µPZT4

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Workshop Seminar
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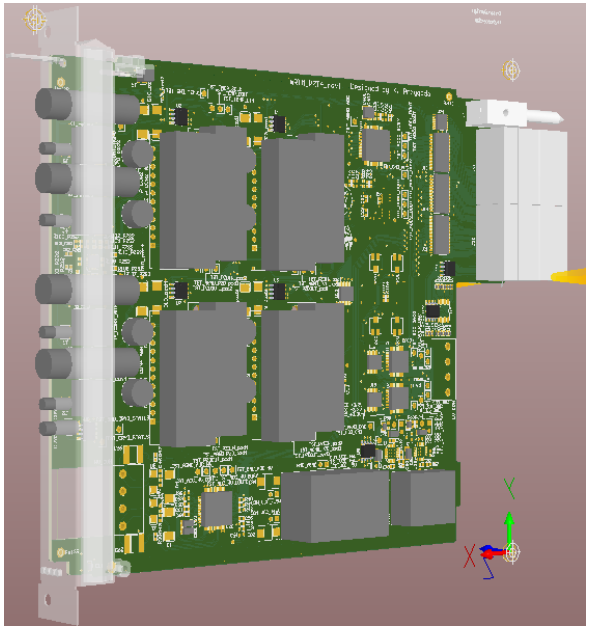
HELMHOLTZ ASSOCIATION

DESY

Motivation

- **HVF_MTCA project (AP1.4.2.3)**
- **Design low cost Piezo driver**
- **Suitable for two main applications in RF technology:**
  - Piezo based freqency tuner control for SC cavity (support for single cavity RF controls)
  - Piezo based laser oscillator control for laser to RF synchronization
- **Control electronics must be fitted to MTCA.4 hardware architecture**

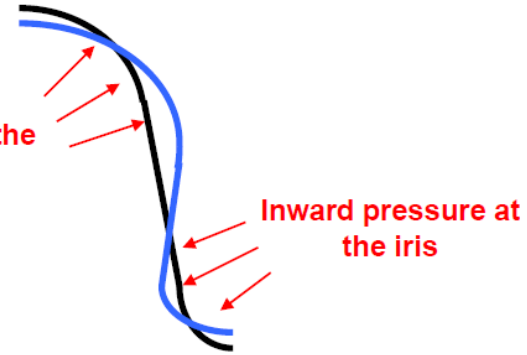


Problem#1

Pressure deforms the cavity wall:

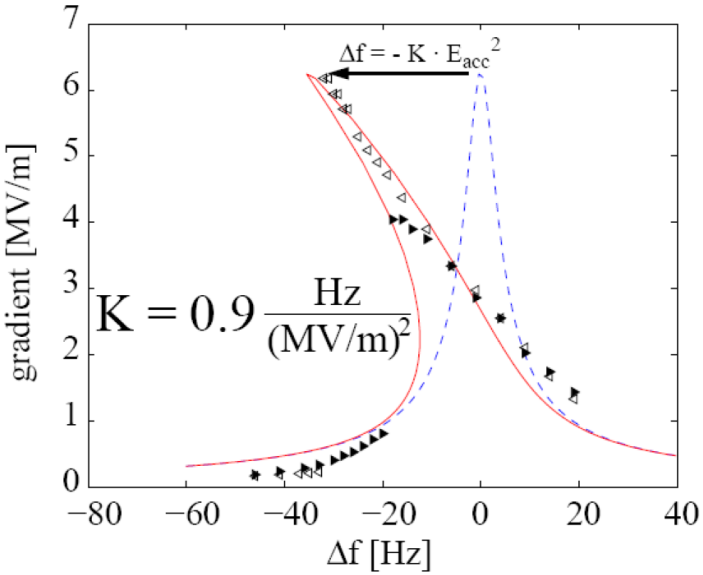
RF power produces radiation pressure:

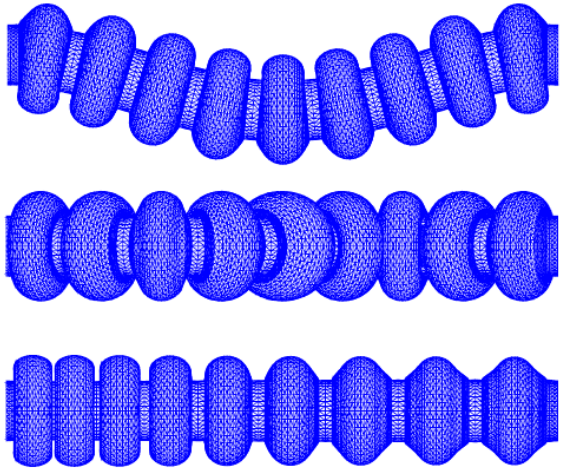
$$P = \frac{\mu_0 H^2 - \varepsilon_0 E^2}{4}$$



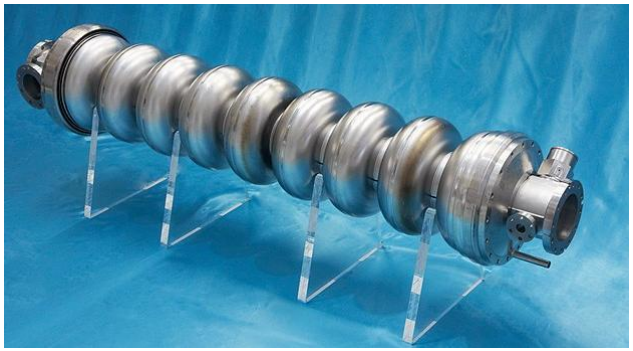
Deformation produces a frequency shift:

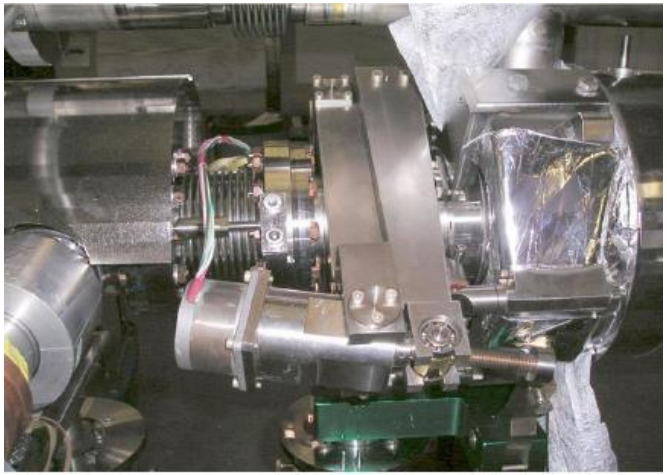
$$\Delta f = -k_L E_{acc}^2$$

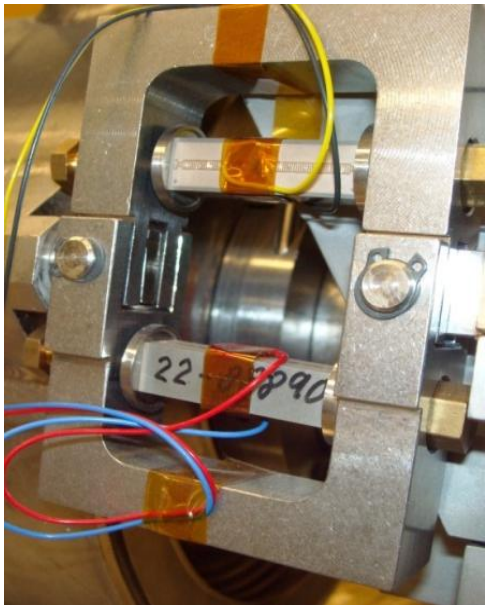


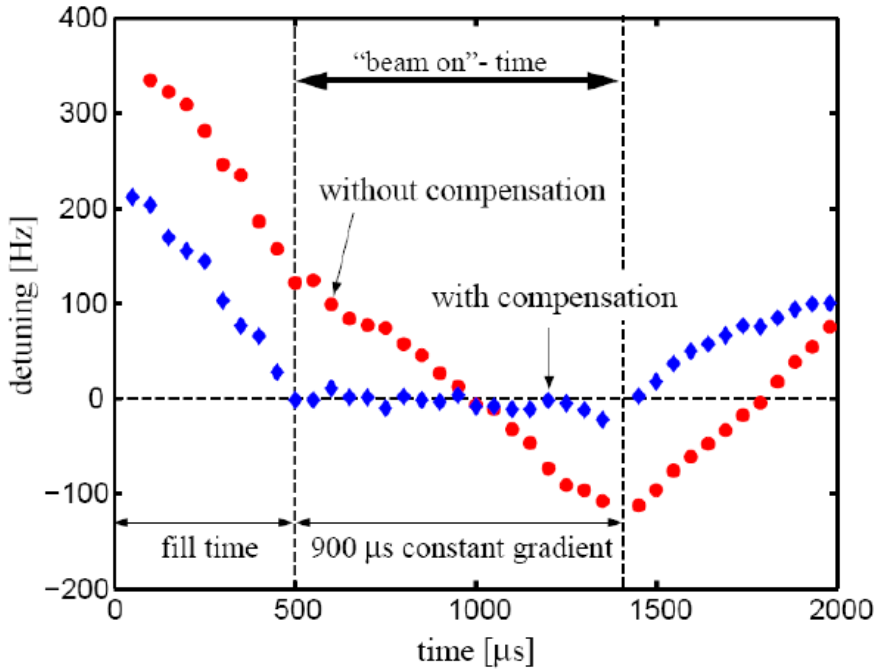


Solution#1



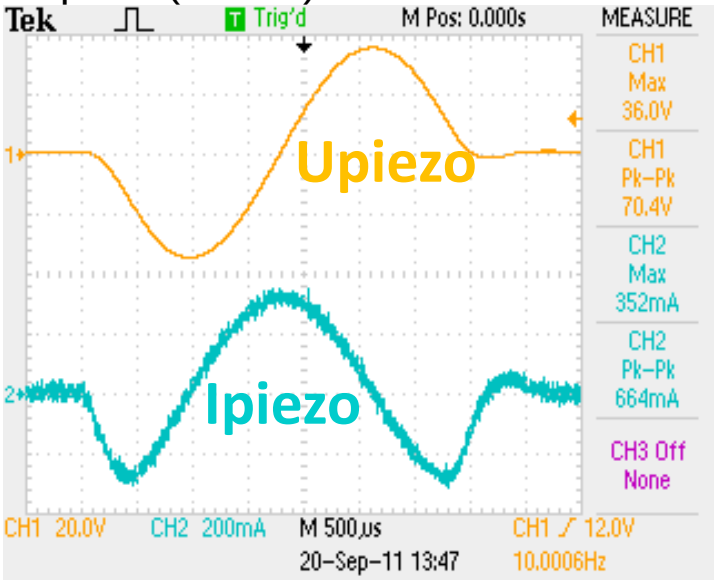




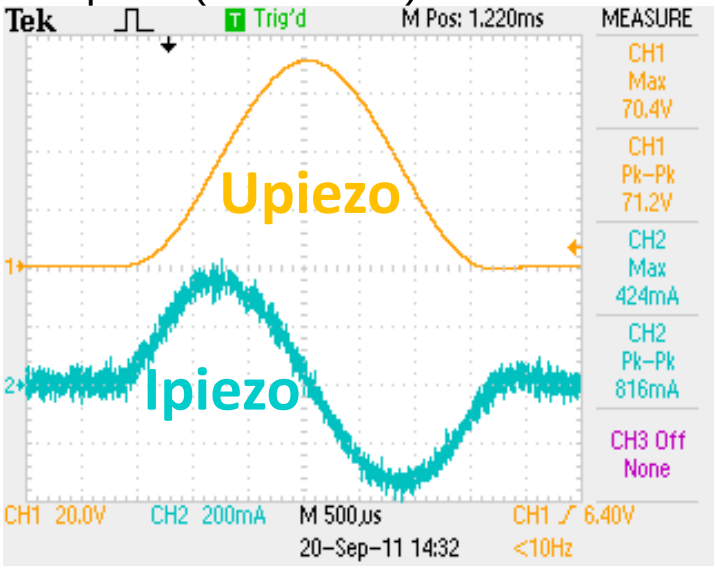

400
300
200
100
0
−100
−200
0
500
1000
1500
2000
detuning [Hz]
time [µs]
"beam on"- time
without compensation
with compensation
fill time
900 µs constant gradient

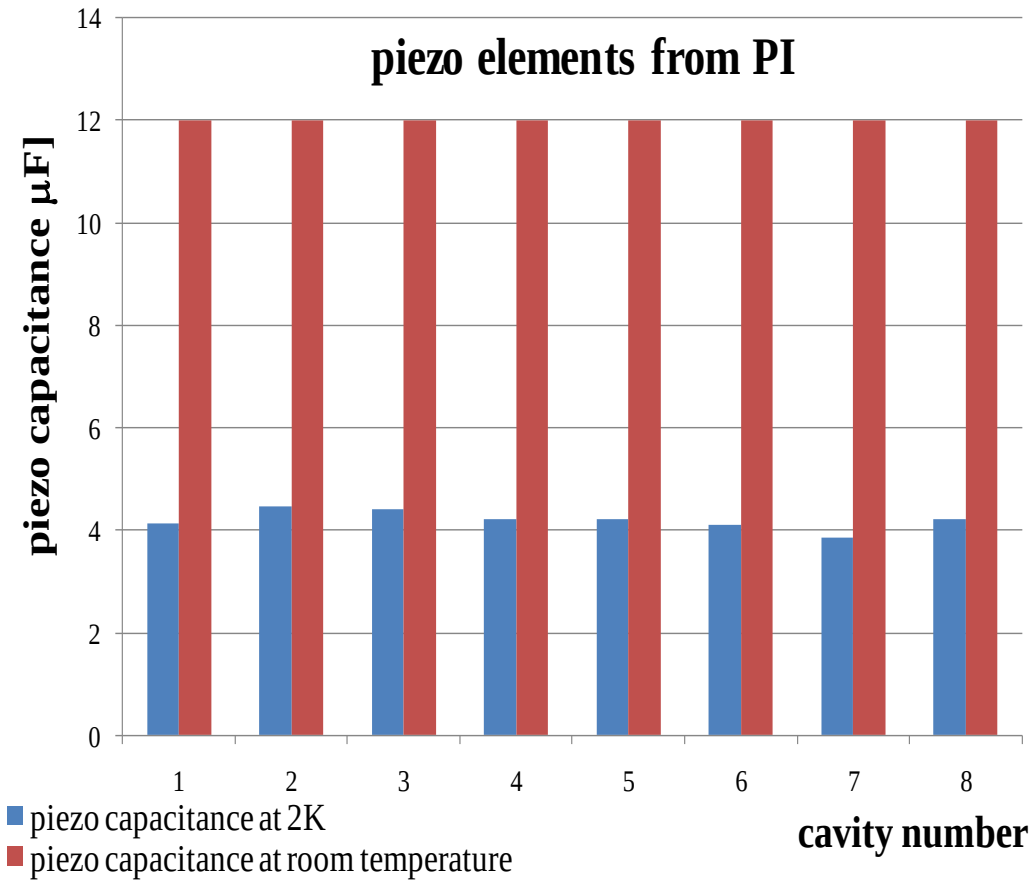
Piezo control drive for cavity tuner (LFD)

Bipolar (±100V)



Unipolar (0V ÷ 100V)

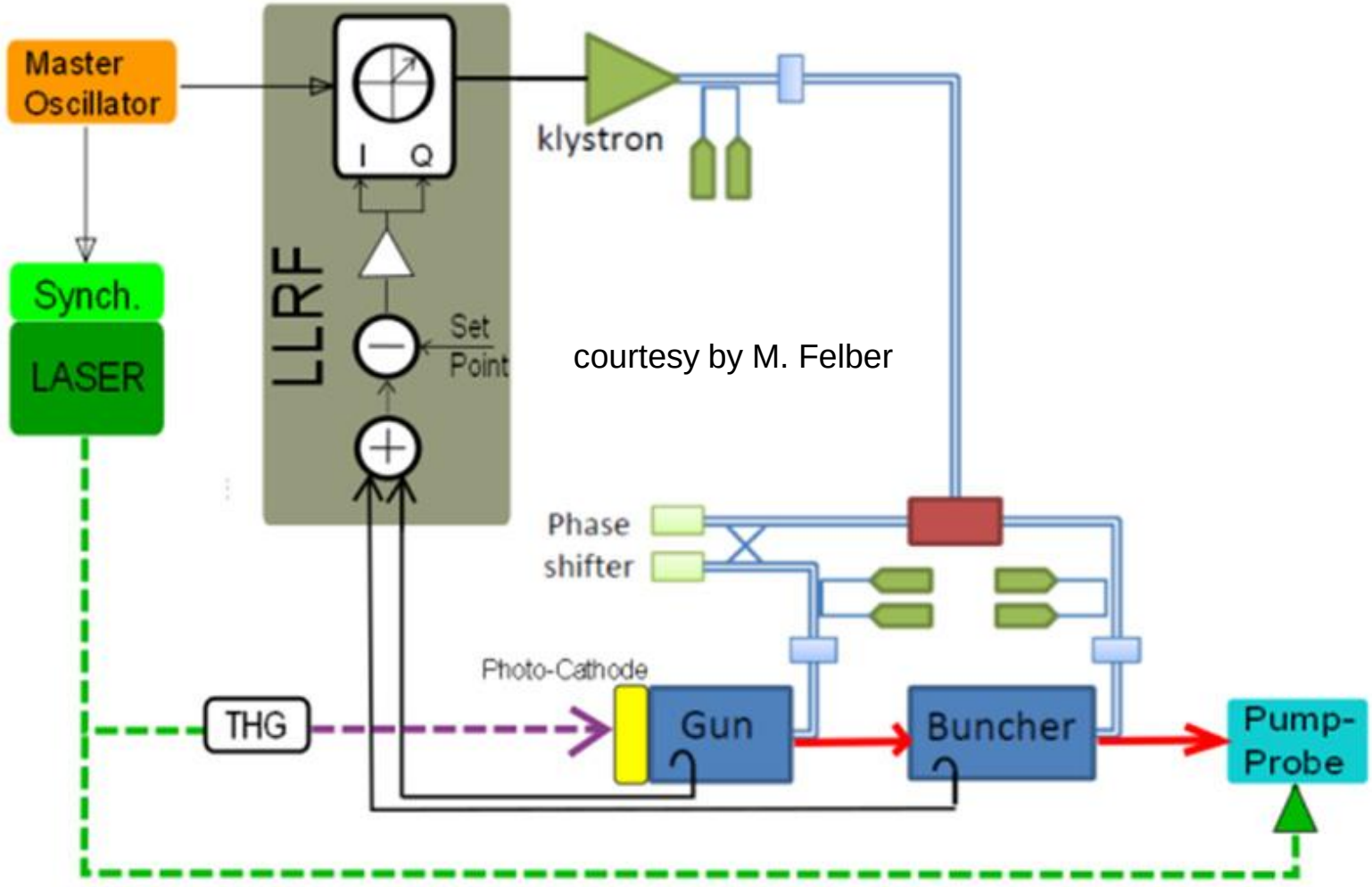




Acceptable voltage range (in room temperature):
-20V÷130V

Problem#2

- Minimize residual jitter between the laser (TI:SA) pulse train and the master oscillator reference (MO)



Expected piezo capacitance

series RA part no.		unit	RA 12/24 P-401-10
motion (±10%)*	open loop	µm	12
capacitance (±20%)**		µF	2.9
resolution***	open loop	nm	0.03
resonant frequency***		kHz	18
stiffness***		N/µm	160
blocking force***		N	2000
pre-load		N	300
dimensions	length L	mm	36.5
	diameter D2	mm	24
	diameter D1	mm	9
weight		g	75

technical data

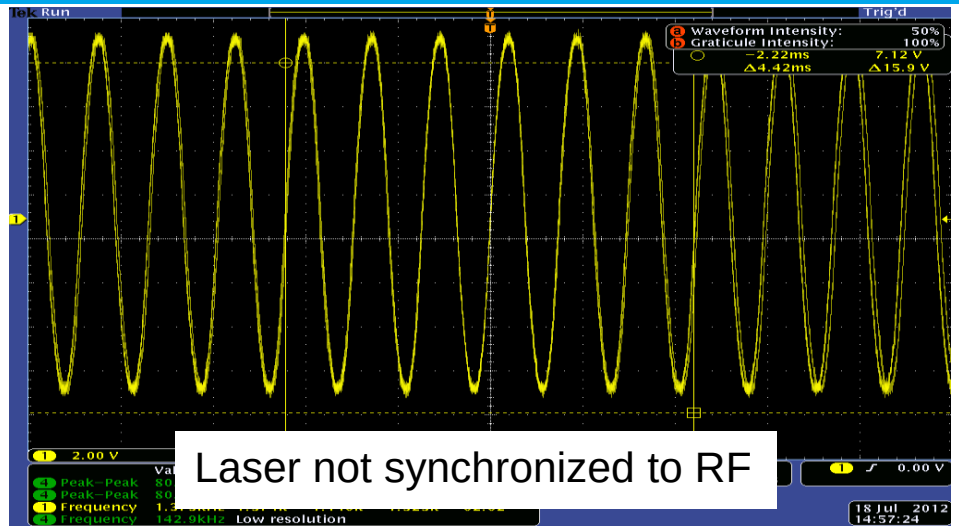
- operating voltage: -20 to +130V
- housing series RA: stainless steel
- bottom plate:
  thread M12x0.5, spanner flats: 20mm for RA XX/24
  thread M18x0.5, spanner flats: 27mm for RA XX/35
- optic adapters for RA series with inside thread
  (part no. P-400-05 for RA XX/24 and P-400-10 for RA XX/35 series)

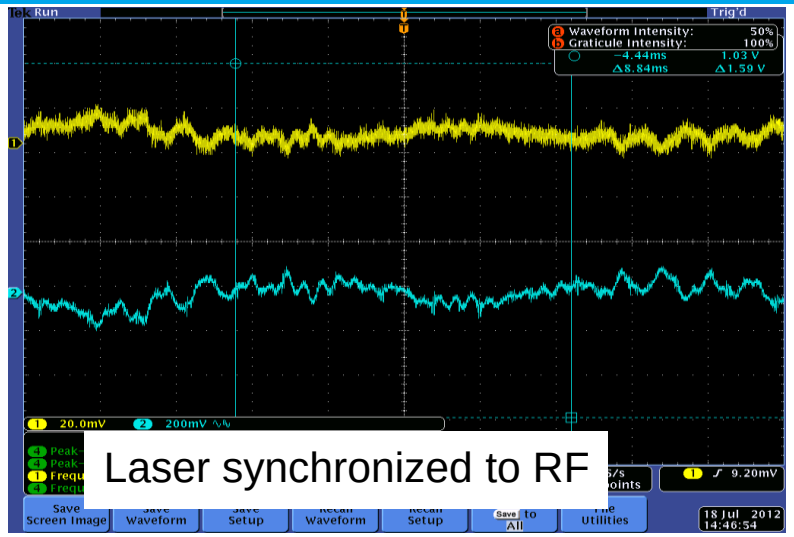
series PA part no.		unit	PA 4/12 P-150-00	PA 8/12 P-151-00
motion (-10/+20)%* open loop		µm	4.5	9.5
capacitance (±20%)**		µF	0.34	0.7
resolution*** open loop		nm	0.009	0.019
resonant frequency***		kHz	65	40
stiffness***		N/µm	190	90
blocking force***		N	850	850
pre-load		N	150	150
dimensions	diameter D	mm	12	12
	length L	mm	22	26
series PA with spherical end R2.5 part no.			**PA 4/12 R2.5 P-150-50**	**PA 8/12 R2.5 P-151-50**
dimensions	length L	mm	23	27

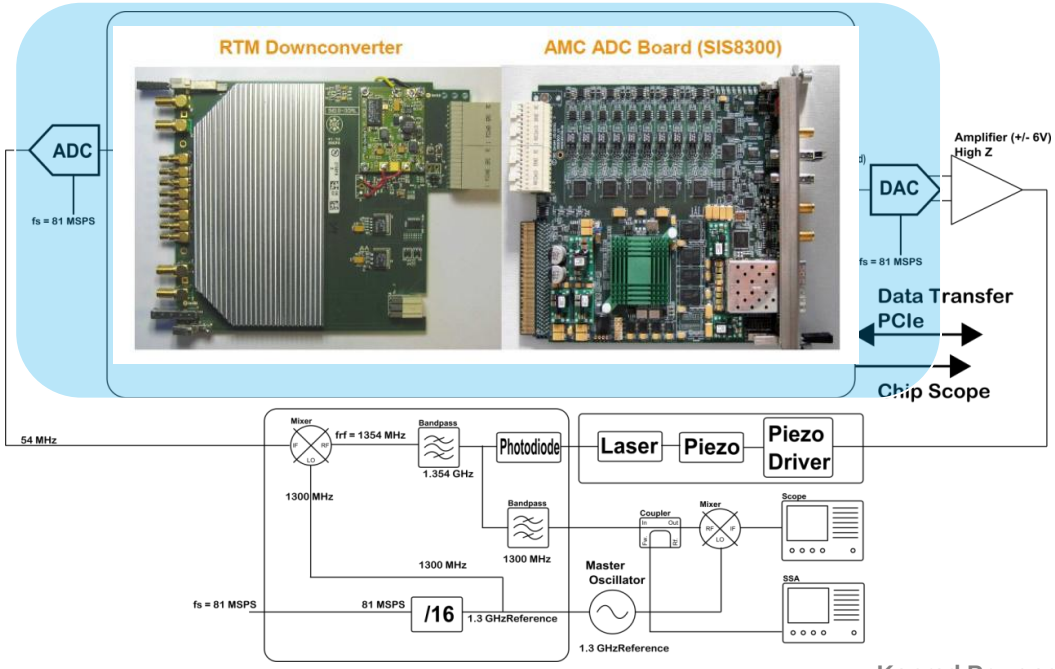
technical data

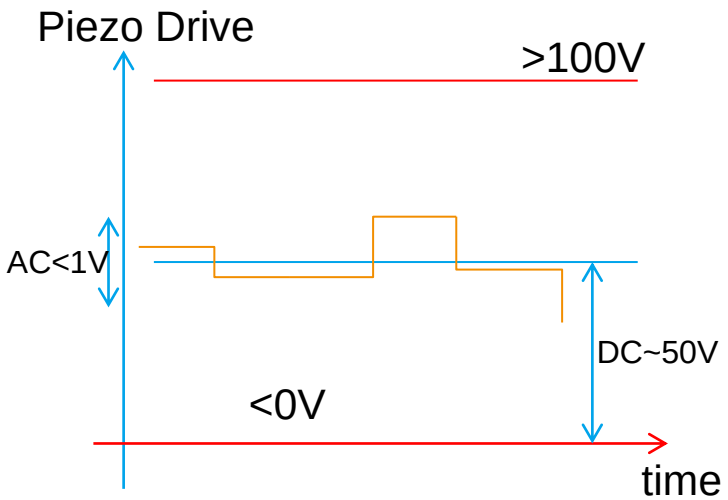
- operating voltage: -20 to +130V
- housing: stainless steel
- top plate: thread M3
  spanner flats: 3.5mm
- bottom plate: thread M3
  spanner flats for PA XX/12 series: 10mm
  spanner flats for PA XX/14 series: 12mm

Solution#2









courtesy by M. Felber & U. Mavric

System requirements (1)

- **Double width MTCA.4:**
  - Rear-Transition Module (RTM), Zone3 Class D1.[0..2] compatible
  - AMC Module support and standalone operation
- **High voltage power supply:**
  - 0 V ; +100 V (unipolar)
  - ±100 V (bipolar)
- **Low voltage power supply:**
  - +3.3 V;+5 V; ±15 V
- **No. of input channels: 4 (4 x piezo sensors):**
  - ADC sampling rate: min.100 kSPS per channel
- **No. of output channels: 4 (4 x piezo actuators) :**
  - DAC sampling rate: min. 100 kSPS per channel

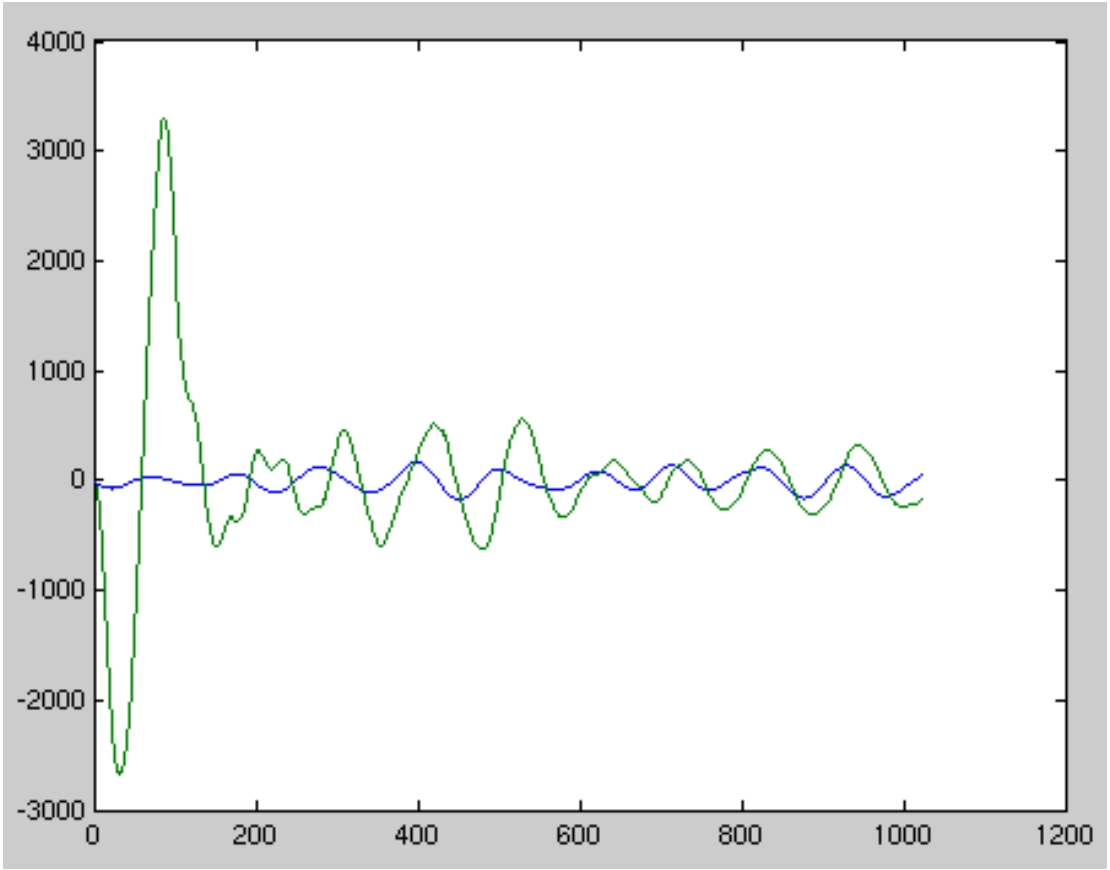
System requirements (2)

- **No. of monitoring channels: 16**
  - 4 x IS – PZT input voltage
  - 4 x VS – PZT output voltage
  - 4 x CS – PZT output current
  - 4 x HV – high voltage sense

    (AC and DC components)
- **Temperature sensors:** as close as possible to each power amplifier radiator
- **Remote switching:** between piezo actuator and sensor functionality
- **Interlock sensor:** to not operate piezo when cryomodule is warm

Piezo sensor input parameters

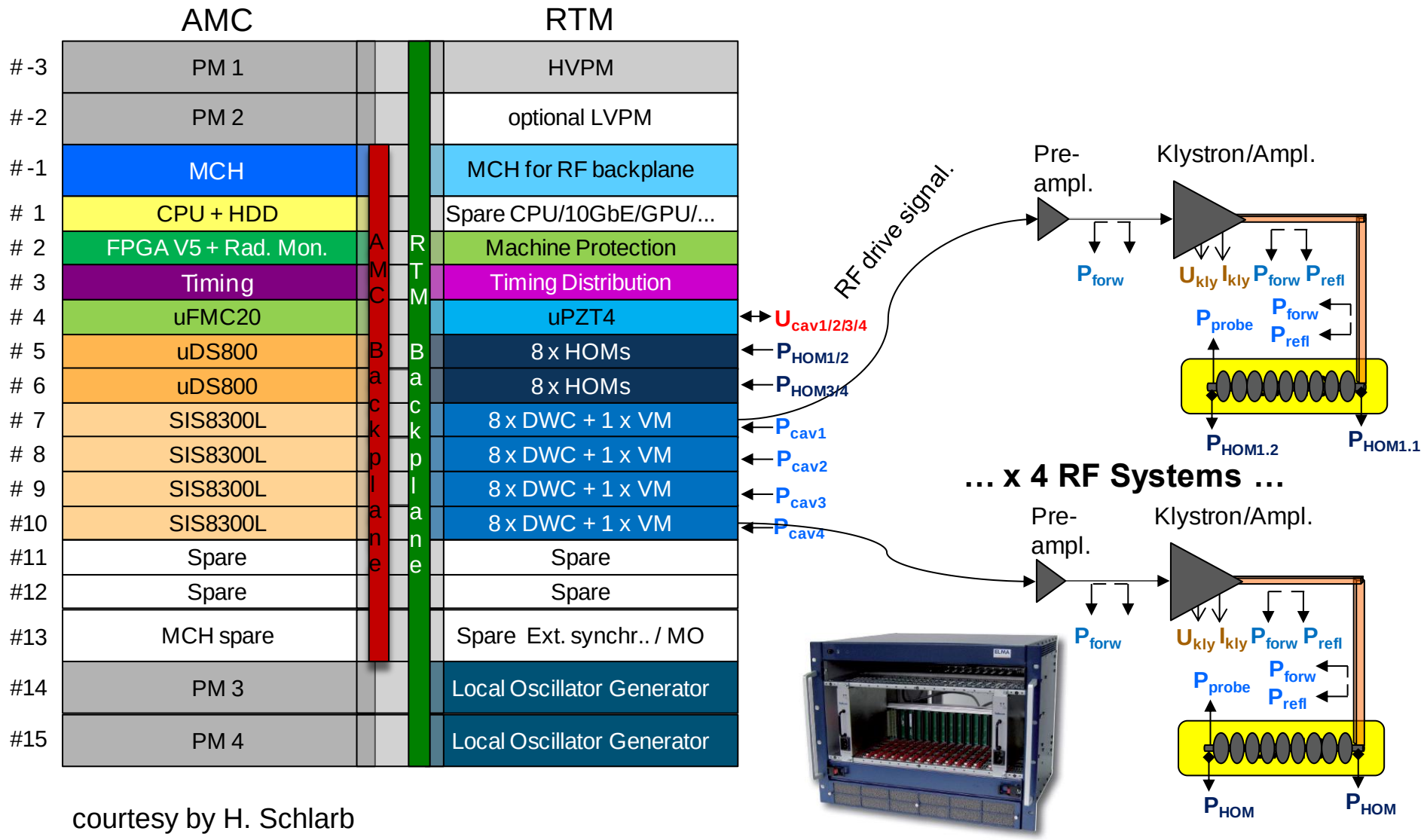
- Input impedance
  - $Z_{in} < 4\ k\Omega$
- Input voltage range
  - ±2.5 V
- Input bandwidth (3 dB)
  - B: DC 100 kHz
- Noise level
  - SNR < -70 dB
- Channel crosstalk
  - XT < -60 dB



Driver output parameters

- Output load
  - R_{load}: capacitive, 0.1 ÷ 6 μF
- Full power bandwidth (3 dB)
  - B: DC ÷ 300 Hz (with maximum amplitude and load): Lorentz force detuning
- Small signal bandwidth
  - B: DC 100 kHz (for nominal load of 1 μF): Laser synchronization
- Noise level
  - SNR < -70 dB
- Channel crosstalk
  - XT < -60 dB between any channels
- Overvoltage protection
- Overcurrent protection
- Current slewrate limitation

Hardware architecture of MTCA.4 system

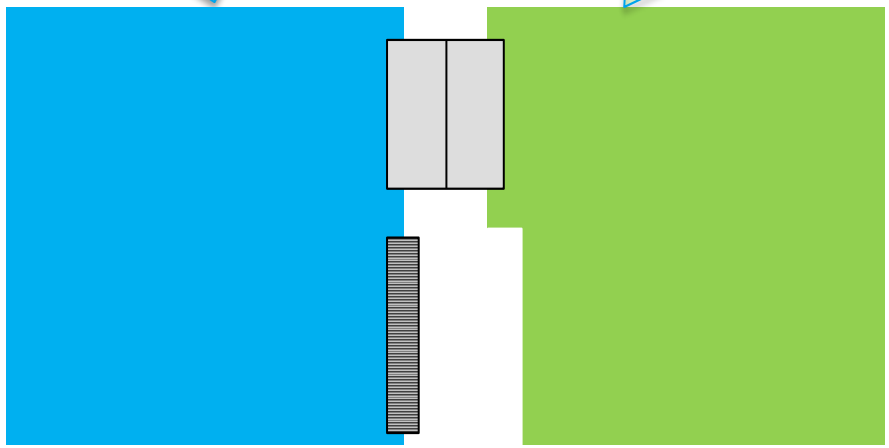


courtesy by H. Schlarb

Single AMC-RTM combinations

FMC20	Simple IO
DAMC02	Small proc.
FMC25	Medium proc.
FMC27?	High proc.
uTC	High proc.

uPZ4	Piezo driver
uAD84	High resolution ADCs
uVM	RF driver



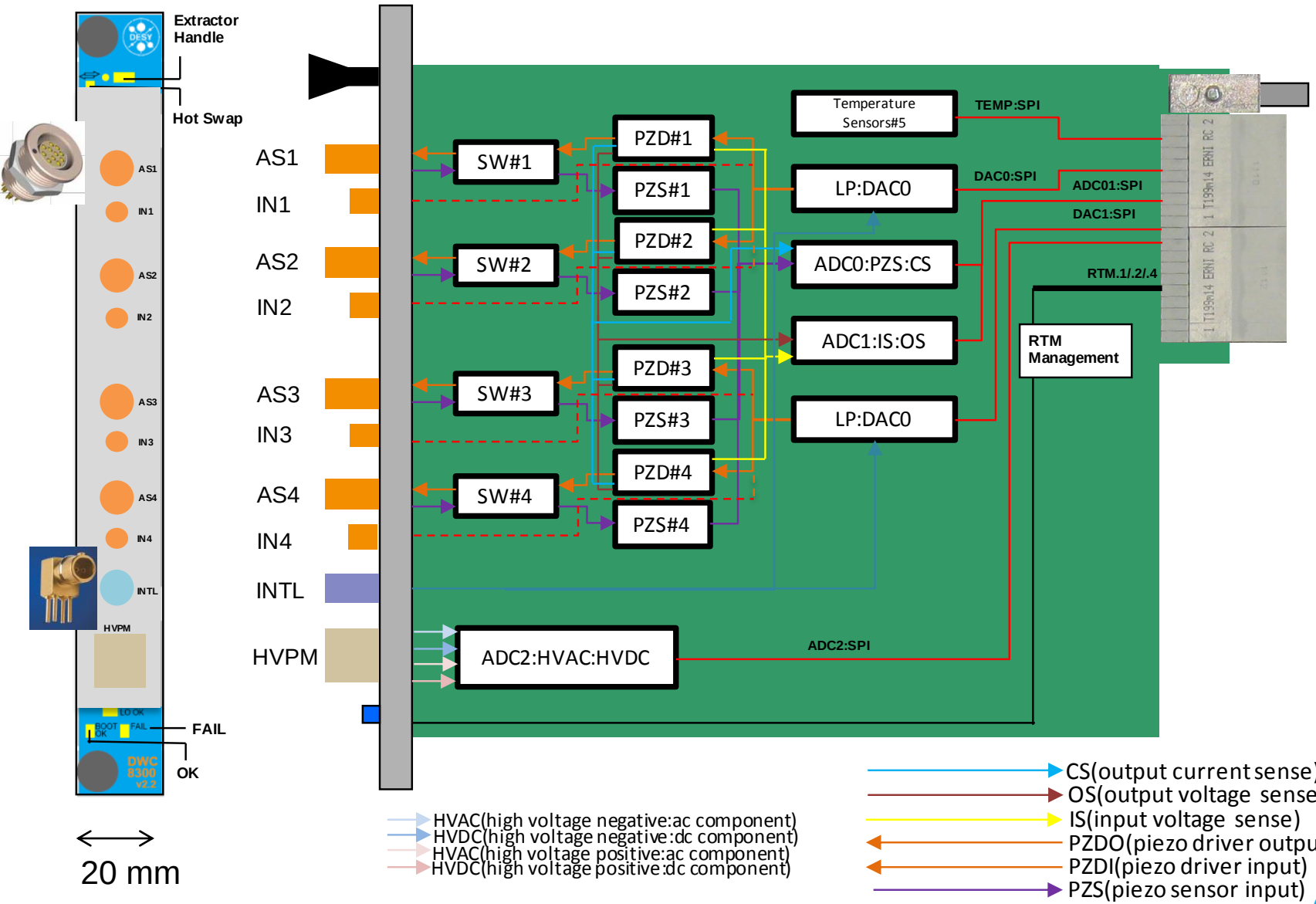
courtesy by H. Schlarb

ZONE3 Class D1.[0..2] compatibility

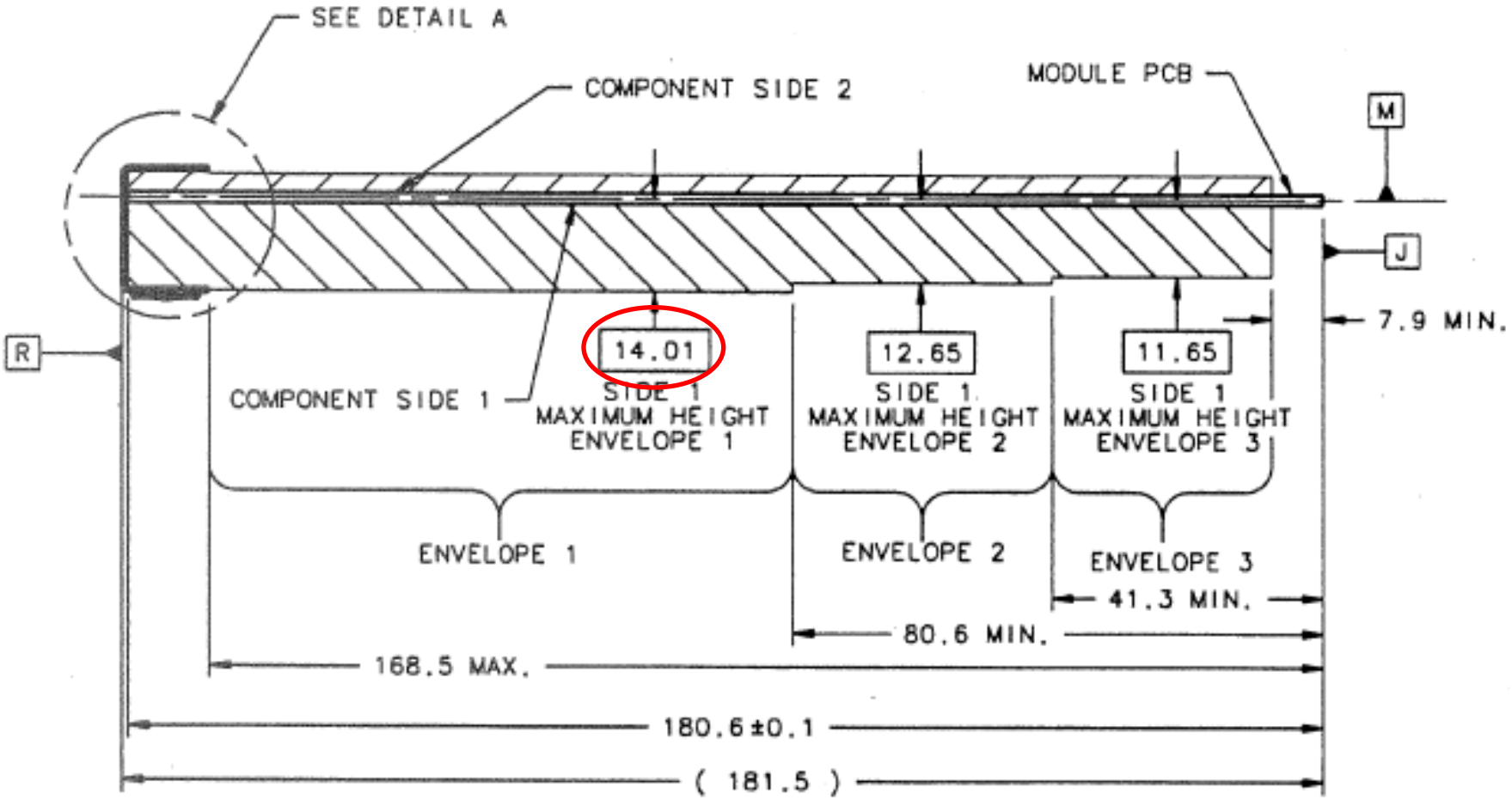
Class D1.2 / Zone			a	b	c	d	e	f
MTCA.4 management	J30	1	PWRA1	PWRB1	PS#	SDA	TCK	TDO
		2	PWRA2	PWRB2	MP	SCL	TDI	TMS
Digital clocks fixed I/O		3	AMC_CLK1+	AMC_CLK1-	RTM_CLK1+	RTM_CLK1-	OUT2+	OUT2-
		4	AMC_TCLK+	AMC_TCLK-	OUT0+	OUT0-	OUT1+	OUT1-
User -configuration		5	P30_IO+ / CC *	P30_IO+ / CC *	P30_IO+	P30_IO-	P30_IO+	P30_IO-
		6	P30_IO+ / CC *	P30_IO+ / CC *	P30_IO+	P30_IO-	P30_IO+	P30_IO-
		7	P30_IO+	P30_IO-	P30_IO+	P30_IO-	P30_IO+ / CC	P30_IO+ / CC
		8	P30_IO+	P30_IO-	P30_IO+	P30_IO-	P30_IO+ / CC	P30_IO+ / CC
		9	P30_IO+ / CC*	P30_IO+ / CC*	P30_IO+	P30_IO-	P30_IO+	P30_IO-
		10	P30_IO+ / CC*	P30_IO+ / CC*	P30_IO+	P30_IO-	P30_IO+	P30_IO-
User Configuaration	J31	1	P31_IO+	P31_IO-	P31_IO+	P31_IO-	P31_IO+	P31_IO-
		2	P31_IO+	P31_IO-	P31_IO+	P31_IO-	P31_IO+	P31_IO-
		3	P31_IO+ / CC	P31_IO- / CC	P31_IO+	P31_IO-	P31_IO+	P31_IO-
		4	P31_IO+ / CC	P31_IO- / CC	P31_IO+	P31_IO-	P31_IO+	P31_IO-
		5	P31_IO+	P31_IO-	P31_IO+	P31_IO-	P31_IO+ / CC	P31_IO- / CC
		6	P31_IO+	P31_IO-	P31_IO+	P31_IO-	P31_IO+ / CC	P31_IO- / CC
Standard Gbit-Links		7	P31_IO+ / CC*	P31_IO- / CC*	GTP3_RX+	GTP3_RX-	GTP3_TX+	GTP3_TX-
		8	P31_IO+ / CC*	P31_IO- / CC*	GTP2_RX+	GTP2_RX-	GTP2_TX+	GTP2_TX-
		9	GTP0-3_CLK_IN+	GTP0-3_CLK_IN-	GTP1_RX+	GTP1_RX-	GTP1_TX+	GTP1_TX-
		10	GTP0-3_CLK_OUT+	GTP0-3_CLK_OUT-	GTP0_RX+	GTP0_RX-	GTP0_TX+	GTP0_TX-

D1.2 – uTC

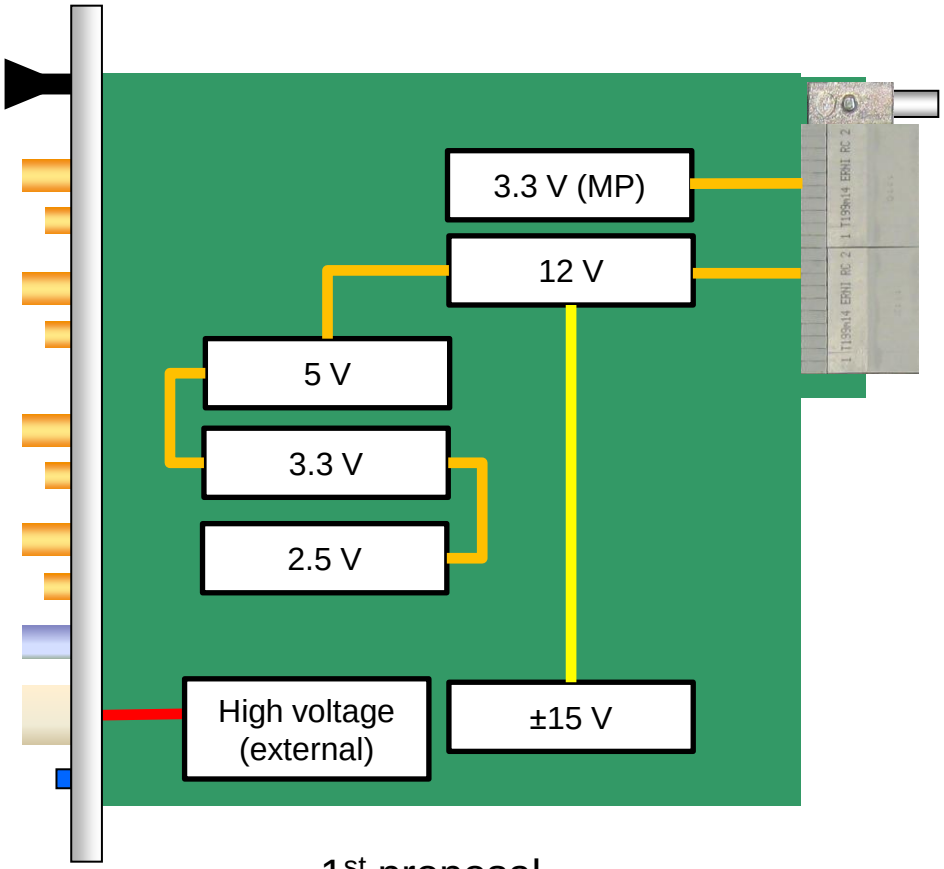
RTM-µPZT4 block diagram



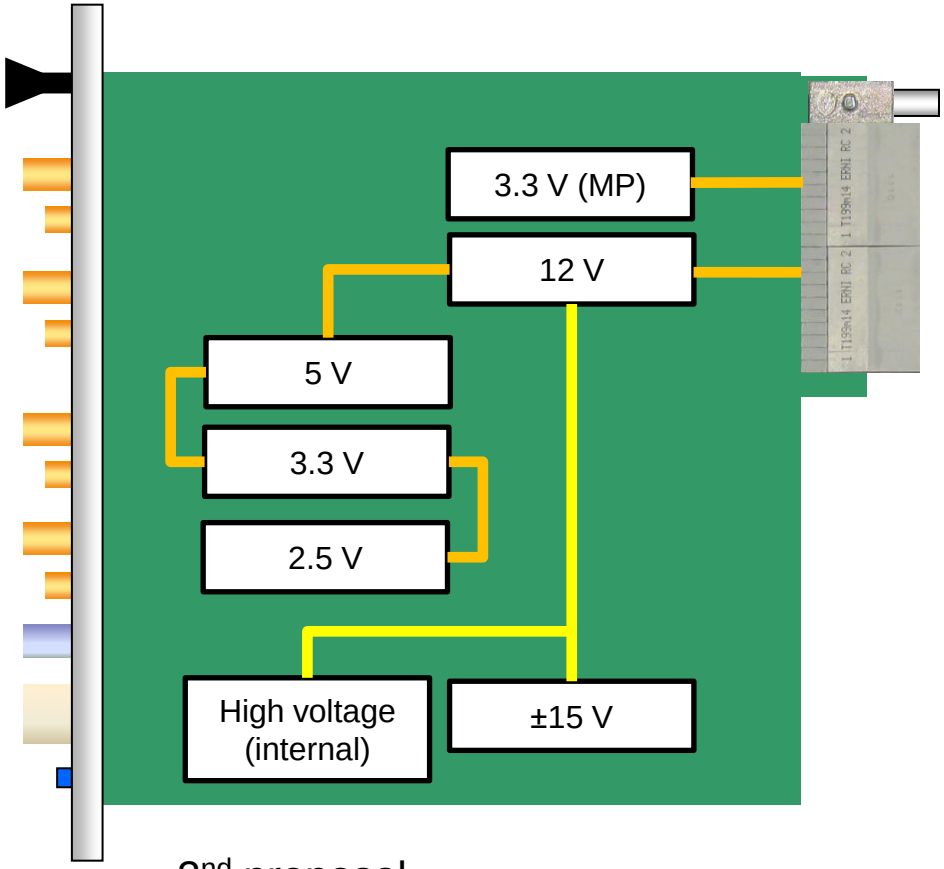
Available Maximum Height of Components for µRTM



RTM-µPZT4 – power supply layout proposal

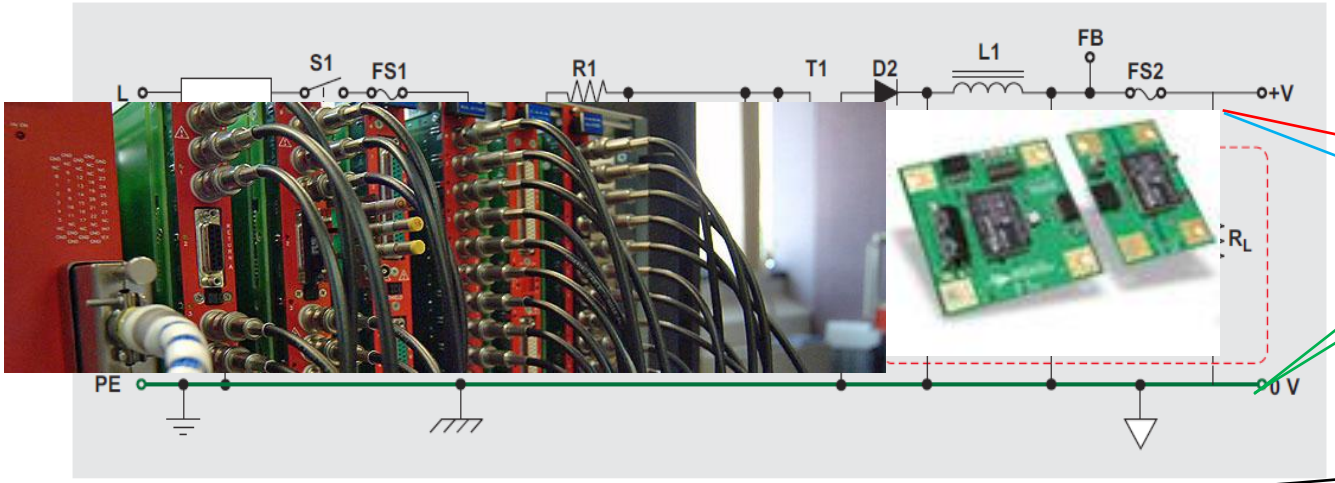


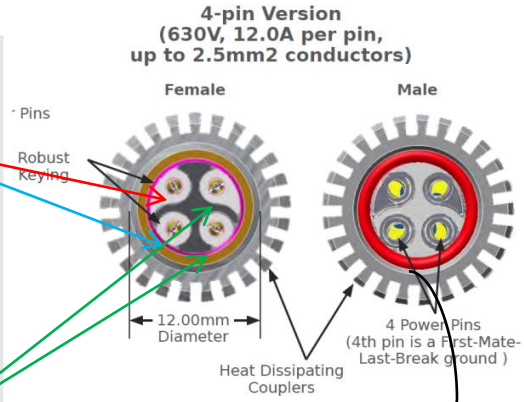
1st proposal

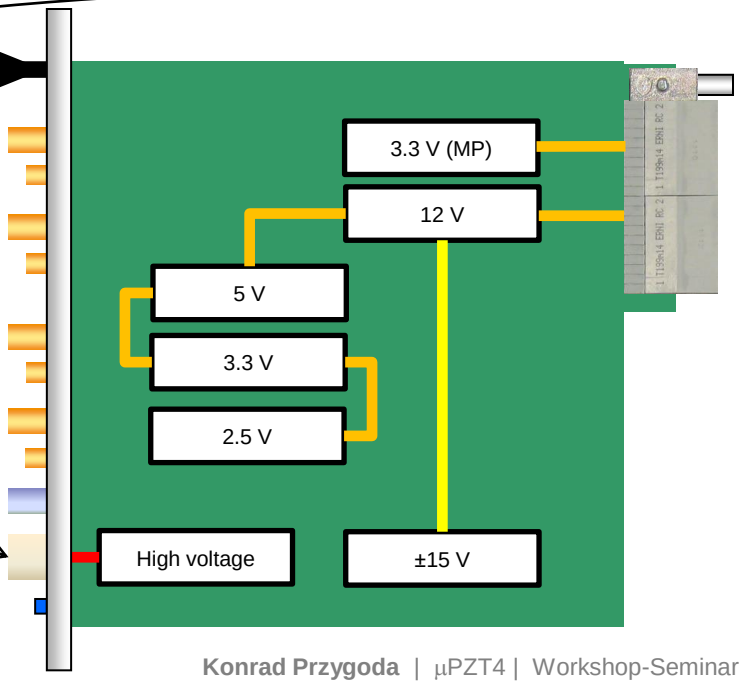


2nd proposal,
(directly or as mezzanine card)

Possible HVPM connection to RTM-µPZT4 (1st proposal)







M12 Brad Power Connectors from Molex

High voltage connector with screw based locking (4th pin is PE and it is first contact pin)

Power consumption – single channel

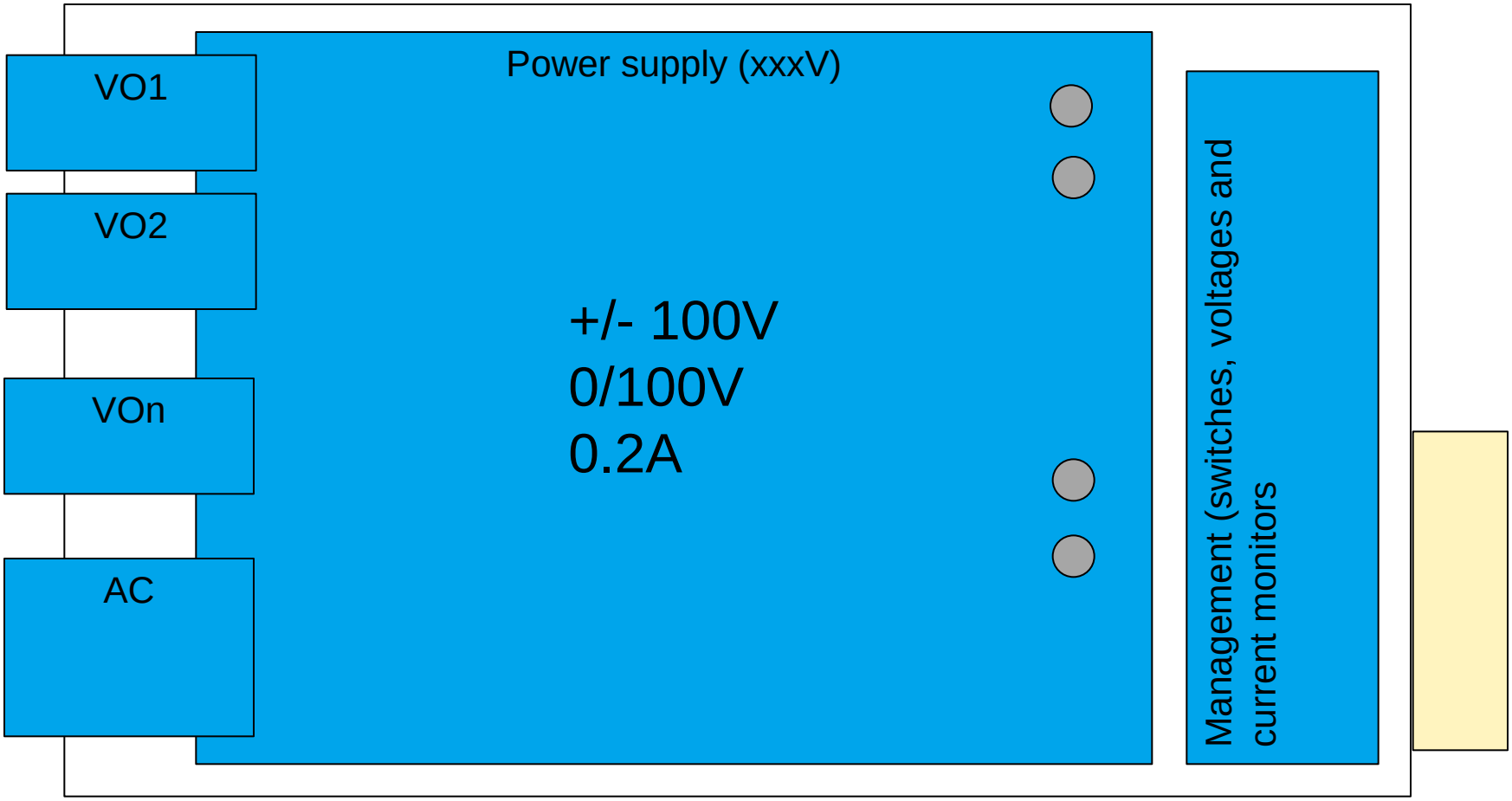
pulse mode

repetition [Hz]	frequency [Hz]	output voltage [V]	Ivcc [mA]	Iout [mA]
100	300	~100	21	~100
25	300	~100	15	~100

cw mode

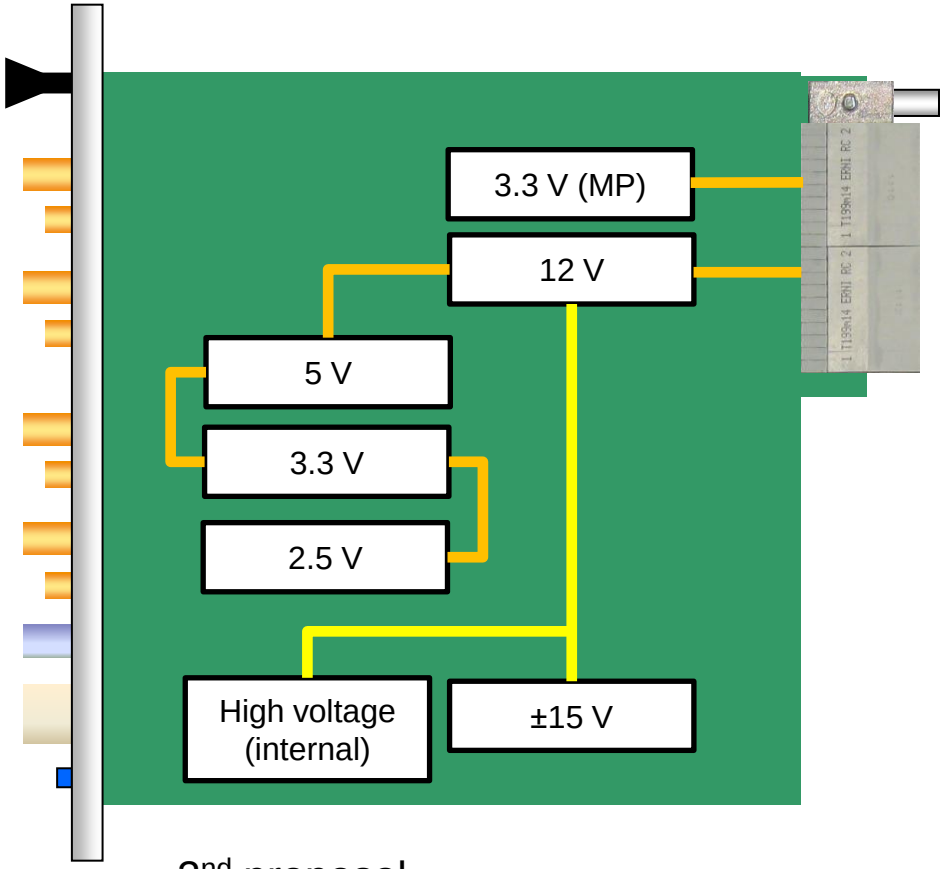
frequency [kHz]	output voltage [V]	Ivcc [mA]	Iout [mA]
100	0.5	18	~10
100	1	24	~10
100	2	36	~10

HVPM idea



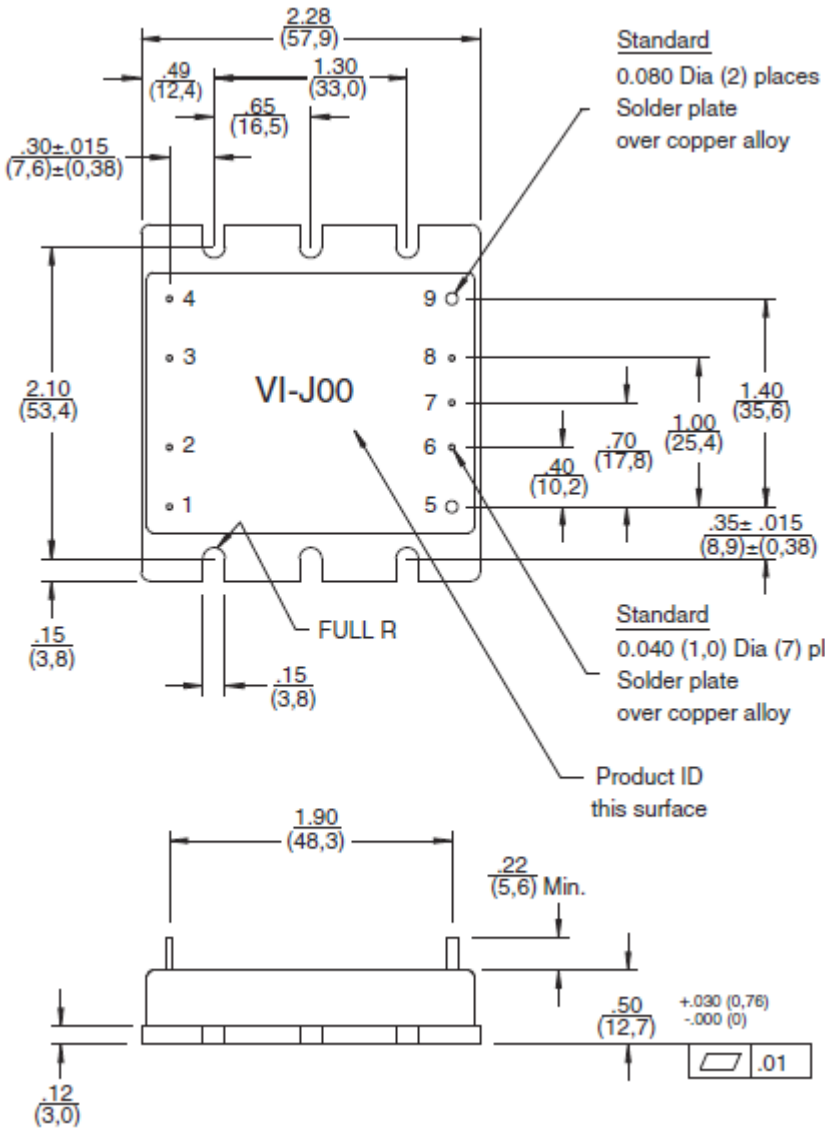
courtesy by T. Jezynski

RTM-µPZT4 – internal HVPM

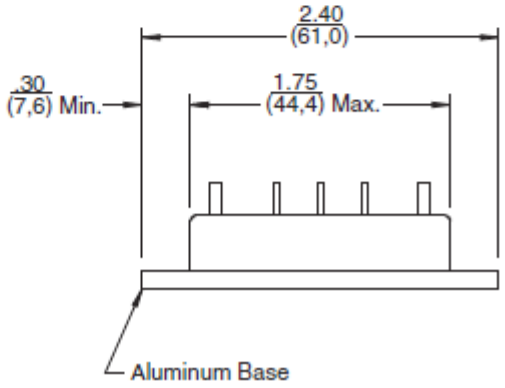


2nd proposal,
(directly or as mezzanine card)

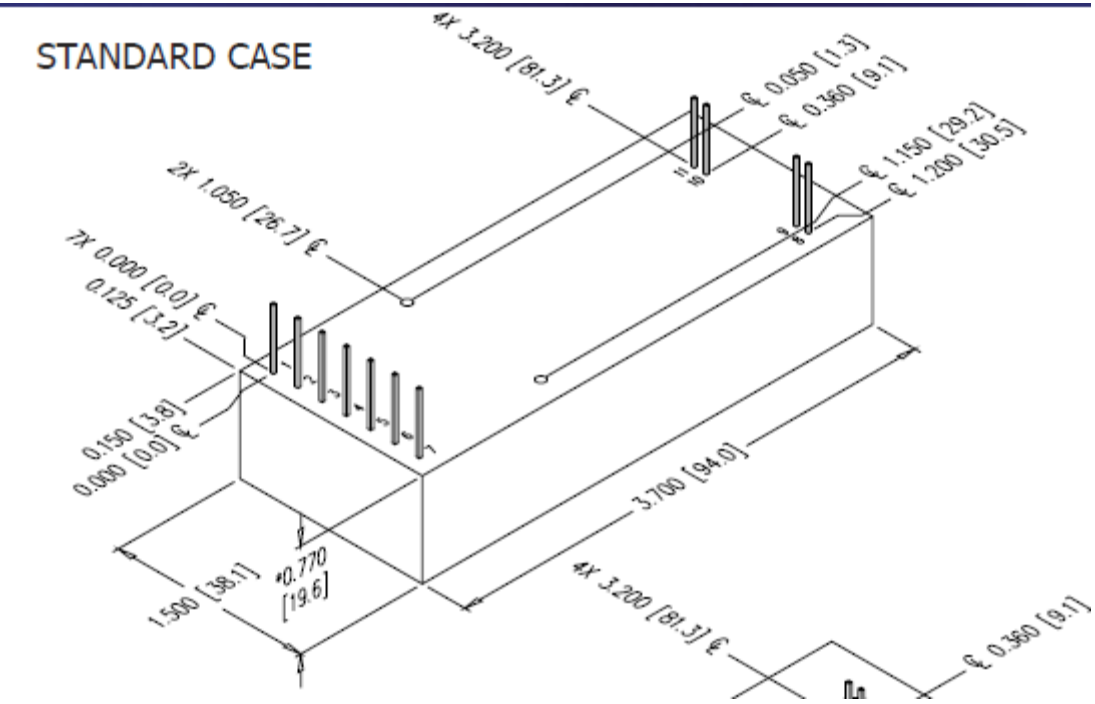
DC/DC converters (Vicor: more than 10W)



Pin #	Function
1	+In
2	Gate In
3	Gate Out
4	-In
5	+Out
6	+Sense
7	Trim
8	–Sense
9	–Out

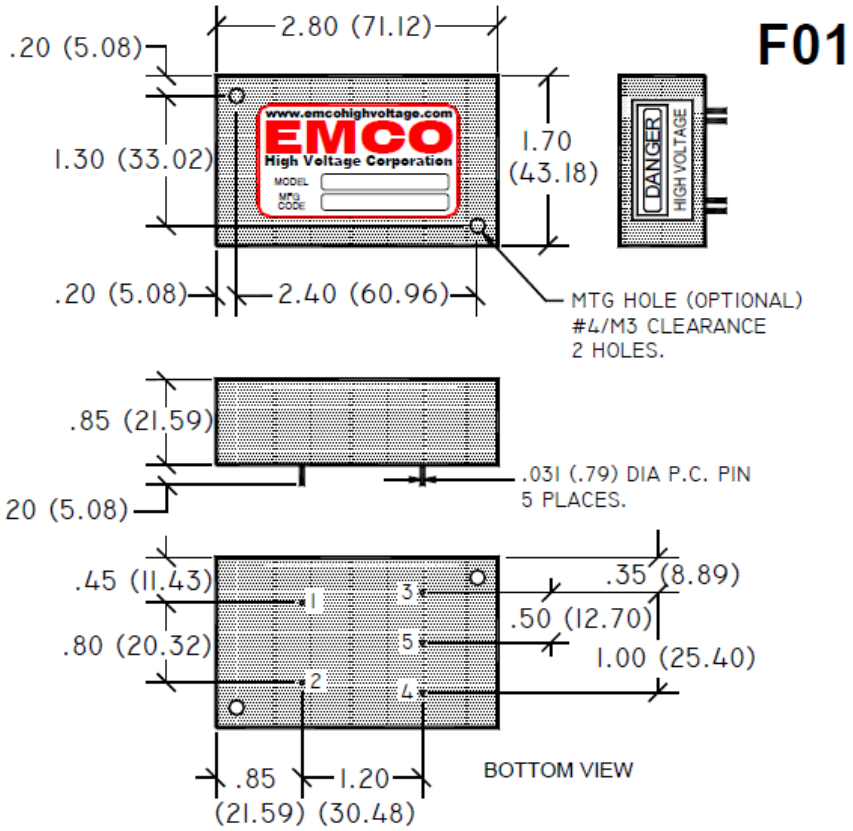


DC/DC converters (Ultravolt: up to 10W)



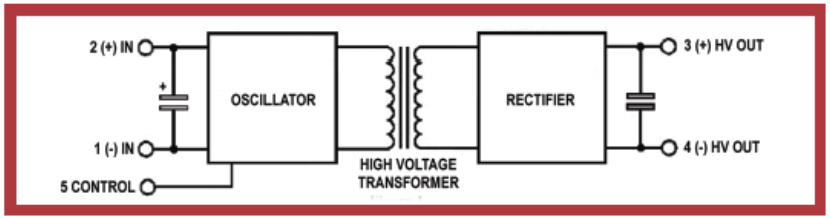
DC/DC converters (Emcohighvoltage: up to 10W)

MODEL	INPUT VOLTAGE	OUTPUT*2 VOLTAGE	OUTPUT*4 CURRENT	RIPPLE P-P
F01	0 to 12V	0 to +/-100V	100 mA	<1.0%



DC/DC converters (Emcohighvoltage: up to 1.5W)

Extremely Low Profile: 0.128 inches and volume of < 0.100 cubic inches[5]

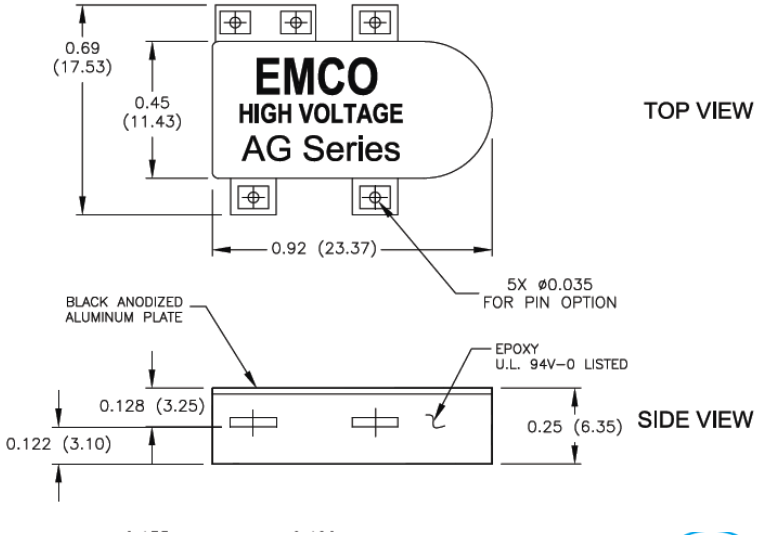


1: mezzanine card with parallel 12V input and 100V output

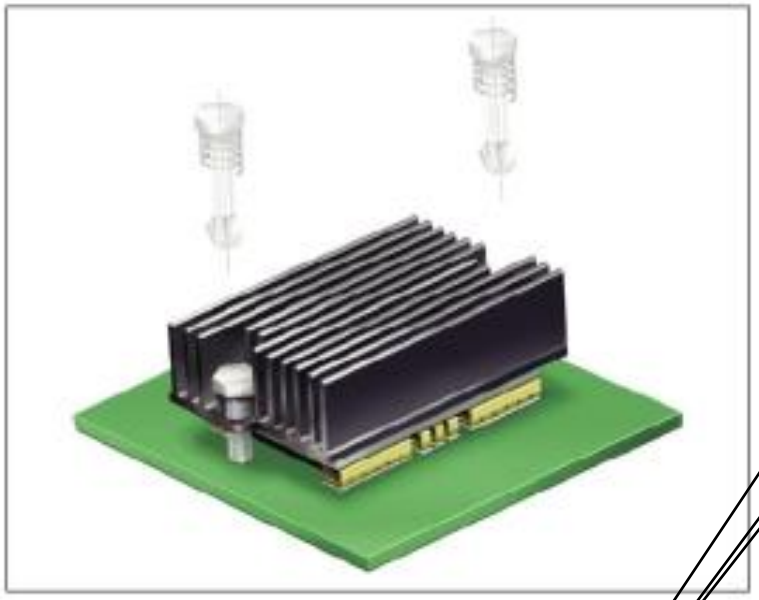
APPLICATIONS

Avalanche Photodiodes
Capacitor Charging
Electrophoresis
Photomultiplier Tubes
Piezo Devices
Mass Spectrometry
Sustaining Ion Pumps

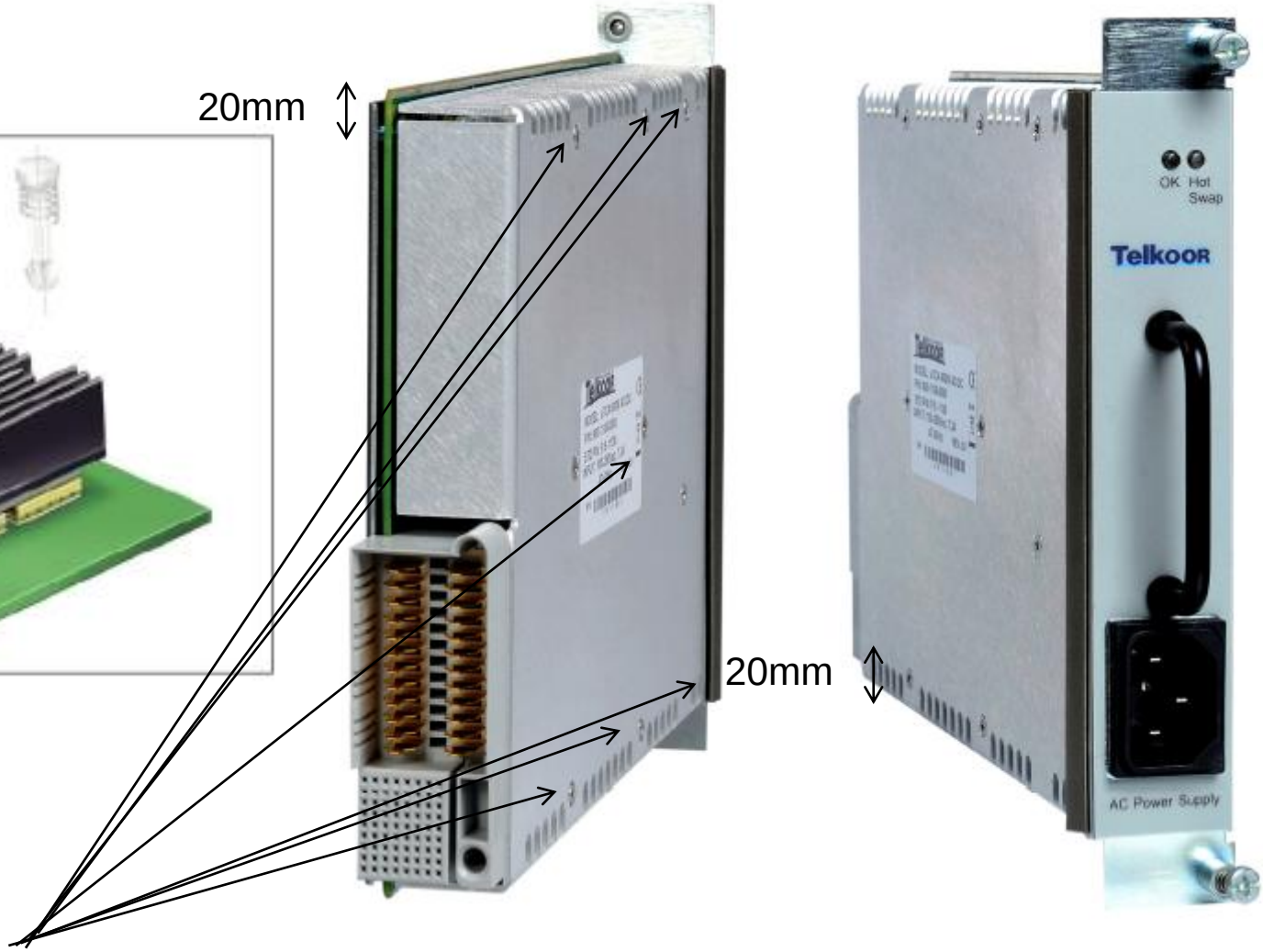
VDC	STANDARD 1 WATT - AG MODEL		1.5 WATT OPTION - AGH MODEL	
	MODEL	MAXIMUM OUTPUT CURRENT*1	MODEL	MAXIMUM OUTPUT CURRENT*1
100 VDC	**AG01**	10 mA	**AGH01**	15 mA



RTM-μPZT4 packaging

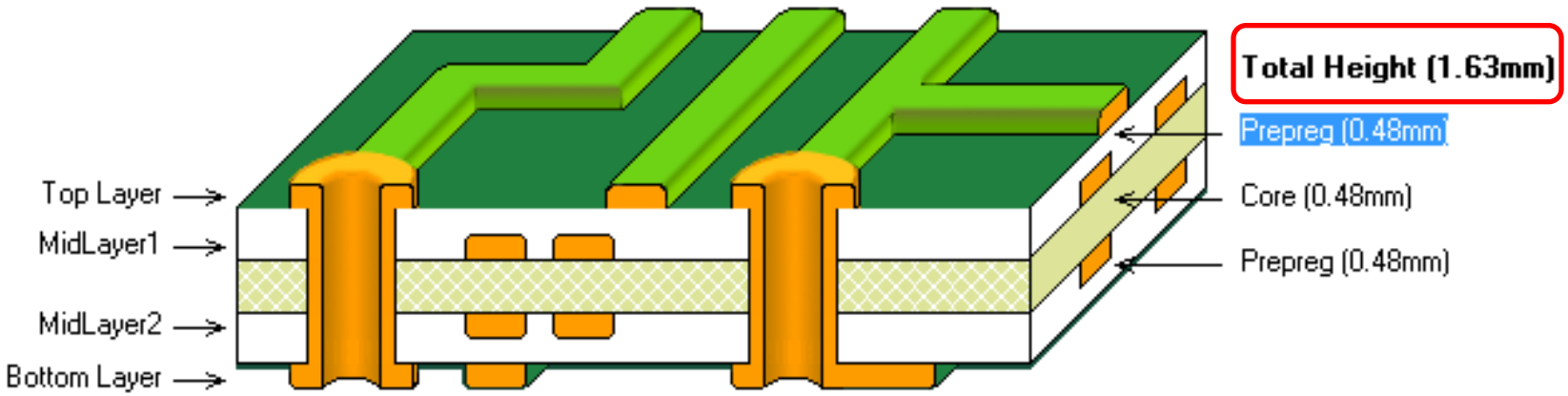


Additional radiator
inside the box



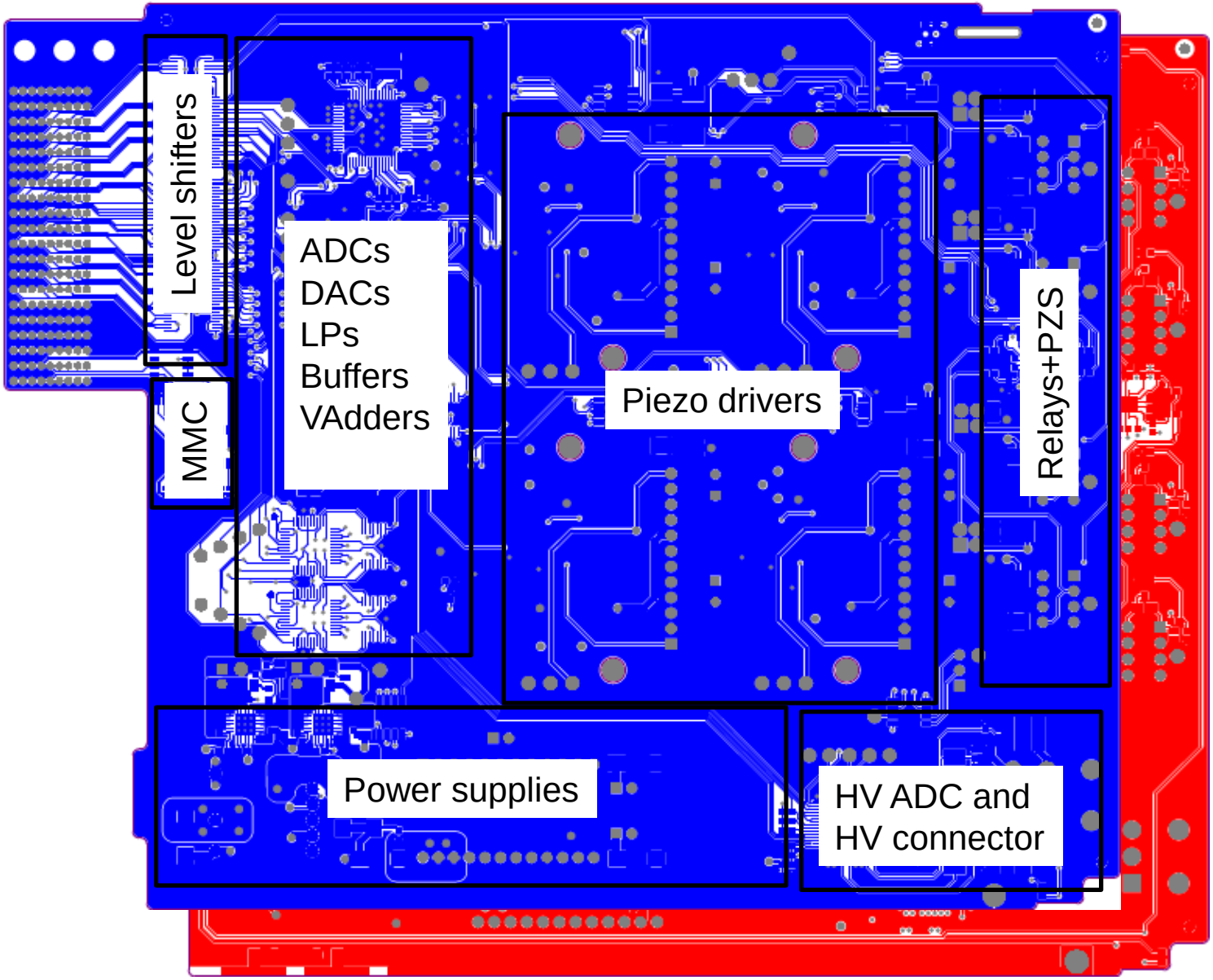
Possible mounting screws placement

PCB Design

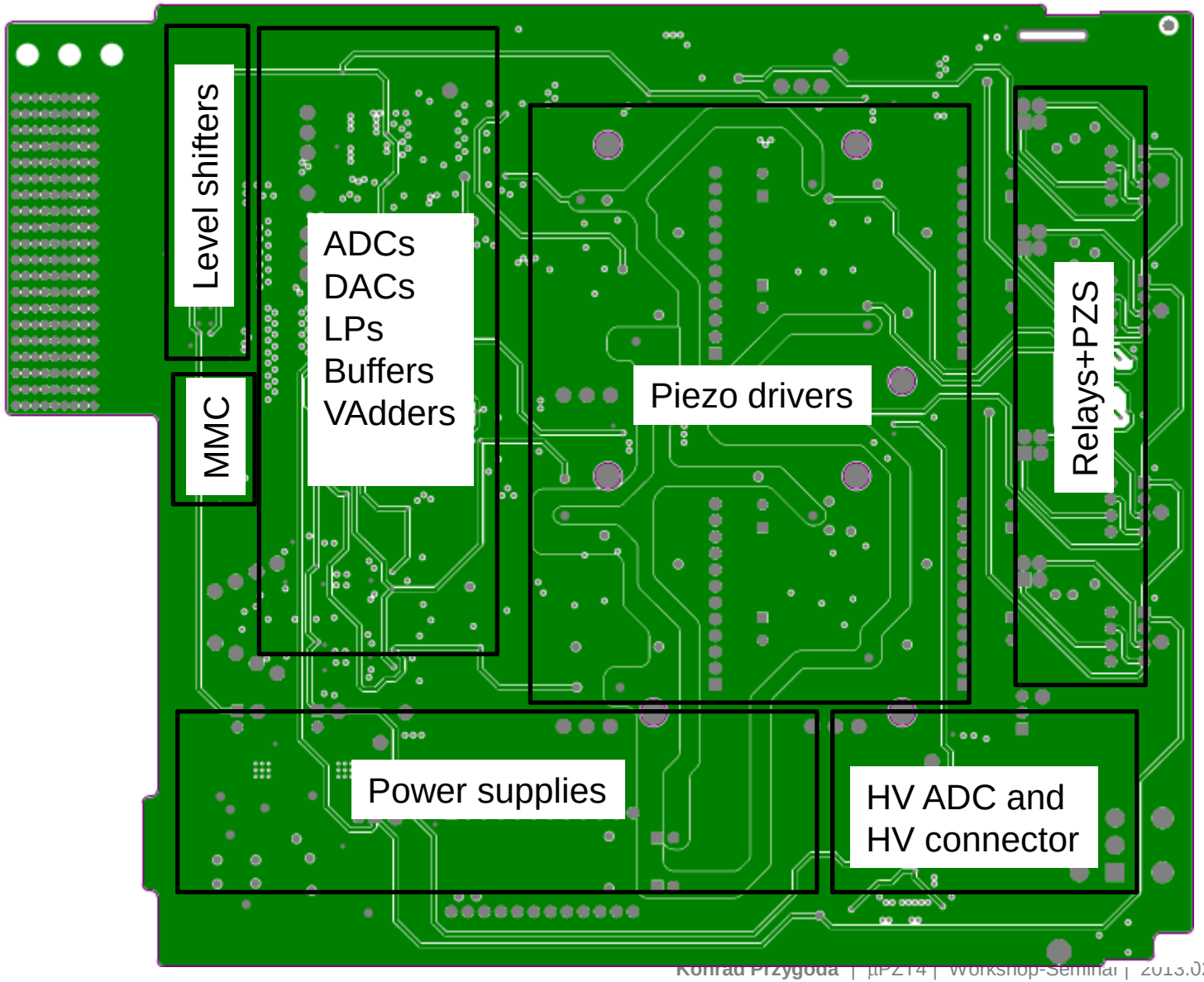


- The PCB board must be designed using 4 layerstack. The low voltage signals must be routed using outer layers. The high voltage signals as high voltage planes should be routed using inner layers and internal planes. The proposed material for PCB is FR-4 with standard cooper thickness of 35 mm and all pads covered with gold. Estimated minimum conductor width and spacing for piezo driver outputs are 0.3 and 0.2 mm respectively (100 V, 1.5 A). Maximum allowed PCB board thickness should not exceed 1.6 mm (4 layers with symmetric height of 0.48 mm should be sufficient) to fulfill maximum allowed height of the crucial components assembled on the PCB. Standard drilling of vias from top to bottom layer should be sufficient (no barried Vias needed).

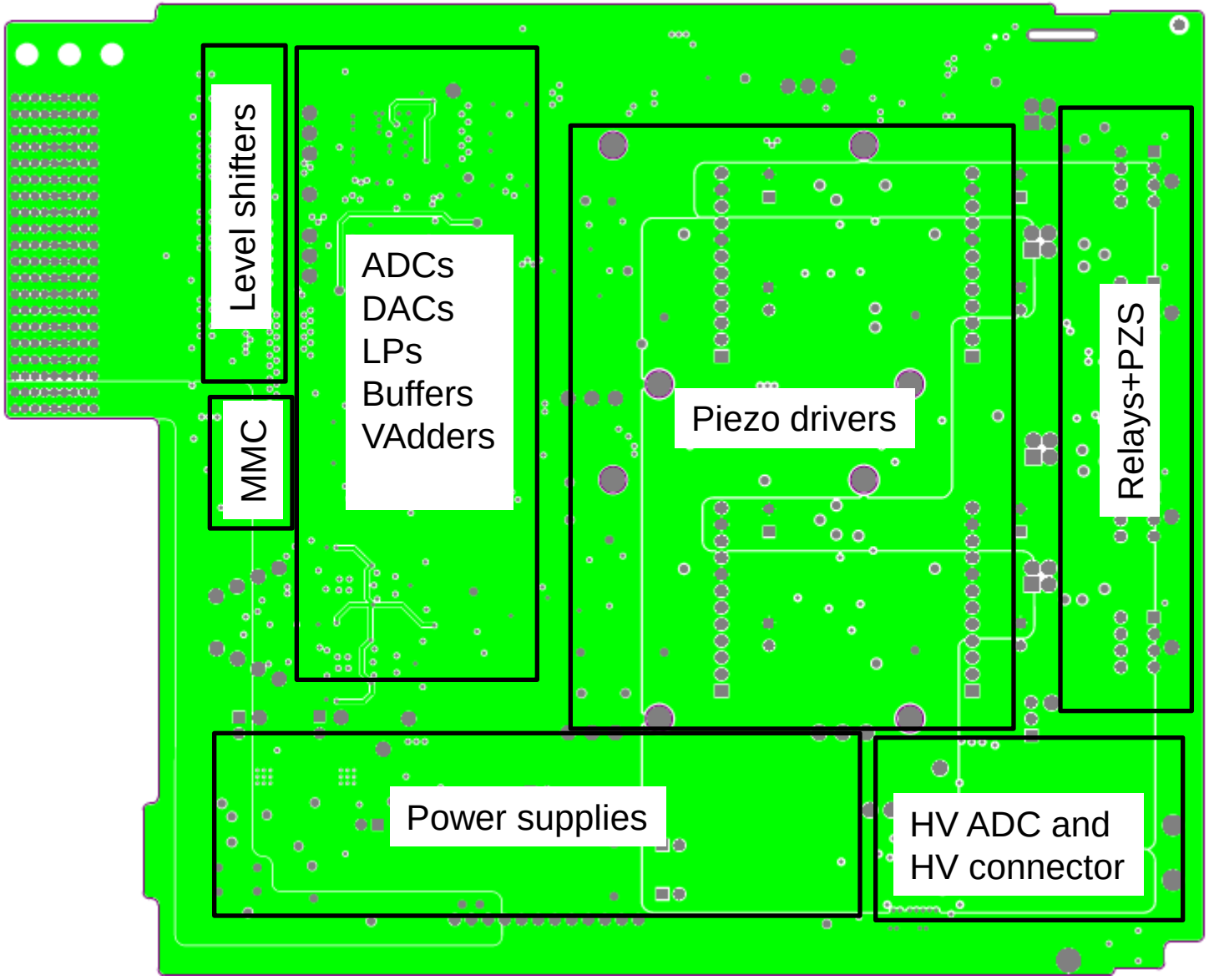
Bottom and Top Layers (digital and low voltage signals)



MidLayer1 Layer (+/-15V; high voltage PZD out)

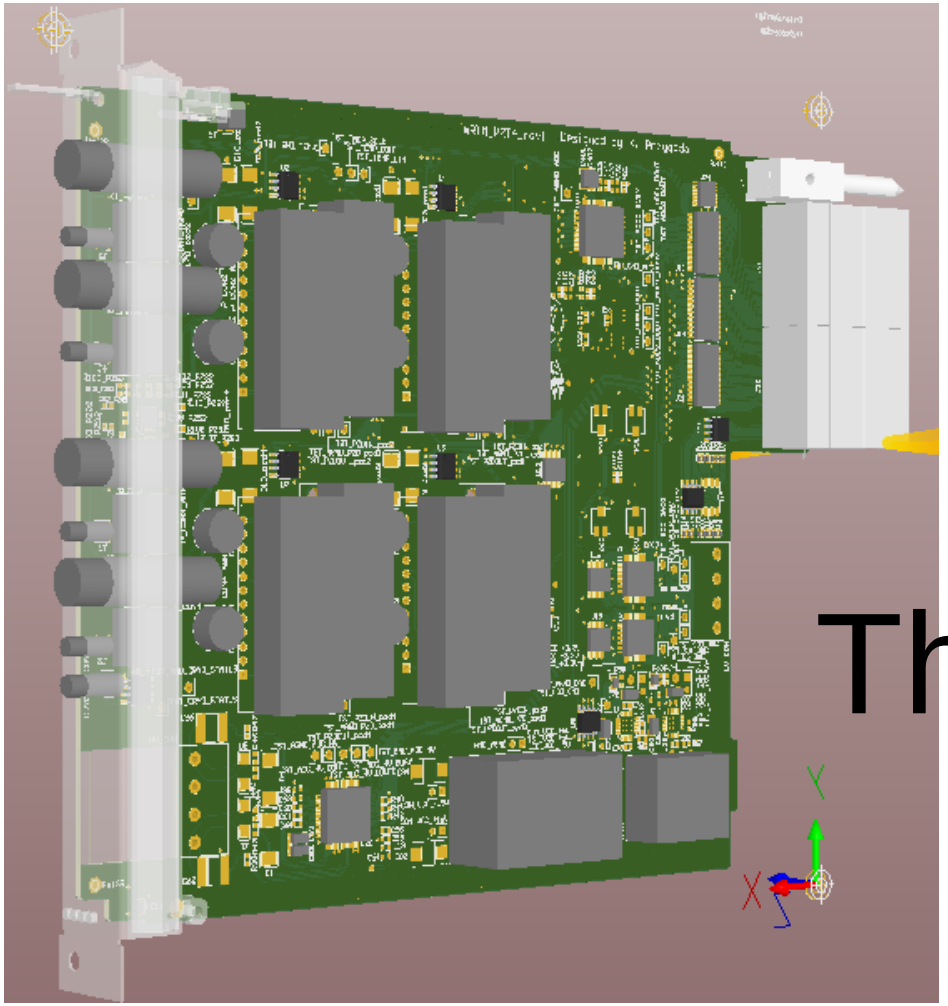


MidLayer2 Layer (HV power supply;12V)



Project status

- Initial electrical schematics finished
- Initial components placement finished
- Initial PCB routing finished
- Zone 3 pinout crosschecks according to last changes
- Crucial components lifte time estimation and ordering processes started
- Requirements collection for safety rules fulfilling i.e. using metalic cover, hv connection (lock connector??), internal power supply??
- Final PCB routing
- Gerber files generation and prototypies production



Thank You!

Possible latency

- i.e. for 100 kHz closed loop bdw, we have delay = pi/4/2/pi/100kHz ~ 1.25 μs delay (when assume of 45 degress phase margin)
- for 5 kHz closed loop bandwidth ~ 25 μs
- DAC, ADC and FPGA data processing with 2 μs (500 kSPS), should give us more than 10 samples of allowed delay (1 sample IQ detection, 1 sample moving avarage, 1 sample PHASE calculation, 3 samples PI, 5 samples LP/NOTCH)
- MGT serial link latency (125 MHz reference clock) up to 3 Gbs with SP6
- ADCs clock at SIS (>81 MHz??)

Comments

- Possibility for internal DC/DC converter 12=>+-100V (0.5A)
- Piezo driver bdw <1V pp starting from 100 kHz
- Spacing for metal housing
- Output current estimation for <1V pp and capacitive load 1 uF

Power consumption – single channel (C_p=~1μF)

Vcc [V]	Ivcc[mA]	frequency [Hz]	output voltage [V]
124	13	off	0
	38	300	~100
	57	500	~100
	104	1000	~100
	150	1500	~100
	193	2000	~100

frequency [kHz]	Output votlage [V]	temperadure [°C]	Ivcc [mA]
10	1	21	20
10	2	21	33
10	5	21	68
10	10	23	127
10	15	28	185