Wireless 50 Watt Transmission **Draft 1.4**

P.A. Neukomm, Sept 8th, 2015

1. Introduction and Material

The purpose of the project is the wireless charging of a battery of an e-bike. The system consists of a 200kHz oscillator with a rectangular waveform, a serial resonance coils system and a load of 51 Ohm The transmitted power at 5mm distance is about 52-61 Watt, the total efficiency about 80-90 %.
The development of a power oscillator is a time consuming job. Oliver Knecht at PES, ETH-Z proposed to use a LM5045 Full-Bridge PWM Controller. There is an evaluation board available for DC-DC conversion 36V/3.3 V with 30 A output current and 92 % efficiency. The modifications were to bypass the internal transformer by our coil system and to open the PWM control loop in order to obtain a 50 % PWM source, see Fig. 1 and 2.
The coils system consists of two coils Mouser AWCCA-53N53H50-C01-B, separated by a 5mm Teflon plate. The serial resonance was achieved by low loss 16.8 nF capacitors.
Many thanks also to Nico Karrer, Kametech AG, who is an expert in broadband current sensors!

2. Test Setup and evaluated data

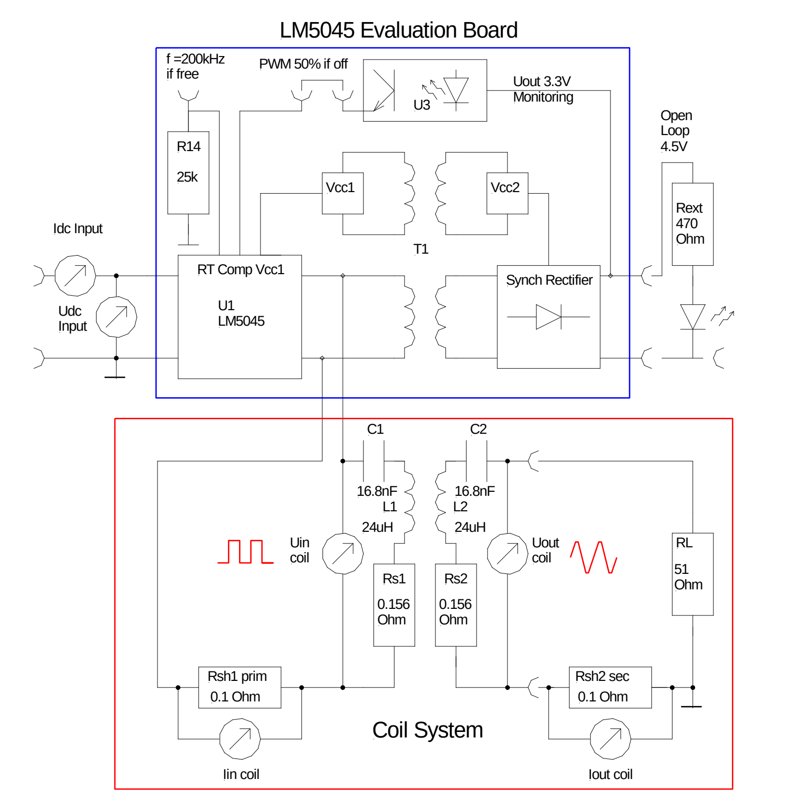


Fig. 1: System Overview
Coils: AWCCA-53N53H50-C01-B, Q=170
L=24 uH, Serial loss resistance=0.156 Ohm, nom. 5.7 A

Parameter	A	B	Unit
Coil distance	5.0	5.0	mm
Rload	51.0	51.0	Ohm
Rshunts	0.1	0.1	Ohm
Udc	36.0	36.0	V
Idc	1.8	1.9	A
Pdc	66.4	69.5	W
Uin coil	34.5	34.5	V
Iin coil	1.5	2.1	A
Pin coil	52.6	72.6	W
Uout coil	53.9	53.9	V
Iout coil	1.0	1.1	A
Pout coil	52.0	60.9	W
Coil Efficieny	98.8	83.9	%
Idle Current	46.0	46.0	mA
Idle Power	1.7	1.7	W
Real Input Power	64.7	67.8	W
Real Efficiency	80.3	89.8	%

Current measuring methode:
A: Urms at shunt 0.1 Ohm
B: Urms at current sensor shunt

Fig. 2: Evaluated data
Important: DVM with True RMS reading, calibrated for 200 kHz

3. Coil System

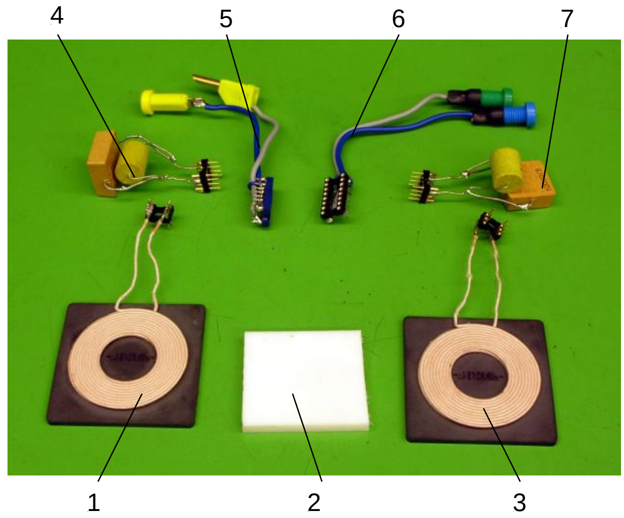


Fig. 3: Coil system
1.: Primary coil, 24 uH
2: Teflon 5 mm
3: Secondary coil, 24 uH
4: Primary serial capacitor
16.8 nF, low loss
5: Input Plug
6: Output plug
7: Secondary serial capacitor
16.8 nF, low loss
Coils:
AWCCA-53N53H50-C01-B, Q=170
Rs=0.156 Ohm@200 kHz
Rdc=0.072 Ohm
I=5.7 Arms
SRF=2.8 MHz

4. Power Oscillator

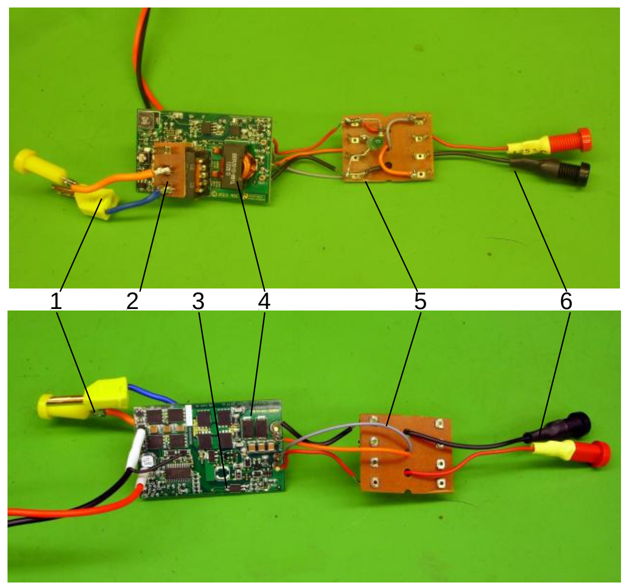


Fig. 4: Power Generator
Upper and lower side
1: DC-Supply Input
min. 36 V, max. 75 V.
2: Bypass connector at internal transformer T1, Pin 2 and 5.
3: Opto Coupler PS2811-1-M-A
DISABLED!
Emitter Pin 3 disconnected
for 50 % PWM.
4: EVA LM5045.
5: DC Output terminal with LED
and Output Voltage control
Pin P5 and P6.
6: 3.3 V DC out if Opto coupler
ENABLED.

5. Resistive Loads

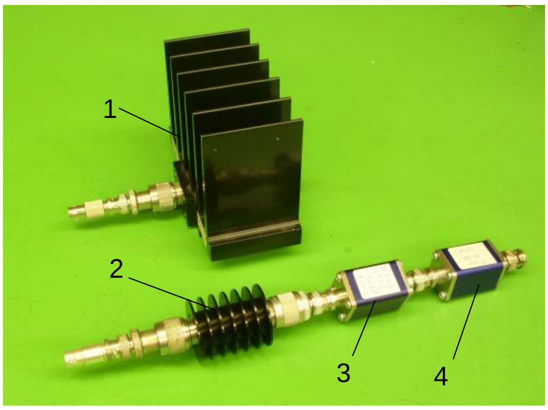


Fig. 5: Resistive Loads
1: 150 Watt 30 dB Attenuator
Rin = 51 Ohm if Output open
Ok for 100 W without cooling.

2: 50 Watt 3 dB Attenuator
3: 4 Watt 20 dB Attenuator
4: 4 Watt 40 dB Attenuator
Rin = 48.7 Ohm if Output open.
Attention: max 8 W Input ok!

6. Current Transformer, Shunts and True RMS DVM

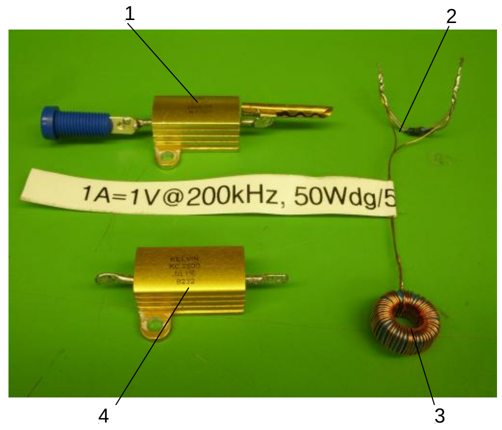
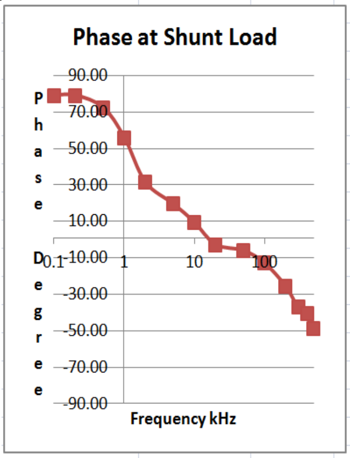


Fig. 6: Current transformer and shunts
1,4: Shunt 0.1 Ohm, 25 Watt
Measured data at 200 kHz:
Ls=49 nH; Rs=0.083 Ohm or
Z= 0.103; Phi 36 ^{0}
2: Transformer Shunt 53.3 Ohm
3: Transformer 1:50,
Ferrite B6429-L45-X27
50 turns with Cu wire D=0.8 mm
Ferrite material ok for frequencies below 100 kHz



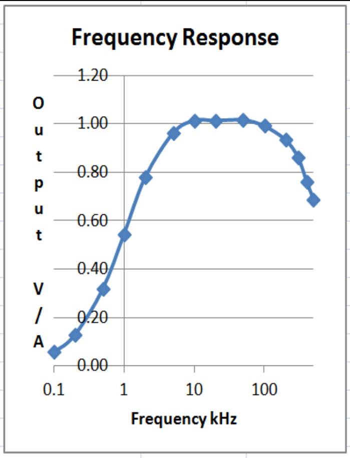


Fig. 7: Specification of the Current Transformer.
Test with sinusoidal currents of 0.5 A at 0.1 kHz to 500 kHz, shunt load 50 Ohm. Correction factor 0.93@200 kHz.

The V/A ratio with a shunt load of 53.3 Ohm is 1V/1A @ 200 kHz, phase 25 ^{o}.

A comparison with the current probe Texas P6128 with signal processing by a Tektronix scope shows the same RMS reading +/-0.2 %!

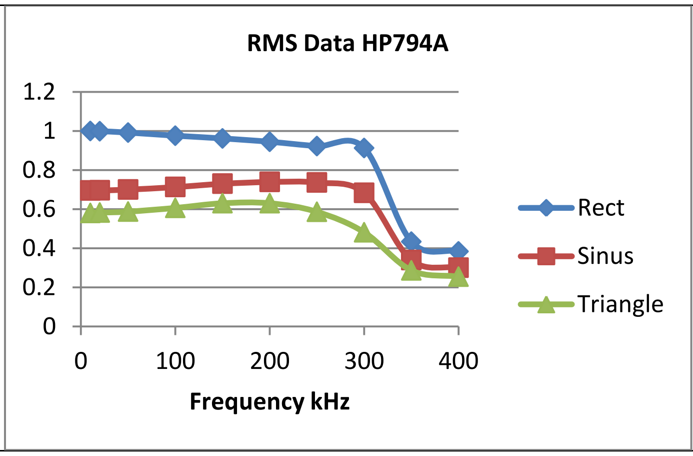


Fig. 8. Specifications of the DVM HP794A for rectangular, sinus and triangle signals

Correction Factor Real/Theory			
Freq kHz	Rectangular	Sinus	Triangle
200	0.945	1.047	1.094

7. Waveforms Coil Input and Coil Output with serial Shunt 15 Ohm at the input of the coil system

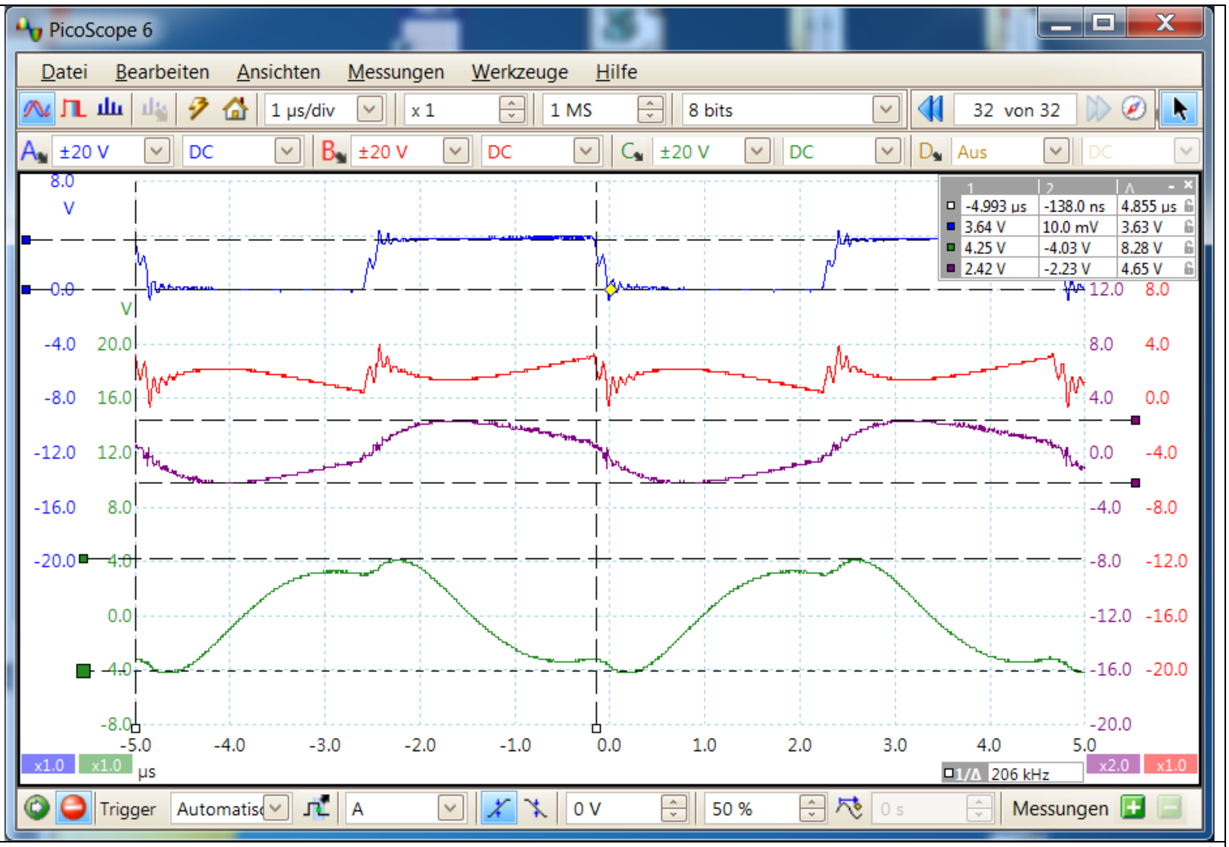


Fig. 9: Experimental Results with a load of 48.7 Ohm and serial input shunt 15 Ohm
Top A: Driver Voltage at the input of the serial Shunt 15 Ohm.
Middle top B: Coil Voltage at the output of the serial Shunt 15 Ohm.
Middle below: A-B, differential shunt voltage, waveform of the coil input current.
Bottom C: Output voltage at a load of 51 Ohm
Note 1: all Probes 10x, thus multiply all recorded amplitudes by a factor of 10!
Note 2: A differential voltage measurement A-B at a serial Shunt < 15 Ohm is not possible, EMC!

8. Overview Test Setup

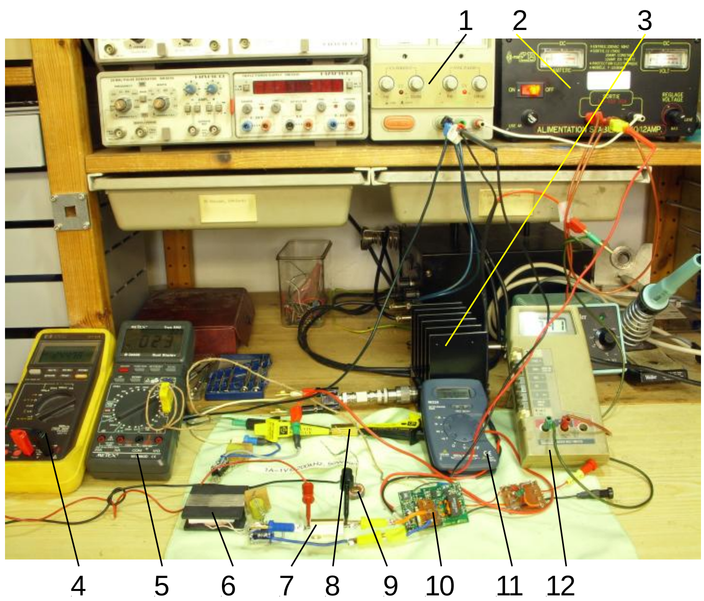


Fig.10: Test Setup
1,2: DC Power Supply 36 V, max. 5 A.
3: Load 51 Ohm, max 150 Watt
4: DVM True rms for shunt and AC input/output voltages measurement.
5: Temperature at EVA, max. 30 °C.
6: Coil System, 5 mm distance.
7: Input Shunt 0.1 Ohm.
8: Output Shunt 0.1 Ohm.
9: Current Transformer I in and I out.
10: EVA LM5045 Power Oscillator.
11: DC Input Voltage, 36 V.
12: DC Input Current, 1.84 A.

Transmitted Power: 52-60 W
DC-AC Efficiency: 80-90 %

9. Experiment with Low Power Signal Generator

Top: Source 50 Ohm Low Power Generator, +/-20V

Middle: Voltage at input Shunt 1 Ohm, +/-0.5 V, 1 V=1 A

Below: Output at 50 Ohm 20 dB Attenuator load, +/-2 V

Fig. 11a: 200 kHz

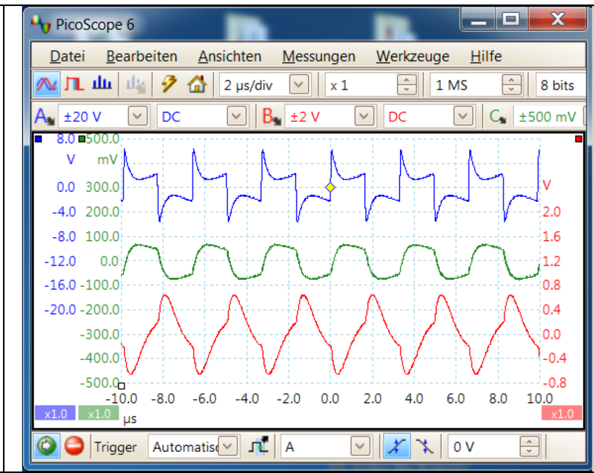


Fig.11b: 300 kHz

10. Simulations

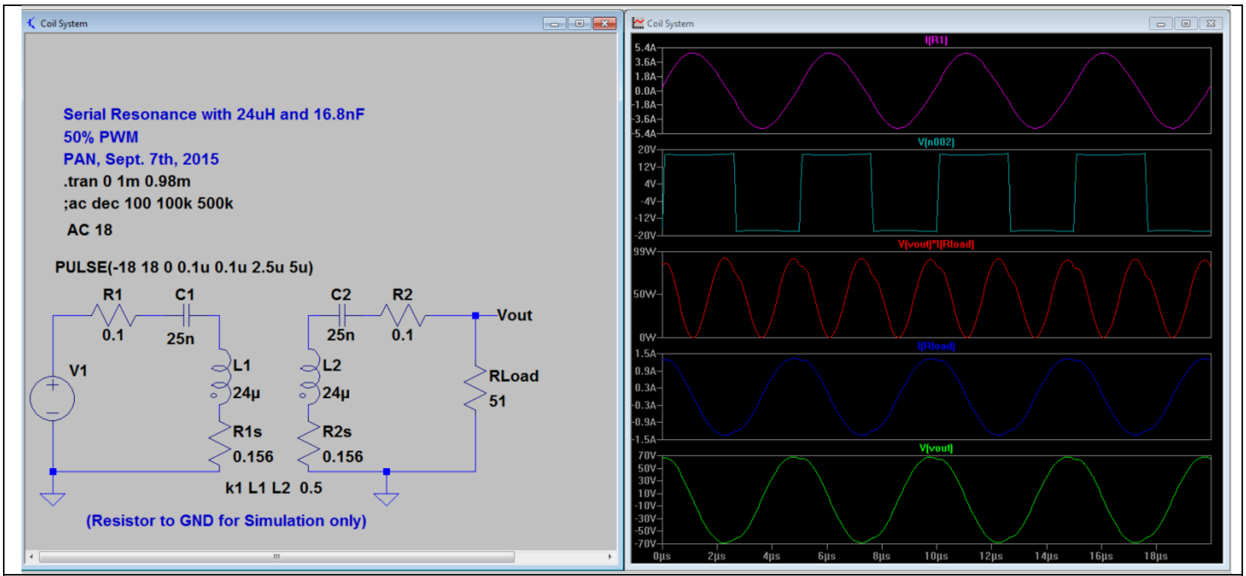


Fig. 12: Simulation with C1,2= 25 nF, Coupling k=0.5

Fits more or less with the experiment: Pout about 50 Watt

11. Conclusion

Wireless Power Transmission of about 50-60 Watt to a 51 Ohm Load is possible with an efficiency of about 80-90 %. The distance of the coils might be extended to about 20 mm, and matching to other loads should be possible, perhaps by PWM loading control at the power receiving side.

A power oscillator can be built with the LM5045 driver, 4 nMOSFET and a few SMD components, material cost about USD20. However, a multilayer PCB has to be carefully designed.

A challenge is the measuring method, up to now only DVM with True RMS reading and the calibrated current sensor gives proper data. An oscilloscope voltage recording at the 0.1 Ohm Shunt resistors failed because of severe EMC problems and also because of the inductivity of the Shunt.