Ferro resonance research
Lab notes 2020

Table of Contents

Introduction .................................................................................................................. 2
Setting up the stage ..................................................................................................... 3
   Bridge driver with current sources ....................................................................... 3
   Half-bridge with extra coil .................................................................................... 5
   Half-bridge with PWM .......................................................................................... 6
   Triac jumper (trigger) ............................................................................................ 7
   MOSFET jumper ..................................................................................................... 8
VA characteristic .......................................................................................................... 11
   Experimentally obtained ........................................................................................ 11
   Analytically built VA characteristics in scilab ...................................................... 12
Coils arrangement for jumper ................................................................................... 14
   Shorting .................................................................................................................. 14
   Capacitor discharge .............................................................................................. 16
Concept device 1 ......................................................................................................... 18
   Laminate core ........................................................................................................ 23
   Driver improvements (spin board) ........................................................................ 25
   Looking for resonance ........................................................................................... 27
   Weird signs of success? .......................................................................................... 29
Concept device 2 ......................................................................................................... 31
Afterword .................................................................................................................... 34
Appendix A .................................................................................................................. 35
Appendix B .................................................................................................................. 36
Appendix C .................................................................................................................. 37
Introduction

During my research I discovered and demonstrated that one most common Nature’s way to “create” energy is to perform phase transitions under different conditions. There is strong mental block to explore and use these processes, so it’s unlikely we will see any practical applications any time soon. I will not go into details here, please check references if interested.

Nevertheless I want share some information about my experiments with ferro resonance.

References:

2. “Rediscovering Zaev’s ferro-kessor” see h2e.pdf in group files or https://ferd041.files.wordpress.com/2016/04/h2e.pdf
3. Ferroresonance see fefr.pdf in group files
Setting up the stage

He I am listing some preliminary experiments which I performed, so anyone can follow the way I went to more advanced setups.

Bridge driver with current sources

pic. 2x 6.8uF capacitor not shown
pic. Waveform generator

pic. Output stage
Half-bridge with extra coil

The results are not very “exciting” (the meander gives a lot of extra harmonics)
Half-bridge with PWM

Pic. PWM generator with ATtiny26 and half bridge driver


PWM gen source code: https://github.com/vasik041/openlab/tree/master/tools/singe_pwm_v2

Half bridge schematic see in fefr.pdpf page 32

I also tried with a series capacitor - it turns out that it creates voltage divider, so I use choke (29mH) and DC isolation capacitor

Pic. trying add “jumper”
**Triac jumper (trigger)**

While it found to be working without extra triggers, adding “jumper”, device which creates abrupt increase of current at particular moment is very beneficial. I discovered two type of “jumpers” shorting and HV capacitor discharge. Will explore both.

![Pic. zero voltage corresponds to maximum current](image1)

Despite the hysteresis zero crossing detector misbehave when the triac fires and it gives extra impulses, for this I inserted 0.1uf but we need to come up with something more radical.

![Pic. Flyback for capacitor charging](image2)
a small problem was discovered with this circuit - the current does not have time to stop and the triac remains open longer than necessary.

I try laminate core trafo and load, the efficiency is not very good, but not hopeless still didn’t get jumper to work properly

**MOSFET jumper**

To not deal with synchronization of the charging of capacitor, I changed circuit to work without a triac, also using a separate winding for pulsing
Testing capacitor discharge “jumper”, choke L is 29mH

Top – voltage on capacitor 1uF
Bottom – voltage on LC

now I can change the polarity of the “ignition”
it is strange, but it looks like a plus (upper half-wave) works better

ferro resonance does not start, the half-cycle in which the “ignition” works just compresses (in time)
I also tried shorting - it doesn’t work as intended probably because primary and secondary winding are wound in two wires - there is too strong coupling between them.

At the same time, just loading the circuit in FR mode produces very good results it seems that it’s not so easy to take OU with brute force; a natural process is needed, resonance :)

Top – shorting driver control
Bottom – voltage on LC
The only problem is that the parallel circuit is poorly decoupled from the driver and when FR occurs, power consumption increases sharply. If you increase choke inductance, you need more voltage in order for FR to come, the same issue with a capacitor, we need to come up with something more radical :)

**VA characteristic**

**Experimentally obtained**

```
\begin{tabular}{|c|c|c|c|c|c|c|c|c|}
| \textbf{U in} | 4 & 8 & 16 & 25 & 40 & 50 & 58 & 58.4 & 66 |
|---------------|---|---|---|---|---|---|---|---|
| \textbf{I max} | 48 & 54 & 56 & 60 & 62 & 76 & 132 & 940 & 1040 |
| U | 58.4 & 46 & 41 & 37 |
| I | 940 & 800 & 660 & 60 |
\end{tabular}
```
Analytically built VA characteristics in scilab

pic. inductance versus current (see appendix A for source code)

pic. voltage versus current (series connection, see appendix B for source code)
pic. dependence of current on voltage (parallel connection, see appendix C for source code)
Coils arrangement for jumper

Shorting

N1 = 25  
N2 = 5  
L1 = 14mH (sec. open)  
L2 = 3mH (sec. shorted)  
Kc = 0.88

N1,2 = 33  
L = 1.2mH (sec. open)  
L = 2uH (sec. shorted)  
Kc = 1

\[
k = \sqrt{1 - \frac{L'}{L}}
\]

L'\(_p\) is the primary inductance measured with the secondary short circuited

L\(_p\) is the primary inductance measured with the secondary open circuited
pic. Trying shorting with different coils arrangement

Top – shorting driver control
Bottom – voltage on LC

Same as above, slowly increasing shorting time
Capacitor discharge

Same as above, at some point starts FR!

Top - “jumper” control
Bottom – voltage on LC

Discharge should happen at the beginning of sine (right after crossing zero voltage), not on top of sine!

(these waveforms showing incorrect timing)
Top - “jumper” control
Bottom – voltage on LC

this is better

Top - “jumper” control
Bottom – voltage on LC

and it works!

Top - “jumper” control
Bottom – voltage on LC

increasing capacitor voltage even more induce this steady mode

it can be seen that at the second half of sine high-frequency oscillations - there is a region of negative resistance
Concept device 1

Using isolated MOSFET switch for shorting.

Top – shorting driver control
Bottom – voltage on LC
Syncronizer source code and schematic: [https://github.com/vasik041/openlab/tree/master/ferd/sync](https://github.com/vasik041/openlab/tree/master/ferd/sync)
Example of synchronizer operation

Top – voltage on LC
Bottom – load connection time

It appeared that there is not much power in these oscillations. Interesting things happen when you short on the voltage rise (before a large peak)

Testing idea to connect load only during NR time – not working.

After some consideration and testing, it turned out that it is better change setup to this

Blue windings 15 turns for shorting, orange also 15 turns for synchronization

Pic. Preliminary test with new arrangement
Top – shorting driver control  
Bottom – on synchronization coil  

It looks like it works better with one winding  
there are “signs” of OU - the measurements are not stable but it is possible to get as much on the load as was spent on driver or a little more.  

I must try a large 100 watt or bigger iron transformer.  

**Laminate core**  

Finally re-wound laminate core trafo  

primary 50 turns 1.0mm L=0.5mH  
secondary around 200 turns 0.6mm L=2.3mH  

It is interesting that the resonance cannot be found by max. output voltage in such setup.
pic. instead is should be searched by minimum input current

Resonance seems to be too high and saturates very sharply, the ferrite choke goes into saturation instantly, without choke over current protection in the power supply is activated, not nice :)

22
in addition, it turned out that the resonance frequency with all the capacitors that I found (about 60 microfarads) is still much higher than 500Hz (about 700) so I have to rewind this transformer again :(

**Driver improvements (sinp board)**

Top – sine output  
Bottom – synchronized pulses with adjusted phase and width for “jumper”  
no need to use separate synchronizer board

Source code and schematic: [https://github.com/vasik041/openlab/tree/master/ferd/sinp_v2](https://github.com/vasik041/openlab/tree/master/ferd/sinp_v2)
I built modulator on TL494 and got nice D-class amplifier
Looking for resonance
pic. it turns out that at resonance we have lowest current consumption, and the voltage does not change at all

in practice, it turns out that the current consumption is approximately the same and the maximum current through the circuit at a low frequency (60Hz), strange!
It is interesting that with a smooth increase of the driver amplitude, there is a moment when the voltage of the power source rises above idle, for example 14 → 14.5v and my current meter shows current consumption 0 (although cheap chinese scale shows decent current 100ma :)

Top – voltage on LC
Bottom – LC current on 1ohm sense resistor

Same as above, more power allied
this setup allows deep saturation
Weird signs of success?

Top – voltage on LC
Bottom – PSU current

current from PSU slghtly asymmetrical (why?) and this probably cause the voltage on the power supply appears to rise above idle

Testing jumper with new setup

pic. I changed the control of HV source so that there is synchronous discharge
Top – voltage on LC

high spike from capacitor discharge

Interestingly, the oscillation frequency does not depend on the capacitor (only amplitude)
Top – voltage on LC
Bottom – LC current

“jumper” capacitor 0.47uf
after the discharge, one period the current amplitude is higher and shape is more “linear”

Still it is not clear how to benefit from this, maybe we need even higher voltage “jumper”? (this one is about 300v)

**Concept device 2**
As it was discovered earlier this arrangement is working better

pic. Case a) shorting, case b) capacitor discharge “jumper”
pic. using choke on open laminate core, it not saturating as easy as ferrite one

Top – voltage on LC
Bottom – LC current on 1ohm sense resistor

shorting coil placed between primary and secondary (blue wire)

notice that current “response” peaks are twice higher than shorting current

Top – voltage on LC
Bottom – LC current

increasing shorting time

It seems that shorting of two small winding works nice
pic. Checking driver current

Top – voltage on LC
load small bulb 24v

Bottom – half bridge output current on 1ohm resistor (LC’s ground wire)

Same as above, slowly increasing driver output
Increasing even more

To be continued...
Afterword

I challenge you to study, build and experiment with these devices. Only we ourselves together can improve our life :)
Appendix A

Scilab program to calculate inductance vs current L(I) graph

```scilab
funcprot(0);
mu0 = 1.2566370614e-6;
Af = 1e-4;
lf = 15e-2;
Nt = 30;
Bs = 0.38; //N30
Br = 0.175;
Hc = 12;
g = Bs/Br-1;
Nl = Nt;
lh = lf;

function f = Bup ( H )
    f = Bs * (H+Hc) / (abs(H+Hc)+Hc*g) + mu0*H;
endfunction

function f = Bdn ( H )
    f = Bs * (H-Hc) / (abs(H-Hc)+Hc*g) + mu0*H;
endfunction

function f = Bmag ( H )
    f = (Bup(H)+Bdn(H))/2;
endfunction

function f = H ( I )
    I = abs(I);
    if(I < 0.001) then
        I = 0.001;
    end
    f = Nl * I / lh;
endfunction

function f = muf ( I )
    f = Bmag(H(I))/(H(I)*mu0);
endfunction

function f = L ( i )
    Rf = lf / (mu0*muf(i)*Af);
    f = Nt*Nt / Rf; // + Rr + 2*Rg
endfunction

Imin=0.01;
Imax=1;
N = 1000;
idata = linspace ( Imin, Imax, N );
l_data = zeros(1,N);
muf_data = zeros(1,N);
for i=1:N
    l_data(i) = L( idata(i) );
    muf_data(i) = muf( idata(i) );
end
clf();
subplot(111); a=get("current_axes"); a.grid=[1,1];
plot ( idata , l_data, "r");
xtitle("L(i)")
```

Appendix B

Scilab program to calculate voltage vs current U(I) graph

```scilab
funcprot(0);
mu0 = 1.2566370614e-6;
Af = 1e-4;
lf = 15e-2;
Nt = 300;
f = 50;
w = 2*%pi*f;
C = 35e-6;

Bs = 0.38; //N30
Br = 0.175;
Hc = 12;
g = Bs/Br-1;
Nl = Nt;
lh = 1/f;

function f = Bup ( H )
f = Bs * (H+Hc) / (abs(H+Hc)+Hc*g) + mu0*H;
endfunction

function f = Bdn ( H )
f = Bs * (H-Hc) / (abs(H-Hc)+Hc*g) + mu0*H;
endfunction

function f = Bmag ( H )
f = (Bup(H)+Bdn(H))/2;
endfunction

function f = H ( I )
I = abs(I);
if(I < 0.001) then
  I = 0.001;
end
f = Nl * I / lh;
endfunction

function f = muf ( I )
f = Bmag(H(I))/(H(I)*mu0);
endfunction

function f = L ( i )
Rf = 1f / (mu0*muf(i)*Af);
f = Nt*Nt / Rf; // + Rr + 2*Rg
endfunction

Imin=0.001;
Imax=0.05;
N = 1000;

idata = linspace ( Imin, Imax, N );
lu_data = zeros(1,N);
cu_data = zeros(1,N);
u_data = zeros(1,N);

for i=1:N
  lu_data(i) = L( idata(i) ) * w * idata(i);
  cu_data(i) = idata(i) / ( C * w );
  u_data(i) = abs(cu_data(i) - lu_data(i));
end
```
Appendix C

Scilab program to calculate inductance vs current L(I) graph

funcprot(0):

mu0 = 1.2566370614e-6;
Af = 1e-4;
lf = 15e-2;
Nt = 300;
f = 50;
w = 2*%pi*f;
C = 35e-6;
Bs = 0.38; //N30
Br = 0.175;
Hc = 12;
g = Bs/Br-1;
Nl = Nt;
lh = lf;

function f = Bup ( H )
    f = Bs * (H+Hc) / (abs(H+Hc)+Hc*g) + mu0*H;
endfunction

function f = Bdn ( H )
    f = Bs * (H-Hc) / (abs(H-Hc)+Hc*g) + mu0*H;
endfunction

function f = Bmag ( H )
    f = (Bup(H)+Bdn(H))/2;
endfunction

function f = H ( I )
    I = abs(I);
    if(I < 0.001) then
        I = 0.001;
    end
    f = Nl * I / lh;
endfunction

function f = muf ( I )
    f = Bmag(H(I))/(H(I)*mu0);
endfunction

function f = L ( i )
    Rf = lf / (mu0*muf(i)*Af);
    f = Nt*Nt / Rf; // + Rr + 2*Rg
endfunction

function f = Lu ( u )
    x = linspace(0.001, 0.1, 1000);
z = x(1000);
for j=1:1000
    if L( x(j) ) * x(j) * w >= u then
        z = x(j);
        break;
    end
end
f = L(z);
endfunction
Umin=0.01; Umax=3.1;

N = 1000;

udata = linspace ( Umin, Umax, N);
li_data = zeros(1,N);
cl_data = zeros(1,N);
i_data = zeros(1,N);

for i=1:N
    li_data(i) = udata(i) / ( Lu(udata(i)) * w);
    cl_data(i) = udata(i) * C * w;
    i_data(i) = abs(cl_data(i) - li_data(i));
end

clf(); subplot(111); a=get("current_axes"); a.grid=[1,1]; plot ( udata , li_data, "r"); plot ( udata , cl_data, "b"); plot ( udata , i_data, "g"); xtitle("i(u)");