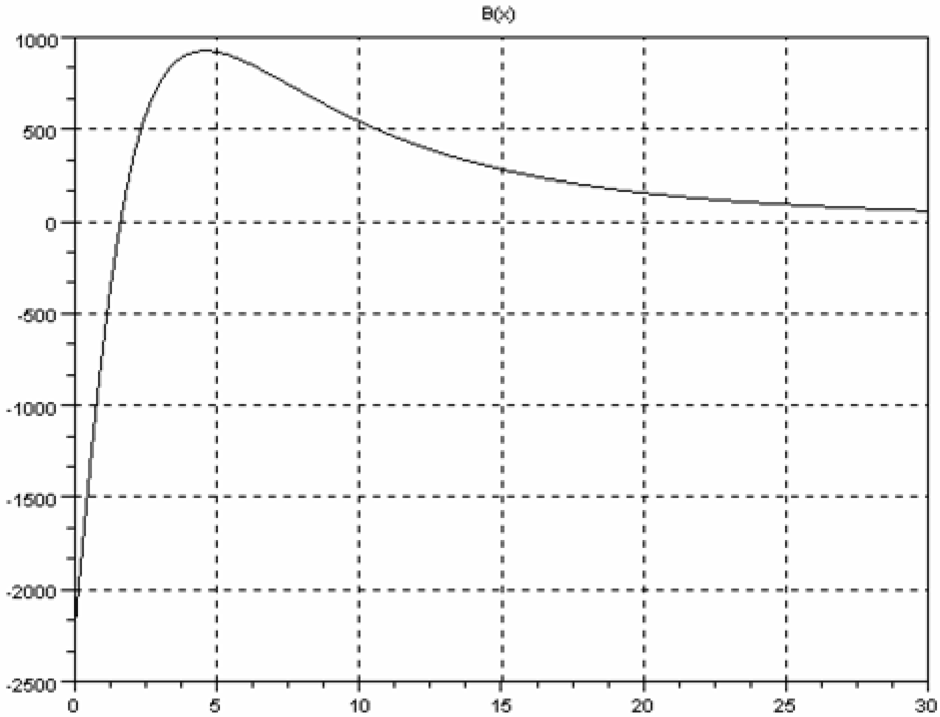


pic4. Magnetic flux density vs distance from magnet for rectangular magnet



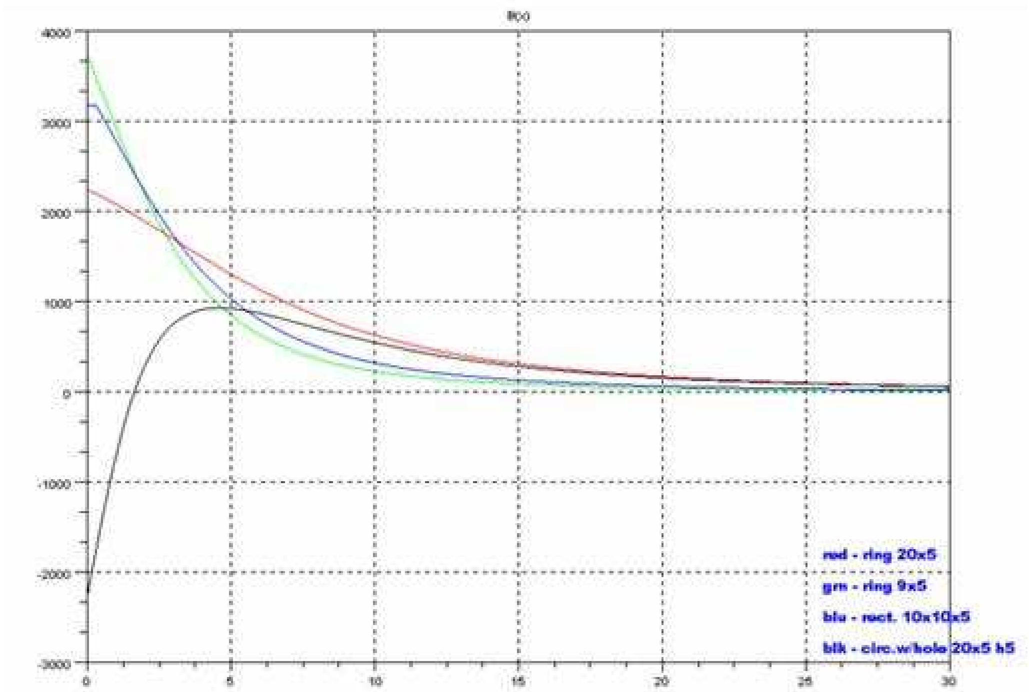
$$\frac{B_r}{2}\left(\left(\left(\frac{L+x}{\sqrt{R^2+(L+x)^2}}\right)-\left(\frac{L+x}{\sqrt{r^2+(L+x)^2}}\right)\right)-\left(\left(\frac{x}{\sqrt{R^2+x^2}}\right)-\left(\frac{x}{\sqrt{r^2+x^2}}\right)\right)\right)$$

pic5. Ring magnet with hole



pic6. Magnetic flux density vs distance from magnet for ring magnet with hole

I was just drawing these graphs and result was quite unexpected for me, according to this graph there is a point at some distance (about 4mm) where flux is zero and changing sign.
So the hole in magnet behave as a magnet with opposite orientation ☺



pic7. Magnetic flux density for different shape magnets
red – ring 20x5, green – ring 9x5, blue rectangular 10x10x5, black circ. 20x5 with hole 5mm

This chart presents some of the magnetic properties of a subset of magnetic materials:

	Maximum Energy Product Bhmax(MGOe)	Residual Flux Density Br(G)	Coercive Force Hc(Koe)	Working Temperature °C
Ceramic 5	3.4	3950	2400	400
Sintered Alnico 5	3.9	10900	620	540
Cast Alnico 8	5.3	8200	1650	540
Samarium Cobalt 20 (1,5)	20	9000	8000	260
Samarium Cobalt 28 (2,17)	28	10500	9500	350
Neodymium N45	45	13500	10800	80
Neodymium 33UH	33	11500	10700	180

Table 1- Selected Material Magnetic Properties

pic8. Properties of different magnets

Links:
http://3gcl.no-ip.org/3GCL/Datasheets/Electronics/Magnetics/Magnetic%20Design.htm
http://www.magneticsolutions.com.au/magnet-formula.html
http://www.kayelaby.npl.co.uk/general_physics/2_6/2_6_6.html
http://www.rare-earth-magnets.com/Permanent-Magnet-Selection-and-Design-Handbook.pdf
http://ether.sciences.free.fr/electrets.htm
http://www.sae.edu/reference_material/audio/pages/Microphones.htm

Magnetic field of a"regular" coil

There is a lot of confusion about magnetic field and especially about anti-aligned or opposed magnetic fields.
Some people tend to believe that field lines and poles are exist in reality, also often said that fields "adding" or "compensating" each other.

When you use geographical map, are you expecting to see geodesic lines on the field or mountain? ;-) No, of course not. We know that these are "imaginary" lines showing places with equal height. Please remember about this when dealing with fields in physics. Don't mix math which used for calculations with reality.

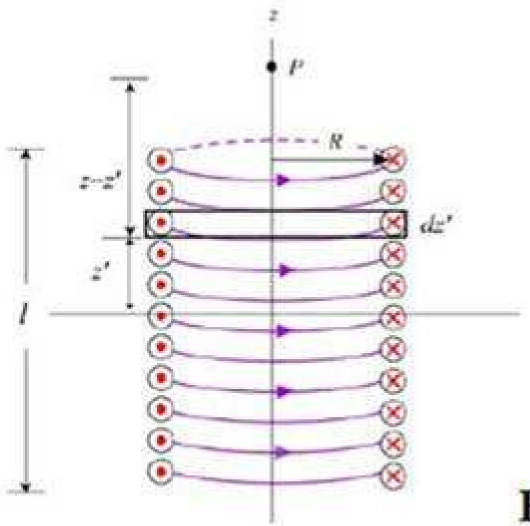
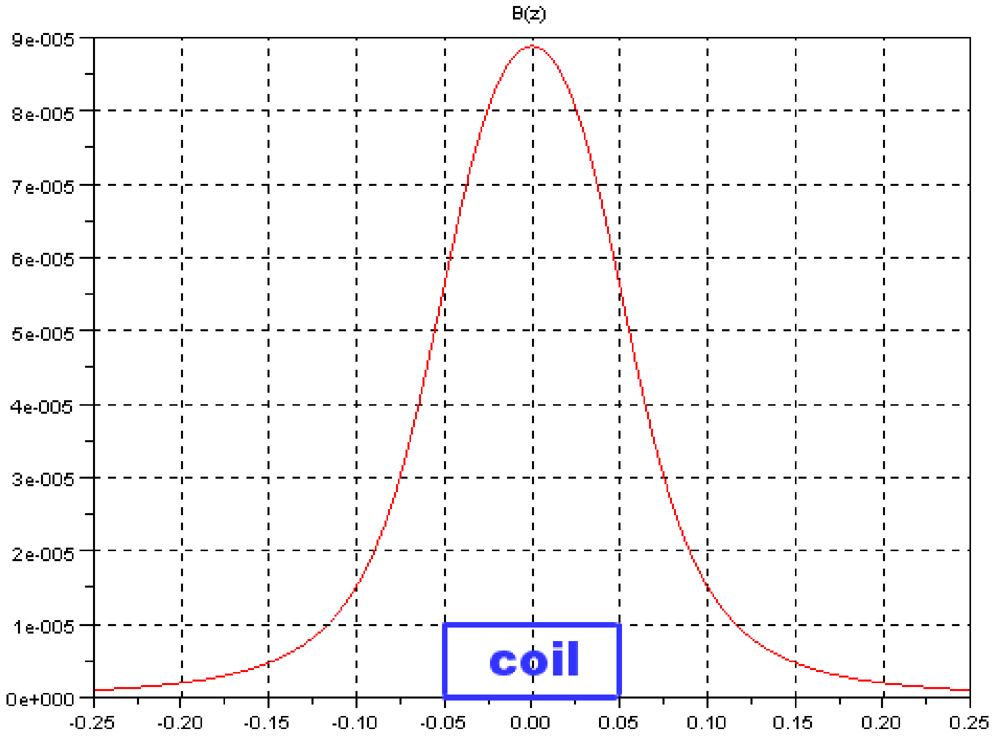


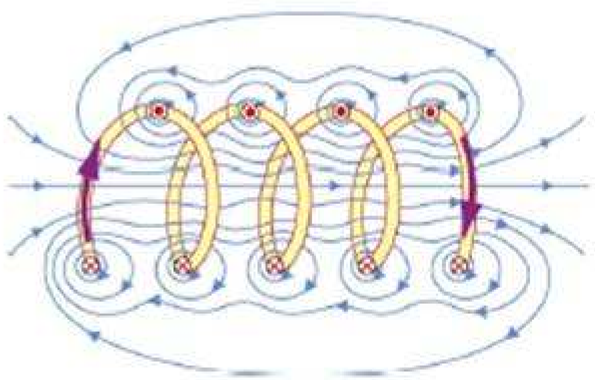
Figure 9.4.3 Finite Solenoid

$$B_z = \frac{\mu_0 n I}{2}\left[\frac{(l/2)-z}{\sqrt{(z-l/2)^2+R^2}} + \frac{(l/2)+z}{\sqrt{(z+l/2)^2+R^2}}\right]$$

pic1. Magnetic field of solenoid, see (1) for more details.



pic2. Magnetic field of solenoid calculated using formula above

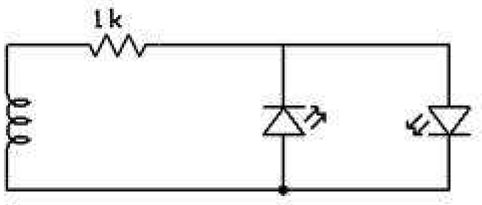


pic3. Magnetic field lines, see (1) for more details.

Links:
http://web.mit.edu/8.02t/www/materials/StudyGuide/guide09.pdf (1)
http://en.wikipedia.org/wiki/Helmholtz_coil
http://ocw.mit.edu/ans7870/8/8.02T/f04/visualizations/magnetostatics/24-coilsopposed/24-coilsopposed320.html
http://homepages.ius.edu/kforinas/physlets/magnetism/magnetism.html
http://www.rakeshkapoor.us/ClassNotes/MagneticFieldduetoCurrent.html

Simple magnetic field probe

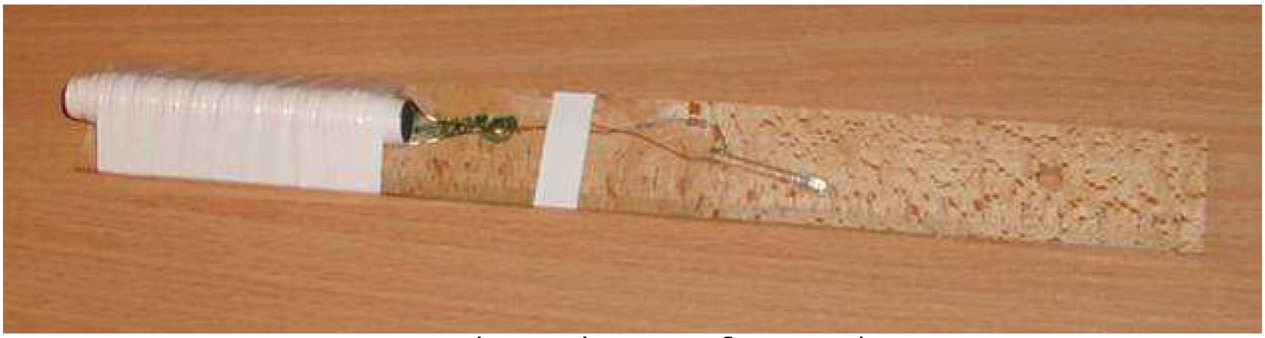
Before going into details, I would like to warn you.
Even mainstream medicine accepts that pulse magnetic fields have very significant effect on human body and consciousness, not always positive effects.
It is known that about 10% of animals can feel magnetic fields. Some people also can feel and even see fields but due to current social conditions these skills are not appreciated, so most people are not even aware that it is possible.
To avoid any potential damage we can (must) build simple magnetic field probe.



pic1. Probe's schematic

* second LED is optional

Wind some coil on the ferrite rod and attach LED thru 1k resistor.
You can use this probe as indicator and as a safety tool.



pic2. Picture of my probe

* Assembled on a wood ruler
** One layer coil, 0.4mm wire on ferrite rod (mu = 400)

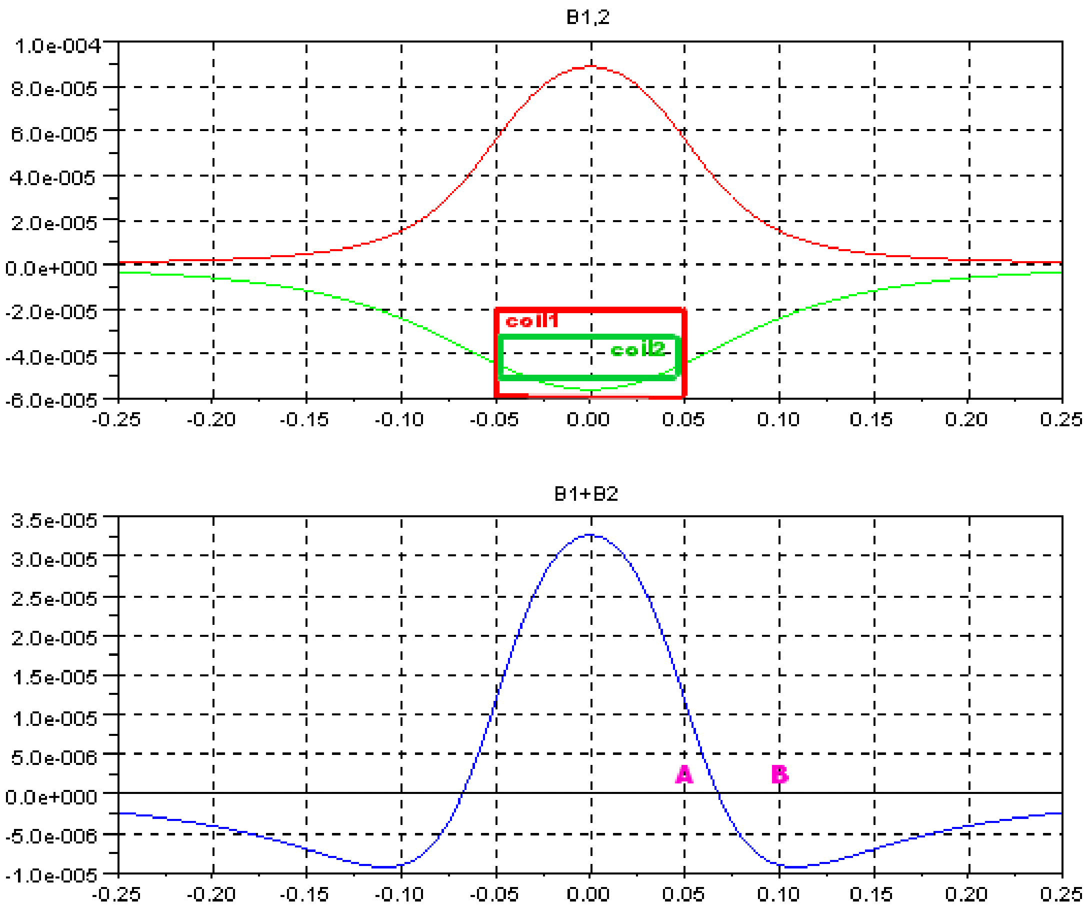
When you see LED glowing, it means that strength of magnetic field is high enough, so you should never be near that place, do not expose your body to magnetic fields until you want risk your health (and may be life).
Please note that that often results of exposure are "cumulative", symptoms appeared after some time and grows exponentially. It could be too late. Do not neglect your health and safety!

Now you have been warned.

Magnetic field of bifilar coil

I will be using word ”bifilar” for coils made of two sections with opposing magnetic fields.
There are many possible variations and I will try to review them one by one.
First setup I would like to discuss made of two cylindrical coils with different diameters, small coil placed inside bigger one. This setup was ”inspired” by magnet with a hole.

pic1. Bifilar coil type 1

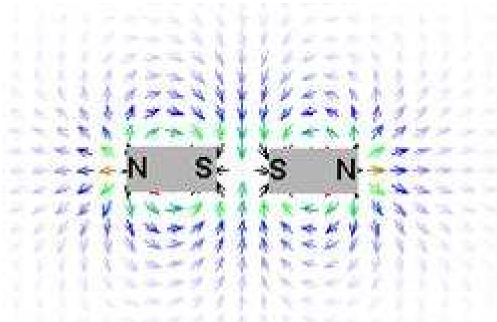


pic2. Magnetic field of bifilar coil

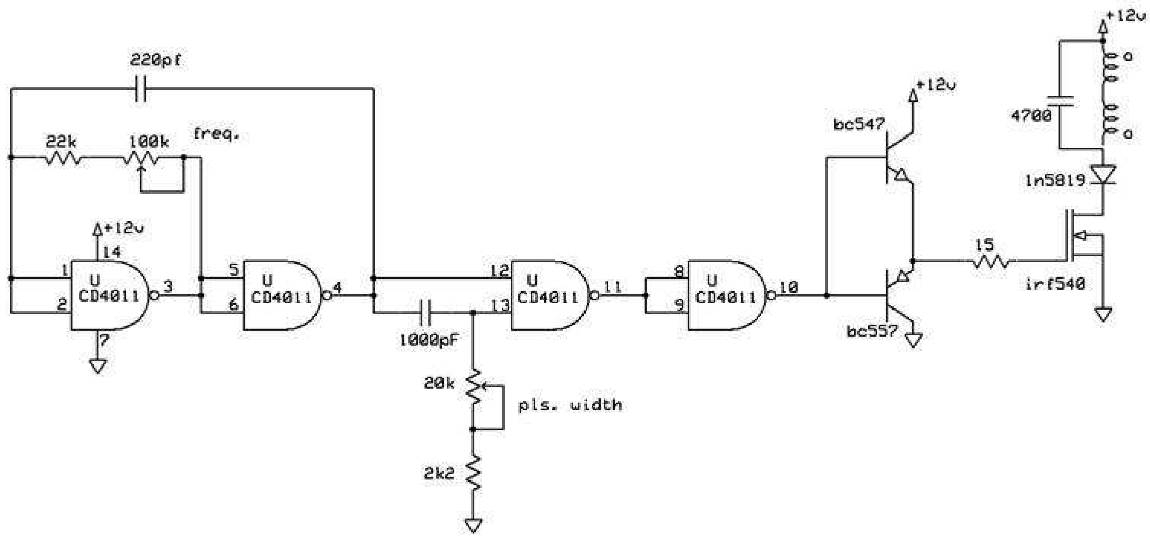
top – red magnetic field of outer(bigger) coil, green - magnetic field of inner (smaller) coil,
bottom – resulting magnetic field (sum)

Please note that this graph represent Bz, component of B which is directed along central axe of the coils.
Don’t be confused, there is a magnetic field at the point where Bz = 0, it is just have vector B perpendicular to z.

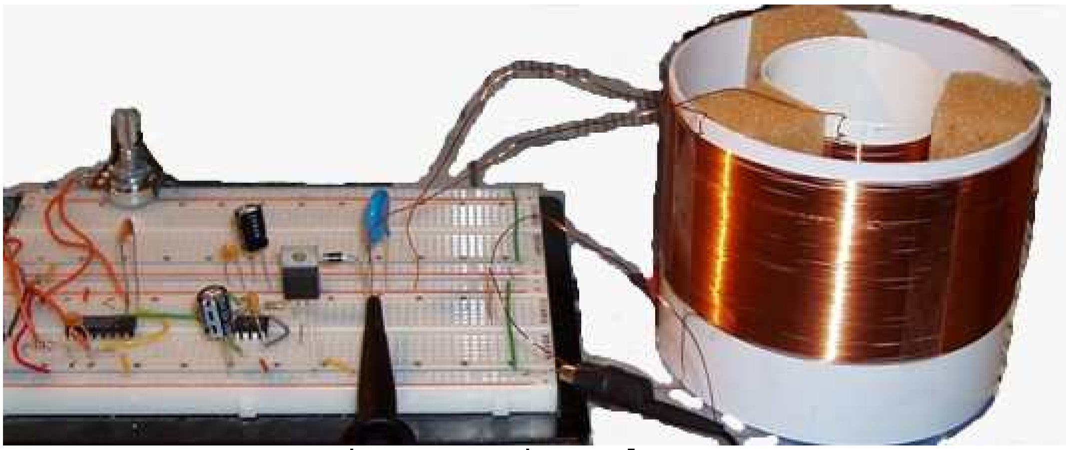
It is similar to situation when two magnets face each other with same poles. Field in the middle is not zero, only horizontal component (on pic2a) is zero in the middle point.



pic2a. Magnetic field lines of two “opposed” magnets



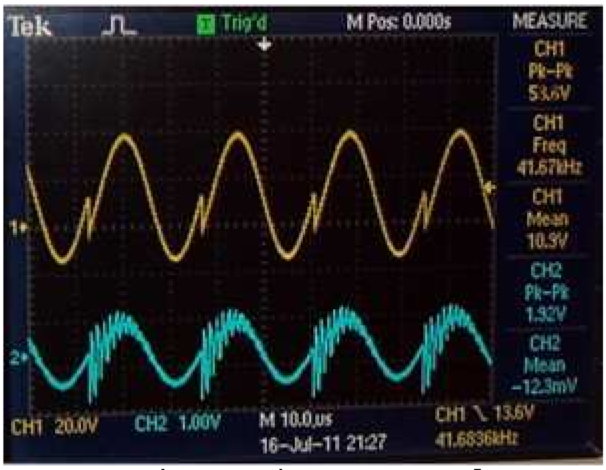
pic3. Driver schematic



pic4. Experimental setup

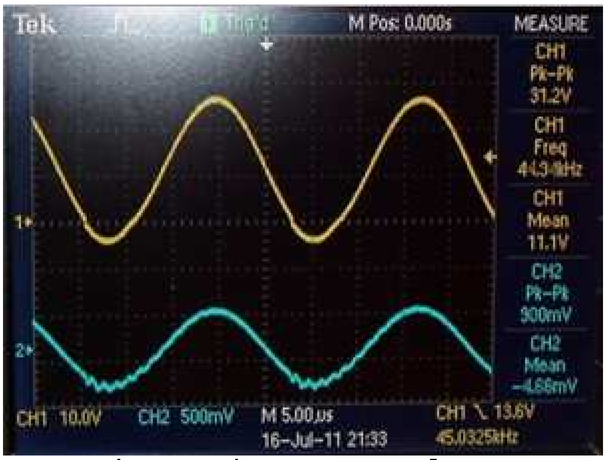
Coils parameters:

Inner coil diameter 5cm,
outer coil diameter 10cm,
height (of winding) 5,5cm,
Approximately 140 turns, wire 0,4mm
Inductance of outer coil L_{10} = 1415uH,
Inductance of inner coil L_5 = 450uH
Inductance when coil connected “same direction” L_+ = 2540 uH,
when connected in opposite L_{--} = 1292 uH



pic5. top – voltage on primary, bottom - voltage on small test coil

pic6. Two pickup coils (connected also in opposite) placed symmetrically related to zero Bz point (see points A and B on pic2)



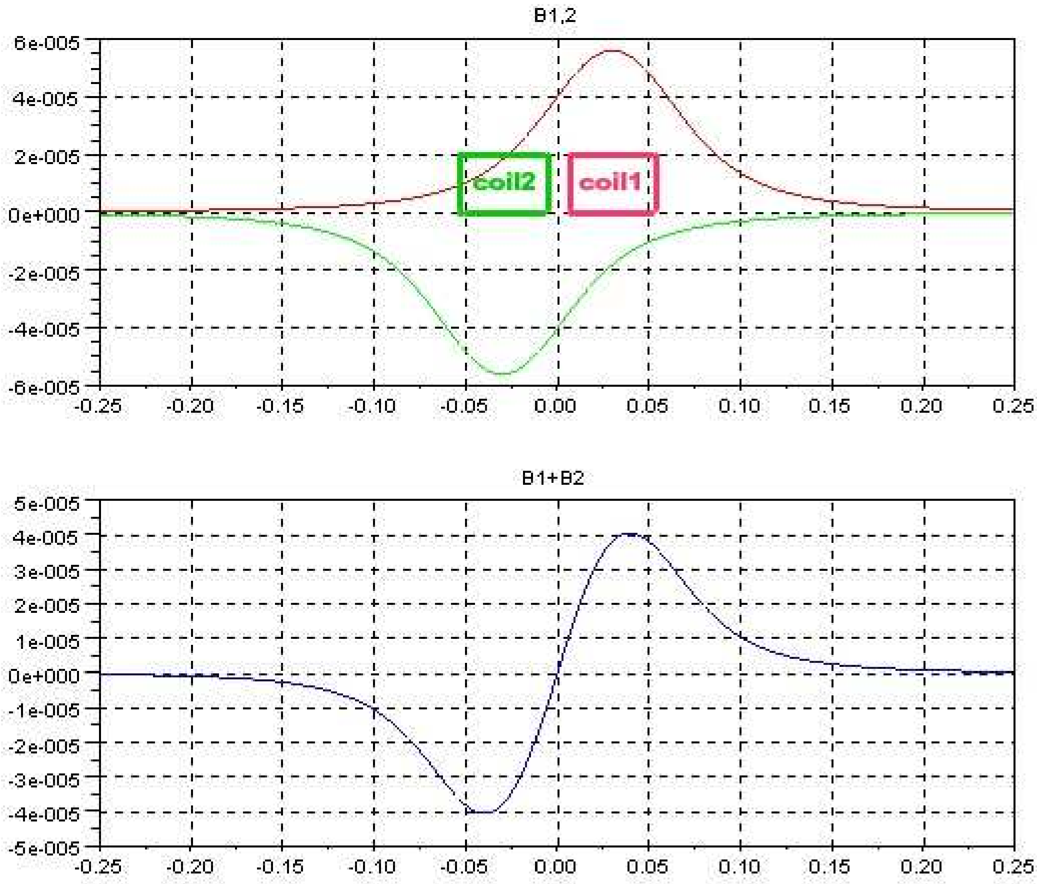
pic7. top - – voltage on primary, bottom – voltage on pickup coils (with some small load resistor)

* It seems that my calculations give realistic shape of the magnetic field,
* Even symmetric bifilar pickup coils affects resonance in primary coil when loaded.

Links:
http://homepages.ius.edu/kforinas/physlets/magnetism/magnetism.html (see case B, anti parallel)

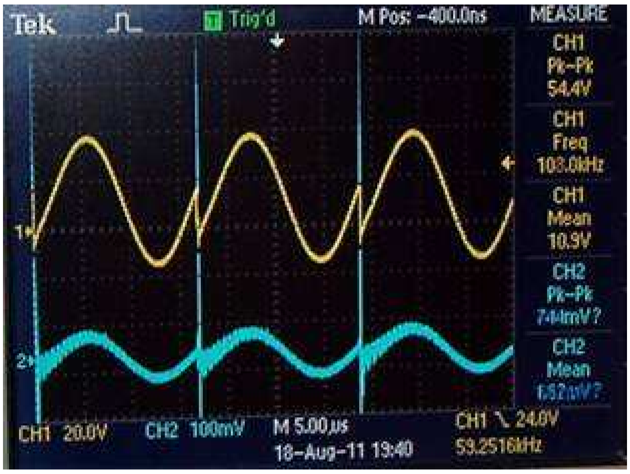
Magnetic field of bifilar coil 2

Next possible setup is - two cylindrical coils near each other (also known as anti aligned Helmholtz coils)

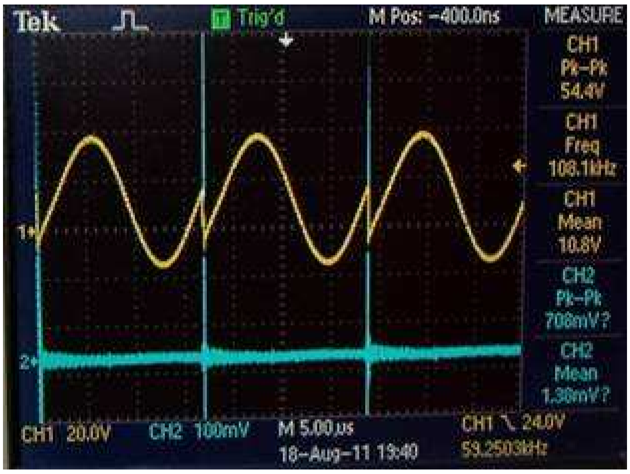


pic1. Calculation of magnetic field of ”anti aligned Helmholtz coils”

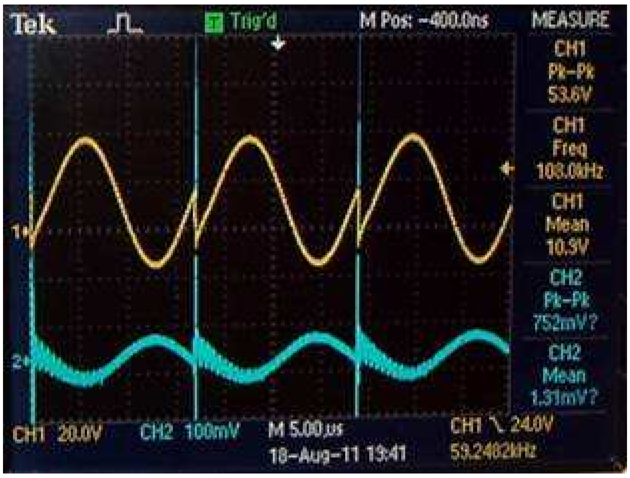
pic2. Bifilar coil type 2



pic3. top-voltage on the coil, bottom – voltage on one turn coil used as magnet field sensor

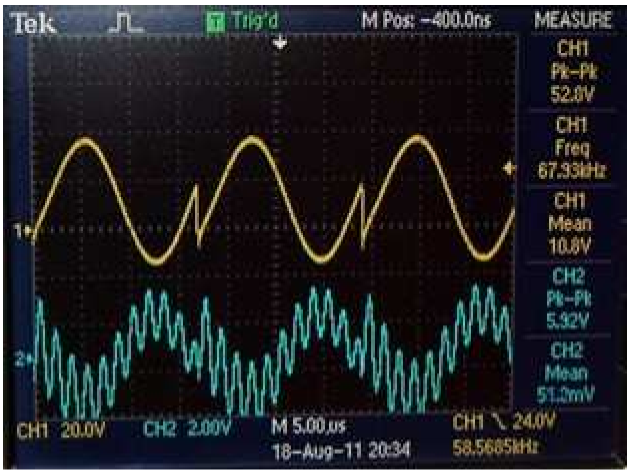


pic4. When moving test coil amplitude decrease and then increase again, phase change when we cross “0” point



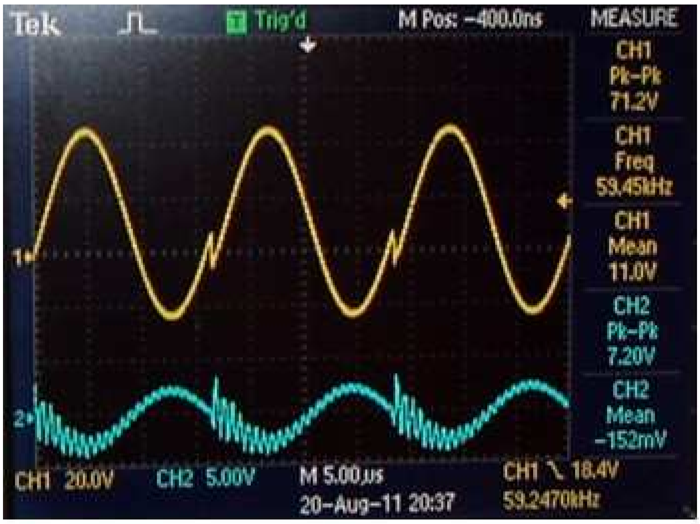
pic5. Phase changed

pic6. Different coil used to see if there is a perpendicular magnet field component



pic7. top-voltage on the coil, bottom – voltage on test coil shown on pic.6

pic8. Two coils wound in opposite direction placed symmetrically relative to 0 point used as pick-up coils



pic9. top-voltage on the coil, bottom – voltage on two coil shown on pic.8

* Loading pickup coils affects resonance in primary coil, again.

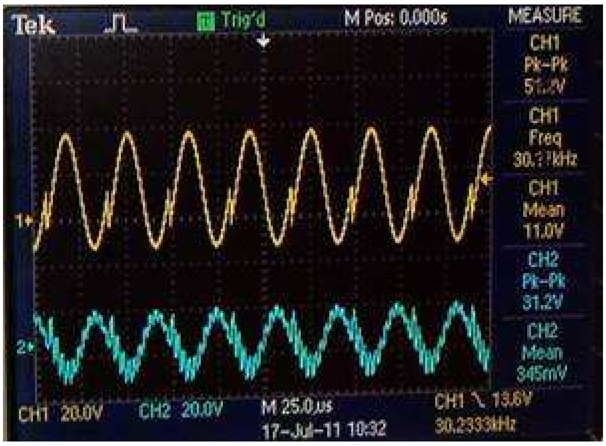
Opposite coils on ferrite rod

It is interesting to see how ferrite (core) affects behavior of our setup. So I decided to try setup with two opposed coils on ferrite rod. Usually it said that core ”absorbs” magnetic field and there is very small part of magnetic field exists outside transformer core. With opposed coils it is not true, significant part of magnetic field is forced out.
(this can be confirmed easily with simple magnetic field probe)

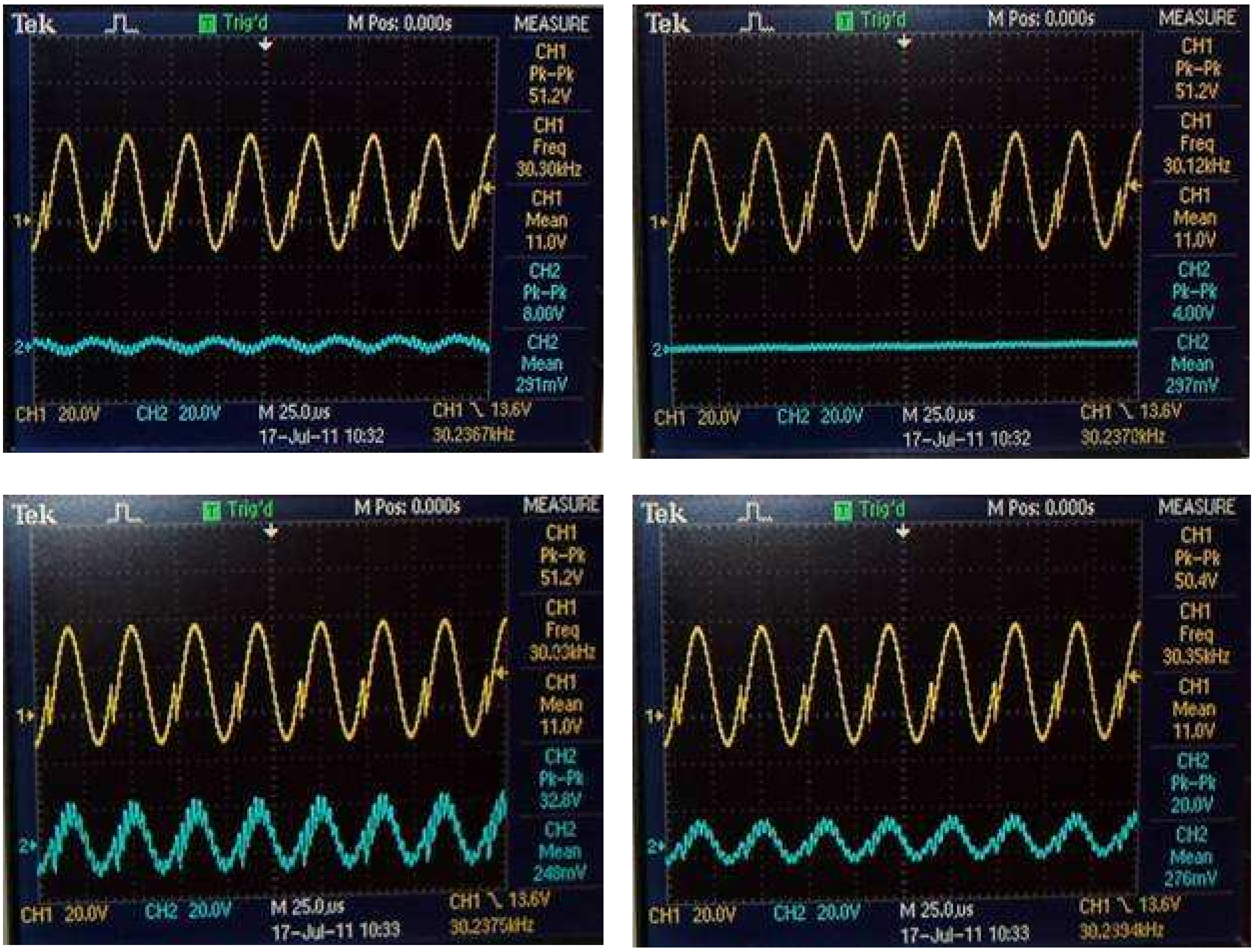
pic1. Similar setup but with ferrite

Two section of primary coil, about 200 turns each, wire 0.33mm

pic2. Moving test coil along the rod

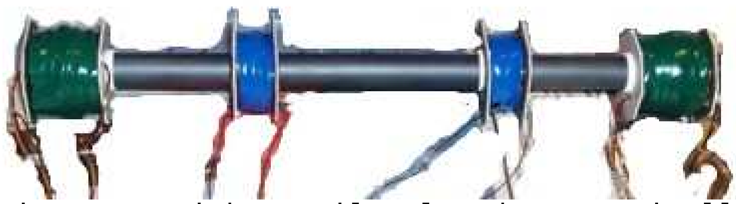


moving small coil from left to right, minimum amplitude in the middle and phase change

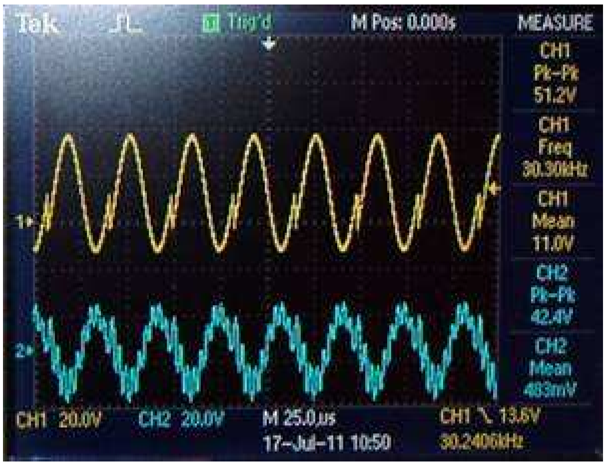


pic3. Moving test coil and observing amplitude and phase change

Often people tend to believe that bifilar coils does not create magnetic field and therefore bifilar pickup coils will not load primary coil. It is difficult to resist checking this again ;-)



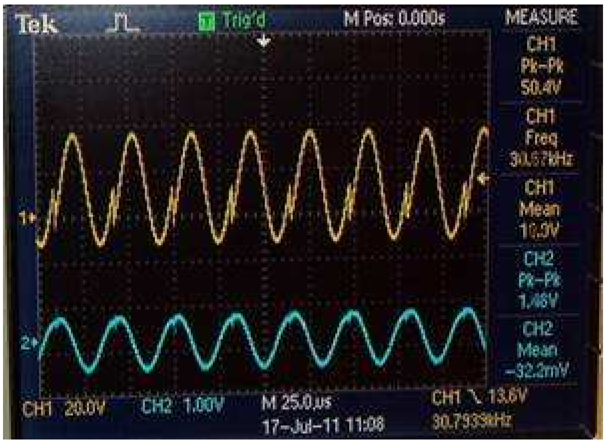
pic4. Two pickup coils placed symmetrically



pic5. Setup for power extraction test

top – on the primary coil, bottom – on pickup coils, both pairs connected in opposite

Circuit consumption
Ups = 11.6v, Ips = 8ma, P = 90mW

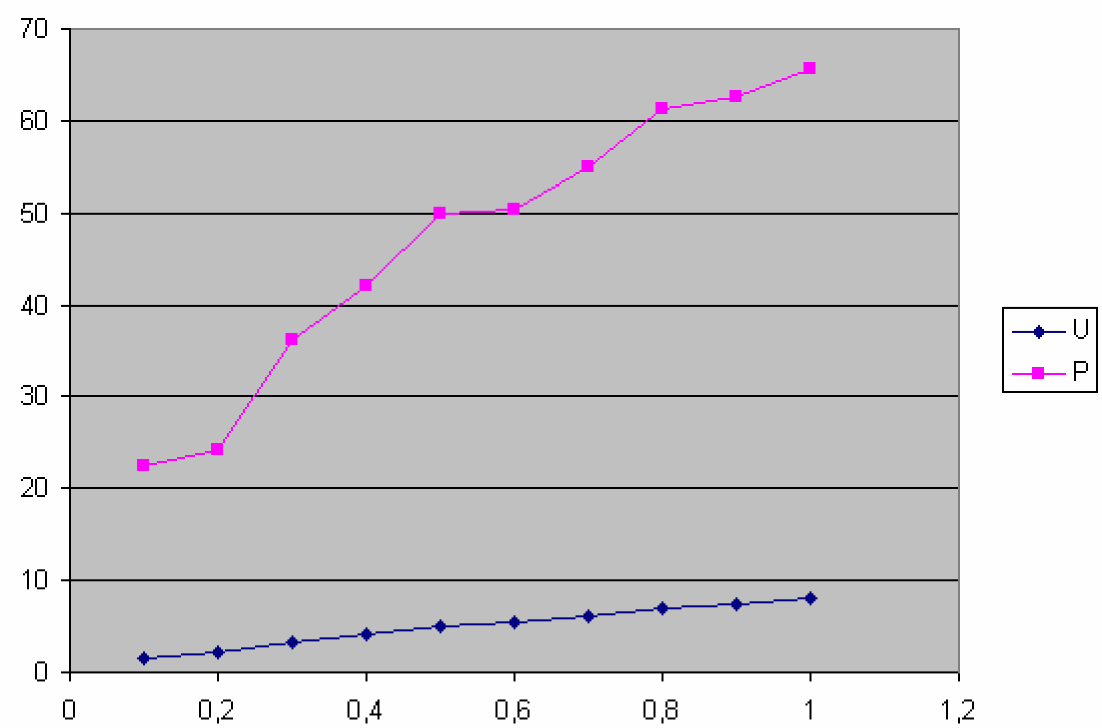


pic6. Under load

R load = 1k

R,k	0,1	0,2	0,3	0,4	0,5	0,6	0,7	0,8	0,9	1
U,v	1,5	2,2	3,3	4,1	5	5,5	6,2	7	7,5	8,1
P,mW	22,5	24,2	36,3	42	50	50,4	54,9	61,3	62,5	65,6

Tab.1 Voltage on pickup coils vs load resistance



pic7. Voltage and power vs load resistance

Some how magic doesn’t work and we can see that load affect primary coils…

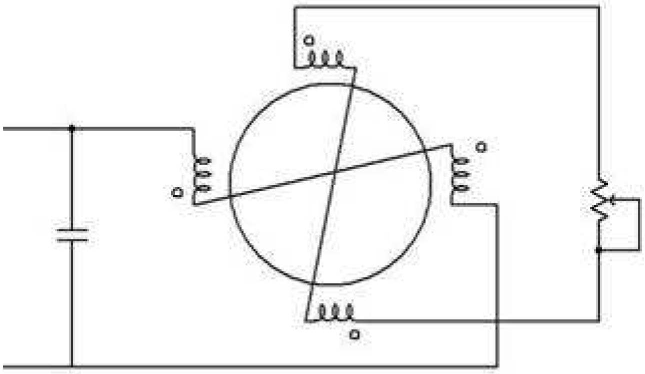
Opposite coils on the ring core

I am continuing fun with opposite coils on ferrite cores and now I decided test ring core.


pic1. Two coils wound on ring ferrite core

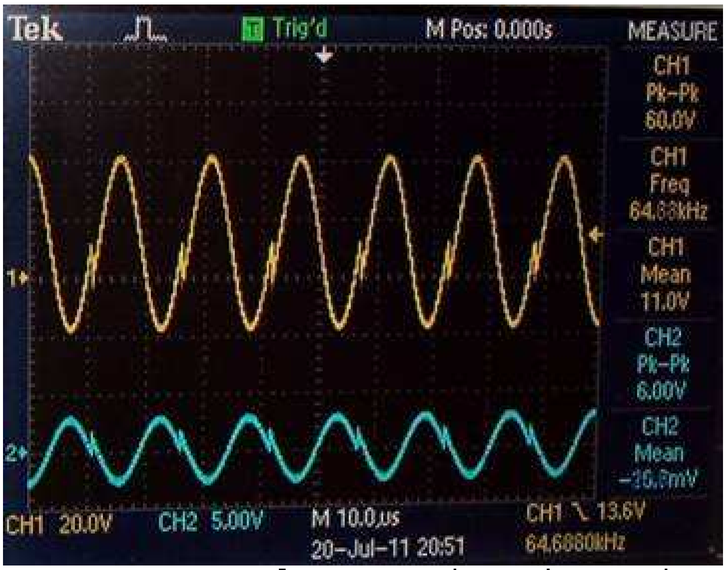
Primary coils parameters:
Two coils about 40 turns each (4m of wire used for each), wire 0.44mm
L1,2 = 2540uH
L1+2 = 9420uH
L1-2 = 540uH

pic2. Test setup



pic2a. Test setup, coils arrangement.

Secondary coils same as primary (40 turns each)



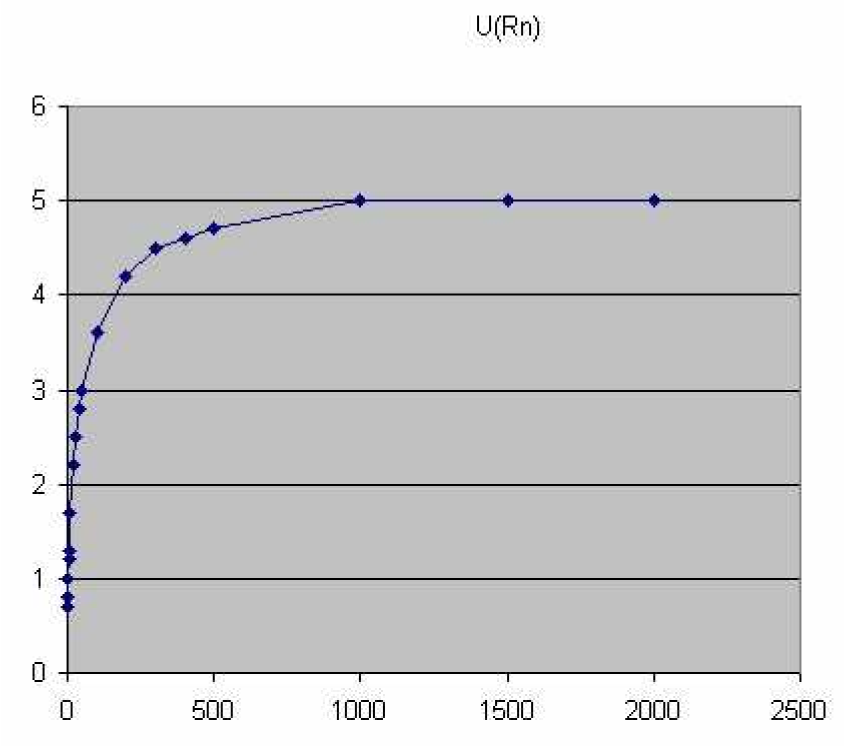
pic3. Testing the setup, top – voltage on the primary, bottom – voltage on pickup coils

R,ohm	1	2	3	4	5	10	20	30	40	50
U,v	0,7	0,8	1	1,2	1,3	1,7	2,2	2,5	2,8	3
P,mW	490,00	320,00	333,33	360,00	338,00	289,00	242,00	208,33	196,00	180,00

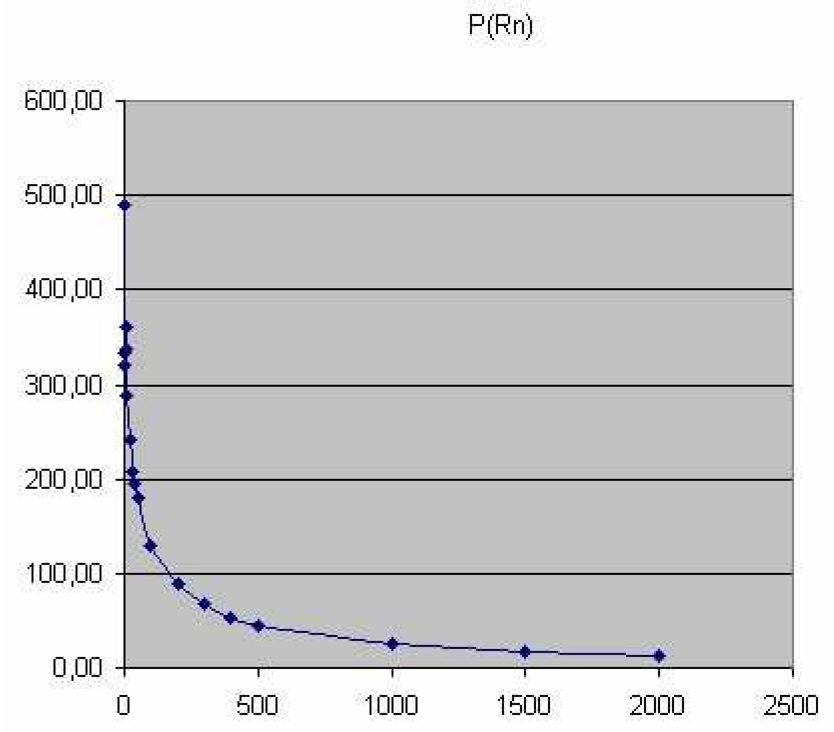
Tab1. Measuring voltage vs load resistance

R,ohm	100	200	300	400	500	1000	1500	2000
U,v	3,6	4,2	4,5	4,6	4,7	5	5	5
P,mW	129,60	88,20	67,50	52,90	44,18	25,00	16,67	12,50

Tab1. part 2



pic4. Voltage on the load vs load resistance

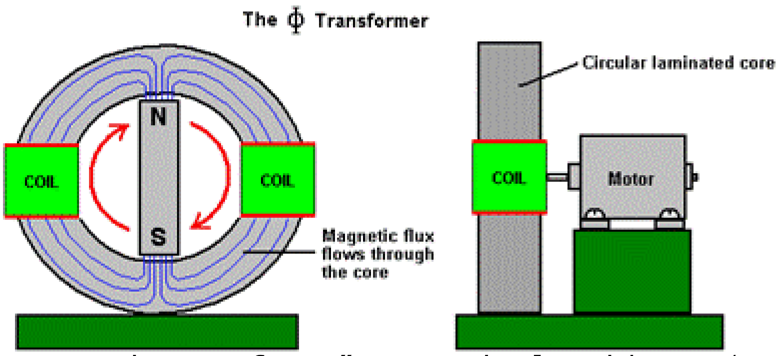


pic5. Power on the load vs load resistance

It is interesting that this setup shows quite ”good” behavior under load (but it’s still not OU, at least in my tests).

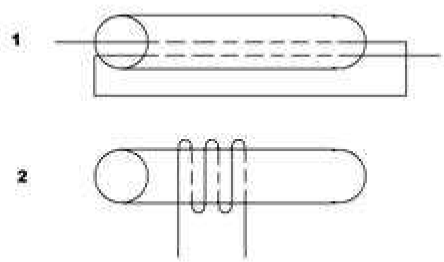
Reversed Phi transformer

- another interesting setup I would like to show.

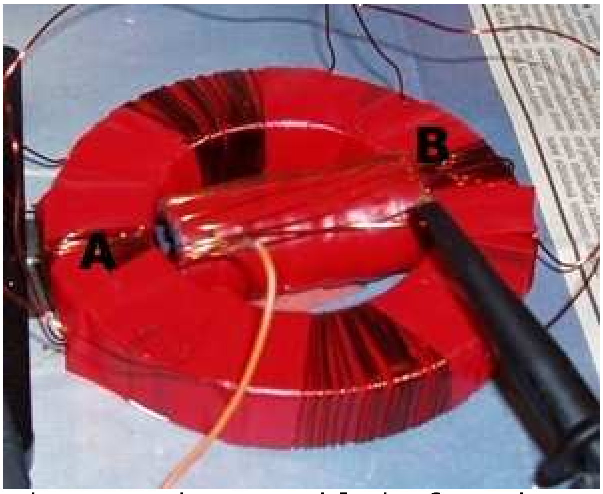


pic. Phi transformer, picture from ”A Practical Guide to ‘Free-Energy’ Devices” by Patrick Kelly

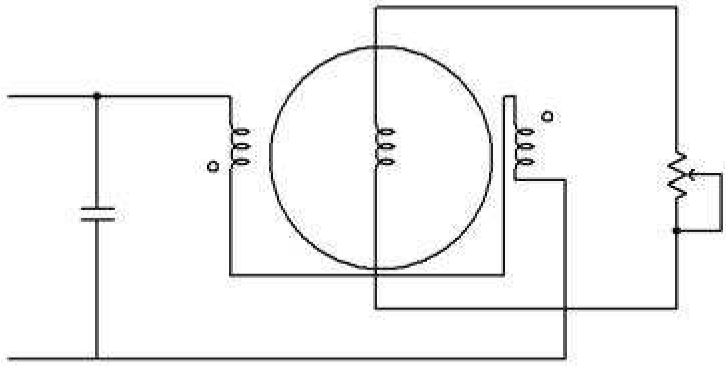
Instead of rotating magnet and attaching load to the coils, we can connect coils in opposite and apply some power to them. Then significant part of magnetic field will be forced out of the core on the points where coils “connects” (points A and B). We can put a pickup coil between these two points.



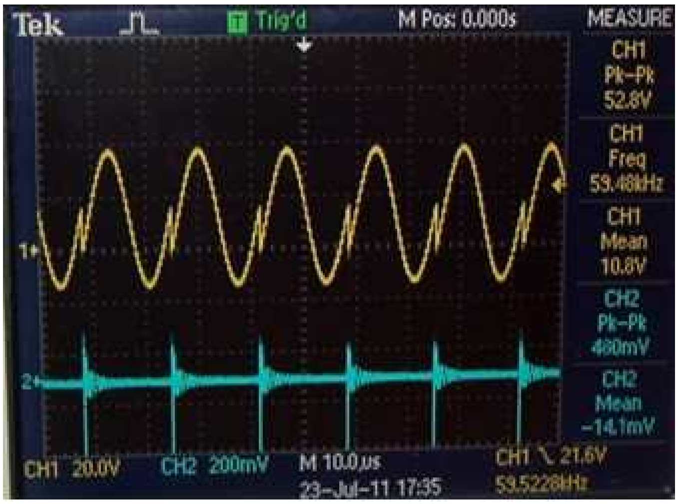
pic1a. Two variants of winding of pickup coils



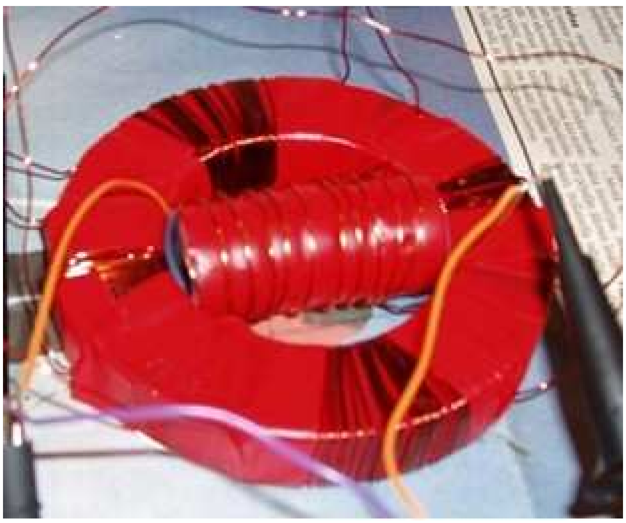
pic1. Pickup coil wound on a tube assembled of 8 ring cores (variant 1)



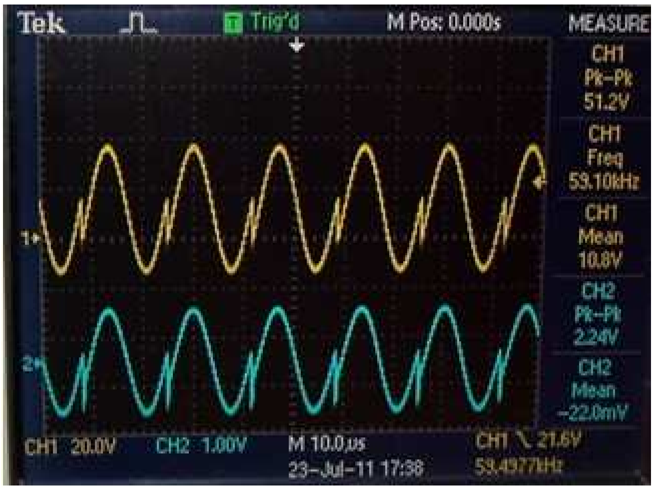
pic2. Test setup schematic



pic3. top – voltage on primary, bottom – voltage on pickup coil, does not work very well



pic4. Rewound pickup coil (variant 2)



pic5. top – voltage on primary, bottom – voltage on pickup coil for second setup, works better.

Second attempt seems to be working ok; it has very small effect on primary under load, but also does not provide much power.

Links:
http://frienergi.alternativkanalen.com/Chapt1.html
http://www.free-energy-info.co.uk/

Scalar coil

If you take two wires and wind two coils together, then connect coils to have opposing magnetic fields you get “non-inductive” bifilar coil. Two variants of connection presented on pic.4 and pic.5. Both variant will have similar magnetic field configuration.

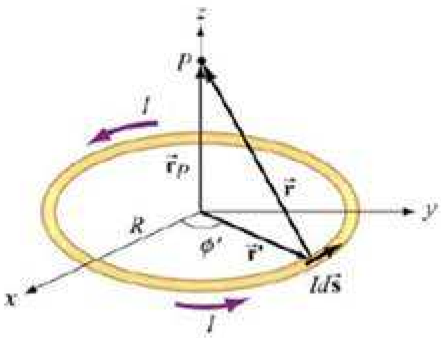
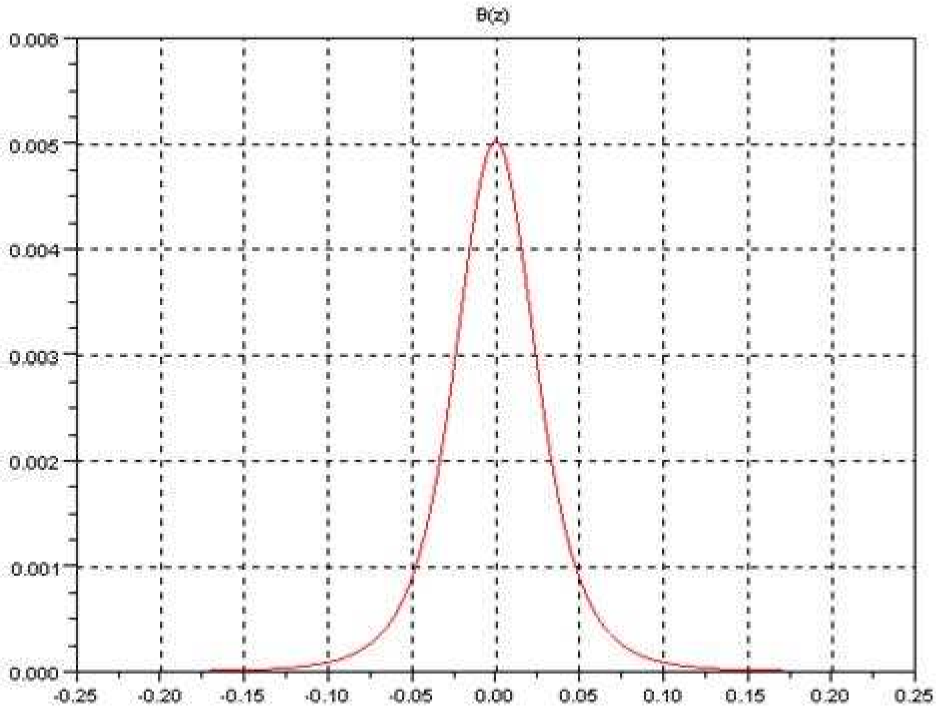


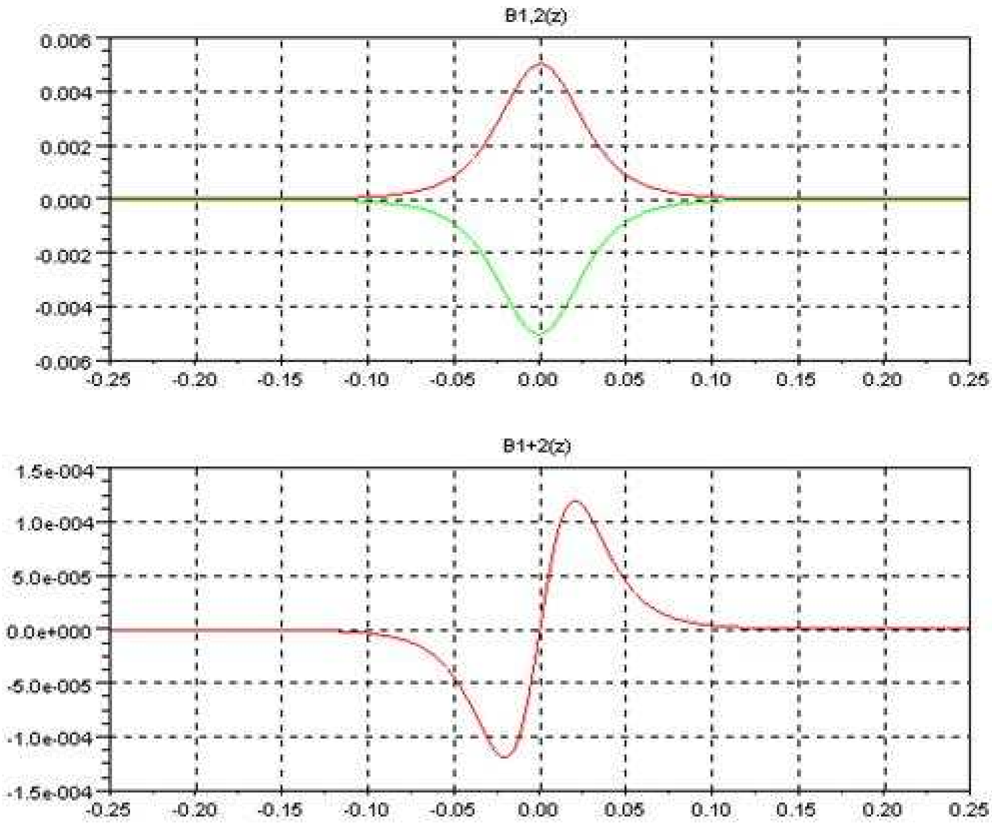
Figure 9.1.6 Magnetic field due to a circular loop carrying a steady current.

$$B_z = \frac{\mu_0 I R^2}{2(R^2 + z^2)^{3/2}}$$

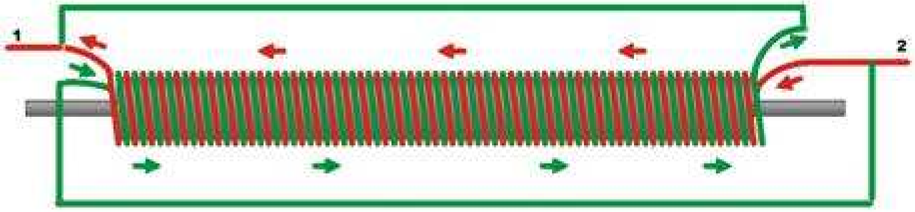
pic1. Picture and formula for magnetic field produced by one turn of wire (from MIT 8.02 physics course chapter 9)



pic2. Magnetic field of one turn.

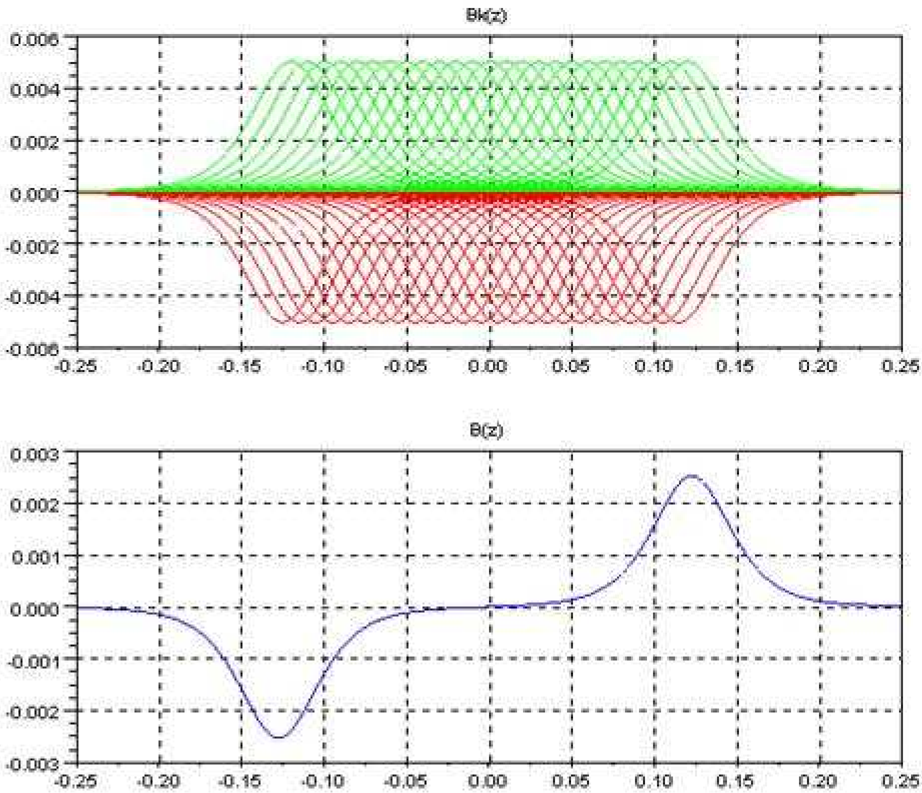


pic3. Magnetic field of two turns with opposite currents (top) and sum (bottom).



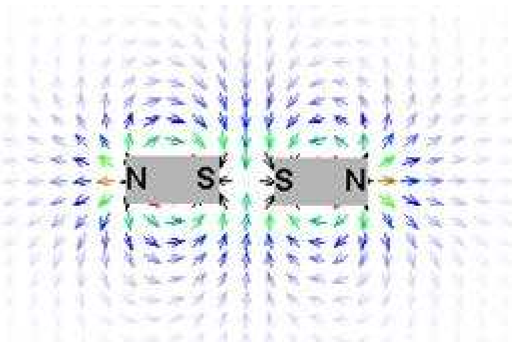
pic4. Parallel connection

pic5. Serial connection



pic6. Drawing field of scalar coil
top – field of separate turns, bottom – resulting sum

Please note that this graph again represent only Bz, component of B which is directed along central axe of the coil.
Don’t be confused, there is a magnetic field at the point where Bz = 0, it is just have vector B perpendicular to z.



pic7. Field of two opposed magnets, similar to field of two opposed turns

So let’s try taking a closer look on the perpendicular (By) component of magnetic field of scalar coil.

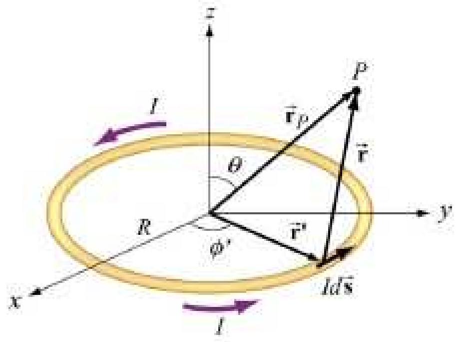


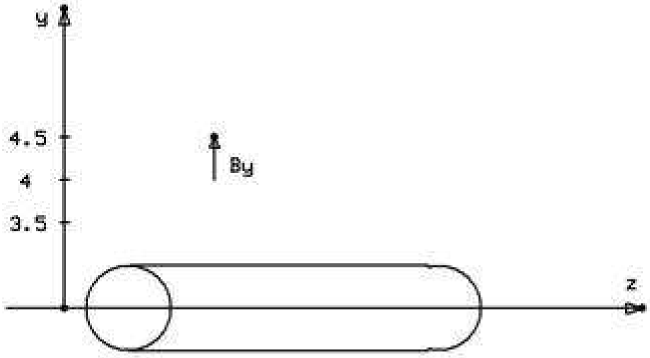
Figure 9.8.1 Calculating the magnetic field off the symmetry axis of a current loop.

pic1. Picture from MIT 8.02 course (see 1)

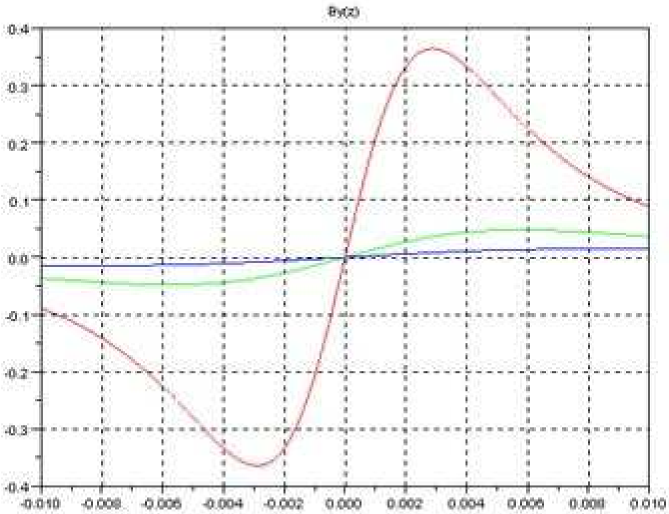
$$B_y = \frac{\mu_0 I R z}{4\pi} \int_0^{2\pi} \frac{\sin\phi' \, d\phi'}{\left(R^2 + y^2 + z^2 - 2yR\sin\phi'\right)^{3/2}}$$

$$B_z = \frac{\mu_0 I R}{4\pi} \int_0^{2\pi} \frac{\left(R - y\sin\phi'\right) d\phi'}{\left(R^2 + y^2 + z^2 - 2yR\sin\phi'\right)^{3/2}}$$

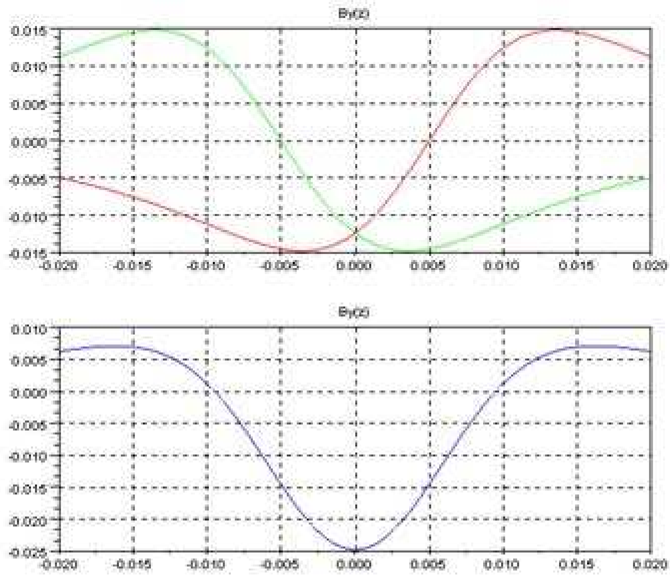
pic2. Formulas for magnetic field (see 1)



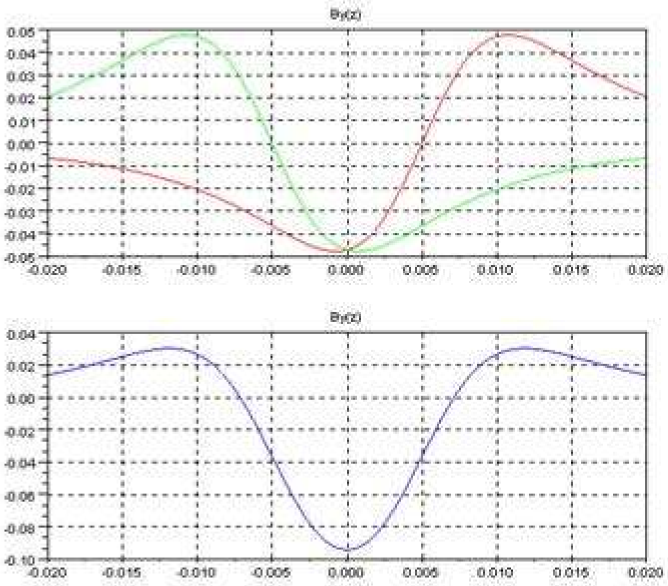
Strength of By change significantly with distance from the coil (y)
I will draw By at tree fixed distance (3.5, 4, 4.5 cm from the coil central axe)



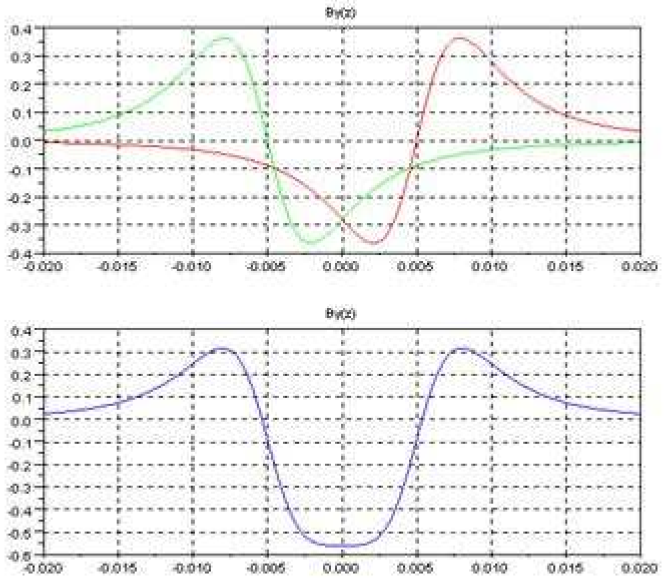
pic3. Field of one turn By(z)
red y=4.5, green y=4, blue y=3.5



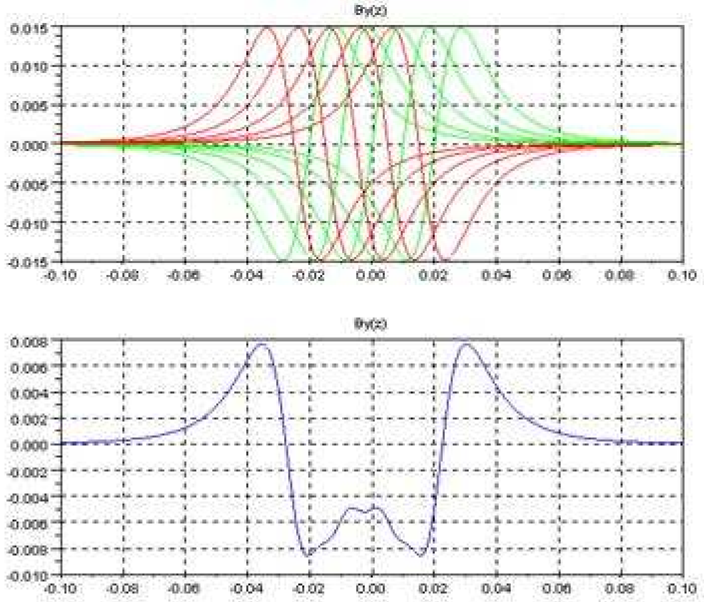
pic4a. By(z), y = 3.5
Field of two turns



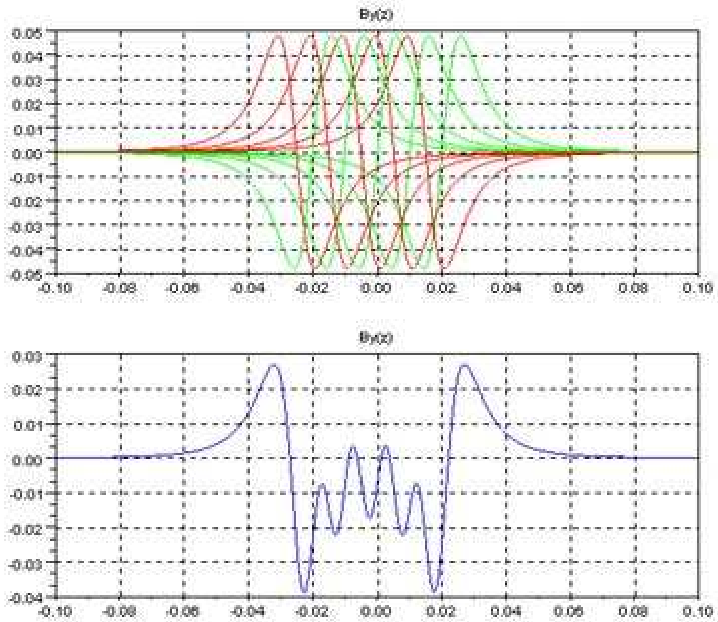
pic4b. By(z), y = 4



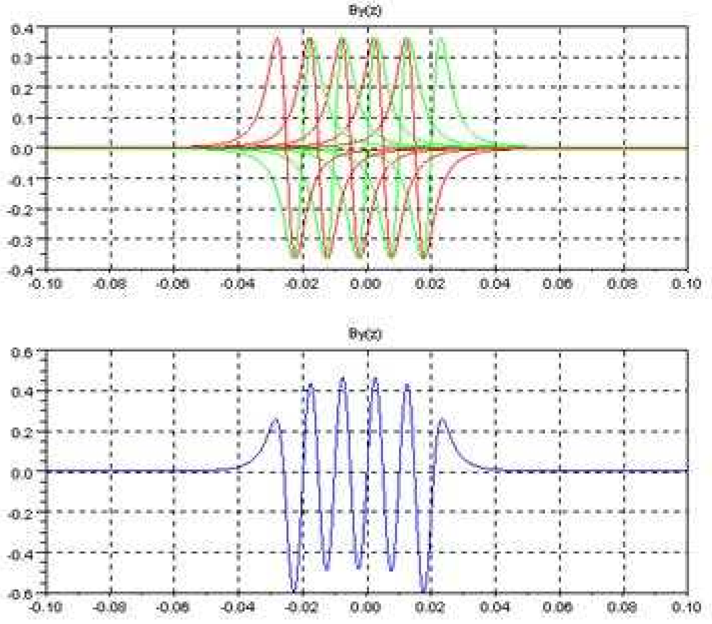
pic4c. By(z), y = 4.5



pic5a. By(z), y = 3.5
Field of 10 turns



pic5b. By(z), y = 4



pic5c. By(z), y = 4.5

The simulation use very simple algorithm for integral calculation, it can give some calculation errors.
However, main point here is that fields of “scalar” coil are far non–zero and mainly located outside the coil and core (if it present).

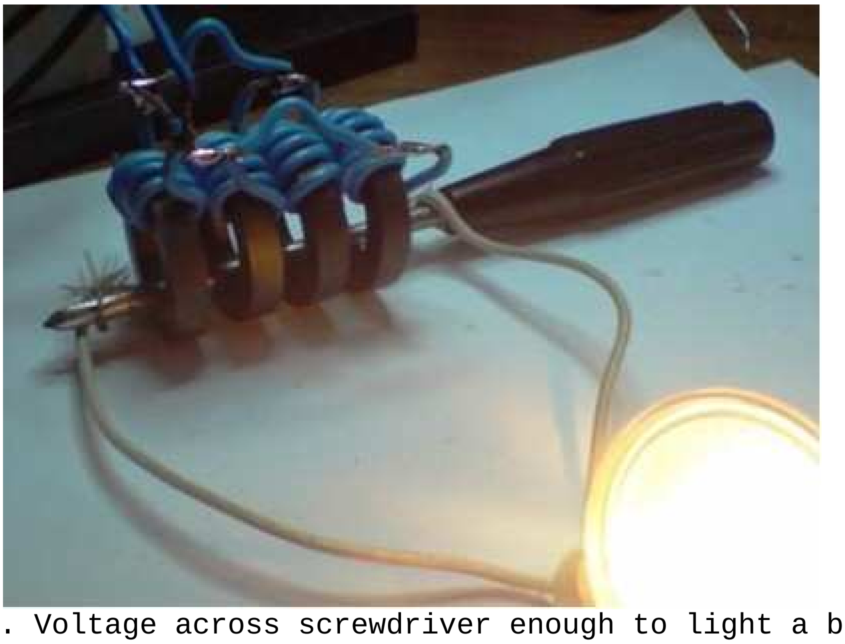
I hope this help to avoid unexpected interference and exposure to magnetic fields.

Links:
http://web.mit.edu/8.02t/www/materials/StudyGuide/guide09.pdf (1)
http://christopherbradshaw.net/The_Project_Bin/Schumann%20Frequency%20Oscillator%20with%20Scalar%20Coil.html
http://en.wikipedia.org/wiki/Bifilar_coil

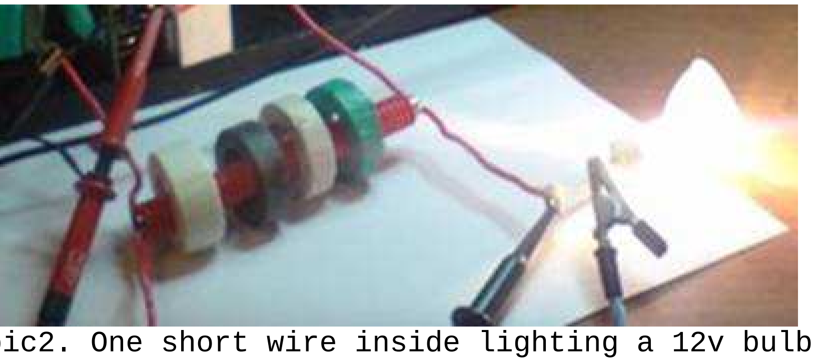
Chapter 5. Displacement current

How they do that?

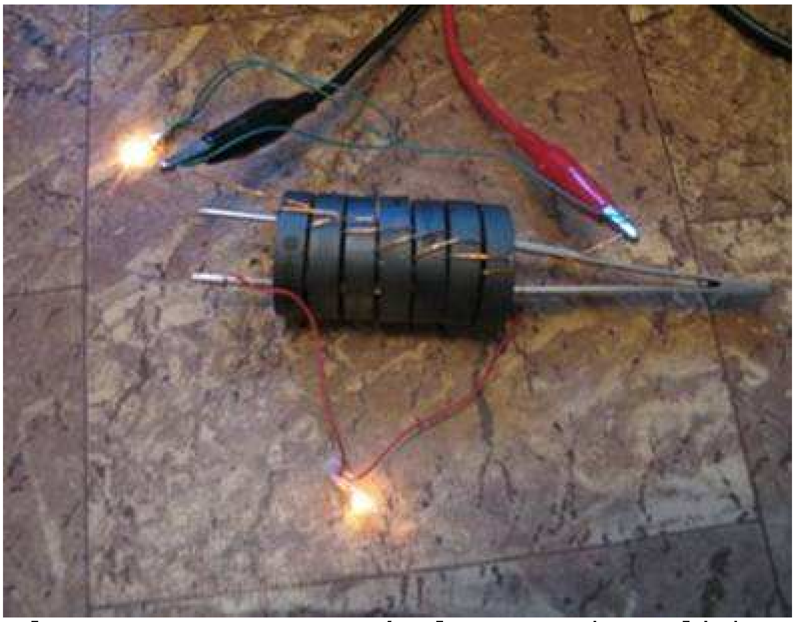
I am starting new thread to discuss not very common transformer arrangements. And for beginning I would like to show some “strange” pictures. When I saw these pictures first time, my reaction was “How they do that?” ☺

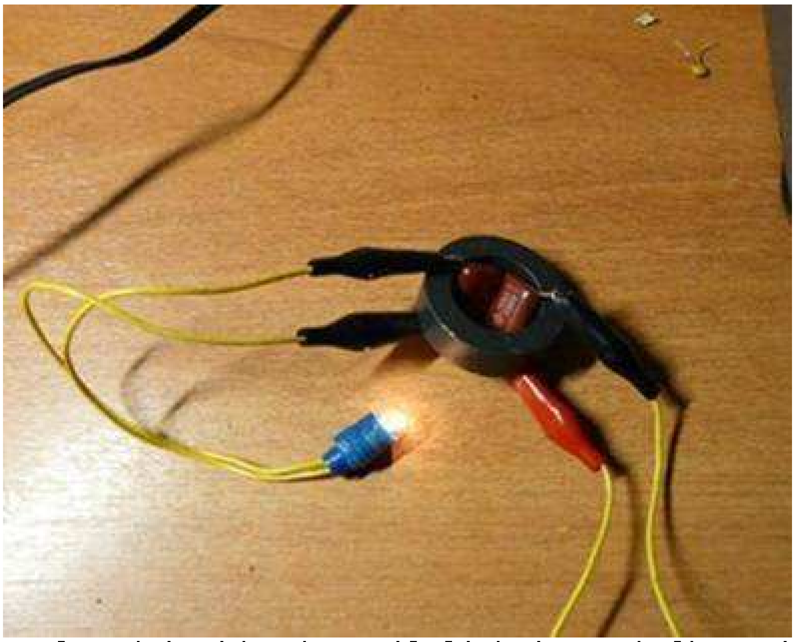


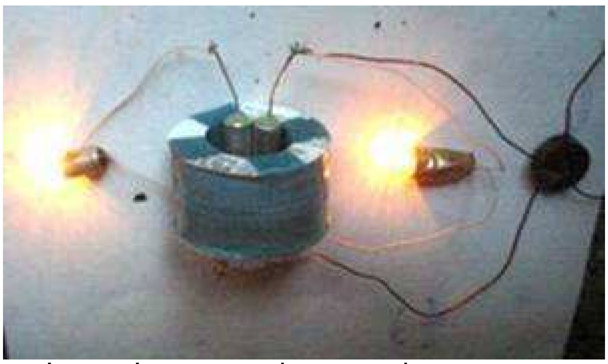
pic1. Voltage across screwdriver enough to light a bulb

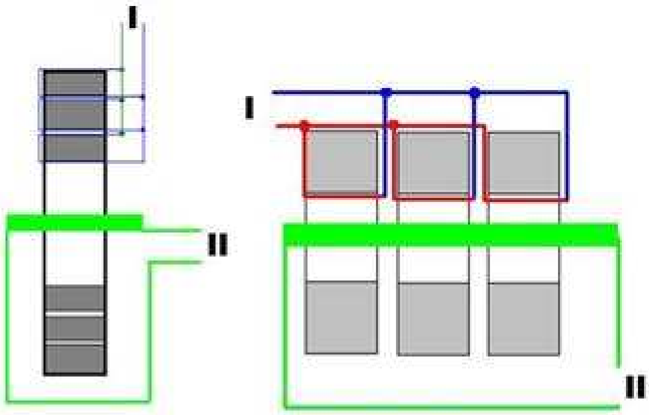


pic2. One short wire inside lighting a 12v bulb

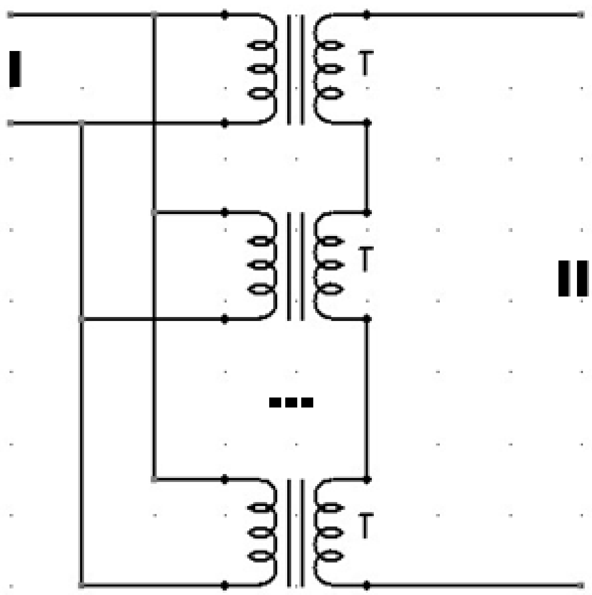

pic3. Voltage across tweezer’s leg enough to light a bulb.


pic4. Capacitor placed inside the coil lighting a bulb, primary coil also capacitor


pic5. Again primary and secondary are capacitors



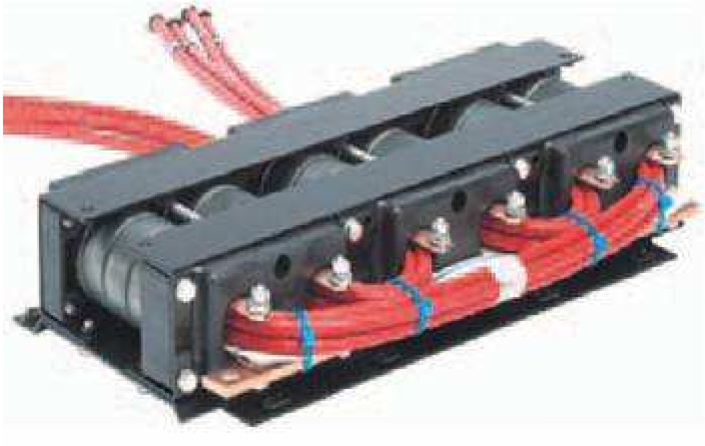
pic6. Transformer layout



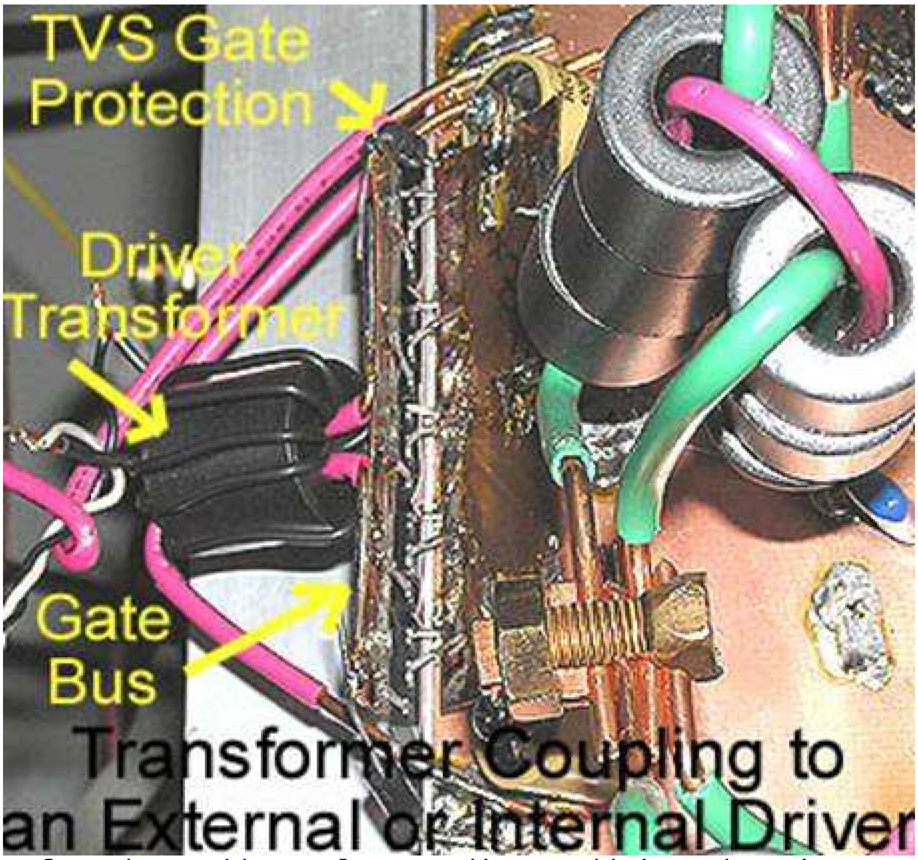
pic7. If we take N transformers with N:1 windings and connect them like it shown on the picture we will get 1:1 transformer.

Inductance is proportional to the square of turns. Ring with 10 turns has an inductance of 100. Ten rings in parallel have inductance 10. This is 10 times greater than a single turn.

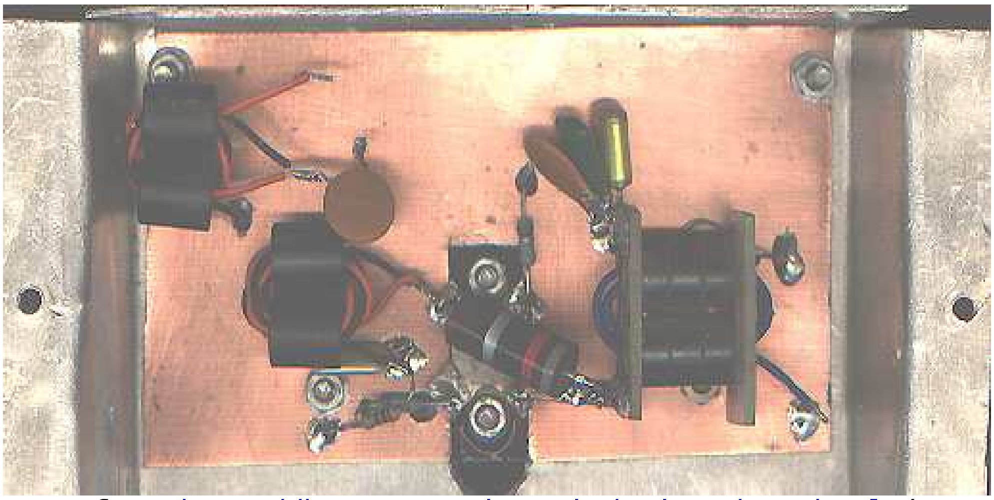
So after consideration it appeared to be just a different step down transformer setup. After studding this subject more I found that such transformers used in different equipment and not invention of some “smart” guy on FE forum (as it usually claimed :-). See below some examples.



pic8. transformer from modern welding machine



pic9. Picture from http://www.classeradio.com/driver.htm (MOSFET driver)

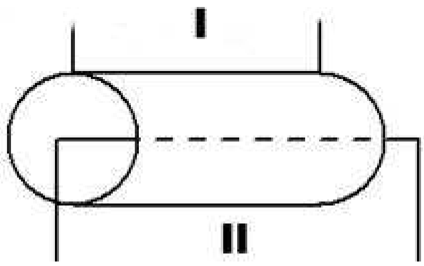

pic10. Picture from http://homepage.tinet.ie/~ei9gq/pa1.html (HF amplifier)

That’s fine, but what about capacitors instead of windings?
Well, it seems that transformer actually don’t care whether winding is a wire or capacitor (some combination of wires or “plates”). I will show more of it in next posts ;-)

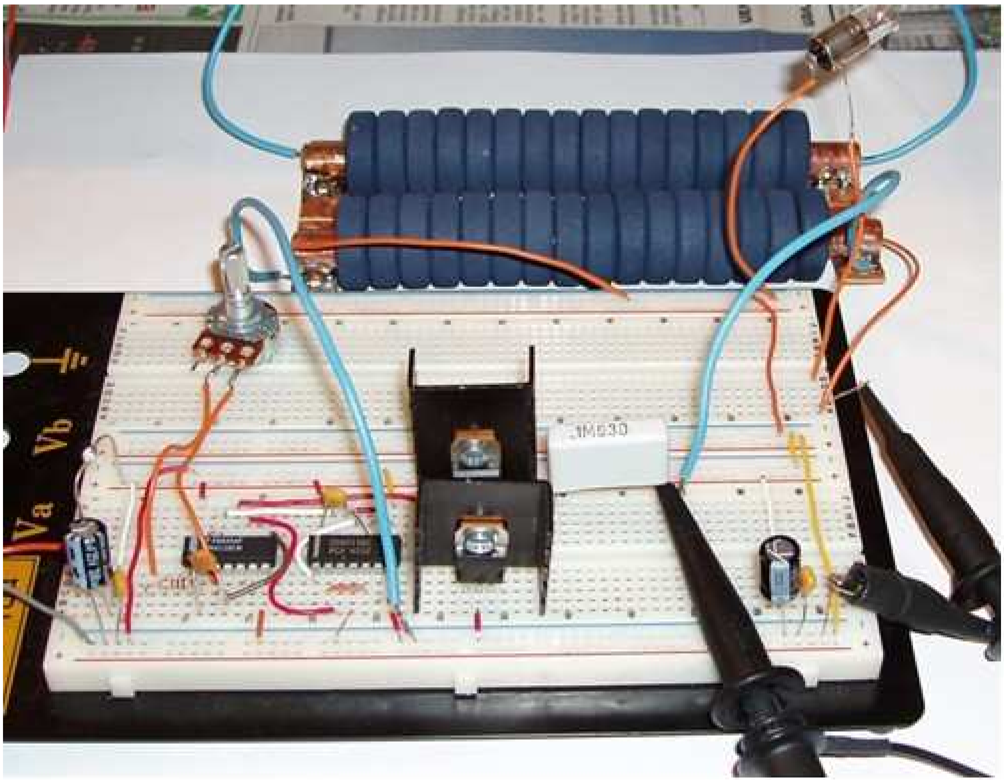
Links:
http://homepage.tinet.ie/~ei9gq/pa1.html
http://www.classeradio.com/driver.htm

Coaxial transformer with a «pipe»

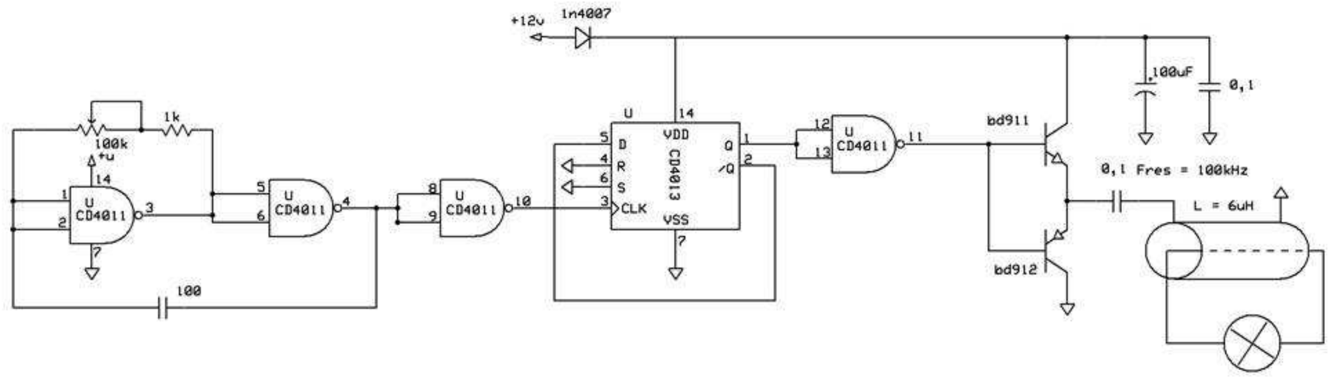
Let’s consider similar setup to what we seen in previous post but this time we will take a copper pipe as a primary and use just one wire as a secondary (and put this wire inside the pipe). Let’s do a simple experiment and let physicists explain why and how it works ;-)



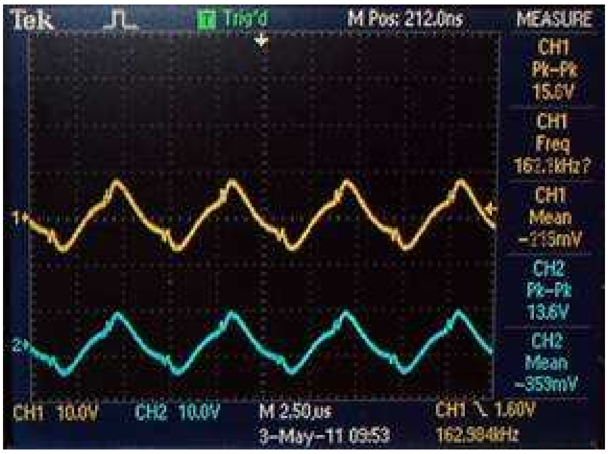
pic. A transformer layout



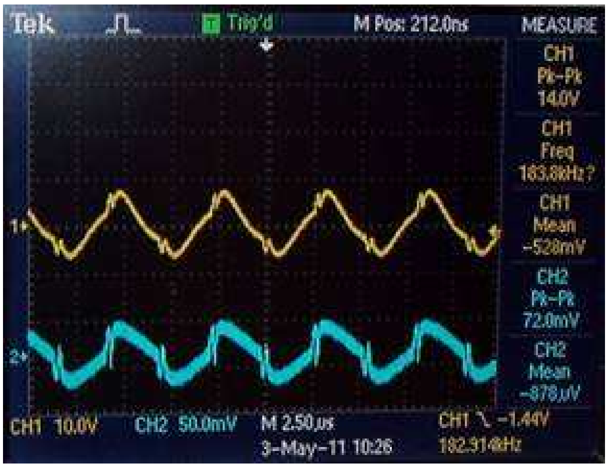
pic1. Experiment with coaxial transformer (only one half used in this experiment)



pic2. Schematic for the experiment



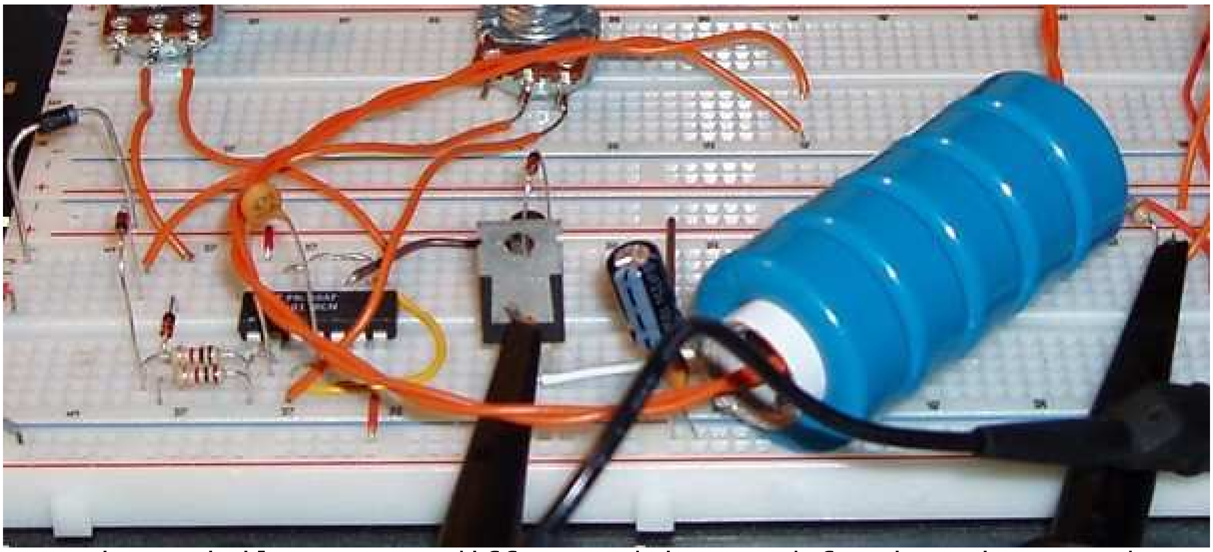
pic3. top – voltage on primary (pipe), bottom - on the secondary (single wire inside pipe) connected to a small light bulb.



pic4. top – voltage on primary (pipe), bottom – current in primary (measured on 0.03 ohm resistor)

Circuit's power consumption:
Ups = 11.6v
Is = 245ma
Ps = 2.7W

Small light bulb from car side lights used as a load.



pic5. Similar setup, different driver and ferrite rings used

Amazingly it works! Do you see something unusual or strange in this setup?

Properties of coaxial transformer

So, what’s wrong with coaxial transformer? Ok, let’s try remember some physics.

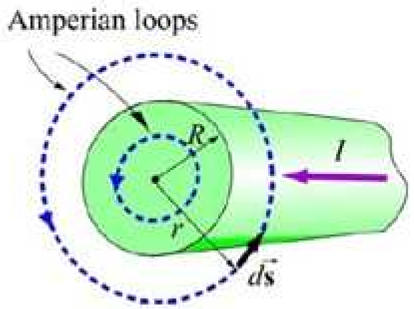
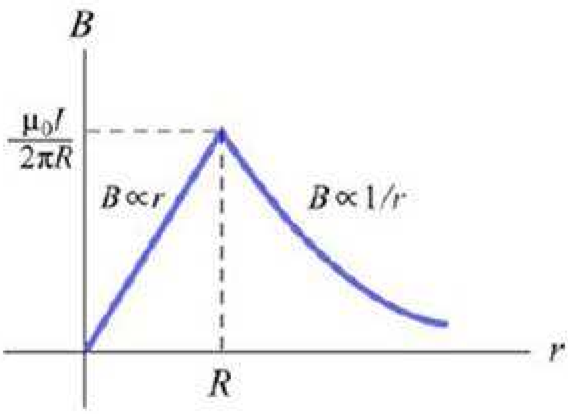


Figure 9.3.5 Amperian loops for calculating the $\vec{\mathbf{B}}$ field of a conducting wire of radius *R*.

pic1. Magnetic field of wire (see 1 for more details)

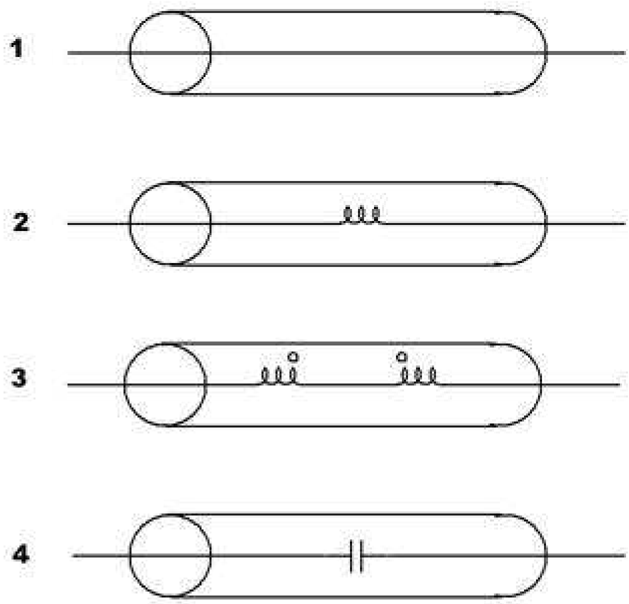


outside $B = \frac{\mu_0 I}{2\pi r}$

inside $B = \frac{\mu_0 I r}{2\pi R^2}$.

pic2. Magnetic field of the wire

1) Based on above information we can conclude that magnetic field inside a pipe (our primary) should be zero (because there is no current inside it). However why then our transformer works? How voltage/current in secondary induced? ;-)



pic3. More weird experiments to consider

2) Why phase of current in secondary same as in primary? (remember oscilloscope sots from previous post ?)

3) Let say if use single wire as a secondary we get 10v output voltage.
Now if we take a longer wire and make a coil of it and insert it in side or primary…
Guess what voltage we get… ok, same 10v.
So we have different inductance but same voltage, isn't it nice?

We can wound bifilar coil, other different types of coils but result will be same, same voltage on the ends.
(Still nothing strange ?)

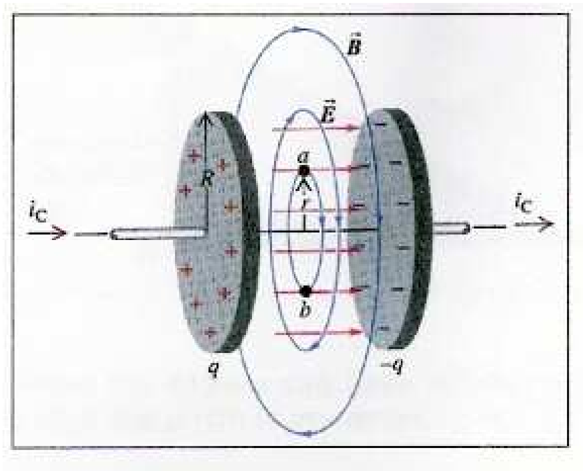
4) We can put capacitor inside "pipe", we will get same voltage on it.
What ever we put inside e.g. screwdriver - same voltage will be on it's ends ☺

Links:
http://web.mit.edu/8.02t/www/materials/StudyGuide/guide09.pdf (1)

Displacement current in capacitor

Some people say that there is a magnetic field inside capacitor, some other people say that this magnetic field created by displacement current and… if we put a coil inside capacitor we will get some voltage induced on the coil and if put load on the coil there will be no reaction on the circuit where capacitor connected.
Despite these claims sounds obscure ”philosophically” let’s try consider them more deeply. (Obscure, because usually we don’t see actions without reactions in nature)

When talking about magnetic field usually picture like this presented



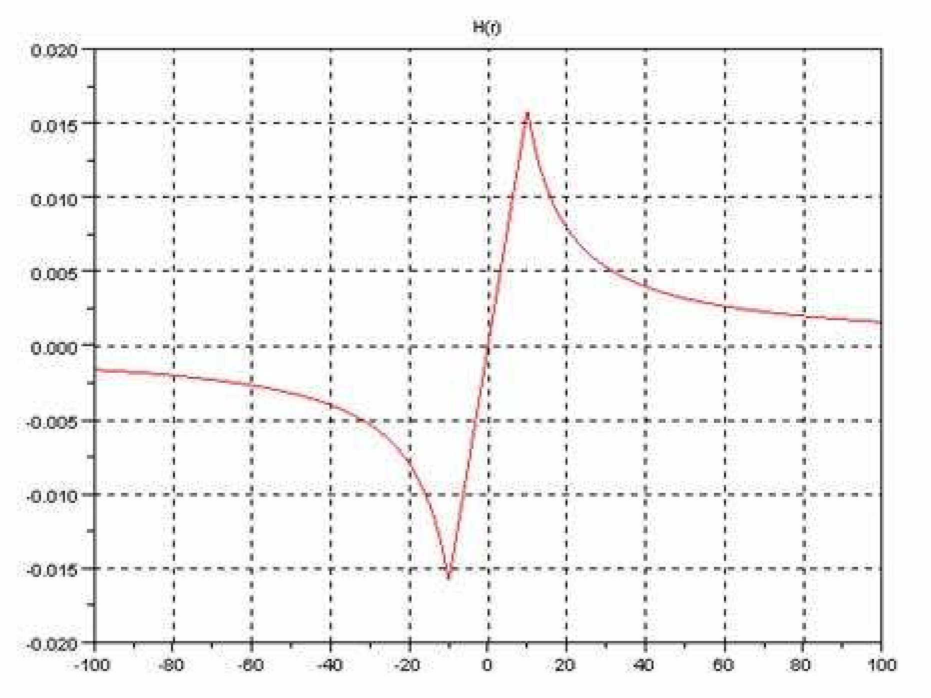
pic1. Calculating magnetic field

and formula like this appeared

$$B(r) = \frac{\mu_0 I}{2\pi} \begin{cases} \frac{r}{R^2} & (r < r), \\ \frac{1}{r} & (r > R). \end{cases}$$

pic2. Magnetic field inside ”thin” capacitor according to (2)

We can even draw the magnetic field using above formula



pic3. Drawing magnetic field inside capacitor

However if you read explanations you see that there is definetly something wrong. To illustrate how really bad situation is I would like to quote explanations about displacement current from (2)

The particular challenge of the present problem is to imagine that the displacement current consists of small filaments, the sum of whose fields should give eq. (5).

The displacement current in a virtual wire of radius $a \ll R$ that runs between the plates of the capacitor is

$$I_{\text{displacement}} = \pi a^2 J_{\text{displacement}} = I \frac{a^2}{R^2} . \tag{6}$$

The magnetic field due to this virtual wire circulates around the wire, and has magnitude

$$B_{\text{virtual}} = \frac{\mu_0 I_{\text{displacement}}}{2\pi s} = \frac{\mu_0 I a^2}{2\pi R^2 s} , \tag{7}$$

pic6. Quote from (2)

Sure, it is a challenge to understand what is ”virtual” wire and ”virtual” magnetic field ;-)
(see 2 for more challenges)

I got impression that the only thing guys care about is to make their equations look nice. And what I actually would like to know - is there really displacement current and magnetic filed inside capacitor ?

After some search I found these measurements results (see 4)

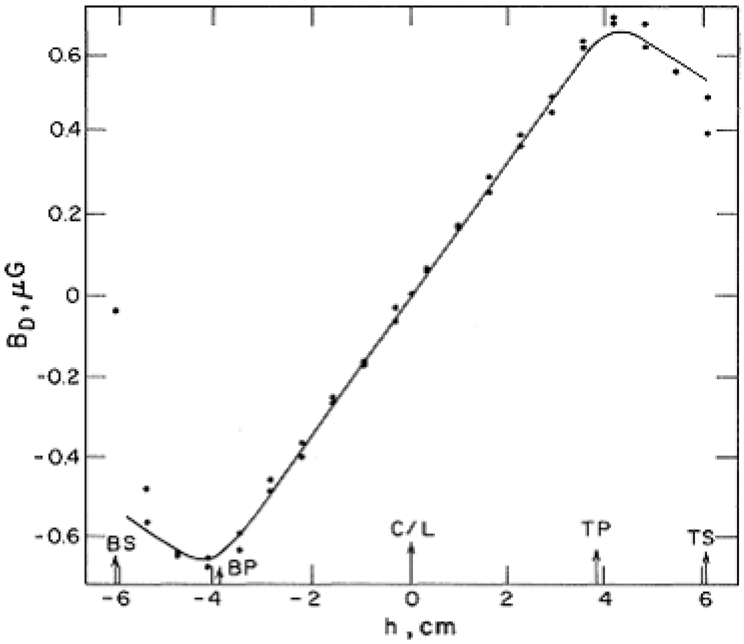
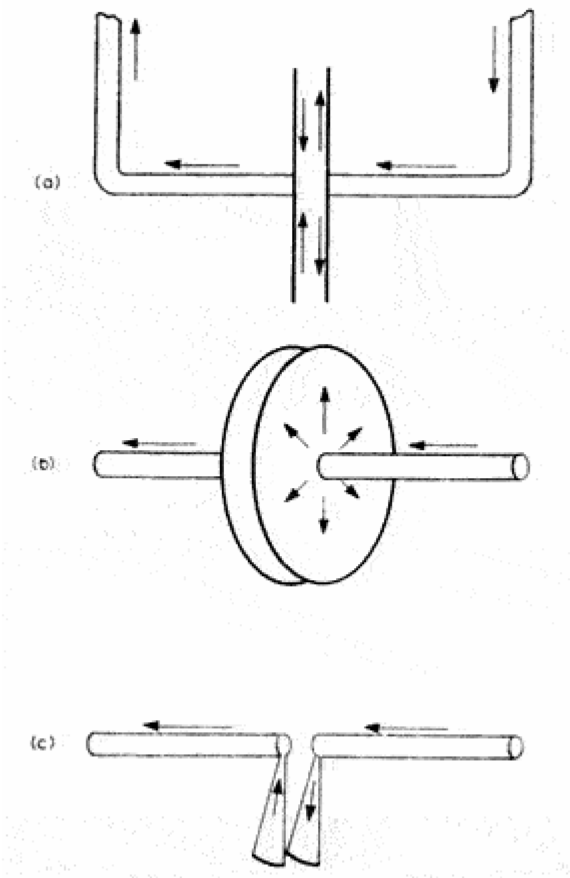


FIG. 4. Results. The scale of B_D was determined in a separate calibration in which the coil was placed inside a small Helmholtz coil carrying a known 1250-Hz current. BS = bottom of sphere, BP = bottom of plates, C/L = center line, TP = top of plates, and TS = top of sphere.

pic4. Magnetic field measured inside capacitor (see 4 for more details)

So it seems that there is really a magnetic field inside capacitor.



pic5. Current in capacitor’s plates (picture from 6)

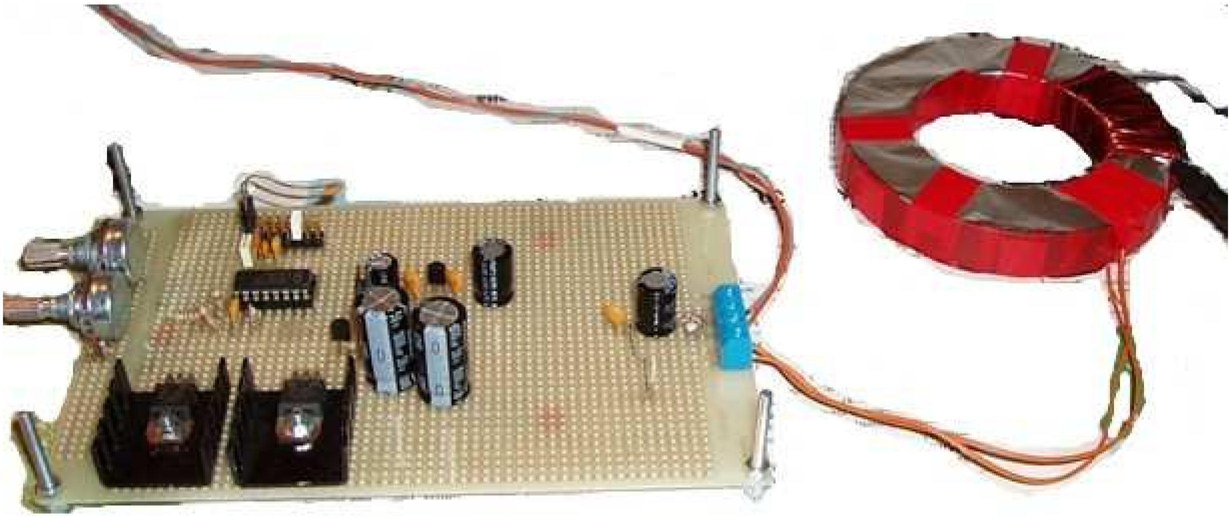
However this fields caused by currents inside capacitor plates and no ”actual” current exists inside capacitor. Let’s try check other ”obscure” claims in practice ;-)

Links:
http://web.mit.edu/8.02t/www/materials/StudyGuide/guide13.pdf
http://www.physics.princeton.edu/~mcdonald/examples/displacement.pdf (2)
http://www.phy.duke.edu/~rgb/Class/Electrodynamics/Electrodynamics/node28.html
https://www.dropbox.com/s/ijvf7o6czndn893/dc_meas.pdf (4)
https://www.dropbox.com/s/8l8uyqwqwk5alsm/809.full.pdf
http://www.ivorcatt.org/icrwiworld78dec1.htm (6)
http://download.antennex.com/preview/Nov02/Nov0602/dca-1.pdf
http://www.antennex.com/shack/Apr07/dc_factfan.pdf
http://www.antennex.com/shack/Aug05/dc-final_piece.pdf
http://itee.uq.edu.au/~aupec/aupec04/papers/PaperID84.pdf
http://www.overunityresearch.com/index.php?topic=210.0

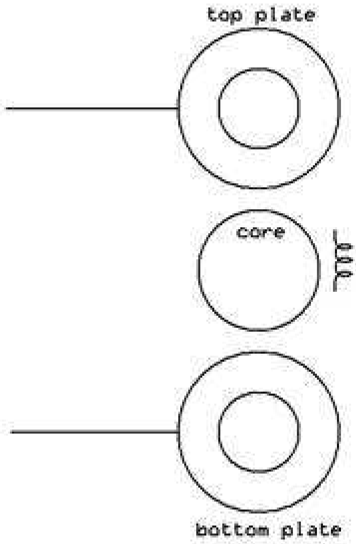
Capacitor with a coil on ring core

I took big ferrite ring core and put two aluminum disks (made from cooking foil) on core sides.
I made about 1/4 length gap in the disks and wound a test coil there.
Here a picture (see layout on pic. 3)

pic1. “Capacitor with coil”



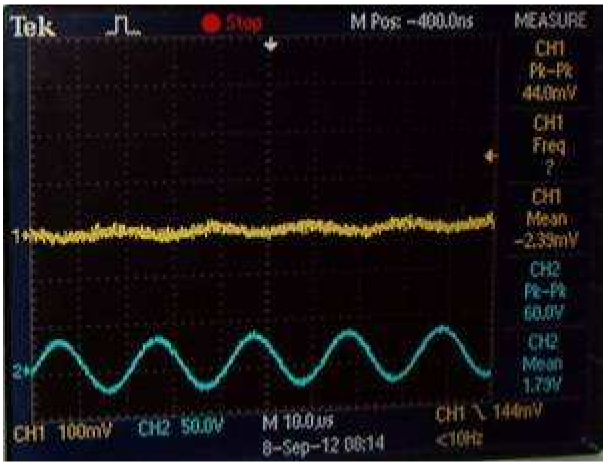
pic2. Experimental setup, half bridge driver connected to capacitor-with-coil

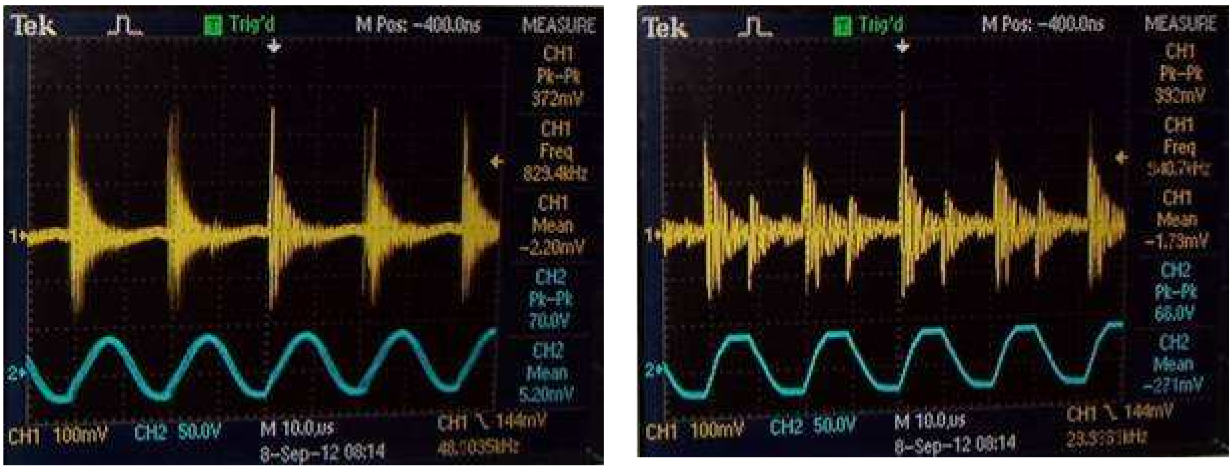


pic3. Capacitor with coil layout

Parameters measured with LC meter:
C = 33pf
L = 1.1mH (30turns wire 0.7mm)

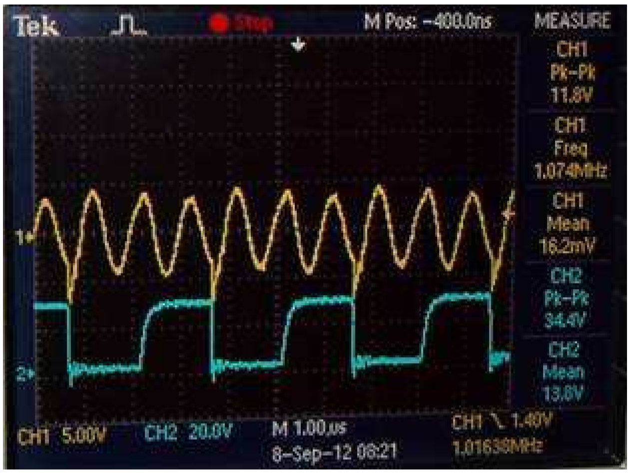
First I attached a signal generator and tried to see how my setup behaves, here some pictures



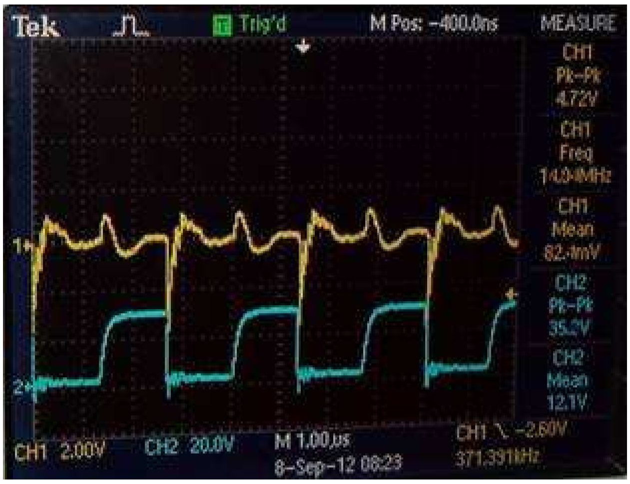


pic4. top-on the output coil, bottom- on capacitor

Then I tried same with half bridge driver.



pic5. "Rectangular" pulses seems produce better results

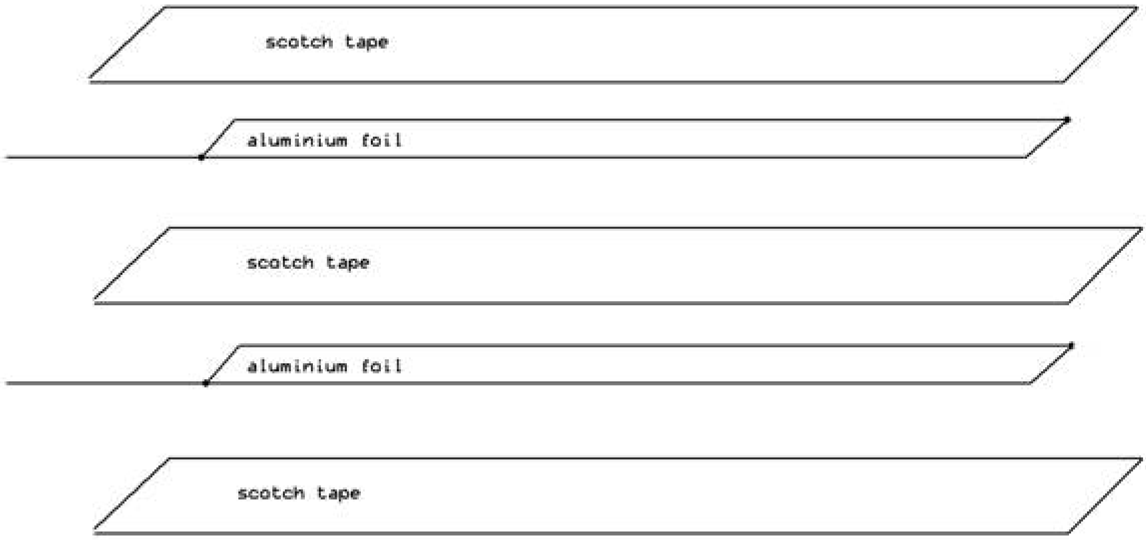


pic6. Load resistance 10K

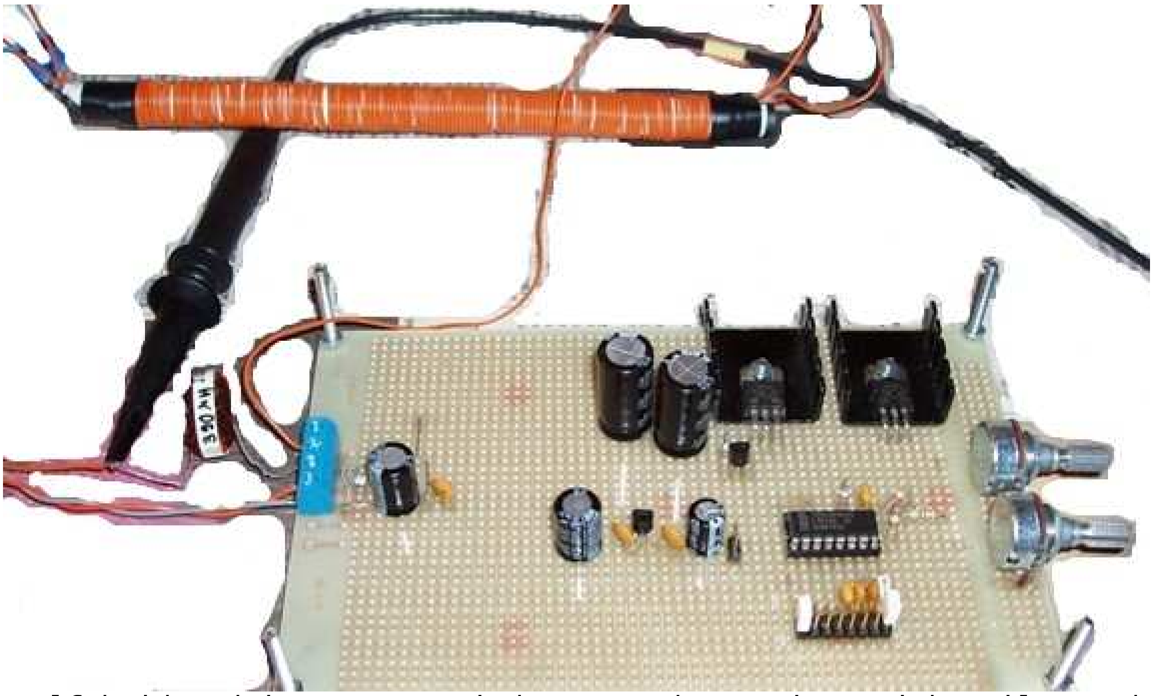
Perhaps capacitance is too small.

Capacitor with a coil of ferrite rod

After failure with “ring capacitor” I decided try slightly different arrangement.
I made a capacitor like this

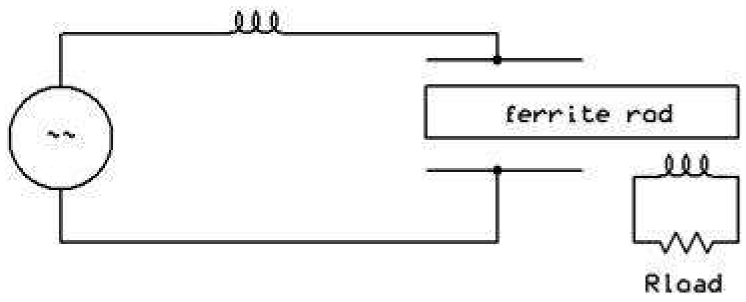


and wound it on ferrite rod, than I wound a pickup coil on top of it.
I used aluminum foil and got about 2000pf capacitance for my capacitor.



pic1. Half bridge driver, 390uH inductor and capacitor-with-coil wound on ferrite rod

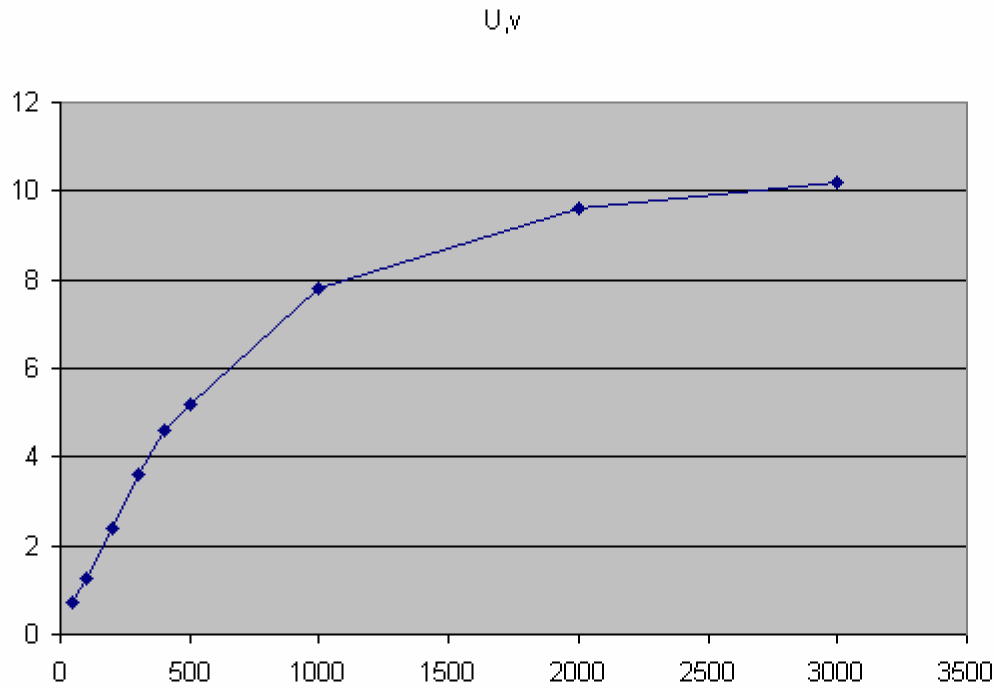
I decided try use resonance in primary; this could help see if load affects driver circuit.



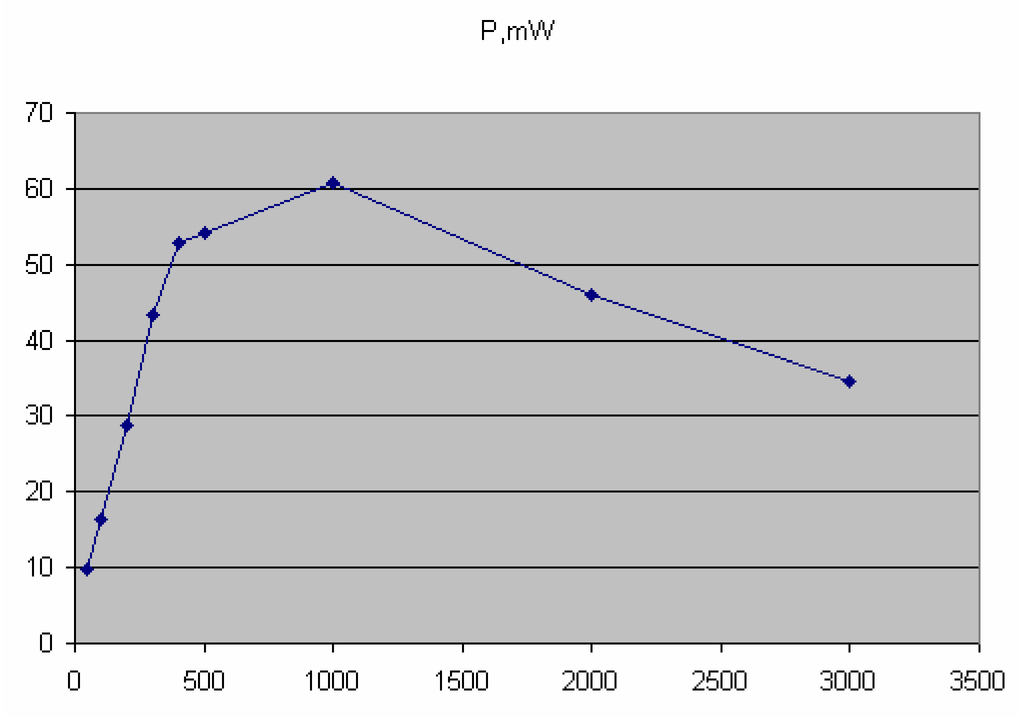
pic2. Capacitor-with-coil on ferrite rod layout (serial resonance)

R,ohm	50	100	200	300	400	500	1000	2000	3000
U,v	0,7	1,28	2,4	3,6	4,6	5,2	7,8	9,6	10,2
P,mW	9,8	16,38	28,8	43,2	52,9	54,08	60,84	46,08	34,68

It seems that load does not affect the much input! I can see even in some cases that amplitude on capacitor increased under load, but Pin/Pout ratio is far from 1. If we manage to optimize the geometry and the driver perhaps…we can get something interesting ;-)

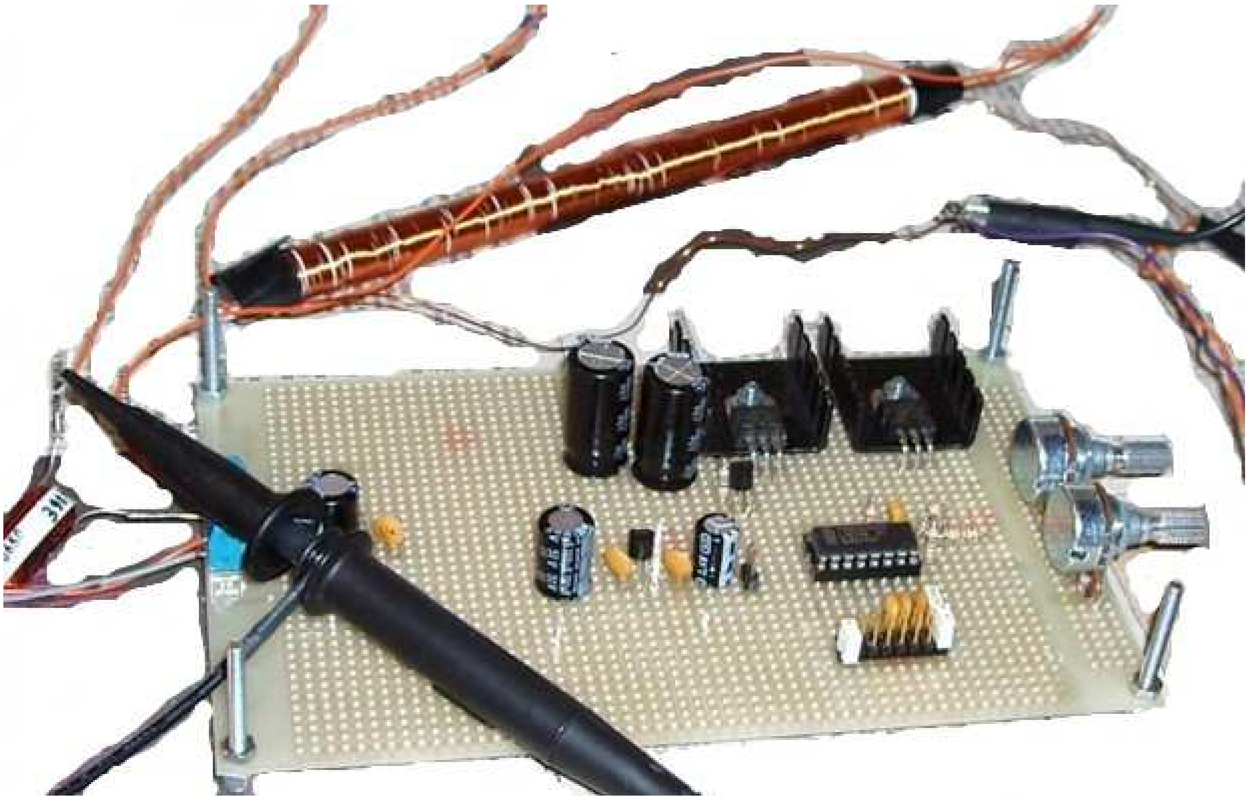


pic3. Voltage vs load resistance

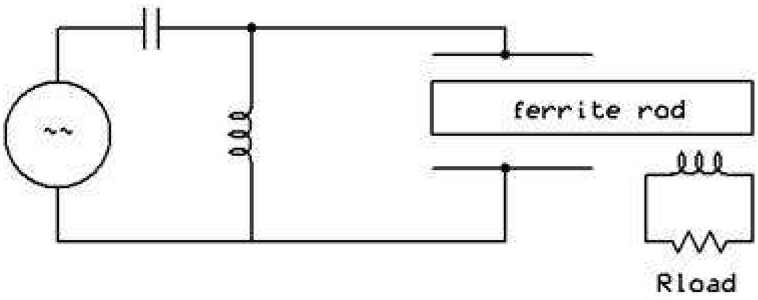


pic4. Power vs load resistance

I also tried longer pickup coil and parallel resonance in primary.

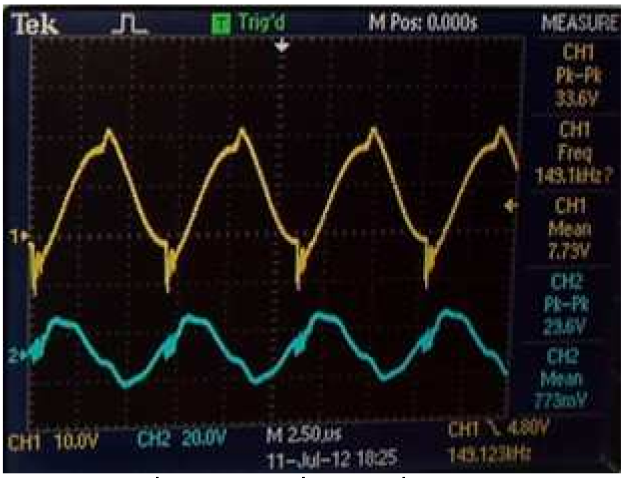


pic5. Experimental setup with longer pickup coil

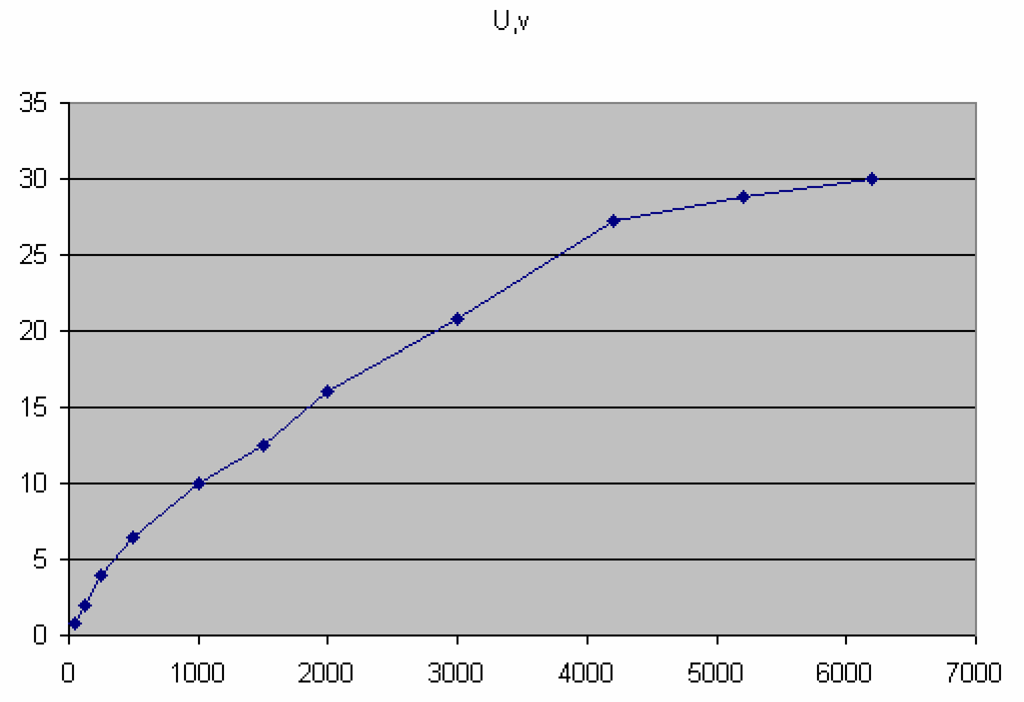


pic6. Capacitor-with-coil on ferrite rod layout (parallel resonance)

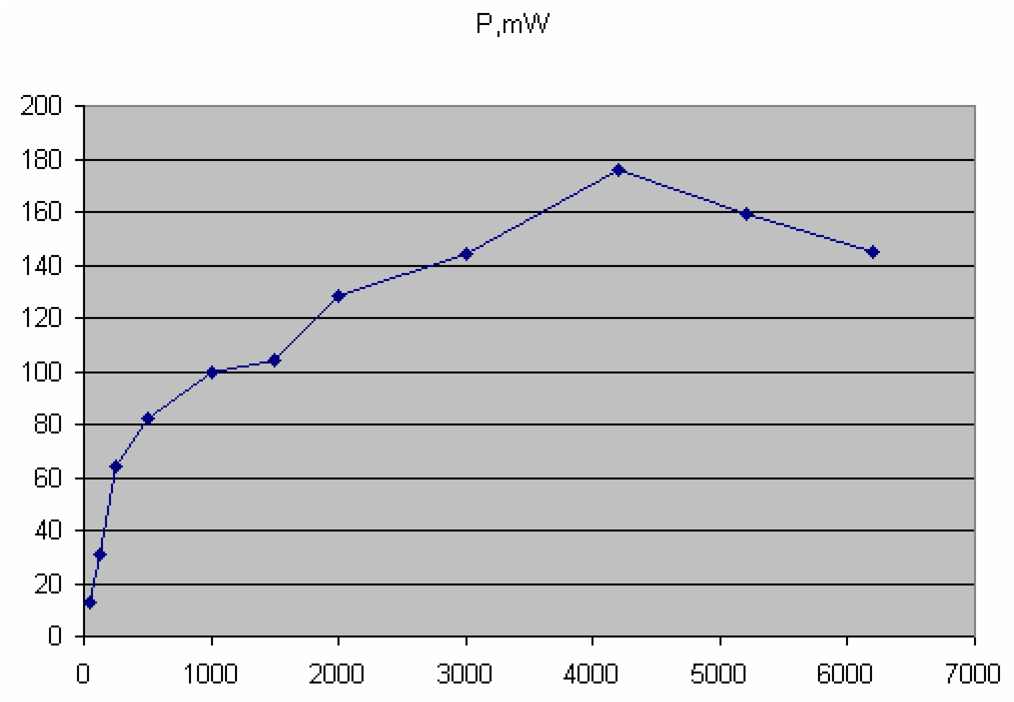
R,ohm	50	130	250	500	1000	1500	2000	3000	4200	5200	6200
U,v	0,8	2	4	6,4	10	12,5	16	20,8	27,2	28,8	30
P,mW	12,8	30,77	64	81,92	100	104,2	128	144,2	176,2	159,5	145,2



pic7. top – on the capacitor, bottom – on the coil



pic8. Voltage vs load resistance

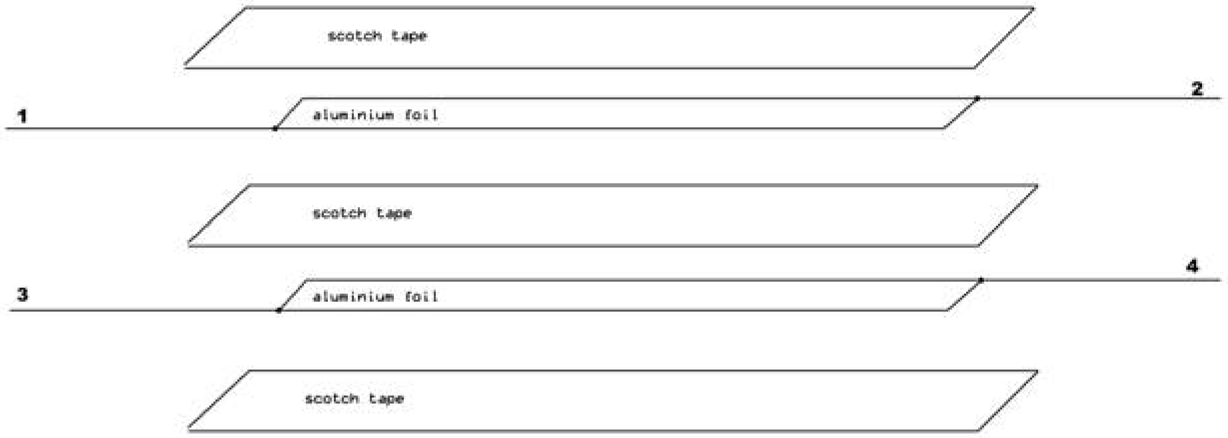


pic9. Power vs load resistance

I thought that this is interesting and I continued efforts in this direction.

Coil - capacitor

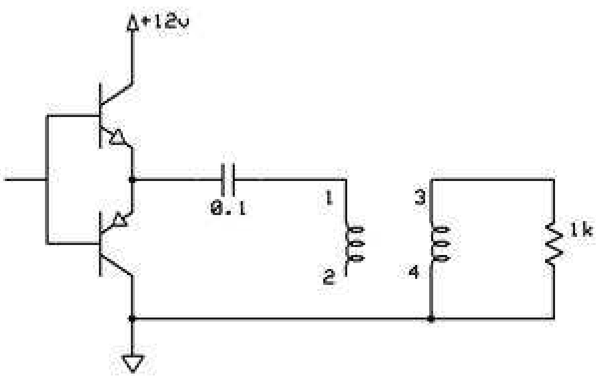
I am continuing with weird transformers setups. After some experiments I found out that we can make a capacitor and wind it on ferrite core. We will have a capacitor and each it's "plate" became an inductor.



Layout of coil/capacitor, two foil stripes isolated with scotch tape and wound into RM ferrite core.

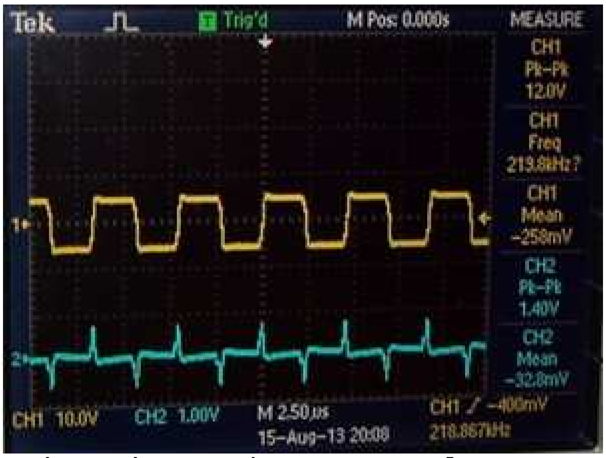
pic1. Coil-cap on RM10 core

Stripes length = 30cm, width = 10mm
Measured capacitance C_{13} = 1000pf,
Inductance L_{12} = 828uH (about 10 turns)

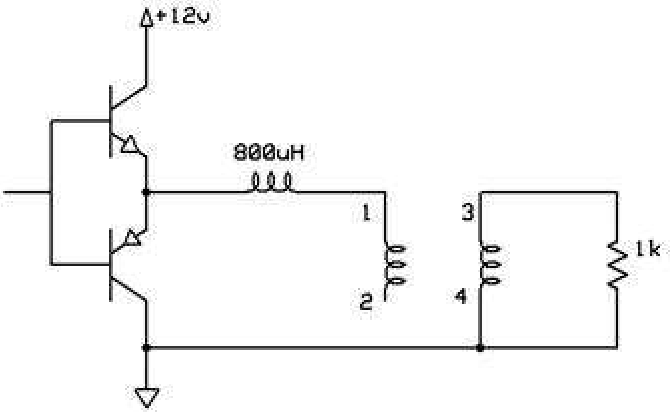


pic2. Experimental setup 1

We have a capacitor (points 1,4) and it is also a primary coil. At the same time we can use one of “plates” as a secondary coil (points 3,4) to connect some load.

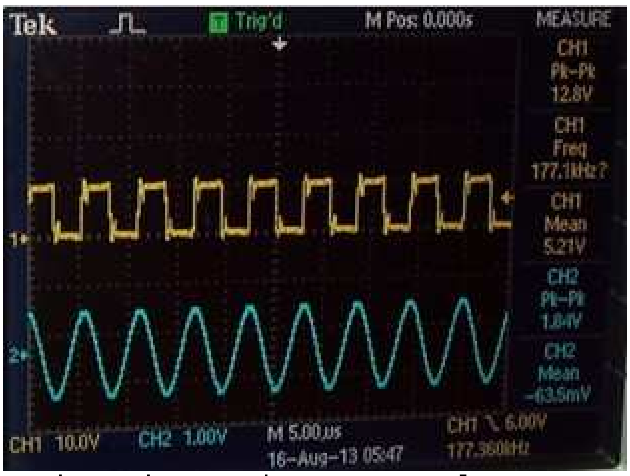


pic3. top – voltage in point 1, bottom – voltage on resistor (point 3)

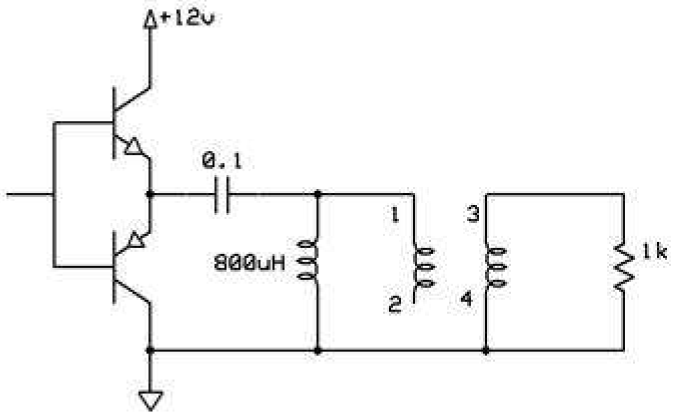


pic4. Resonance setup 1 (serial resonance inductor + our capacitor 14)

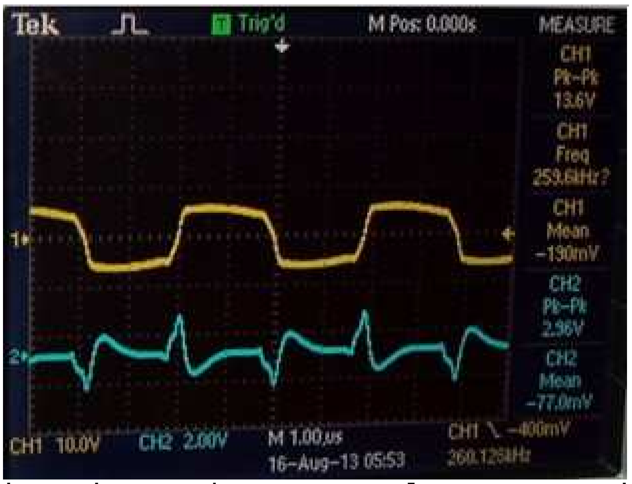
We can have resonance in this setup by adding extra inductor and using corresponding frequency.



pic5. top – voltage in point 1, bottom – voltage on resistor (point 3)



pic6. Resonance setup 2 (parallel with extra inductor)

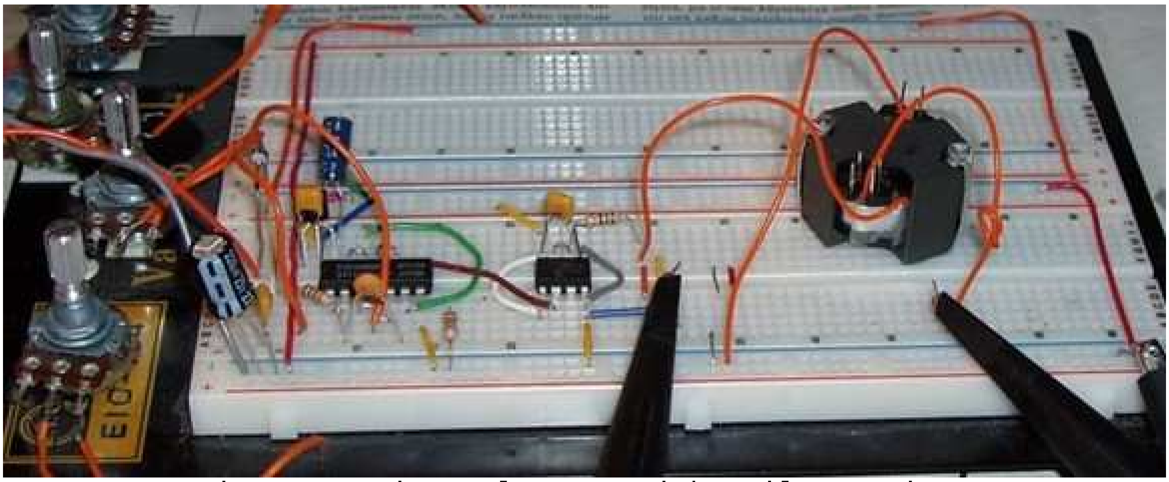


pic7. top – voltage in point 1, bottom – voltage on resistor (point 3), frequency too small for resonance on this picture.

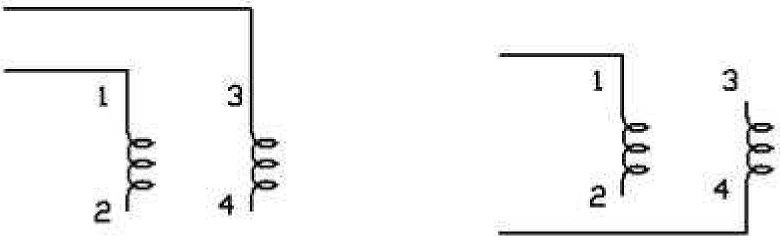
In all these setups we can also use extra “normal” winding as a secondary and our “capacitor” as a primary winding.

Aligned and anti-aligned connection

Thinking more about different combinations and how coil-capacitor can be used I found that there are two different connections possible.

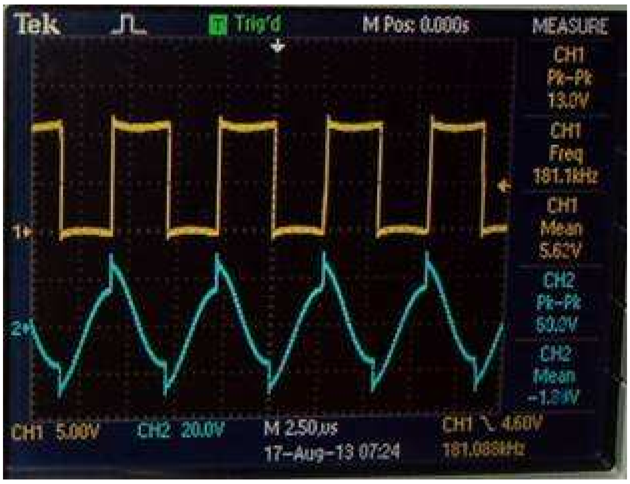


pic1. Experimental setup with coil-capacitor



pic2. Two connections

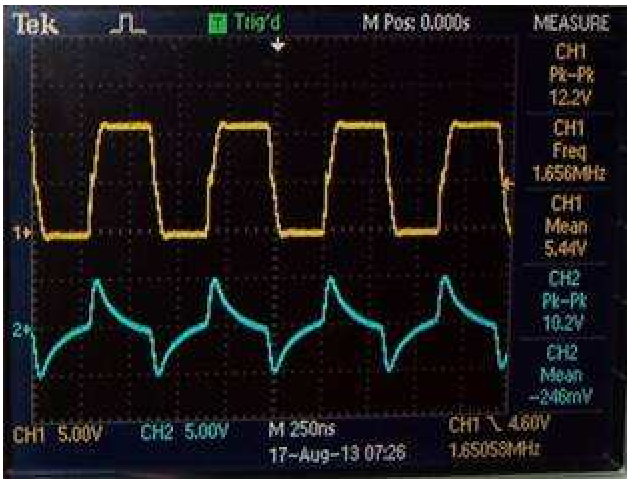
When we use points 1,2 as a capacitor connection currents in ”plates” will flow in opposite directions and will have anti-aligned magnetic fields. But if we use points 1,4 currents in ”plates” will flow in same direction and will have aligned magnetic fields. In both cases external circuit will “see” our coil-capacitor as a capacitor.



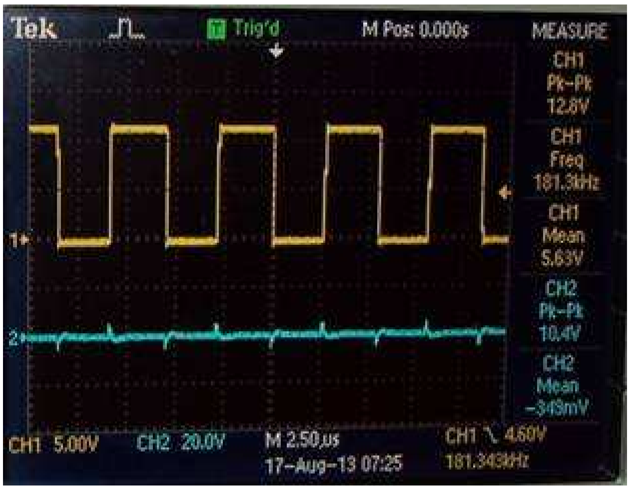
pic3. «aligned» connection

top – voltage on the driver connected to our capacitor (point 1, 4 connected to the ground); bottom – voltage on ”free” plate end (point 3)

Found resonance and apparently it depends on the length of the “plates”.



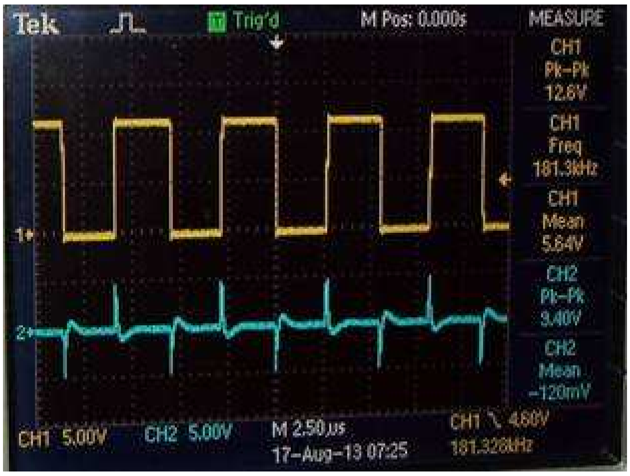
pic4. Effect of load resistor (1к connected to 3,4)



pic5. Anti-aligned connection

top – voltage on the driver connected to our capacitor (point 1, 3 connected to the ground); bottom – voltage on ”free” plate end (point 4)

(same voltage scale on top and bottom)



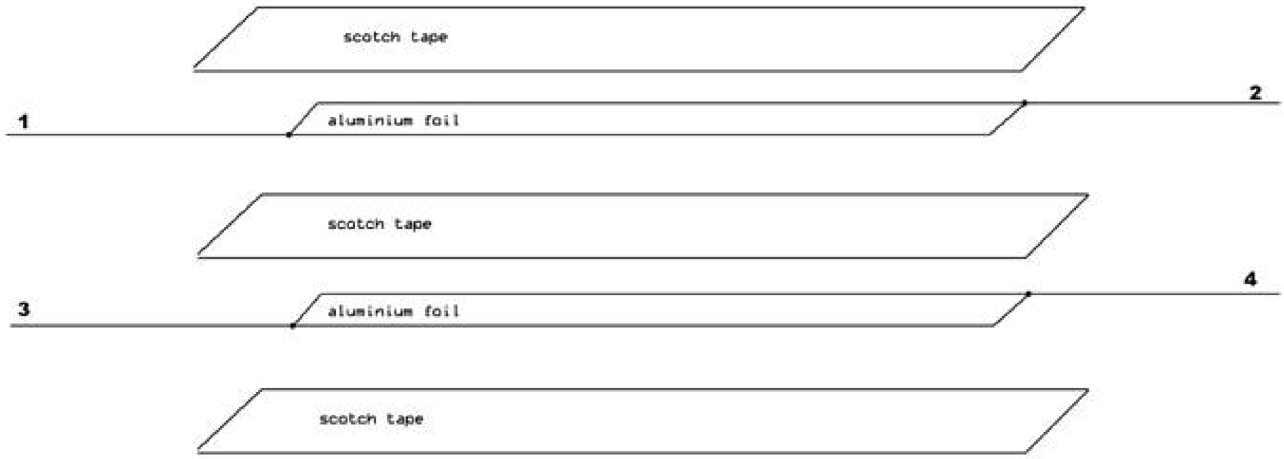
pic6. Same as pic.5, but bigger scale on bottom

After all these exercises it seems that coil-capacitor behaves more like a transmission line (line with distributed inductance and capacitance)

Links:
http://en.wikipedia.org/wiki/Transmission_line

Coil-capacitor on the ring core

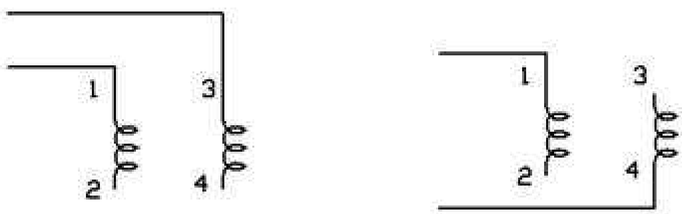
First successful experiments with coil-capacitor were performed on RM cores; it was interesting for me to see if it will work same way on core with different shape, so I made a coil-capacitor on ferrite ring core.



pic. Coil-capacitor layout, prepared to be wound on the core

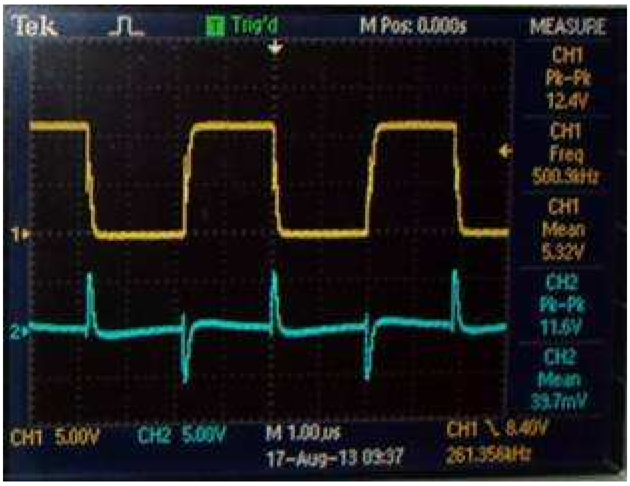
I used foil stripes with length 30cm and width 15mm.
I got capacitance 3400pf and inductance 270uH

pic1. Coil-capacitor on a ring core (Epcos N30 34x20,5x12,5)



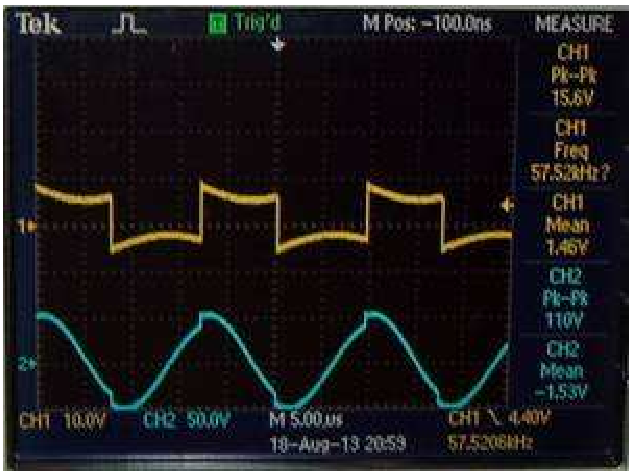
pic2. Aligned and anti-aligned connection

I tried how aligned and anti-aligned connection works



pic3. Anti-aligned connection (1-3)

top – voltage on the driver connected to our capacitor (point 1, 3 connected to the ground);
bottom – voltage on ”free” plate end (point 4)



pic4. Aligned connection (1-4)

top – voltage on the driver connected to our capacitor (point 1, 4 connected to the ground);
bottom – voltage on ”free” plate end (point 3)

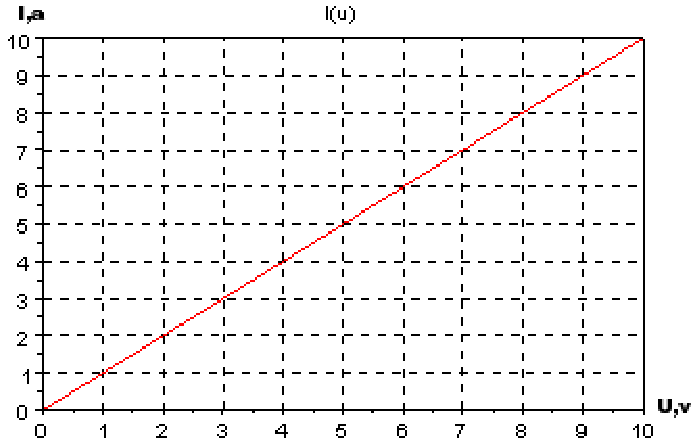
Behavior looks very similar to coil-capacitor made using RM-10 core.

Links:
http://www.ferroxcube.com/prod/assets/rm10ilp.pdf

Chapter 6. Negative resistance

- is next topic I would like to discuss.

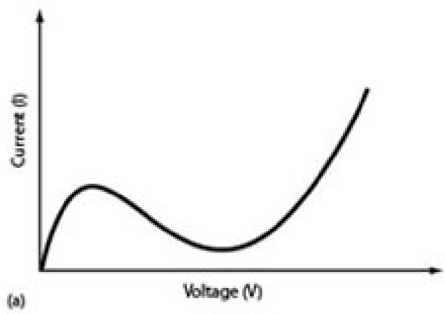
Every one (probably) remember the Ohm’s law, it relies on linear behavior of resistors. However we see in nature “circuits” with non-linear resistance, also we can create such circuits ourselves. Here we will take a closer look on “negative” resistance.



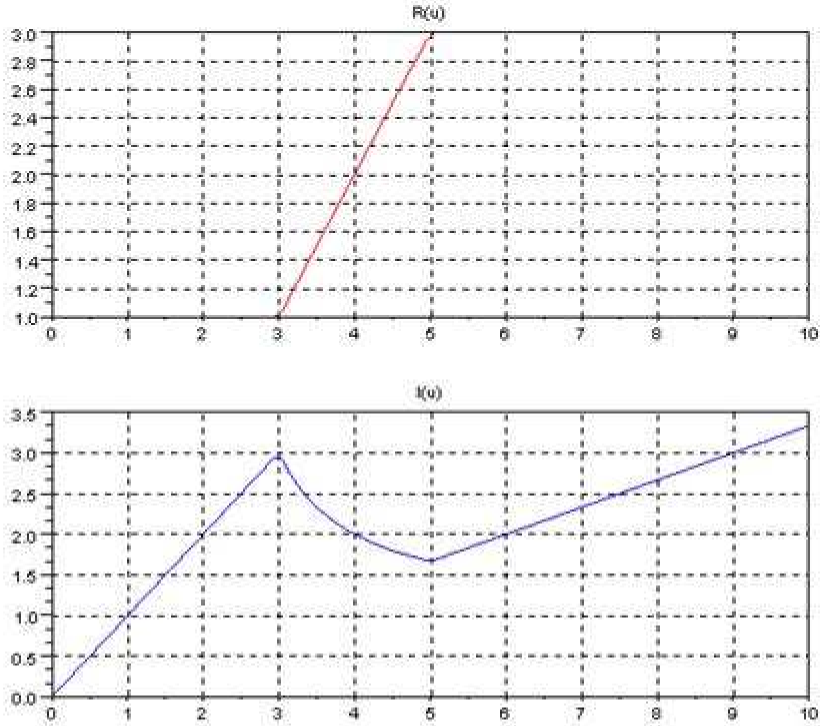
pic1. “Normal” resistance behavior

Negative resistance is a property of some electric circuits where an increase in the current results in a decreased voltage. This is in contrast to a simple ohmic resistor, which exhibits an increase in voltage under the same conditions.

There are two types of negative resistance usually discussed, one with N-shape and one with S-shape I-V characteristic.



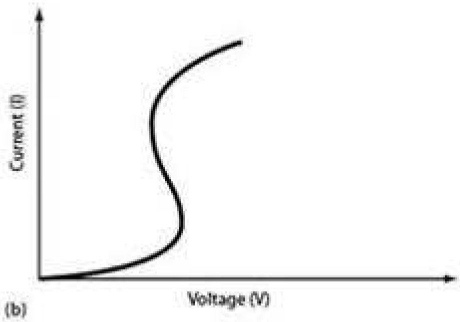
pic2. N type negative resistance I-V characteristic



pic2a. Here a simulation which tries to create N type of negative resistance top – R(U), bottom – I(U)

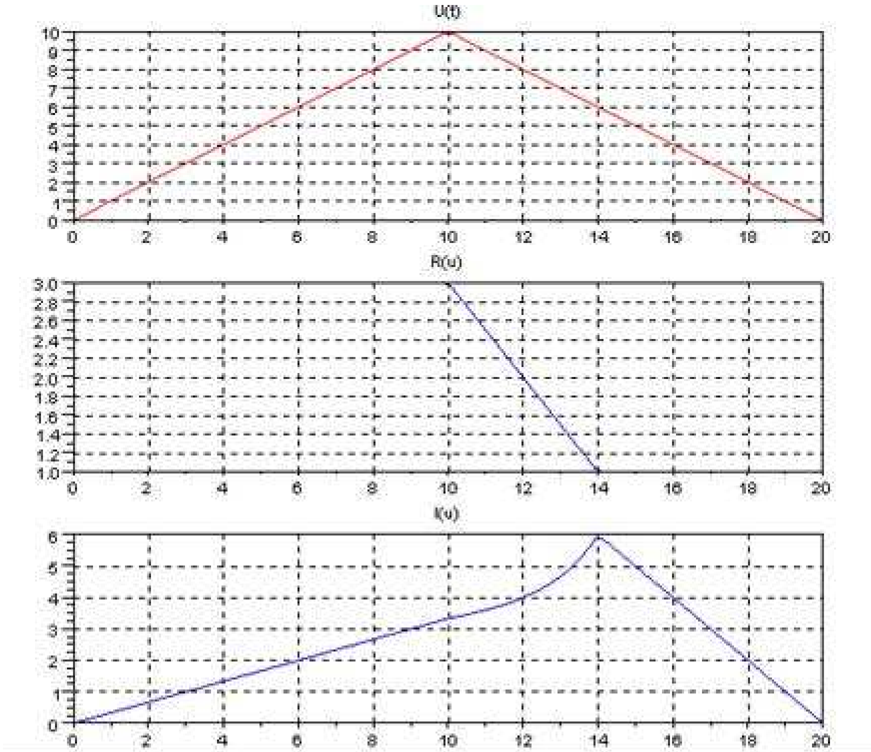
I think it is obvious that even resistance changes here overall behavior of circuit will be similar to “normal” resistance, so all power in the circuit comes from power source. Often people give this as an argument when they saying that “it’s negative differential resistance” and no power comes from it. Yes, it is true but only for this type of NDR.

Second type of negative resistance is S type.



pic3. S type negative resistance I-V characteristic

Here some more consideration required because we have to increase voltage and decrease it in order to enter negative resistance region. I tried make a simulation where voltage grows linearly and then decrease back to zero.

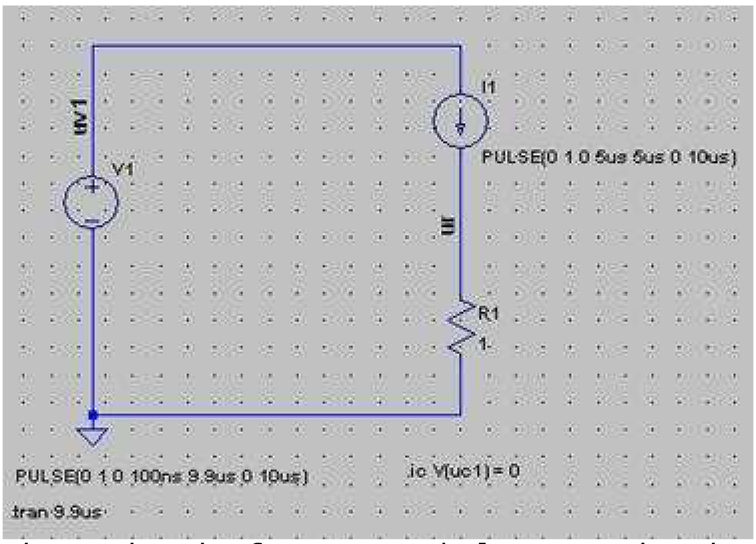


pic3a. Simulation of S type NDR, top-voltage, middle-R(U),bottom-I(U)

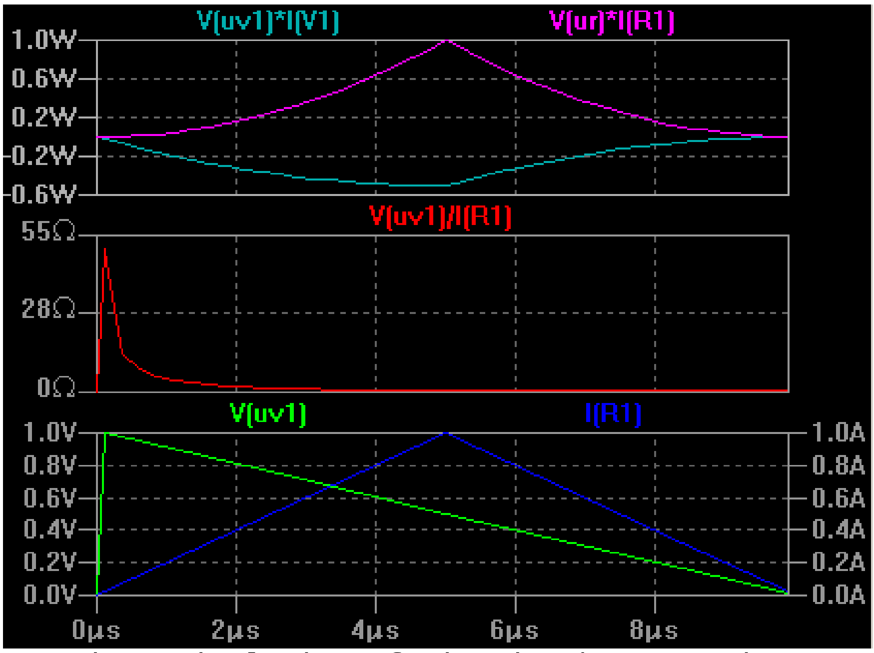
I think it is obvious that in some cases circuit with negative resistance have to deliver extra power into circuit in order to “implement” S shaped I-V curve. (Even Wikipedia admits it :-)

So theoretically, if we subject some circuit with S type NDR to short pulses we could have some extra power (Short pulses needed because we have to enter negative resistance region with a minimal energy loses).

I tried to illustrate this with the next simulation



pic4. Circuit for energy balance estimation



pic5. Simulation of circuit shown on pic.4

pic6.Energy consumed from power source

pic7. Energy on load (R1)

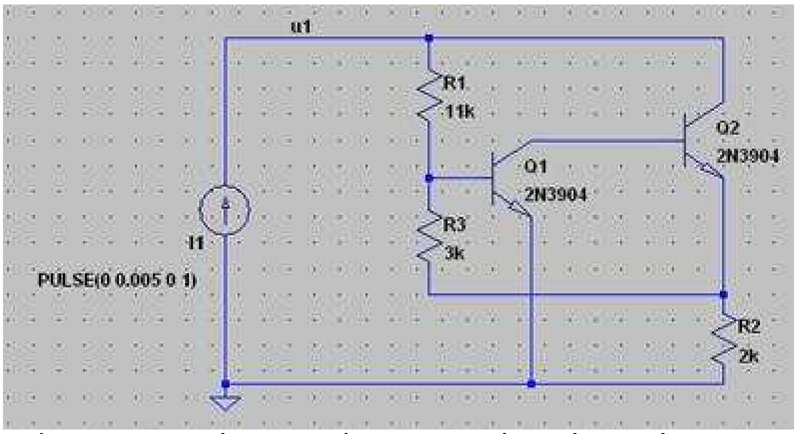
I think this is very interesting theoretical conclusion which can help us in a search for FE. There are many “natural” circuits with S shaped NDR characteristic.

I will try list different NDR circuits in next posts.

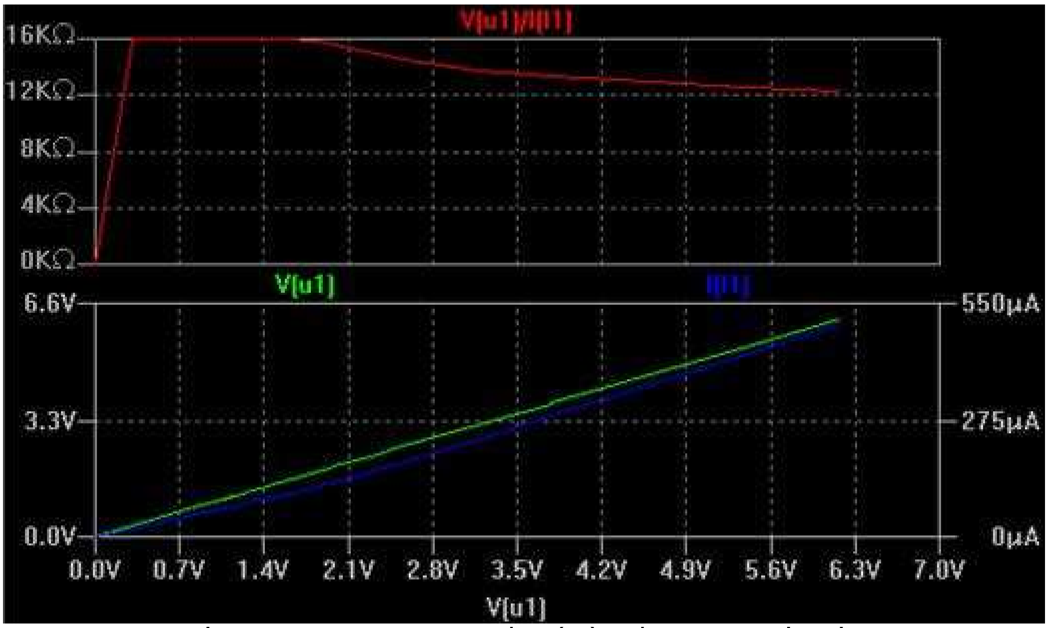
Links:
http://en.wikipedia.org/wiki/Ohm%27s_law
http://users.tpg.com.au/ldbutler/NegativeResistance.htm
http://encyclopedia2.thefreedictionary.com/S-Type+Negative-Resistance+Semiconductor+Device
http://en.wikibooks.org/wiki/Circuit_Idea/Revealing_the_Mystery_of_Negative_Impedance
http://en.wikibooks.org/wiki/Circuit_Idea/Negative_Resistance
http://www.sparkbangbuzz.com/els/zincosc-el.htm

Examples of NDR with transistors

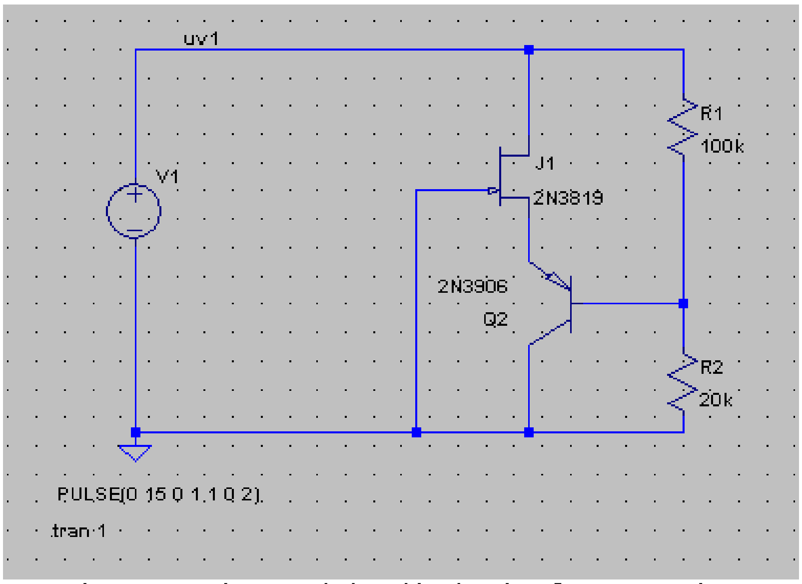
Let’s see two example circuits with “artificially” created N-shape negative resistance type.



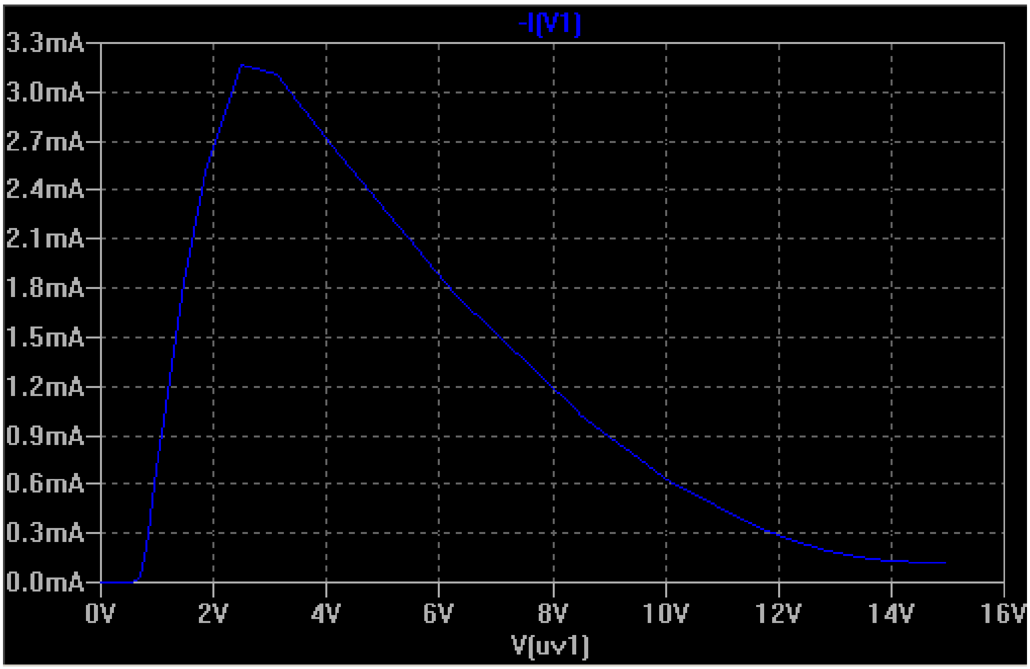
pic1. N-shape negative resistance circuit using transistors



pic2. I-V curve and R(I) characteristic



pic3. Basic Lambda diode implementation



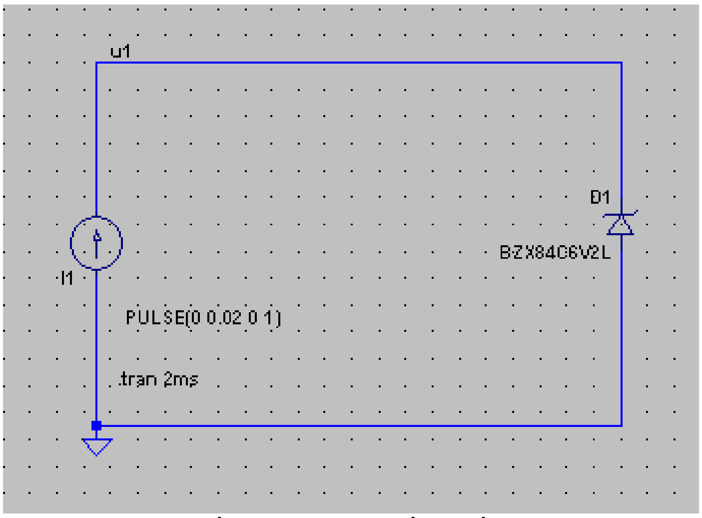
pic4. I-V curve of Lambda diode

This lambda diode replacement circuit used very often in different RF applications.

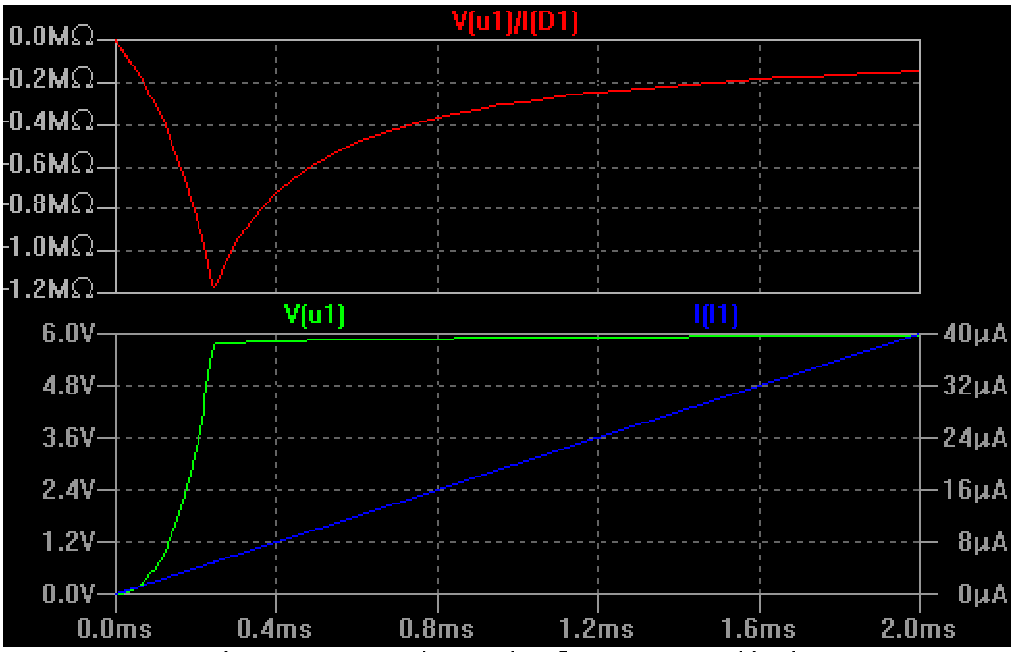
Links:
http://electronbunker.ca/NegativeResistance.html
http://www.zen22142.zen.co.uk/Theory/neg_resistance/negres.htm
http://users.tpg.com.au/ldbutler/NegResDipMeter.htm

Zener diode

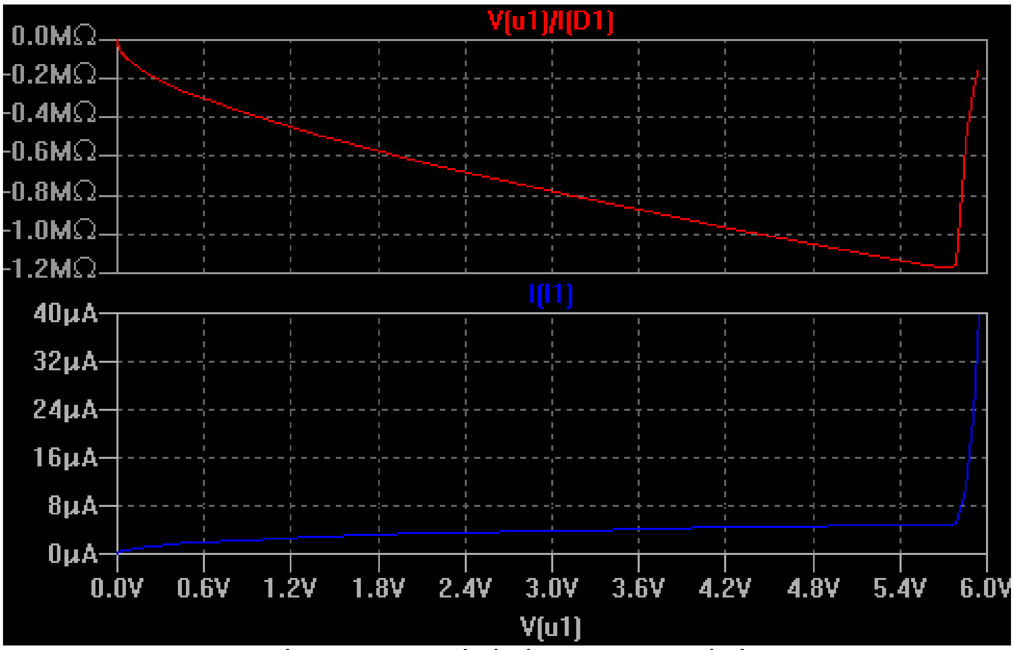
- also can be seen as an negative resistance in some cases



pic1. Test circuit



pic2. U,I and R=U/I for zener diode

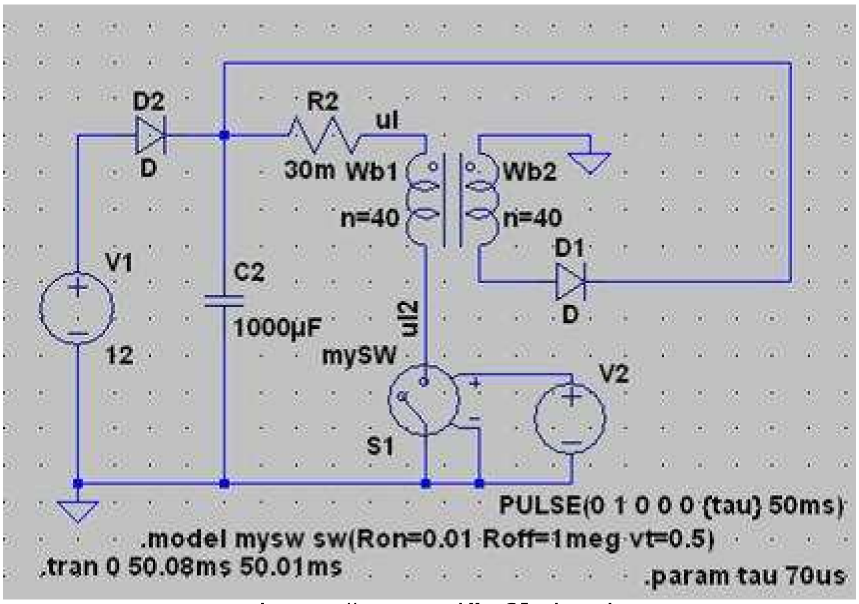


pic3. top-R(U),bottom - I(U)

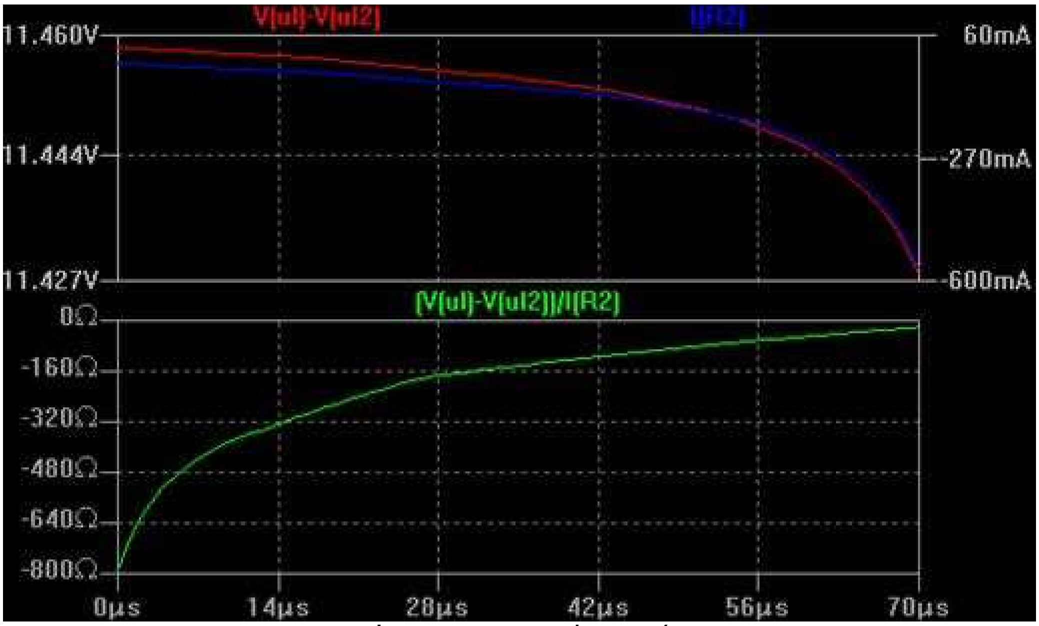
Links:
http://www.fairchildsemi.com/ds/BZ/BZX84C6V8.pdf
http://www.onsemi.com/pub_link/Collateral/HBD854-D.PDF

Core saturation

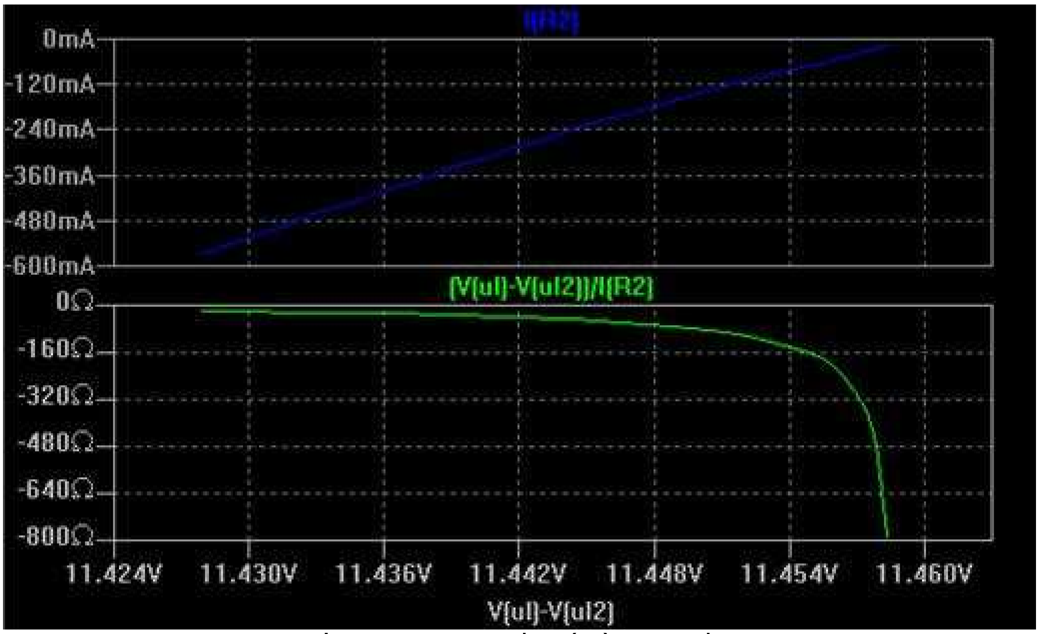
We saw that inductance decreases due to saturation; this gives us interesting natural non linear resistance behavior.



pic1. “Looped” flyback



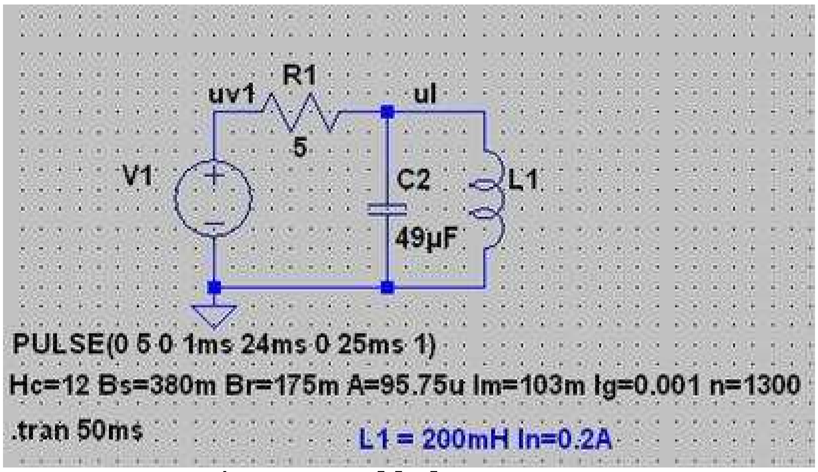
pic2. V,I and R=V/I



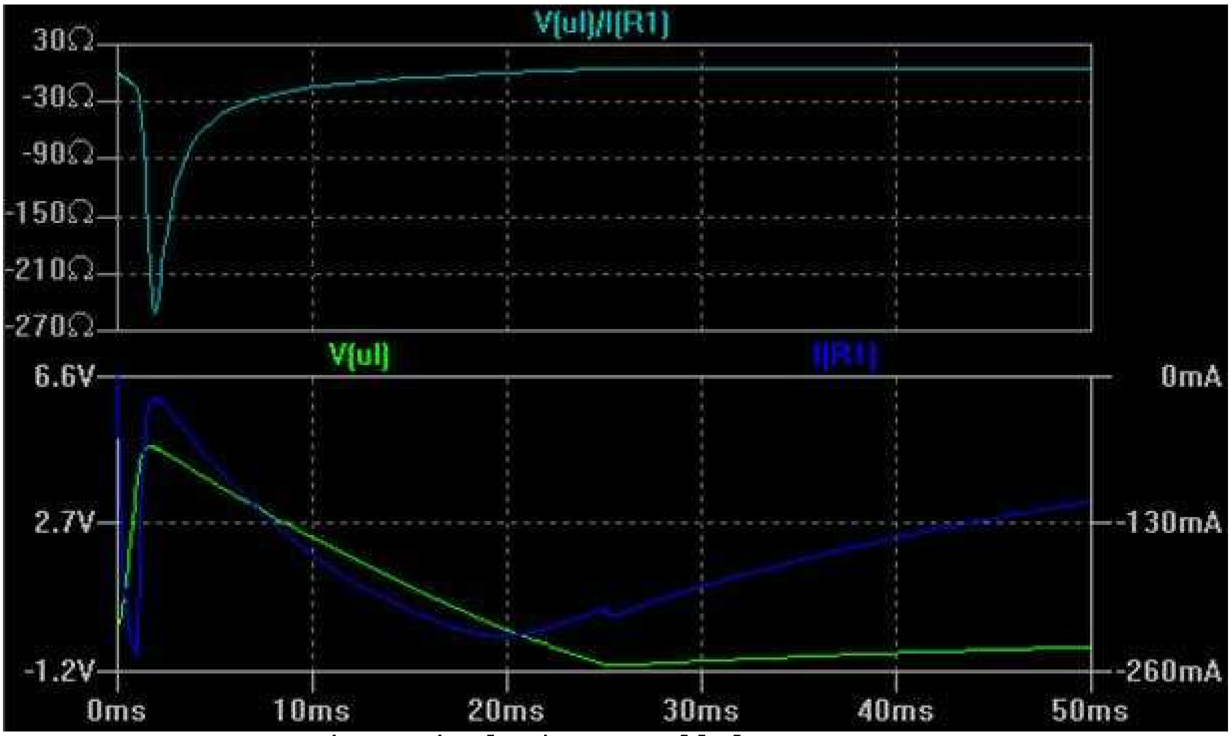
pic3. I-V and R(V) graphs

LC circuit as negative resistance

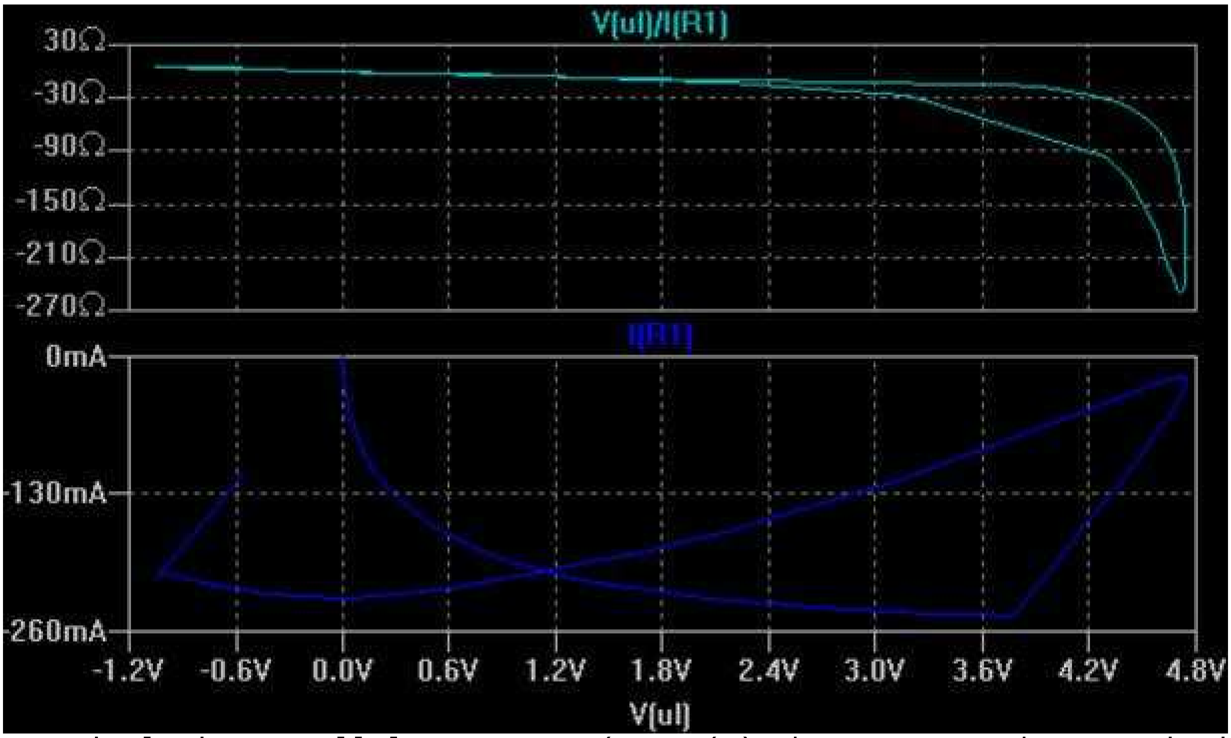
Core saturation in inductor together with capacitor can behave as negative resistance. This often causes “unwanted” oscillations in power lines and serious efforts made to prevent it.



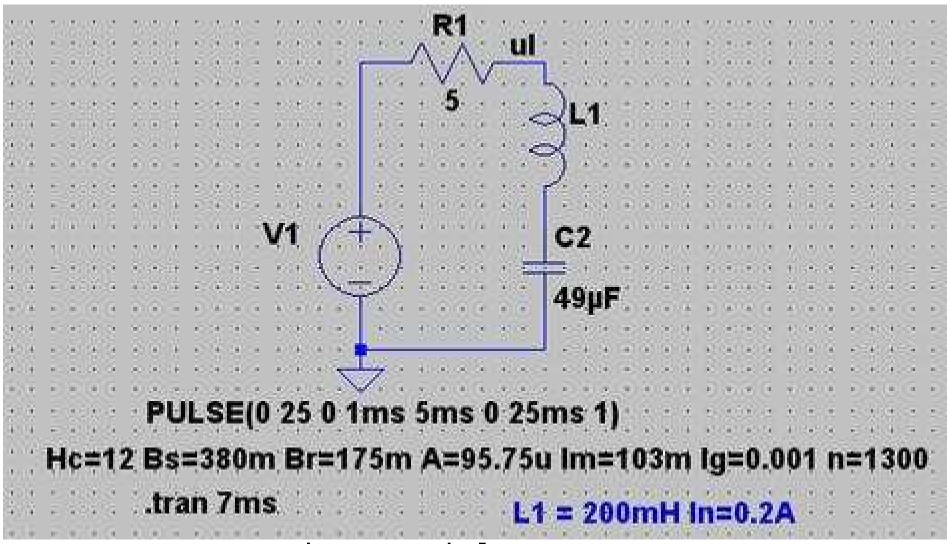
pic1. Parallel LC as NDR



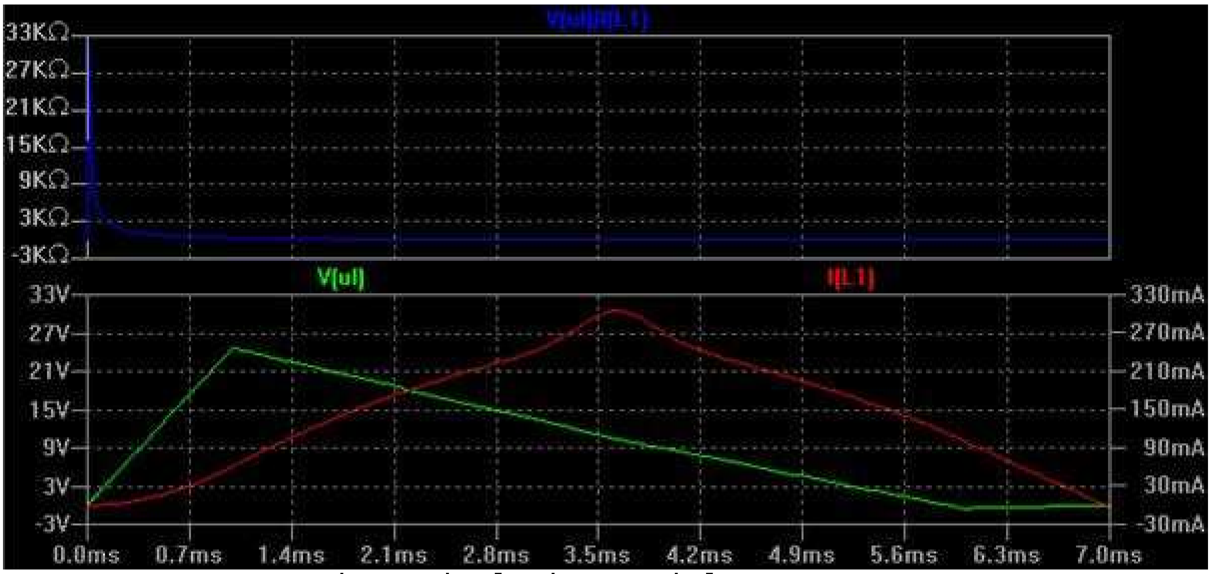
pic2. Simulating parallel LC as NDR



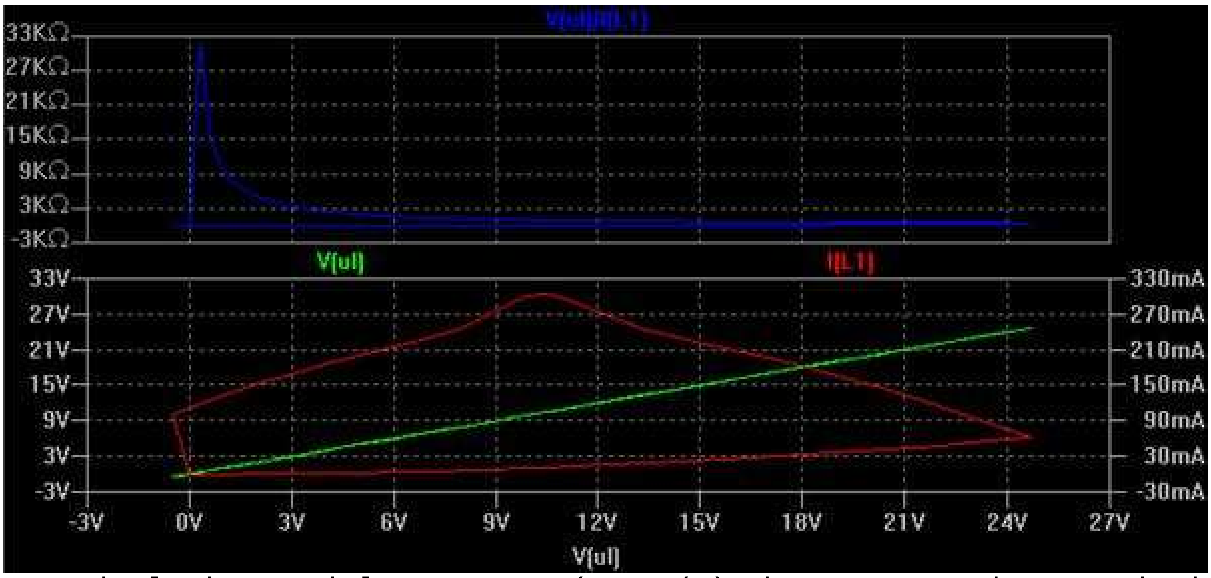
pic3. Simulating parallel LC as NDR (top-R(U), bottom- I-V characteristic)



pic4. Serial LC as NDR



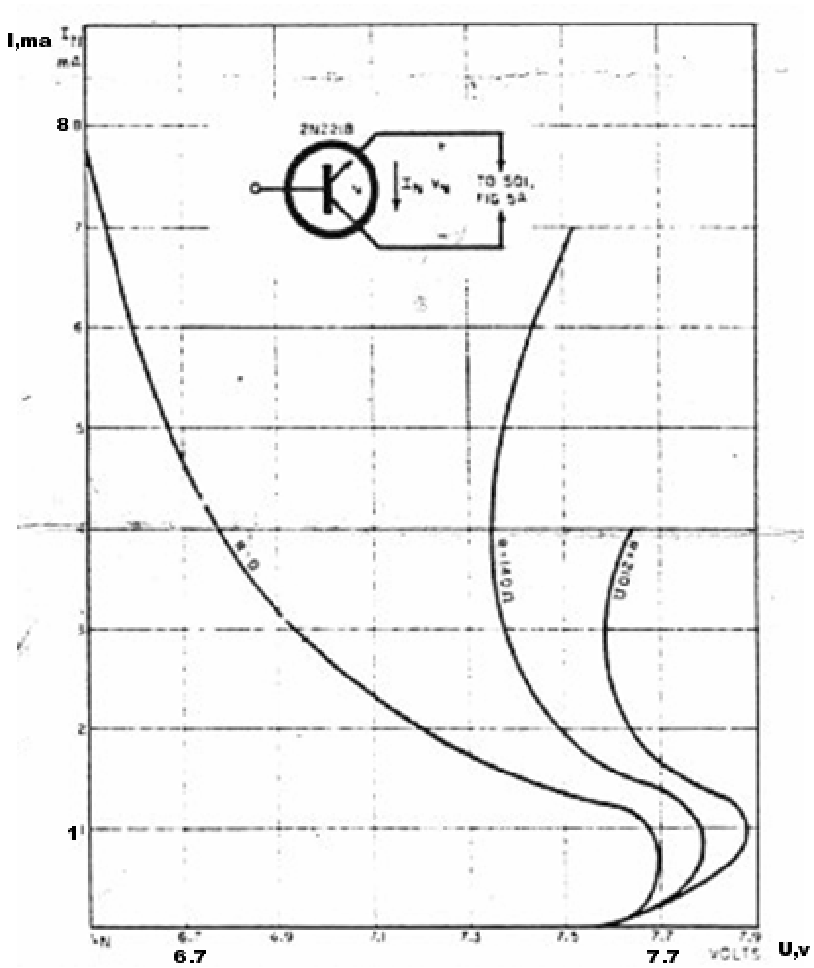
pic5. Simulating serial LC as NDR



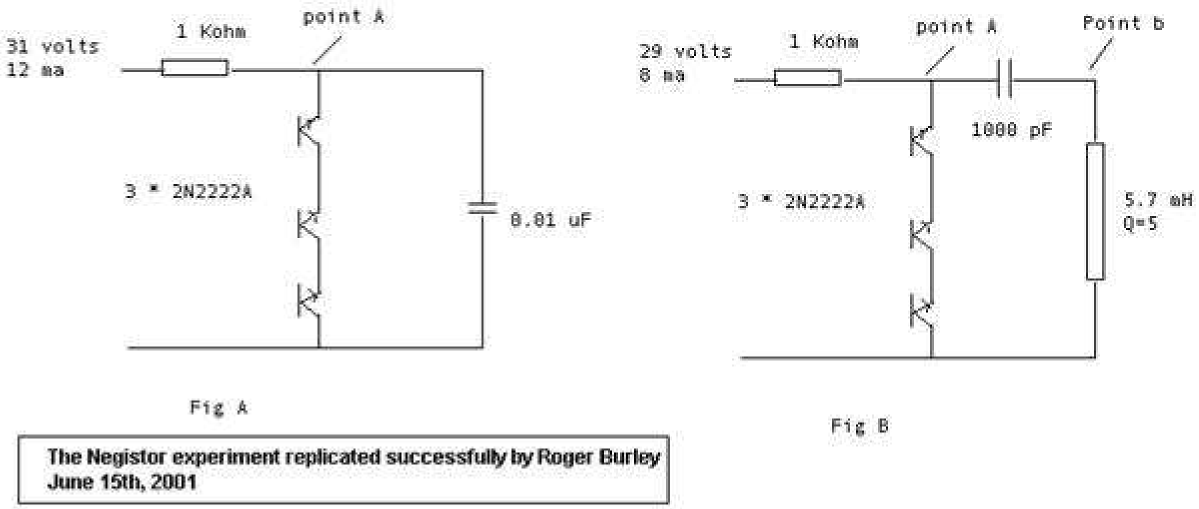
pic6. Simulating serial LC as NDR (top-R(U), bottom- I-V characteristic)

Avalanche breakdown effect in transistor

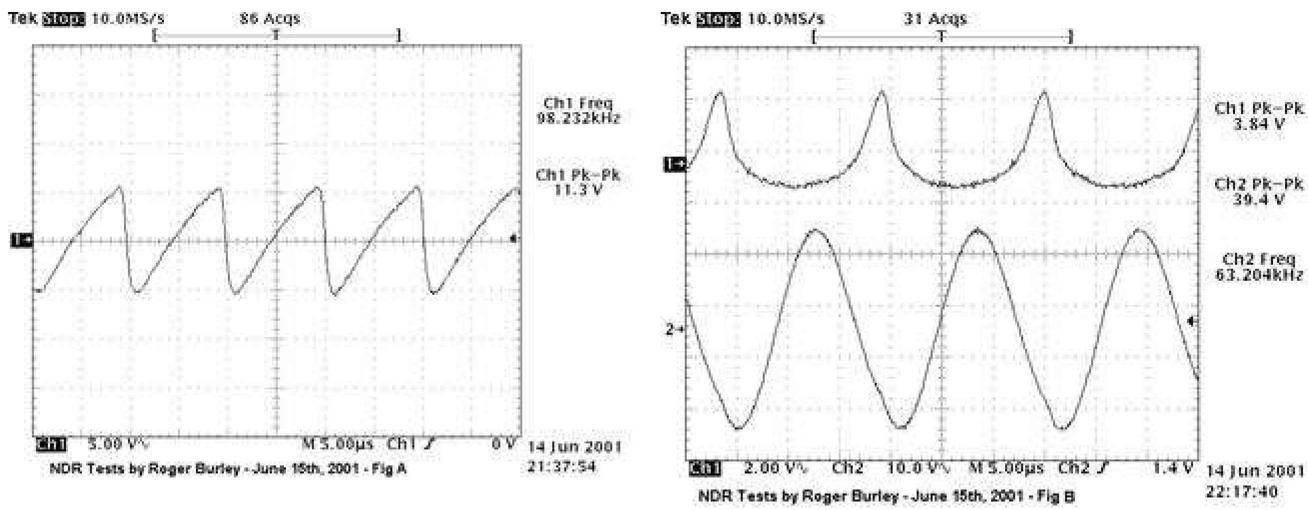
Almost any bipolar transistor can be used as a negative resistance. Below shown S type I-V curve for npn transistor. (Unfortunately can’t find any better quality picture)



pic1. I-V curve for reverse biased npn transistor



pic2. Test schematics with transistor in avalanche mode (see 1 for more details)

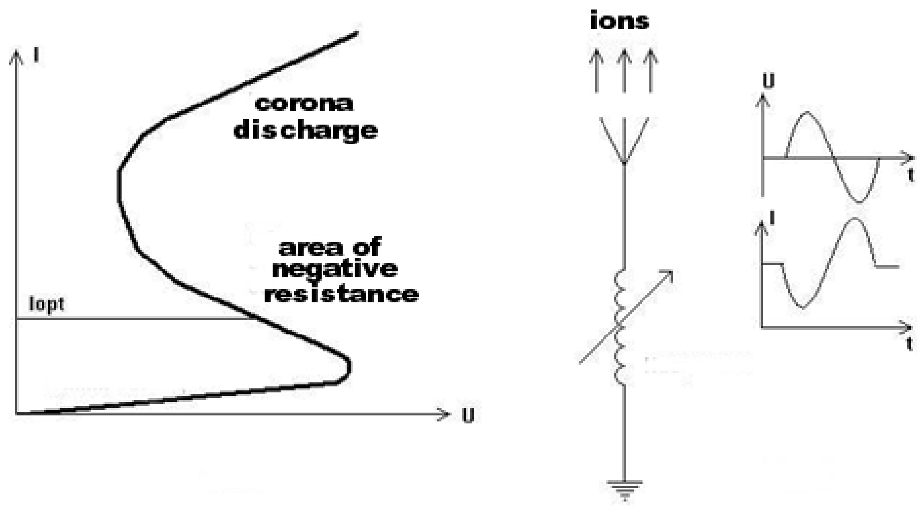


pic3. Waveforms for above circuits

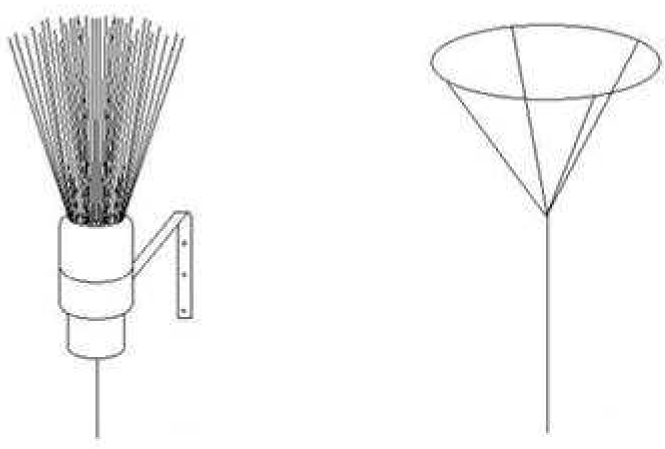
Links:
http://jlnlabs.online.fr/cnr/negosc.htm (1)
http://www.onsemi.com/pub_link/Collateral/AN1628-D.PDF
http://www.elektor.com/magazines/2012/september/electronics-for-starters-%287%29.2235967.lynkx (3)

Broomstick antenna

“Broomstick antenna is known for a very long time, since the 30s of the last century, and is sometimes still used as radio receivers for the LW and MW bands.”



pic1. The antenna has S-type NDR characteristic

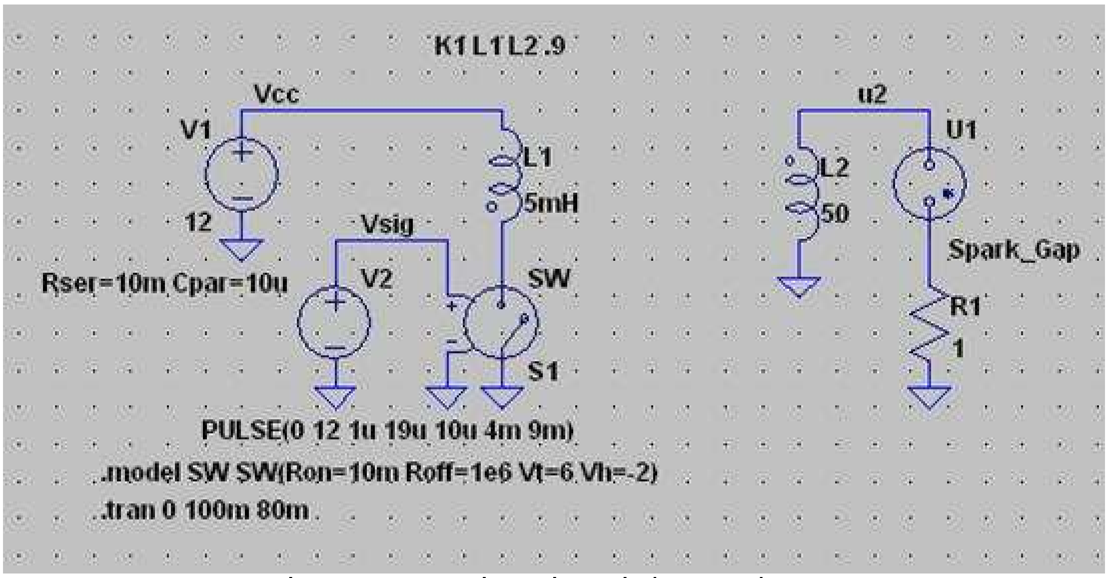


pic2. Construction of broomstick antenna

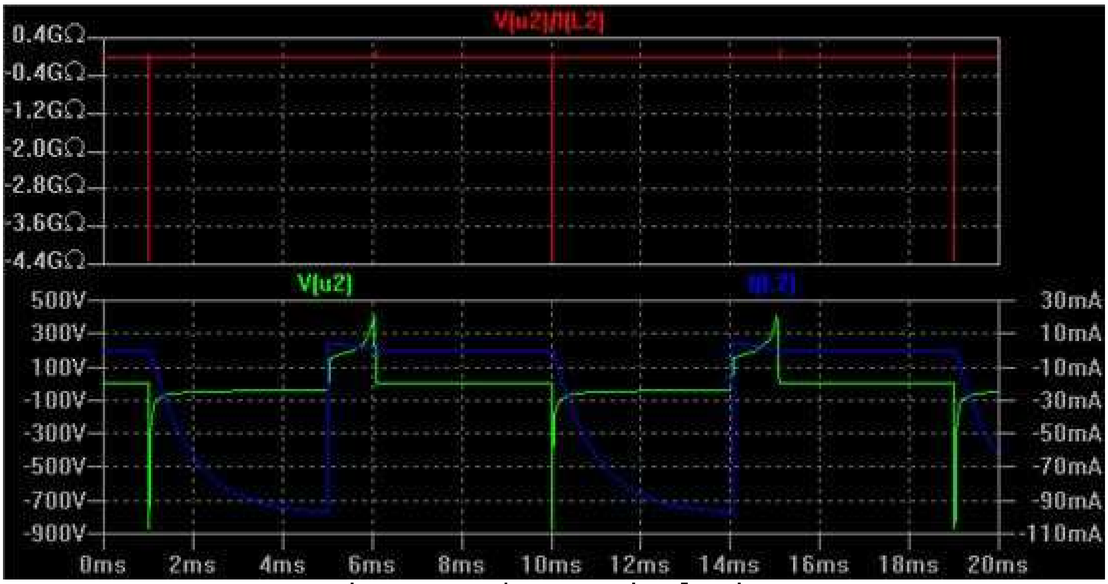
Links:
http://translate.google.com/translate?sl=ru&tl=en&js=n&prev=_t&hl=en&ie=UTF-8&u=http%3A%2F%2Fqrp.ru%2Farticles%2F56-ra3aae-articles%2F474-%D0%BC%D0%B5%D1%82%D0%B5%D0%BB%D0%BA%D0%B0&act=url
http://www.km5kg.com/negative.htm

Spark gap

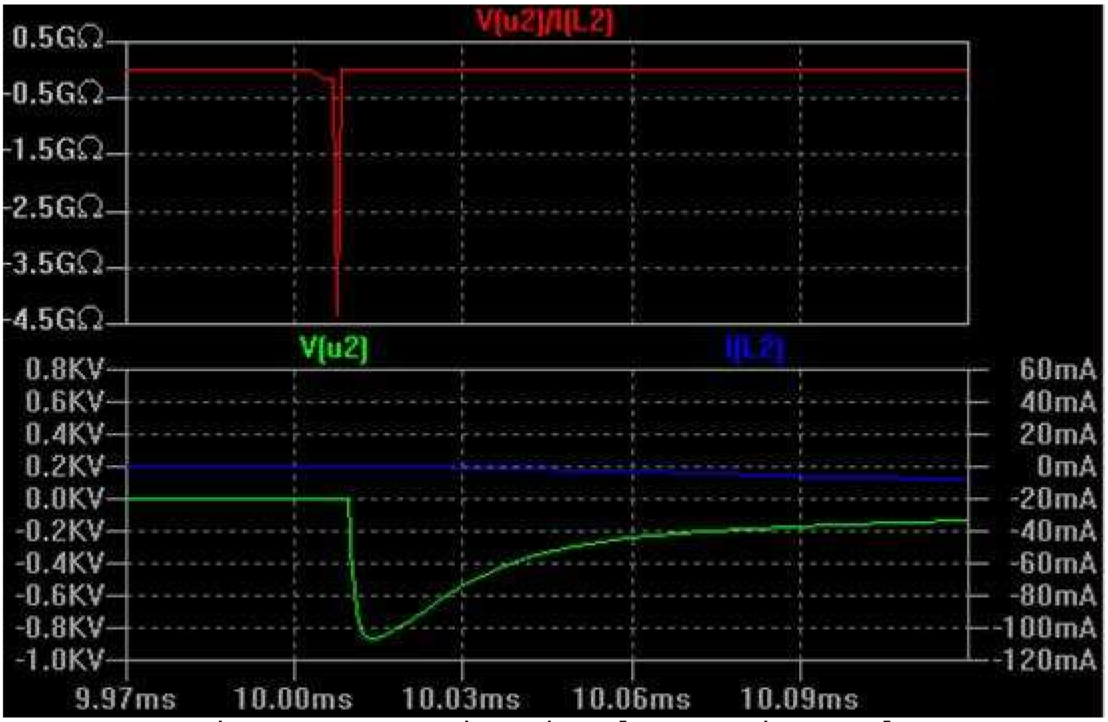
The spark gap is most common "effect" used by FE researchers since 19th century. However not many researchers recognize it as S type NDR and therefore good candidate for energy source itself.



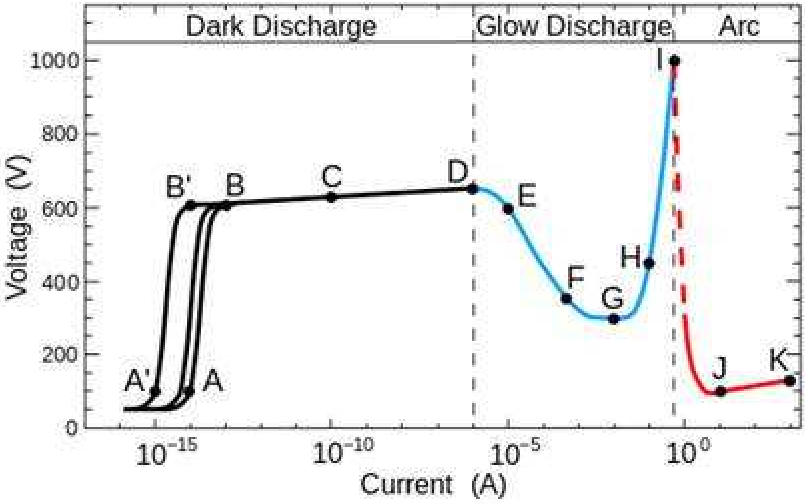
pic1. Test circuit with spark gap



pic2. Spark gap simulation



pic3. Same as pic.2 but larger time scale



pic4. Voltage versus current characteristics for neon gas (turn picture 90 degree to see S shape I-V NDR)

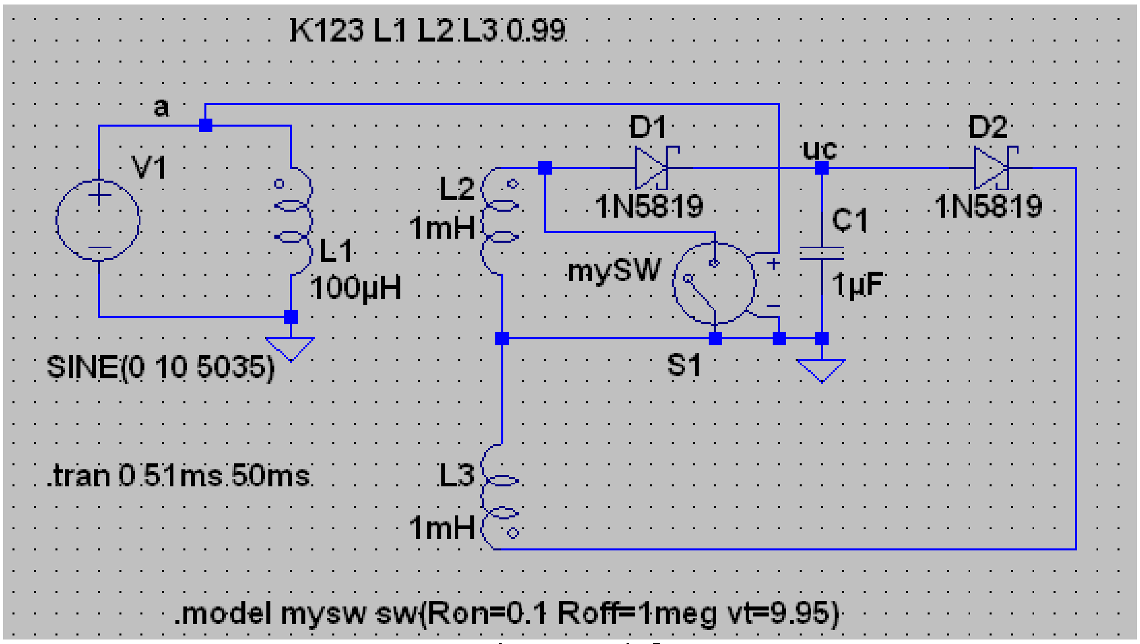
“Voltage versus current characteristics for neon gas at 1 Torr pressure between flat electrodes spaced 50 cm. A-D dark discharge, D-I glow discharge, I-K arc. A-B represent non-self-sustaining discharge and collection of spontaneously-generated ions. B-D is the Townsend region, where the cascade multiplication of carriers takes place. D-E is the transition to a glow discharge, breakdown of the gas. E-G represents transition to a normal glow; in the regions around G, voltage is nearly constant for varying current. The region G-I represents abnormal glow, as current density rises. I-J represents transition to an arc discharge.”

*picture and text from (1)

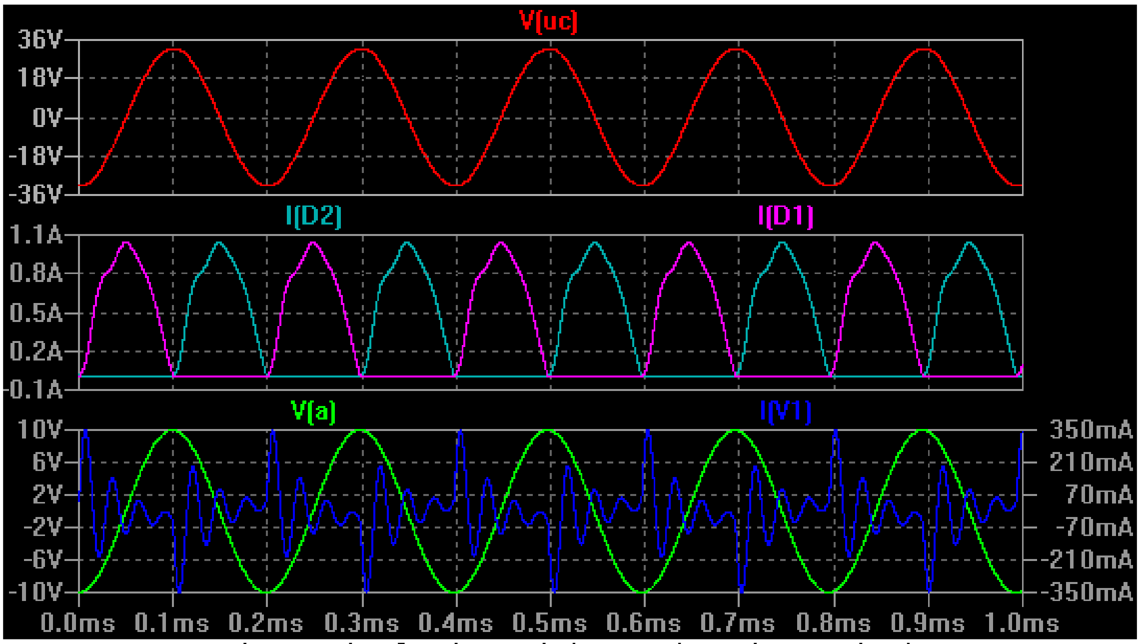
Links:
http://en.wikipedia.org/wiki/Electric_discharge (1)
http://mysite.du.edu/~jcalvert/phys/dischg.htm

Shorting

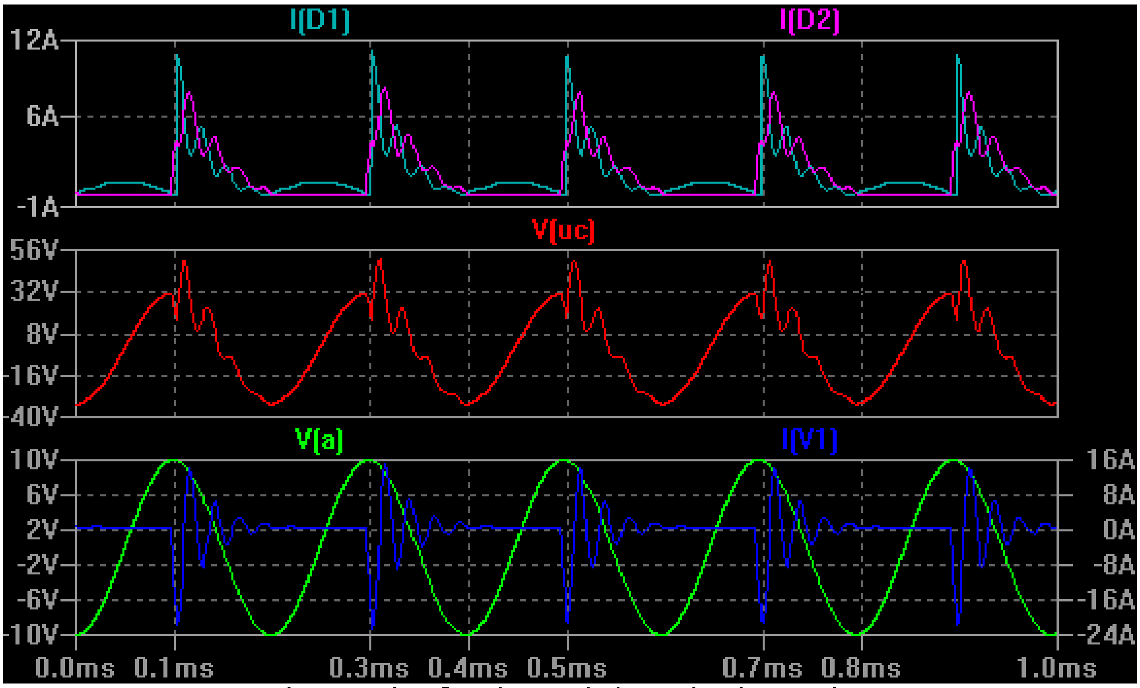
The idea of shorting transformer secondary often discussed on EVGRAY group. Shorting creates an "artificial" negative resistance and oscillations.



pic1. Model



pic2. Simulation without shorting switch



pic3. Simulation with switch active

In last posts I tried to show different types of NDR and theoretical possibility to get some extra energy. This is just an idea. I hope it helps somebody who wants research this subject deeper.

Afterword

I tried present some practical stuff and provide many theoretical links. I hope that is was interesting and you found something new and useful. This knowledge will be a “common ground” for further development. I think that we can’t build a FE device without a precise understanding how it supposed to work, so next book will be about different FE device concepts.

Software

Simulation software used in this book can be found

- LTspice IV is a high performance SPICE simulator
http://www.linear.com/designtools/software/?gclid=CLbO1aT367kCFZN8cAodRQIAMQ#LTspice

- Scilab is free and open source software for numerical computation providing a powerful computing environment for engineering and scientific applications. See www.scilab.org

Good luck!