Integration of piezo contol with ATCA system

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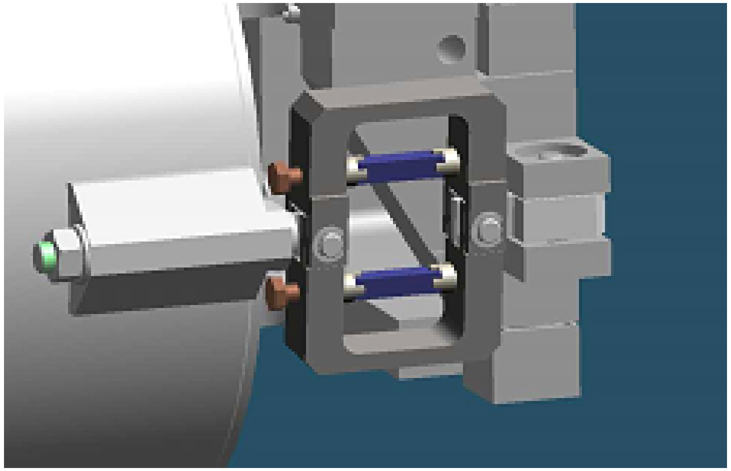
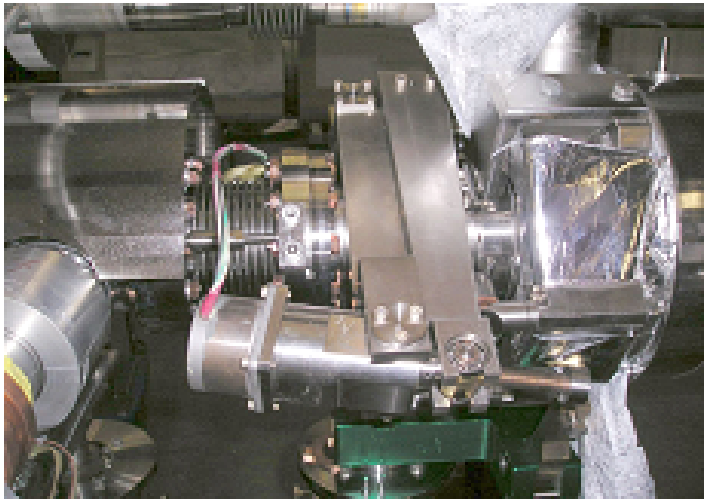
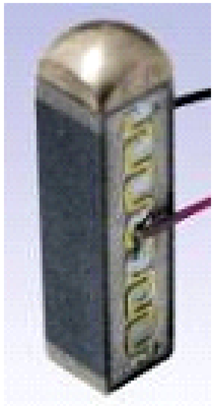
Goal of Piezo Control system

- Drive the piezoelements assembled in fast tuners frames to minimize the Lorentz force and microphonics effects
- On-line frequency detuning calculation
- Microphonics measurement (i.e. diagnostics of cryogenic system)





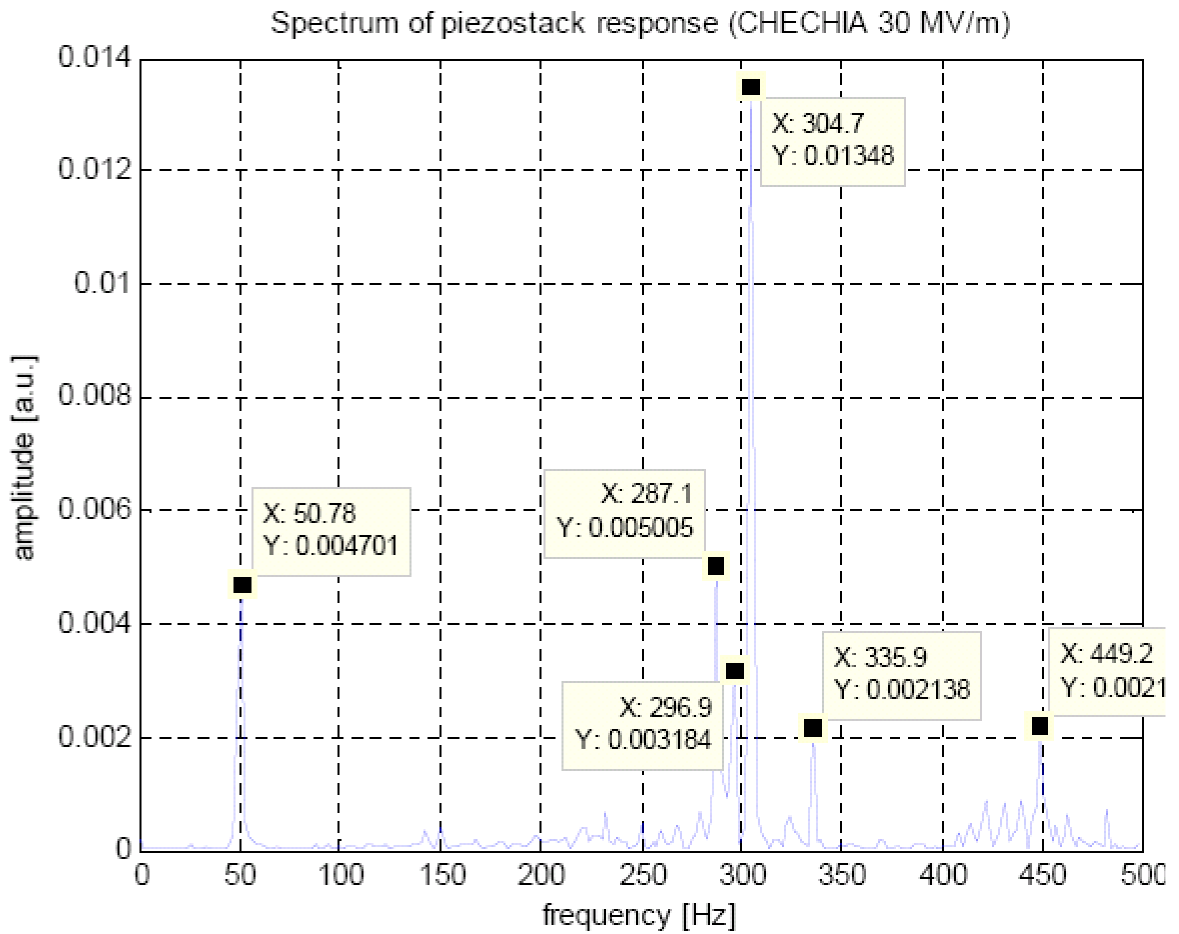


Dimensions: **10x10x30mm**
Manufacturer: **NOLIAC**

Dimensions: **10x10x36mm**
Manufacturer: **PI**

Deriving requirements

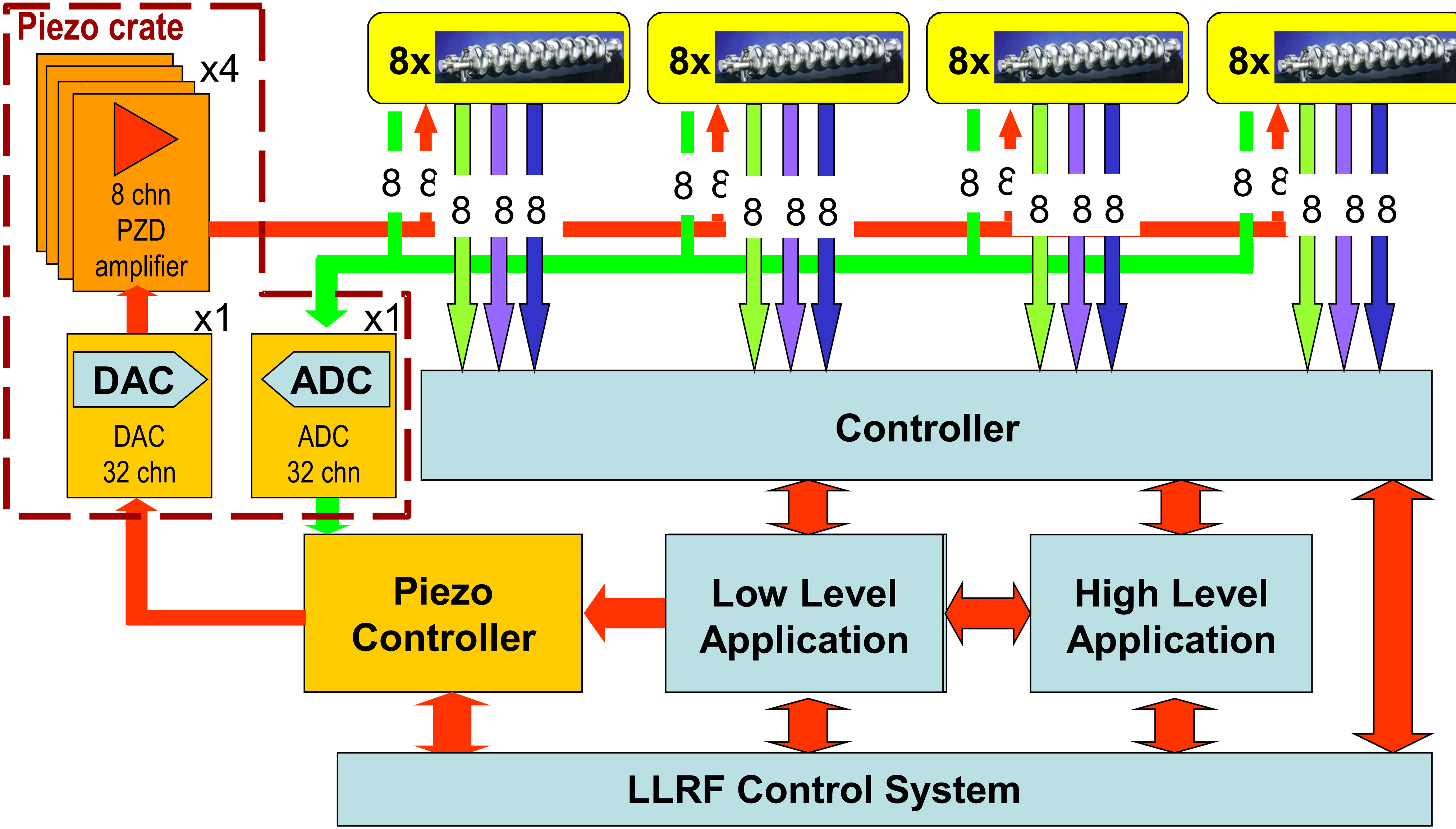
- cavity
  - several mechanical resonances around 200-300Hz
- piezo
  - capacitive load (about 5 μF)
  - ~100V driving signal
- long cables (several tens meters)
- $I=\omega CU$
  - 5 μF, 300Hz, 100V => I=1A



General requirements of Piezo Control system

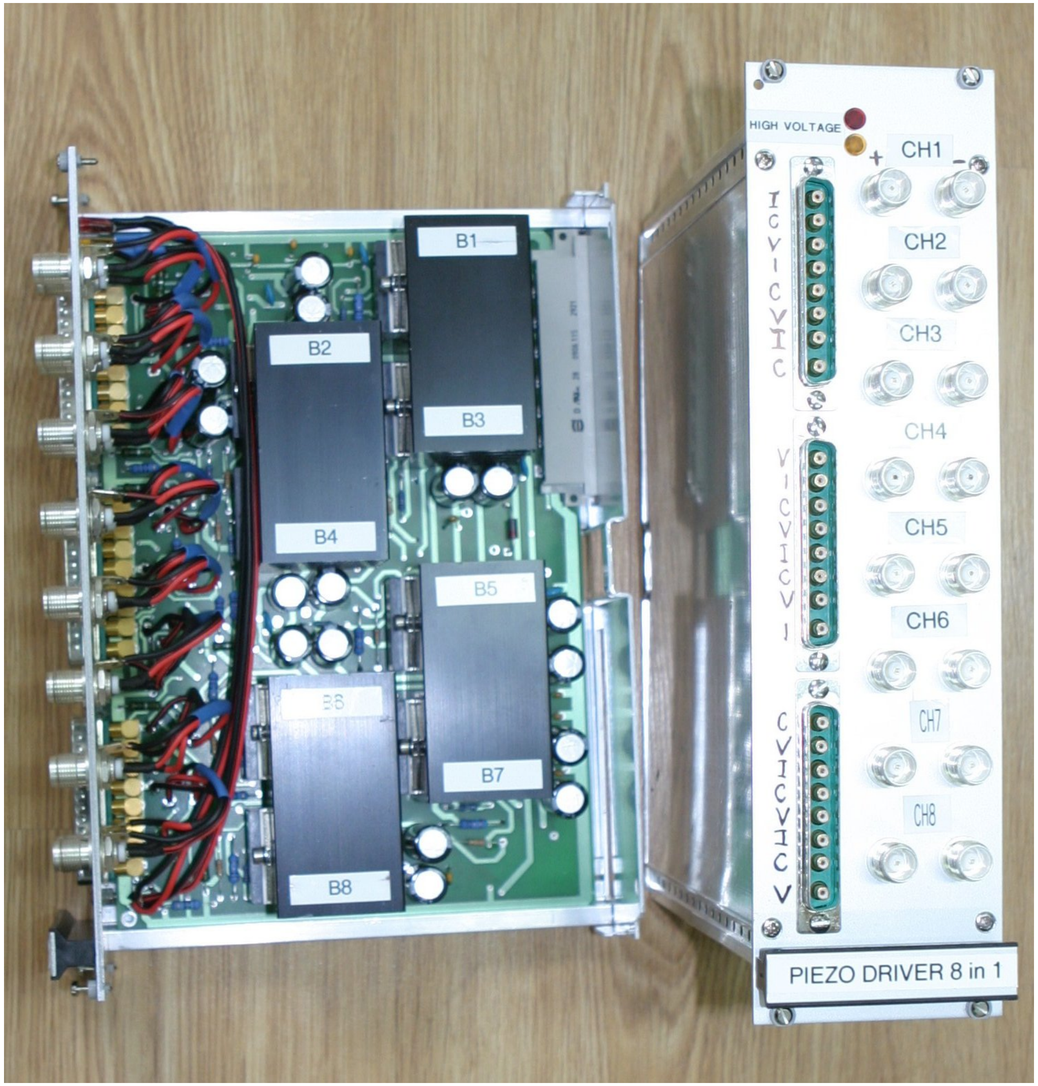
- Lorentz force detuning (LFD) during flat-top $\Delta\omega$< 10 Hz for field up to 30 MV/m (compensation up to 600 Hz – possible resonance compensation up to 1kHz)
- Commercial available piezoelements (PI and NOLIAC) C_{2K}= 3÷5 μF, V_{max}= 100 V, operating freq. for LFD/microphonics up to 300 Hz (full voltage scale), → I_{load} ~ 1A
- Maximal repetition rate of RF (LFD compensation) pulse 10 Hz
- Piezo must be protected and monitored (piezo is fragile to over current and over voltage (>150÷200), piezo lifetime must by over 1010 pulses, resonance in the cables, piezo might fall out when stepper motor is wrongly tuned)
- Possible microphonics compensation between the RF pulses (sensor/actuator mode)(microphonics has smaller impact than LFD, constant offset of $\Delta\omega$ during flat top, feedback loop

Piezo control for XFEL



Main parameters of Piezodriver

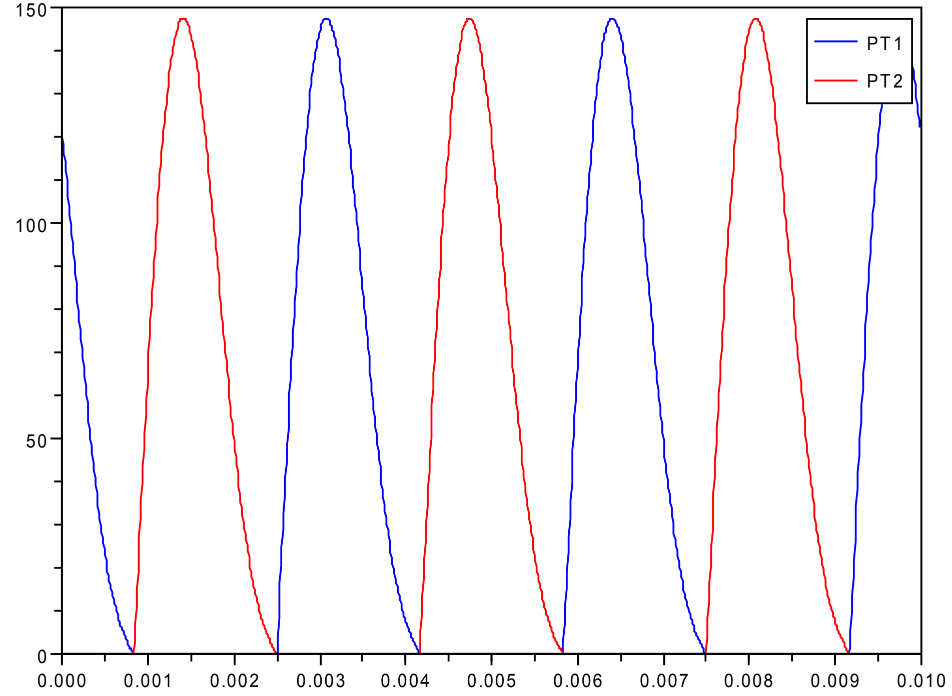
- Suitable for both types of piezostacks up to 5μF:
  - Physik Instrumente (P-888.90 PIC255); C_{2K}4,4 μF
  - NOLIAC (SCMAS/S1/A/10/10/20 /200/42/6000); C_{2K} 2,4 μF
- Maximal supply voltage up to ± 150 V (nominal operating voltage ±80V)
- Input voltage ± 1 V
- Amplifier gain Gu= 100V/V,
- Operational temperature Tc < 75°C (Tj <125 °C)
- Pass-band frequency up to 5 kHz (for load 5μF)
- Monitoring of output voltage and current
- Single channel PZD with Apex PB51
- 8 channels on single board
- Up to 4 periods of sinus wave 80V, 200 Hz in 5μF load, 10 Hz repetition rate (thermal limit)

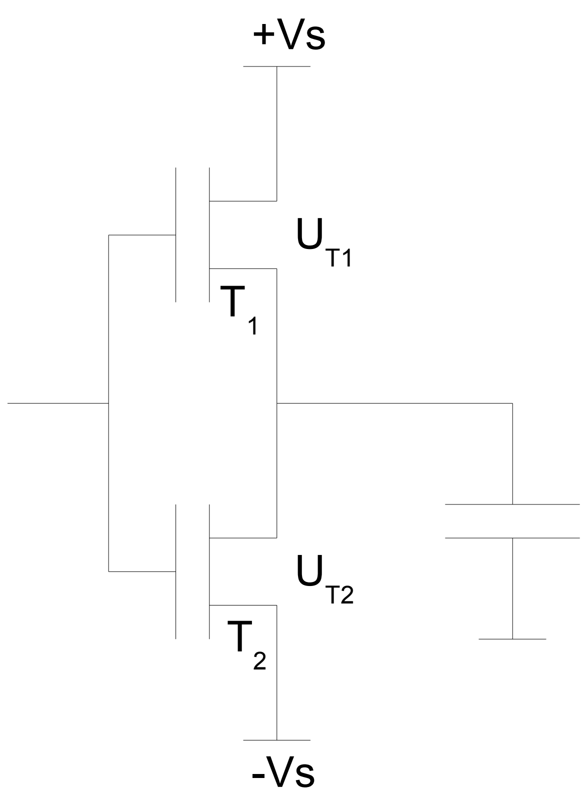


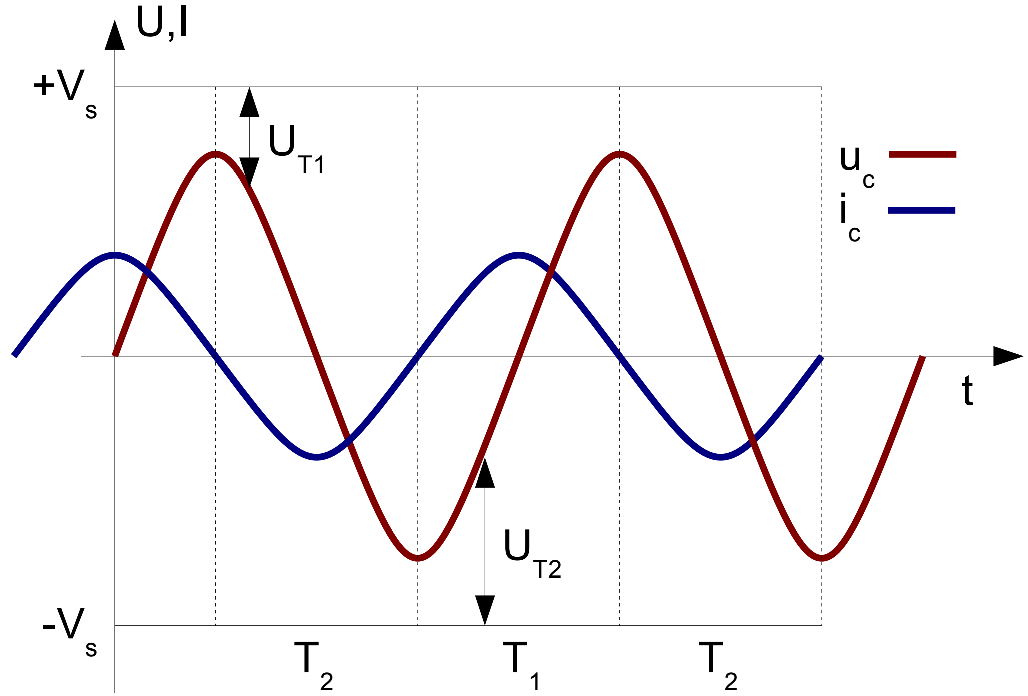
Power loses

power loses for Vs=120, Uc=100V, I=1A, f=300Hz
integral for single period W=2*0.13J, P=78W

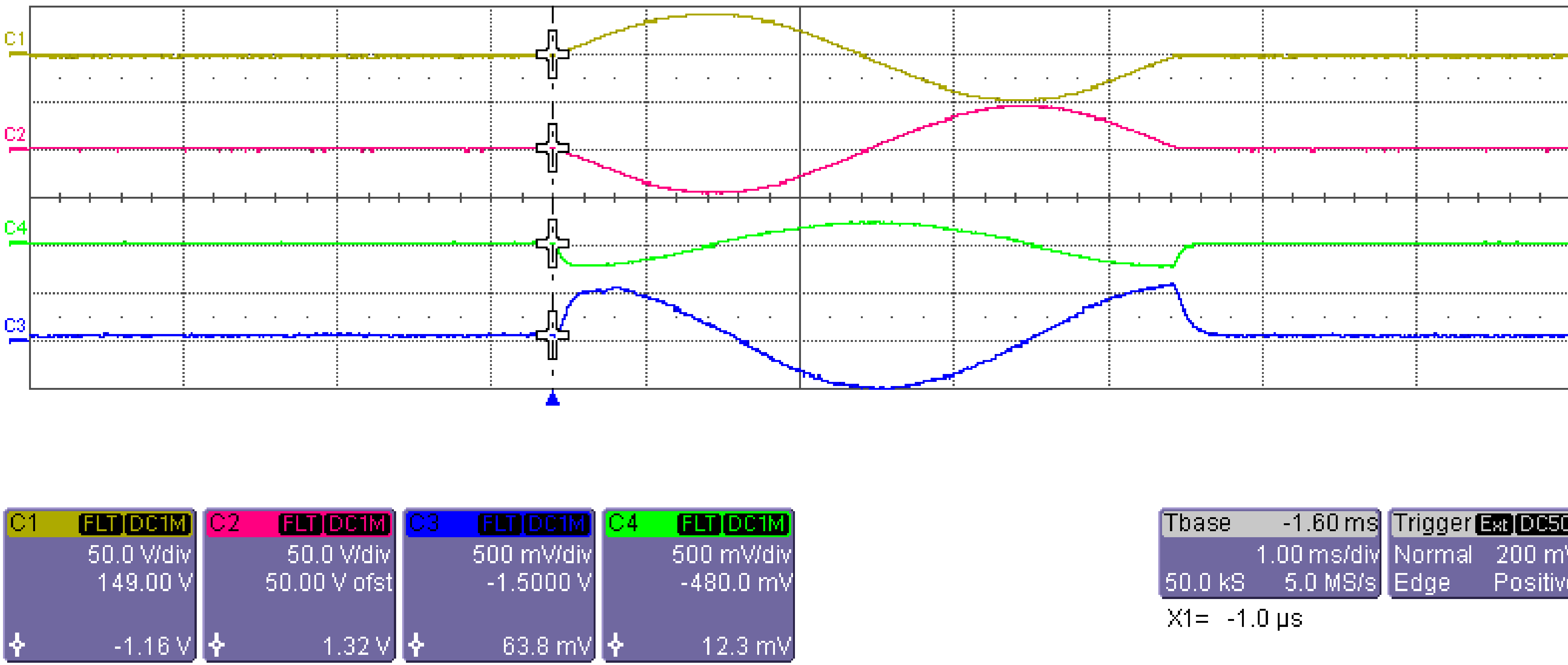
average dissipated power depends on duty cycle



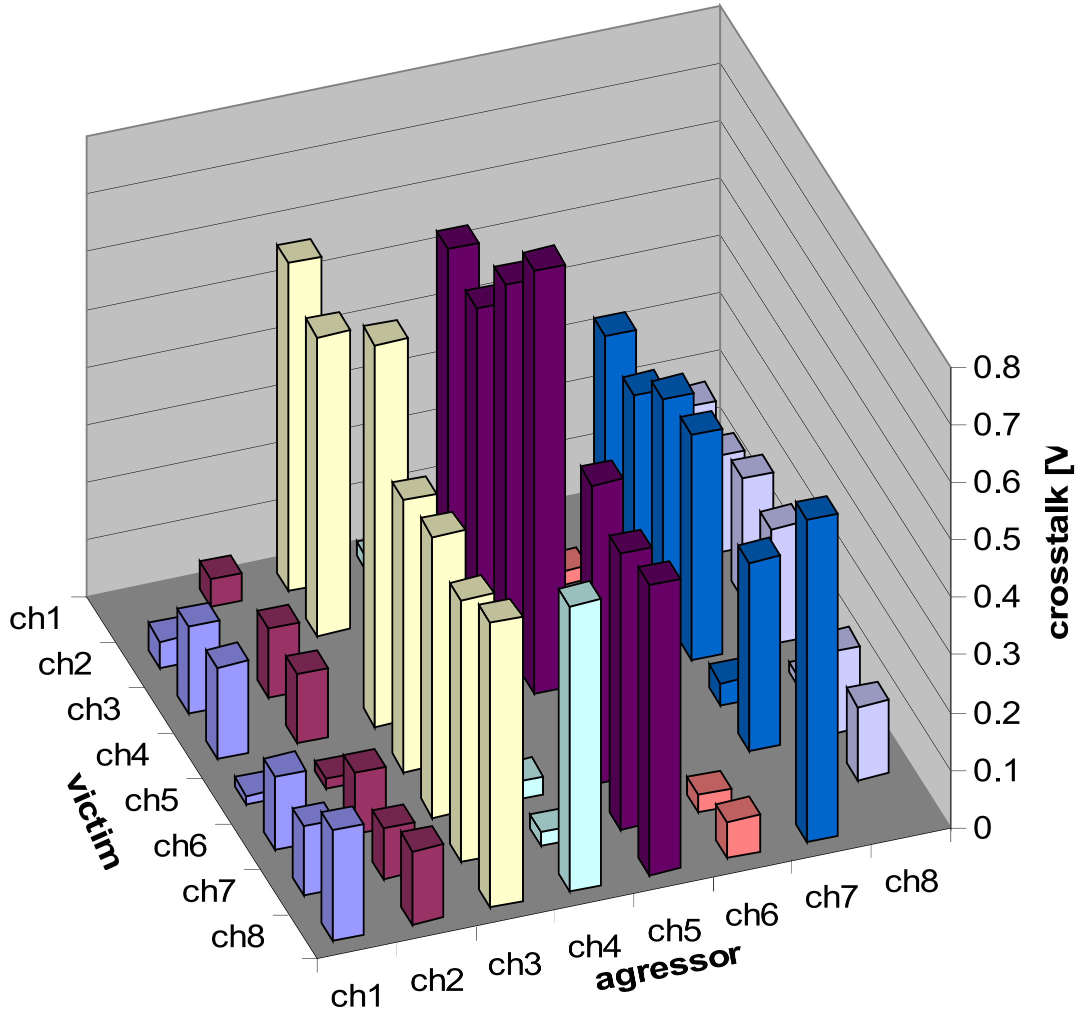


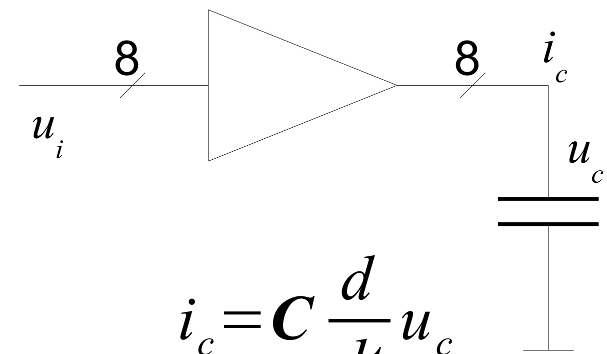


Crosstalk in PiezoDriver



Crosstalk compensation





$$i_c = C\frac{d}{dt}u_c$$

cross talk matrix

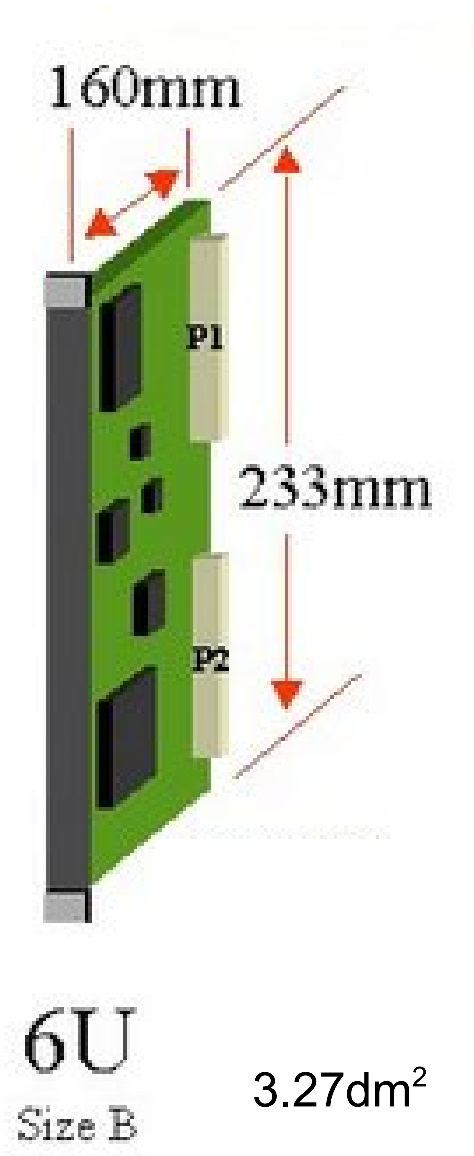
[V]	ch1	ch2	ch3	ch4	ch5	ch6	ch7	ch8
ch1		0.048	0.152	0.16	0.016	0.128	0.12	0.192
ch2	0.048		0.12	0.12	0.016	0.106	0.088	0.128
ch3	0.57	0.52		0.664	0.472	0.488	0.456	0.496
ch4	0.024	0.048	0.016		0.016	0.032	0.024	0.496
ch5	0.536	0.512	0.632	0.736		0.52	0.48	0.504
ch6	0.024	0.024	0.024	0.024	0.016		0.032	0.064
ch7	0.328	0.304	0.376	0.392	0.04	0.328		0.56
ch8	0.176	0.168	0.208	0.2	0.016	0.144	0.128	

$$u_c = \boldsymbol{A}u_i + \boldsymbol{B}i_c$$

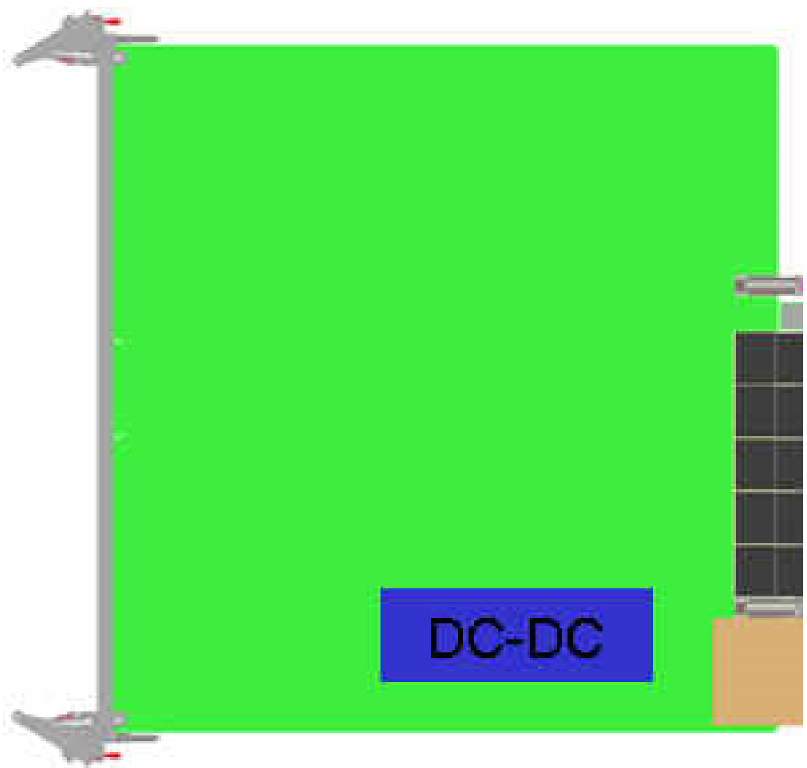
$$u_i = \boldsymbol{A}^{-1}u_c - \boldsymbol{A}^{-1}\boldsymbol{BC}\frac{d}{dt}u_c$$

$$u_i = \frac{1}{\boldsymbol{A}}\left(u_c - \boldsymbol{BC}\frac{du_c}{dt}\right)$$

ATCA integration (1)



3.27dm^2



8U x 280 mm

8.7dm^2

150 - 200 W

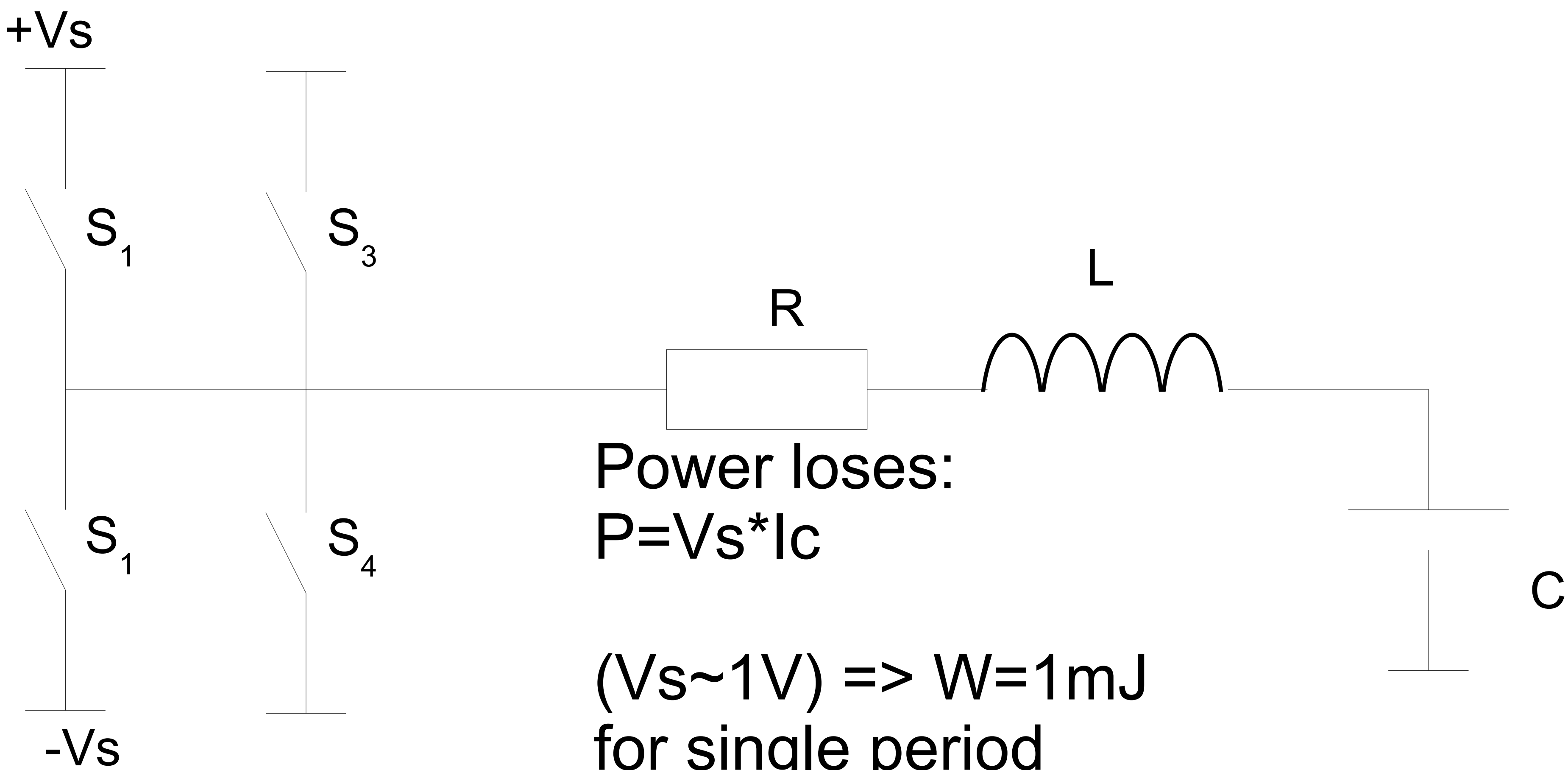
ATCA integration (2)

- Advantages:
  - No need for separate piezo crate (place, crate, power supply etc.)
  - The control link through the backplane
- Bigger form factor than Eurocard (2.5 more space) allows to integrate in the single board 8 channel piezo driver together with DACs and ADCs, probably it is also possible to put DC/DC converter (48V -> ±100V) in the board
- Ideally would be to put 32/16 channels on the single board
- Special care for piezo connectors (high voltage, backside through customized RTM?, front side?)

Piezo driver of class D

- To reduce power losses (and thus reduce heatsinks) – higher assembling density
- APEX SA50CE may be used – will be discussed on tomorrow meeting with APEX application engineer
- Possible EMC interaction with other system components

Other concept of piezo driver

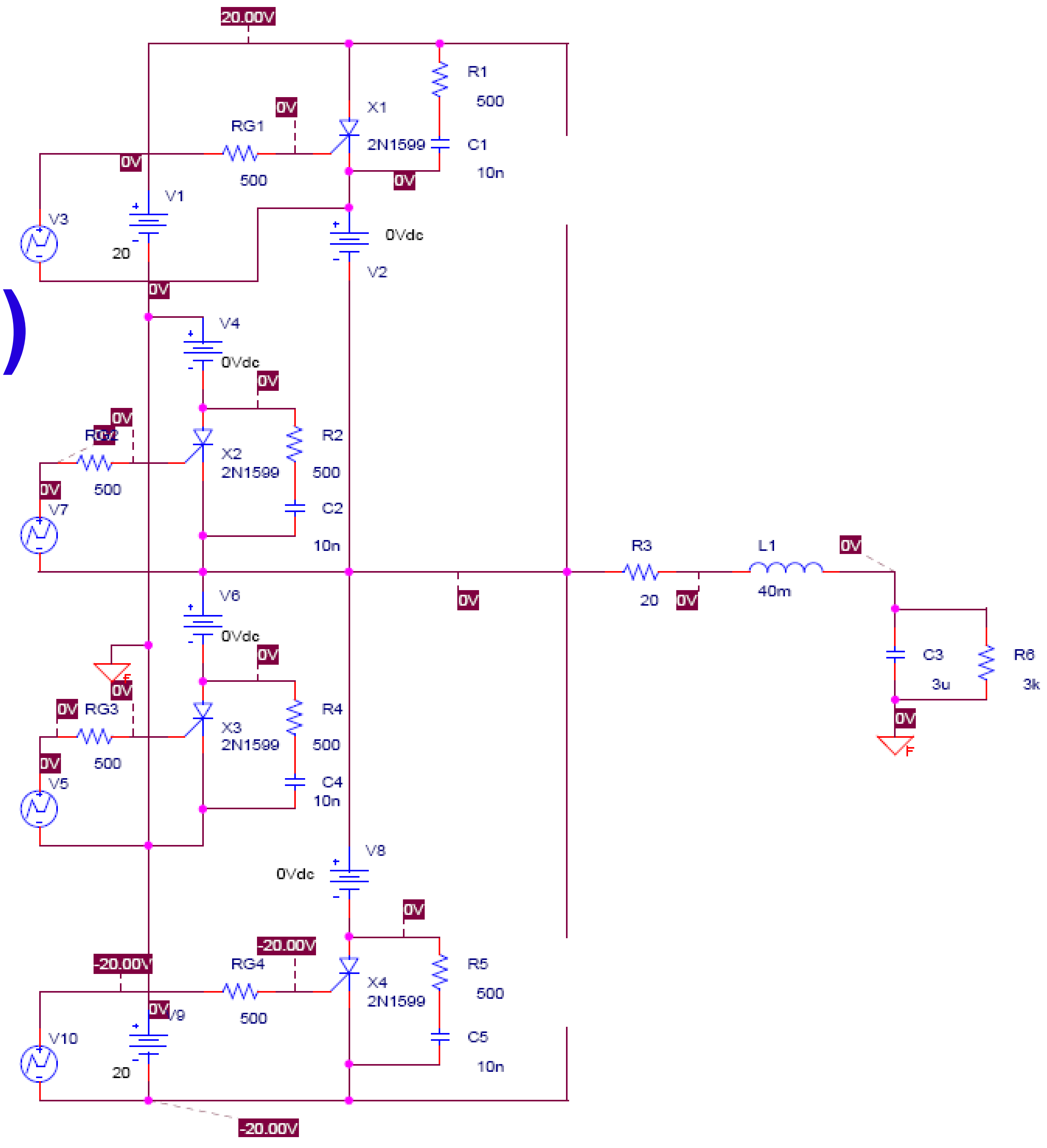


Power loses:
P=Vs*Ic

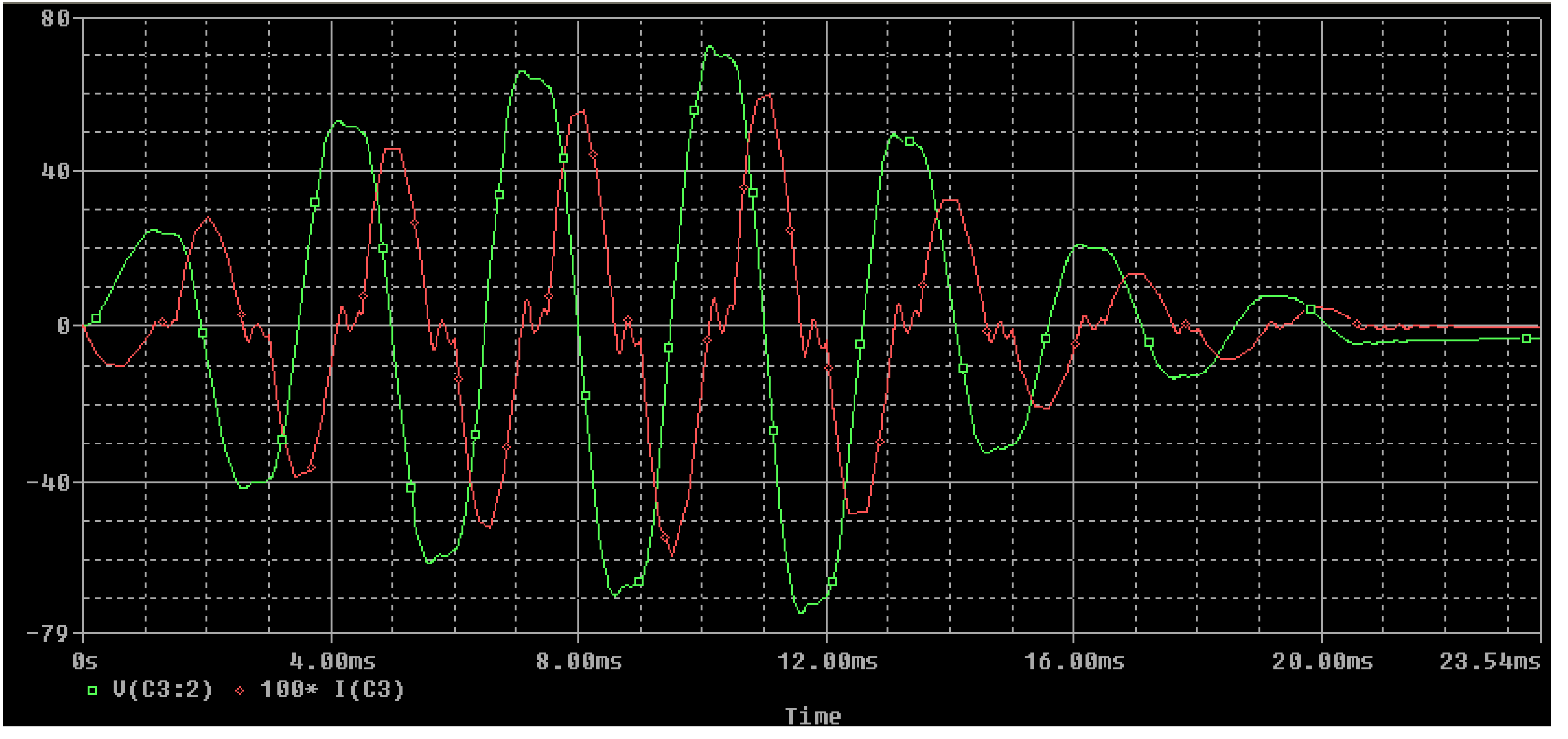
(Vs~1V) => W=1mJ
for single period

Due to resonant excitation the supplying voltage can be quite small, also the power dissipation is very low

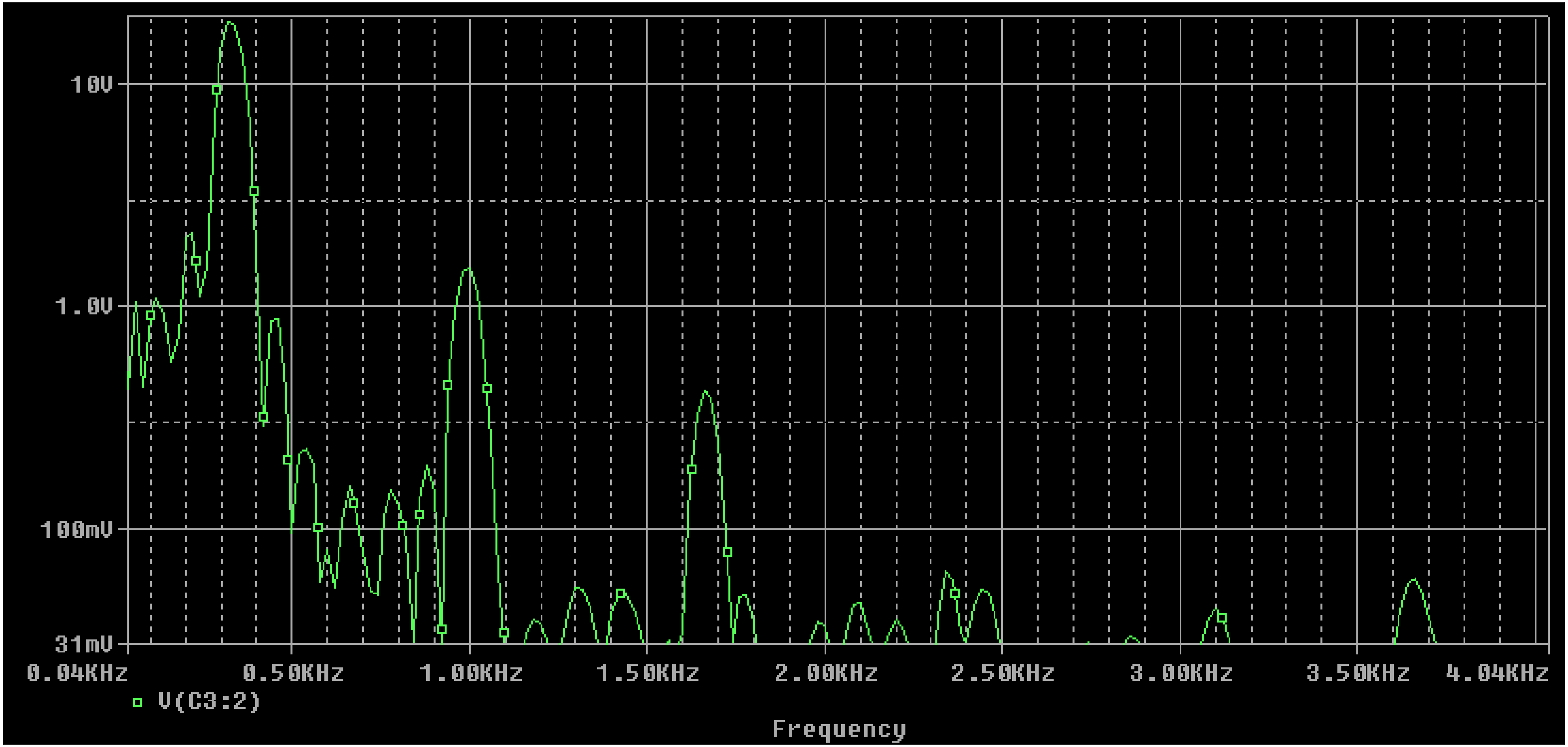
Schematic diagram (simulation)



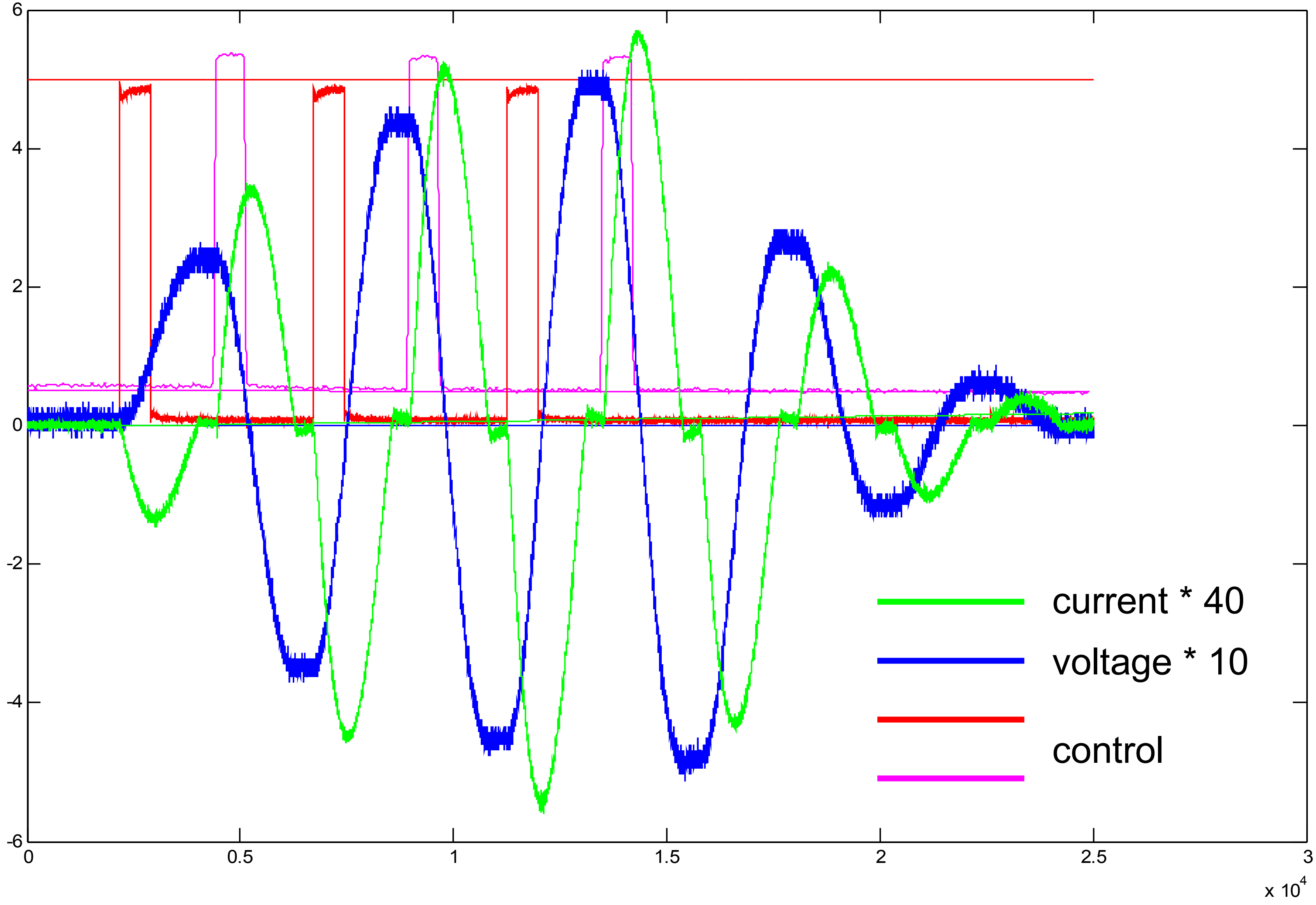
Simulation results (1)



Simulation results (2)



Measurements



Conclusion

- The integration of piezo control in ATCA looks possible and promising, however more tests are needed to check ideas
- Future plans
  - Permanent installation of piezo control in FLASH and routine operation, initially without piezo sensing
  - Design of 32 channel ADC board
  - Tests in of resonant piezo driver in Chechia (planed for January 2009)
  - Design and tests of switching piezo driver
  - Design of HV Power Supply unit