Mobile Flexible Gassystem

status update for 4th Detector Workshop

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PHYSICS AT THE TERA SCALE
Helmholtz Alliance

RWTH AACHEN

Outline

Summary on the requirements

System should be able to mix all common used gas mixtures.

Flexibility

is needed to adjust functionality and behaviour (pressure & flow) to different chamber types used (TPC, GMC, RPC, MSGC etc.)

Mobility

Use the **same** system both for development in the lab and for test runs at test beam centers. It should be transportable without much effort.

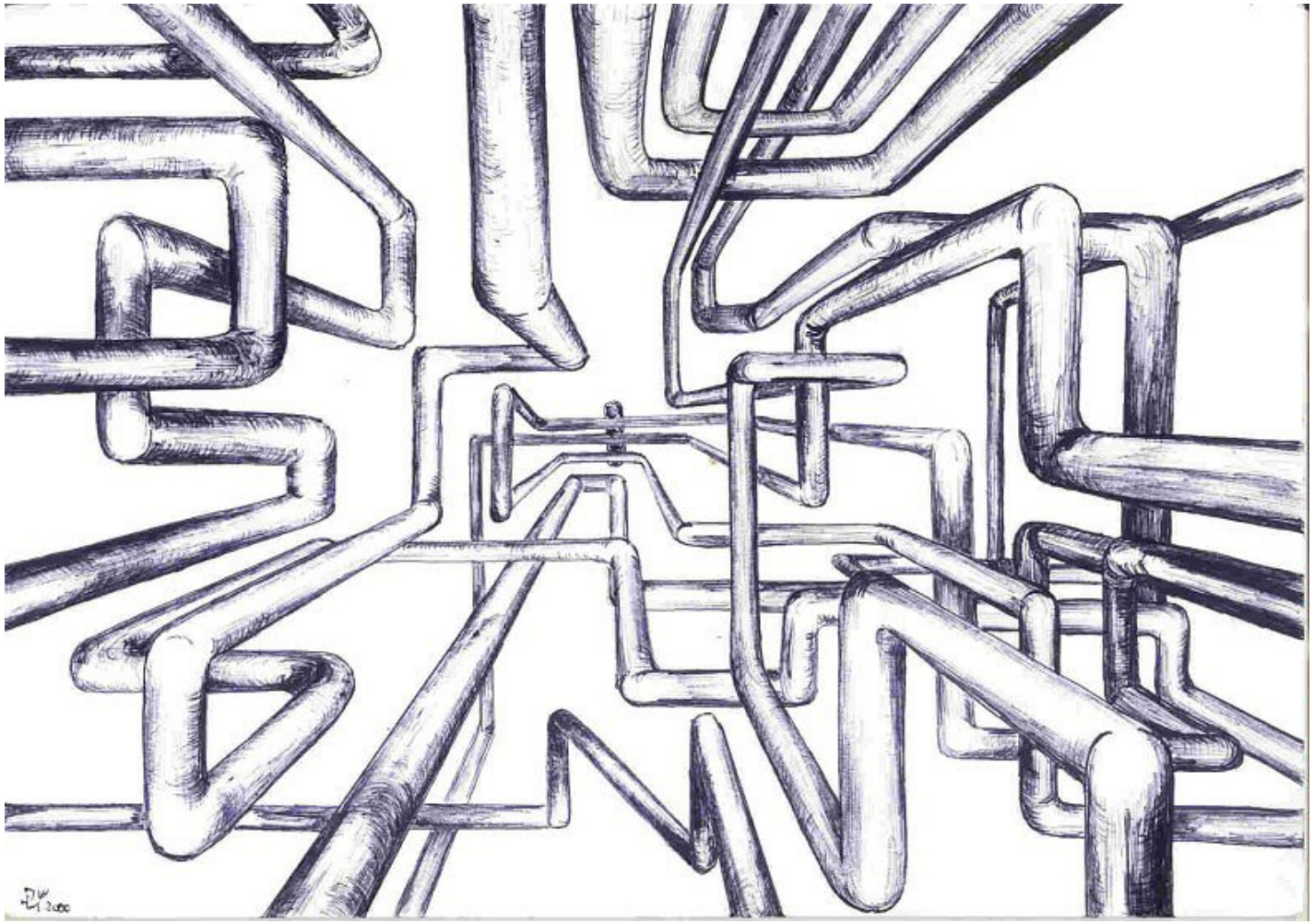
Safety

System must be consistent with the current safety norms and laws (mainly regarding operation with burnable gases)

What is the system able to do?
(or better what is planned)

- create various mixtures of three out of 8 gases
  Ar, CH_4, iC_4H_{10}, CO_2, Xe, He, CF_4, Air
  all most common drift gases could be mixed.
- in addition more gases (even some exotic ones and mixtures) could be used via conversion constants
- creation of mixtures from ppm to %-level
  $\Rightarrow$ Needed for testing the effect of contaminations on the detector.
- open, closed and halfopen operation mode
- analysis of the mixed drift gas
  - gas chromatography
  - special analysis devices for H_2O and O_2
  - further analysis devices (optional)
    - analysis of trace gases, very sensitive to small amounts
      $\Rightarrow$ analysis solution from atmospheric physics (CE DOAS)
    - gas monitor chamber: measurement of driftvelocity and gas amplification

mechanical concept



by Iris von Knobelsdorff

basic elements

mixing

done by MassFlowController

purification

removal of O_2 & H_2O

Buffer

gas storage & mixture

analysis

gas parameter

chamber

parameters:

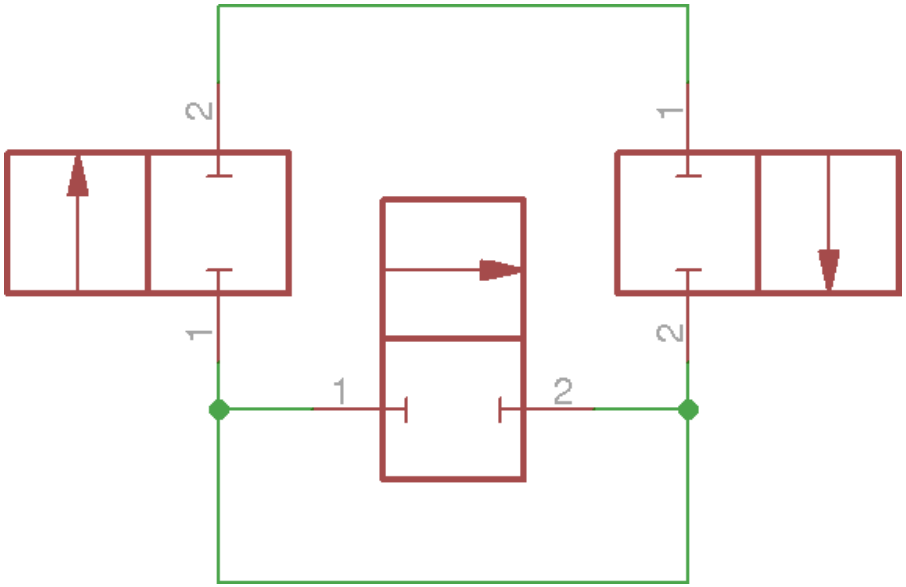
- flow
- pressure
- mixture

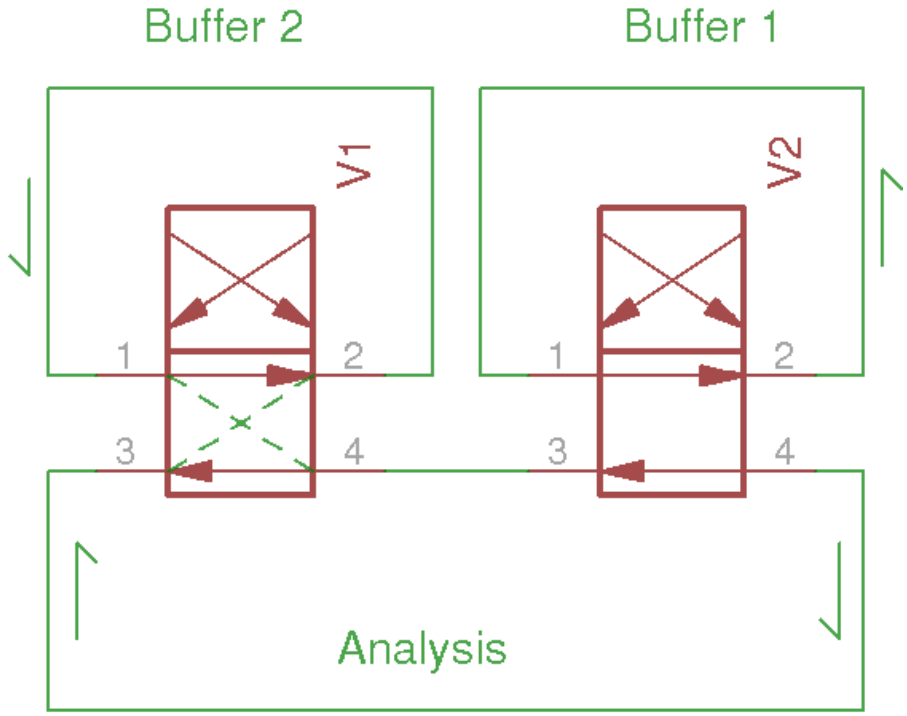
operation

- without interruptions
- 24/7, but not the whole year. This means service interals are possible.

interconnection of devices

This can be replaced by one 4/2





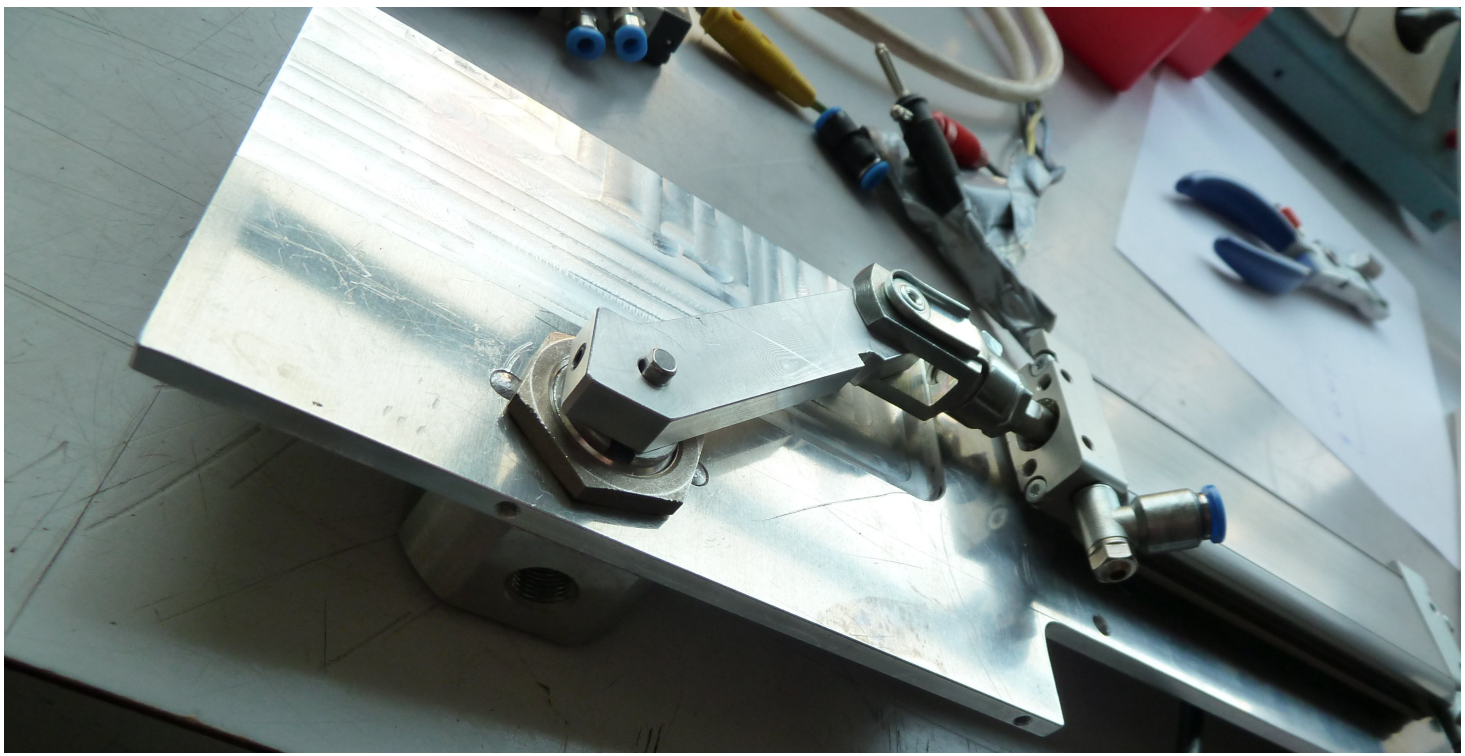
use of 4/2 way valves

- saves 2 valves per loop connection ⇒ failsafe
- saves 1/3 of all connections ⇒ tightness

4/2 way valve (Prototype)

development of 4/2 way valve actuator

no commercial 4/2 way process valve with actuator available.
$\Rightarrow$ development of own actuator for a 4/2 way hand valve.



concept

basic concept

closed loops, which can be connected with each other.
Gas is always circulating, even inside the loops

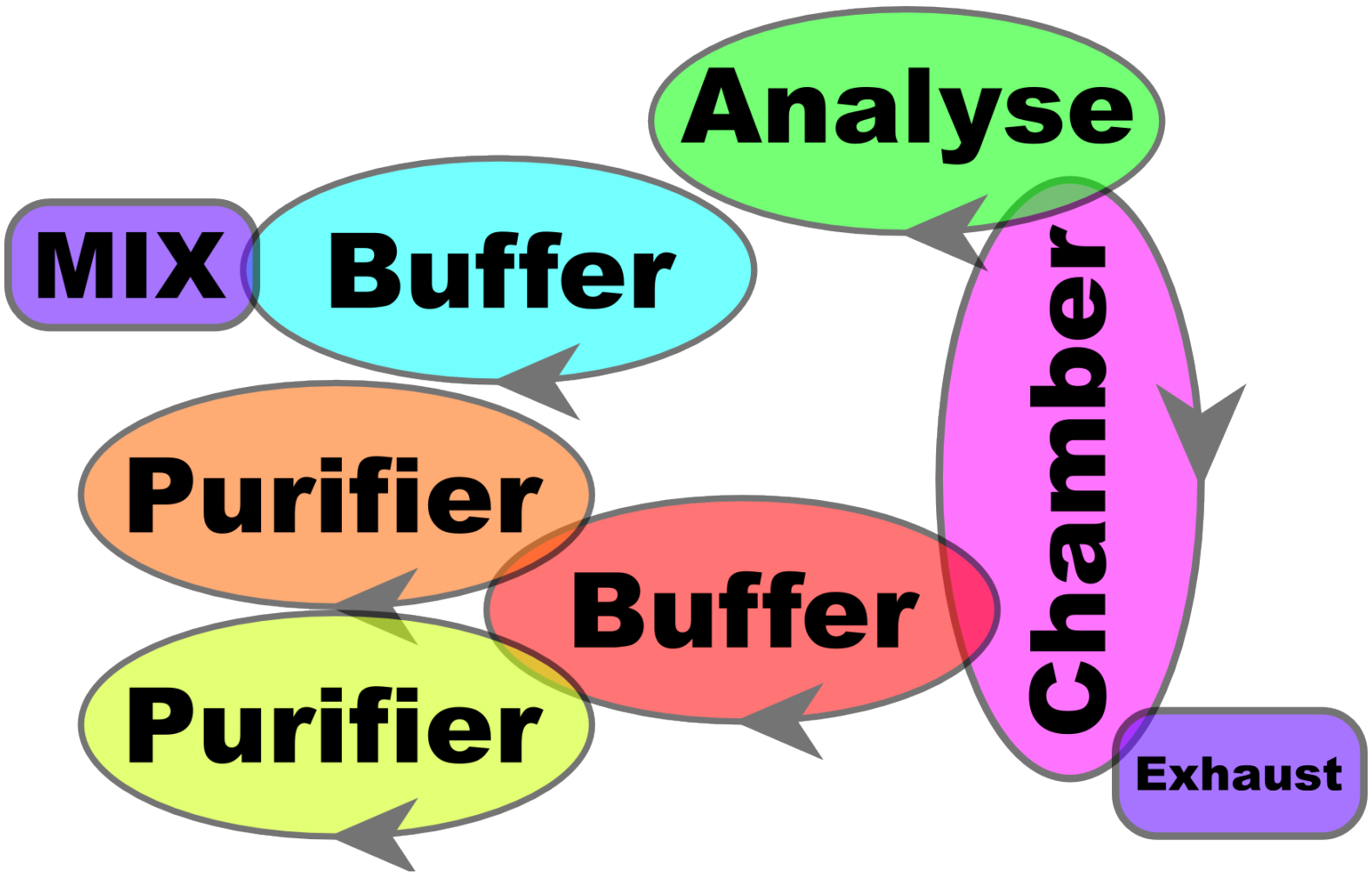
Loops

Each Loop represents an assembly group. Dividing the concept into modules rejected, because the number of connections is increasing $\Rightarrow$ tightness.
Each loop is intrinsically safe without power. It can be maintained during operation.

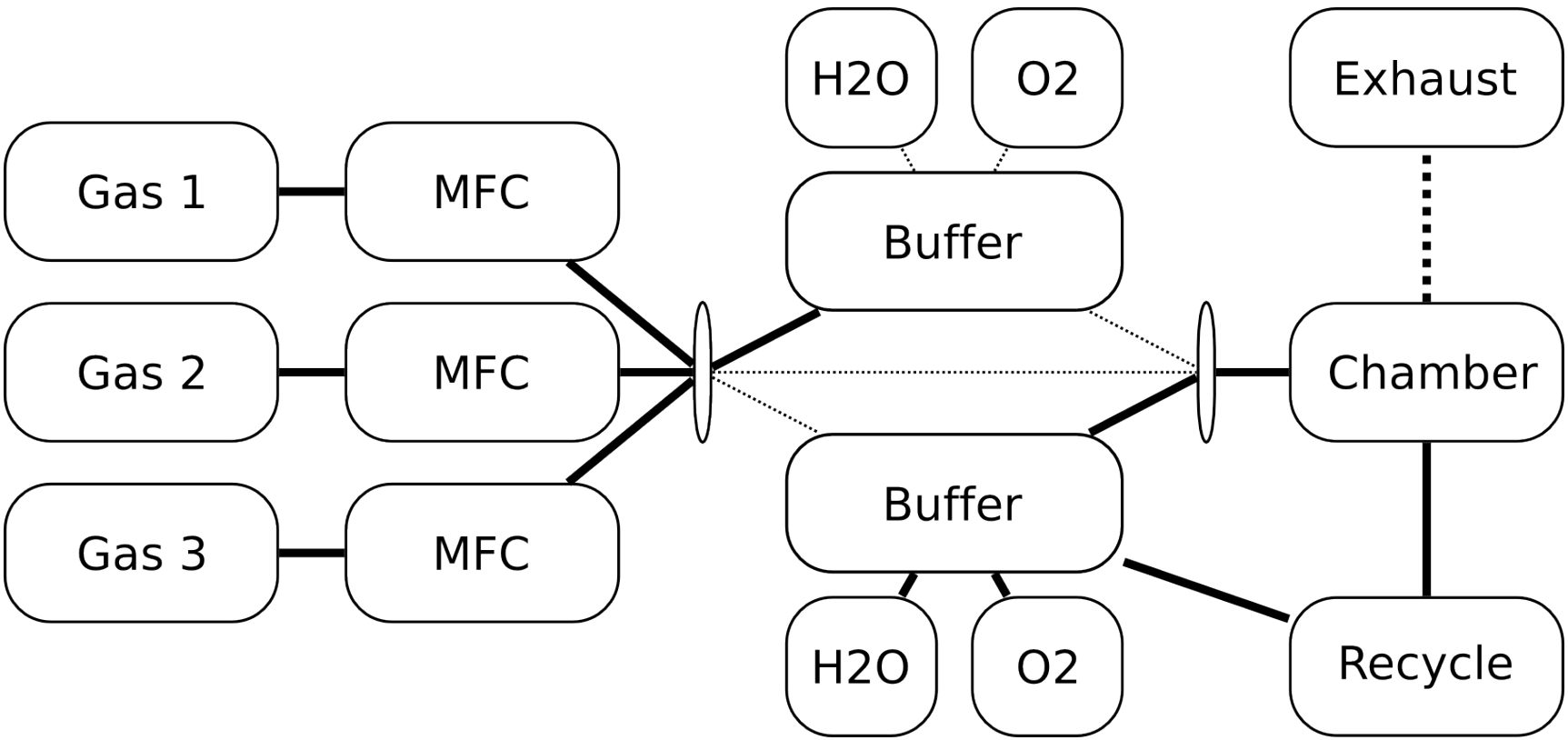
Integration of non Loop devices

Source and sink of the gas are not loop able, but it is possible to integrate them easily.

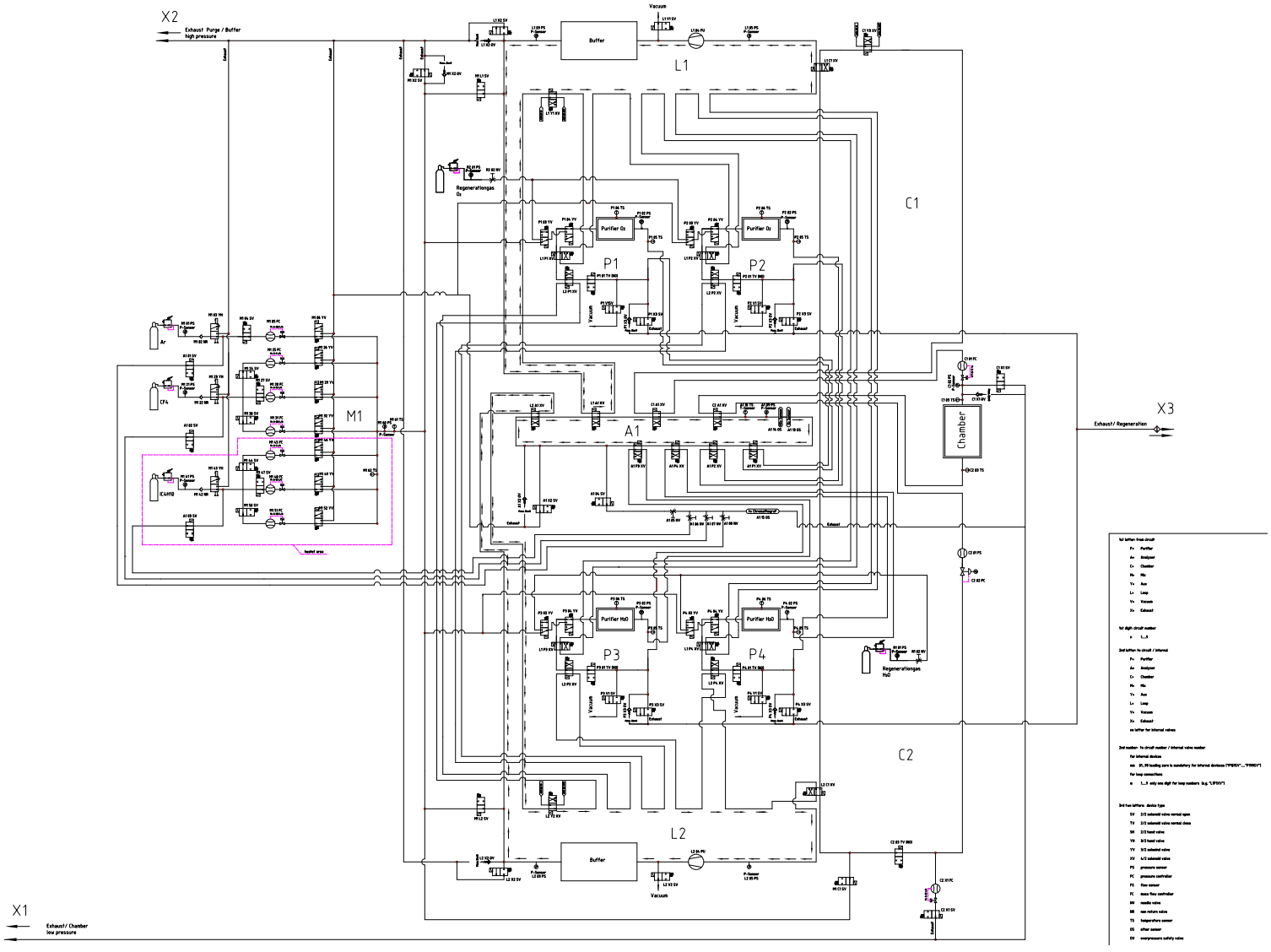
schematic concept



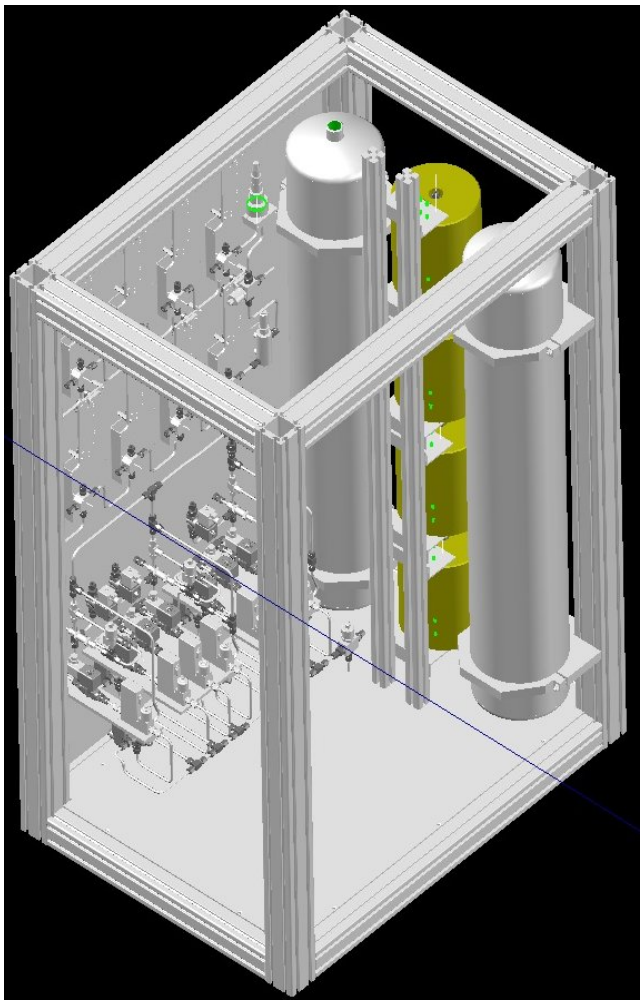
concept II


H2O
O2
Exhaust
Gas 1
MFC
Buffer
Gas 2
MFC
Chamber
Buffer
Gas 3
MFC
H2O
O2
Recycle

overview


X2
Exhaust Purge / Buffer high pressure
Buffer
L1
Vacuum
C1
P1
P2
Purifier O2
Purifier O2
Regenerationgas O2
M1
Ar
CF4
A1
Chamber
X3
Exhaust / Regeneration
P3
P4
Purifier H2O
Purifier H2O
Regenerationgas H2O
C2
L2
Buffer
Vacuum
X1
Exhaust / Chamber low pressure

3D sketch



status 15.03.2011

size

- about $80 \times 150 \times 180\,\mathrm{cm}^3$
- only mechanical part shown
- electrical rack missing
  $80 \times 50 \times 180\,\mathrm{cm}^3$
  will be attached to one unit

Maintenance

- all parts are easy accessable
- exchange / modification should be possible

uncertaincies of the mixture

Example: Flow Mixing

gas	amount		6 l/h	30 l/h	60 l/h	
Ar	95	±	**0,051**	0,074	0,051	%
CF_4	3	±	**0,036**	0,053	0,036	%
iC_4H_{10}	2	±	**0,029**	0,045	0,029	%

Uncertaincies are related to the maximum range of the used flowmeters. Due to this, there are some „regions“ of total flow, where the error on the mixture is minimal.

improve with buffer

By using the buffer, it is possible to use the minimal uncertaincies.

These computations where derived from the datasheet of the MFCs.

Status of the mechanical system

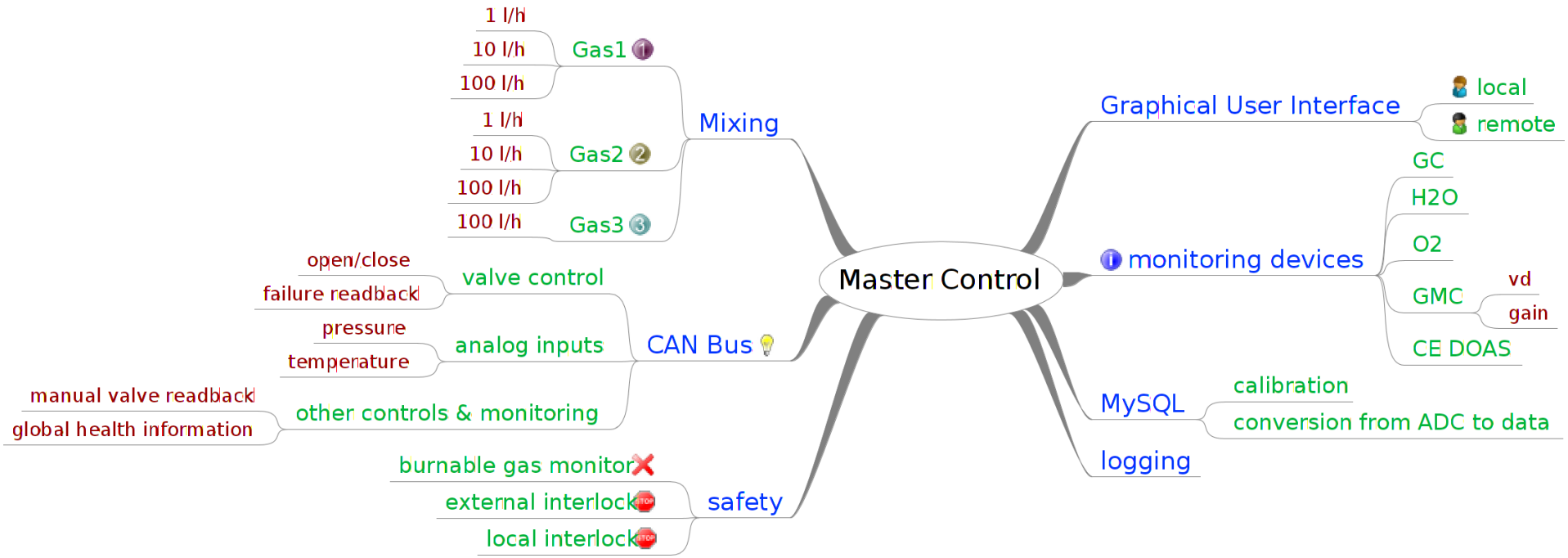
hardware selection

- almost all components selected and specified
- few components specified but not selected
- developing some solutions to get the perfect match
- a lot of work spent for safety issues
  dimensioning, ventilation, gas warning system, etc.

concept and 3D design

- flow diagram finished. Needs to be adapted to some changes because of other hardware
- 3D design study almost finished.
- Safety checks and calculations needs to be done. Many calculations depend on the mounting positions and sizes of the system.

electrical control system



electrical concept

development of own electronics

best suited solution for a system, which is that flexible. There is no such commercial solution available.
Even the costs per channel are much lower, because we pay only for those things, we really need. In commercial solutions, you pay for a lot of features, which we would never use.

interfaces

analog input industrial 4...20 mA current loop input.

digital output 5 V TTL level

digital input OpenCollector output of device required, 5 V biased input

module connection CAN-Bus: industrial use, cheap and easy accessable

control system

Electronic Requierements are derived from the mechanical part

- 80 digital outputs
- 120 digital inputs
- 48 analog 4...20 mA 12 bit inputs

Hardware amount

9	FC	Flow Controller
1	FS	flow sensor
3	NR	non return valve
6	NV	needle valve
3	OS	other sensor
9	OV	overpressure safety valve
1	PC	pressure controller
17	PS	pressure sensor
2	PU	pump
30	SV	2/2 way solenoid valve (normal close)
13	TS	temperature sensor
5	TV	2/2 way solenoid valve (normal open)
21	XV	4/2 way solenoid valve
3	YH	3/2 way hand valve
15	YV	3/2 way solenoid valve

In total the electronic must control $\approx$ 120 devices. Further 20 devices bring their own electronics, but they have also been integrated.

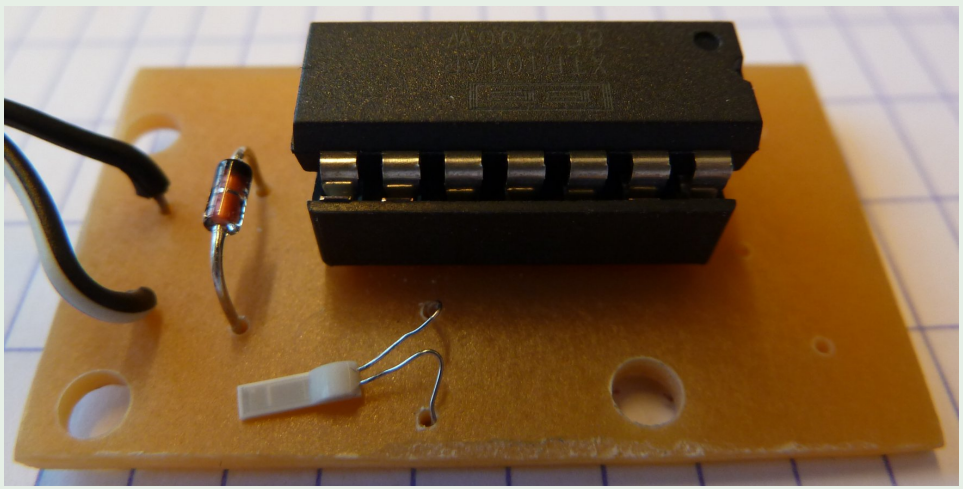
Temperaturesensor

PT100 $\Rightarrow$ 4...20 mA

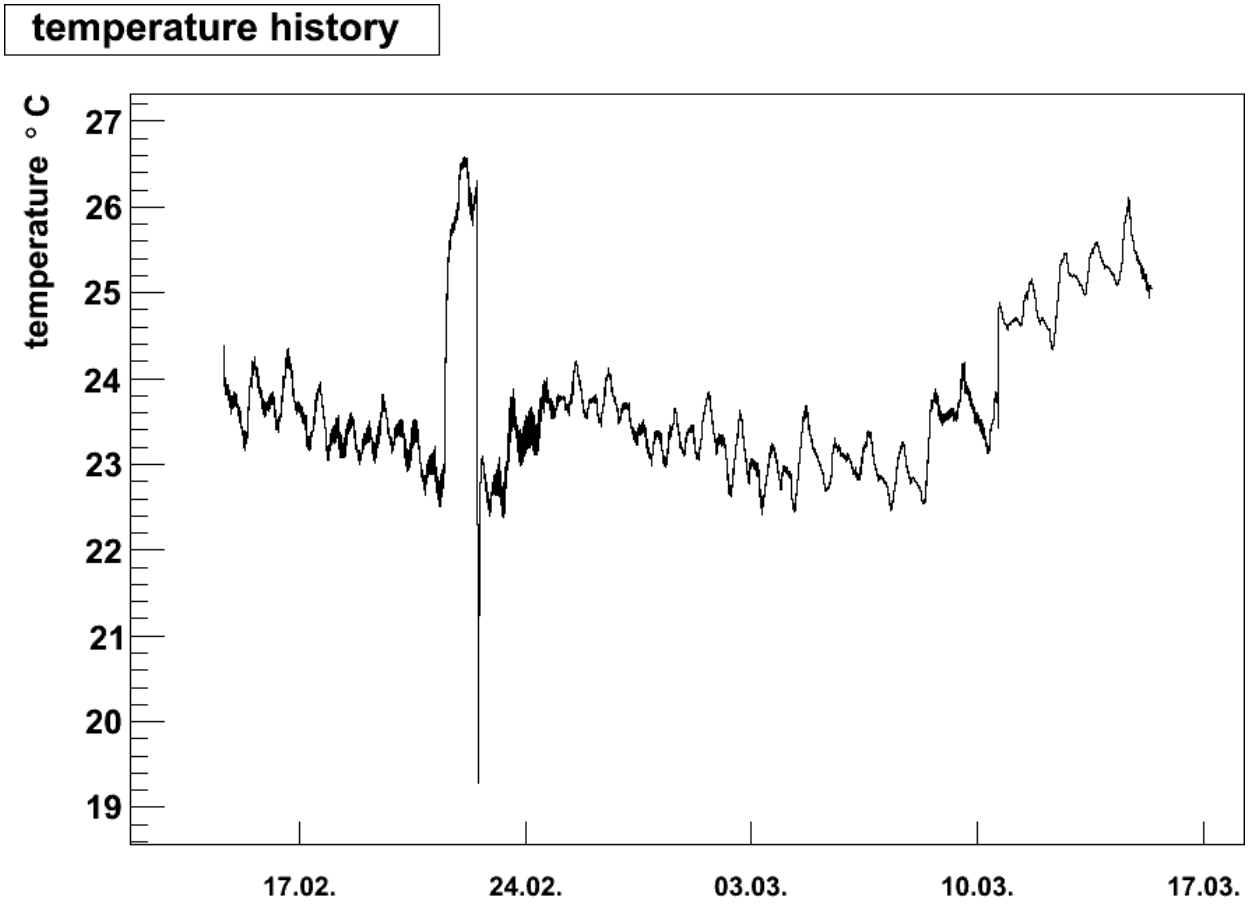
converter from standard PT100 sensor to industrial interface

- 1 IC
- PT100
- diode 1N4148
- three resistors & capacitors

size of prototype: 40 $\times$ 20 mm
final version will be smaller



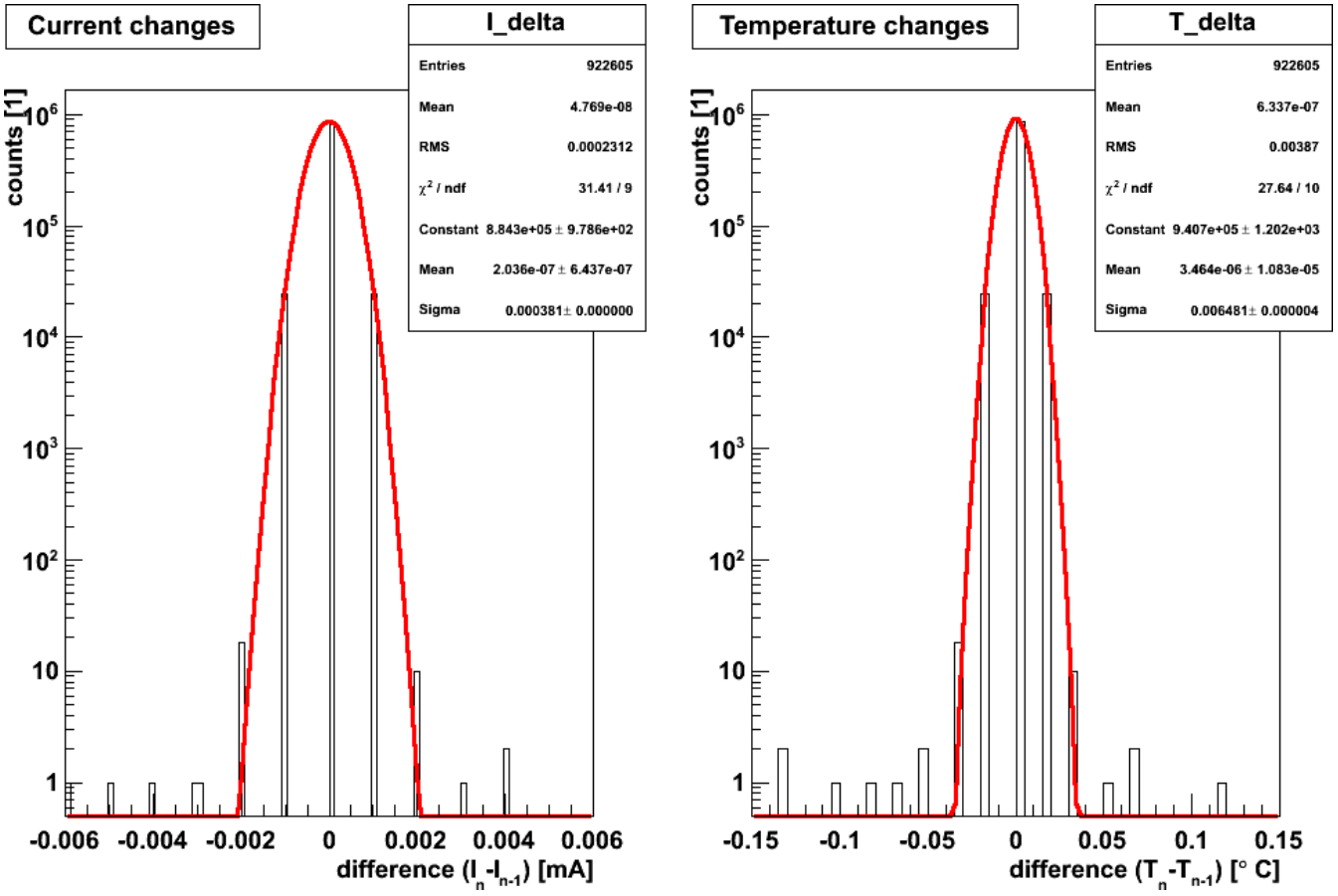
first tests



sensor temperature was ambient temperature

The sensor was covered to protect it from air conditioner flow.

first tests



noise (defined as $T_n - T_{n-1}$)

Measurement frequency was about 0,01 Hz. Sigma of 6,5 mK (!).

minimizing the heat emission

Problem:

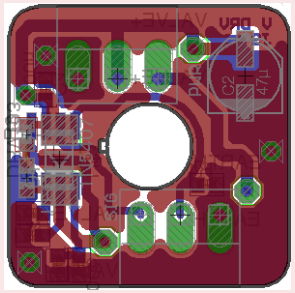
A normal valve emitts up to 10 W. So it heats up to about 75 °C on its surface and only a few degrees less on its body.

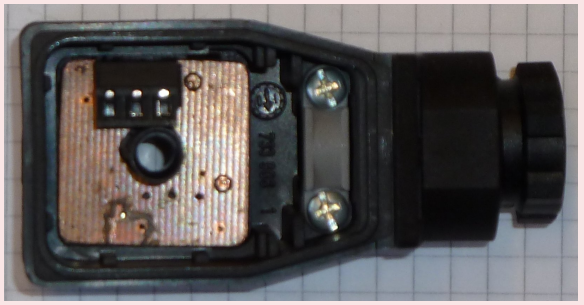
How to minimize the heat dissipation?

Use of special valve driver. They reduce the avaraged current through the coils. But they also ensure that the valve switches by using one large pulse to open it, before applying the reduced current.

Implementation

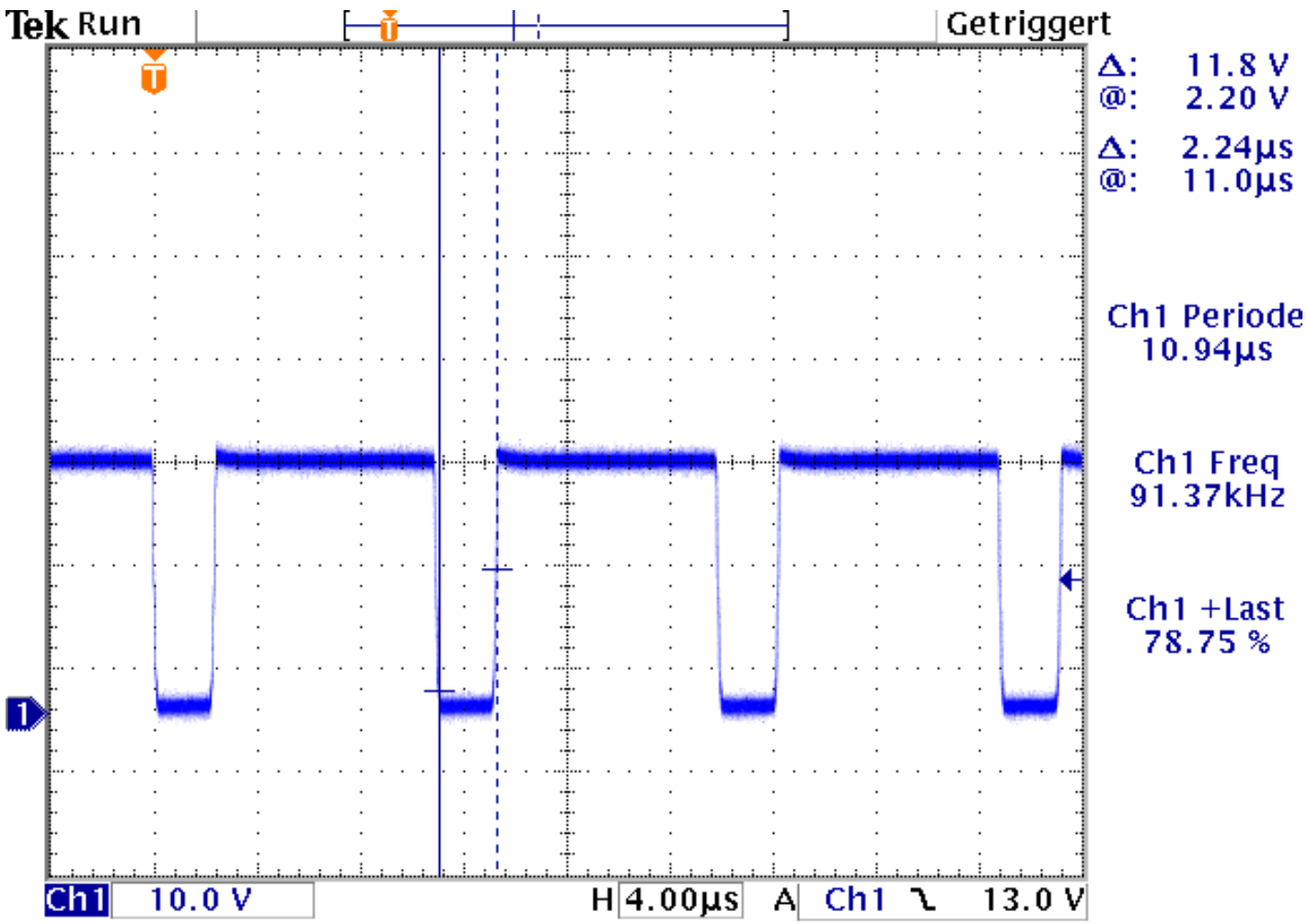
⇒ mounting inside the valve plug.
(as near as possible to the coil)
But: only $25 \times 25\,\mathrm{mm}$ with a central hole.





results from a first test

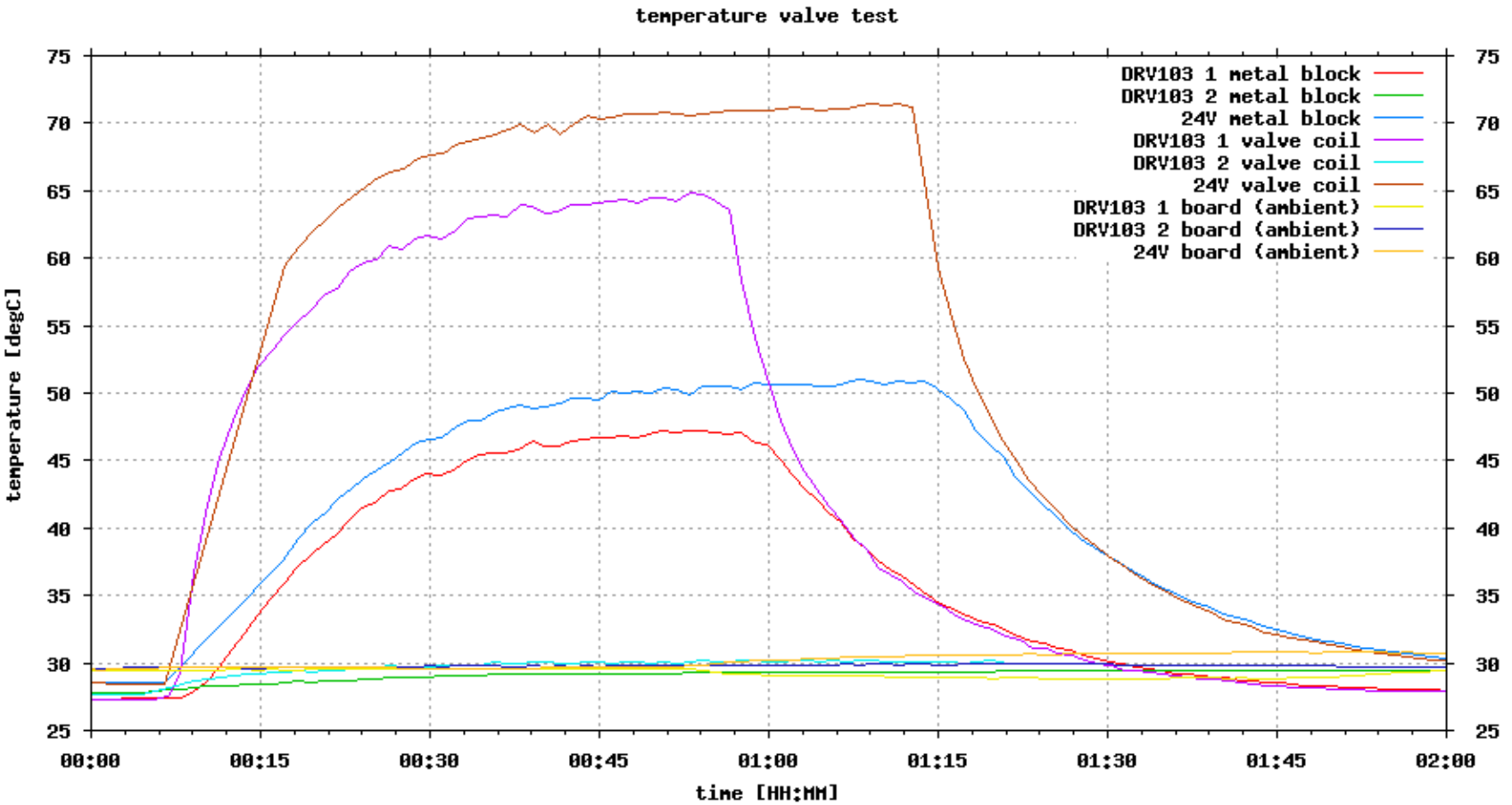
transient behaviour of valve driver



output signal (inverted due to control of the valve driver)
24 V @ 100 kHz & 20 % duty cycle

results from a first test

temperature increase of various duty cycles



Status of the control system

analog inputs

- schematic and PCB ready for production
- final review pending (some values missing)

digital I/O

- schematic done (if nothing changes the valve control)
- PCB needs final steps

Temperaturesensor & valve driver

- Prototypes already tested
- schematic & PCB layout done ready for production
- result of final tests pending

What about the software controlling the system?

concept

1. Firmware for Mikrocontrollers
2. Controlsoftware running on a PC
   based on liblab and subserver written in C++
3. GUI with Webserver (same for remote & local usage)

liblab and subserver are DAQ & data distribution frameworks written at the III. Physikalisches Institut B, RWTH Aachen University

Web-GUI

Web GUI

- optimized for local touchscreen, but it can also requested with the same appearance via network.
- interaction with subserver and through this the devices to control the system
- written in HTML, PHP and AJAX (Javascript)
- every „stupid“ untrained user should be able to operate the system via this GUI without half a year of training. You just have to „learn“ one GUI, no matter, whether you are operating from local or remote site.
- very abstract design. The user must not know that valve A1X2SV controls the exhaust of the analysis loop.

Web-GUI

example page of mixture control

Status of the software

concept

- the concept with many interfaces is defined.
  Only need to start programming when hardware has proceeded more.
- Started at both ends to speed up.
  Top (WebGUI) and bottom (device drivers) at the same time.
- have many snippets and short examples for many parts of the system.

status

- Started implementation and test of the CAN-Bus device driver.
  Firmware of Interface and PC implementation is working well.
- Dummy implementation of WebGUI almost done.
  Implementation of (dummy) functionality has been started.
- tested concept of calibration and conversion database

current safety difficulties

safety

For use of burnable gases, there are very strict rules in Germany and also at CERN. Not easy to adapt the rules from Germany to this „small“ project. The CERN rules are mainly based on these common ATEX rules.

solution

after talking to our local safety officer we developed a solution how we can handle burnable gases inside this system.
But there is a lot of calculations left, which must be correct.

operation permission

after the complete 3D design and selection of all parts, we will ask for the permission to use the system in Aachen and at CERN. This permit will be granted by the responsible safety officers.

current status

already done:

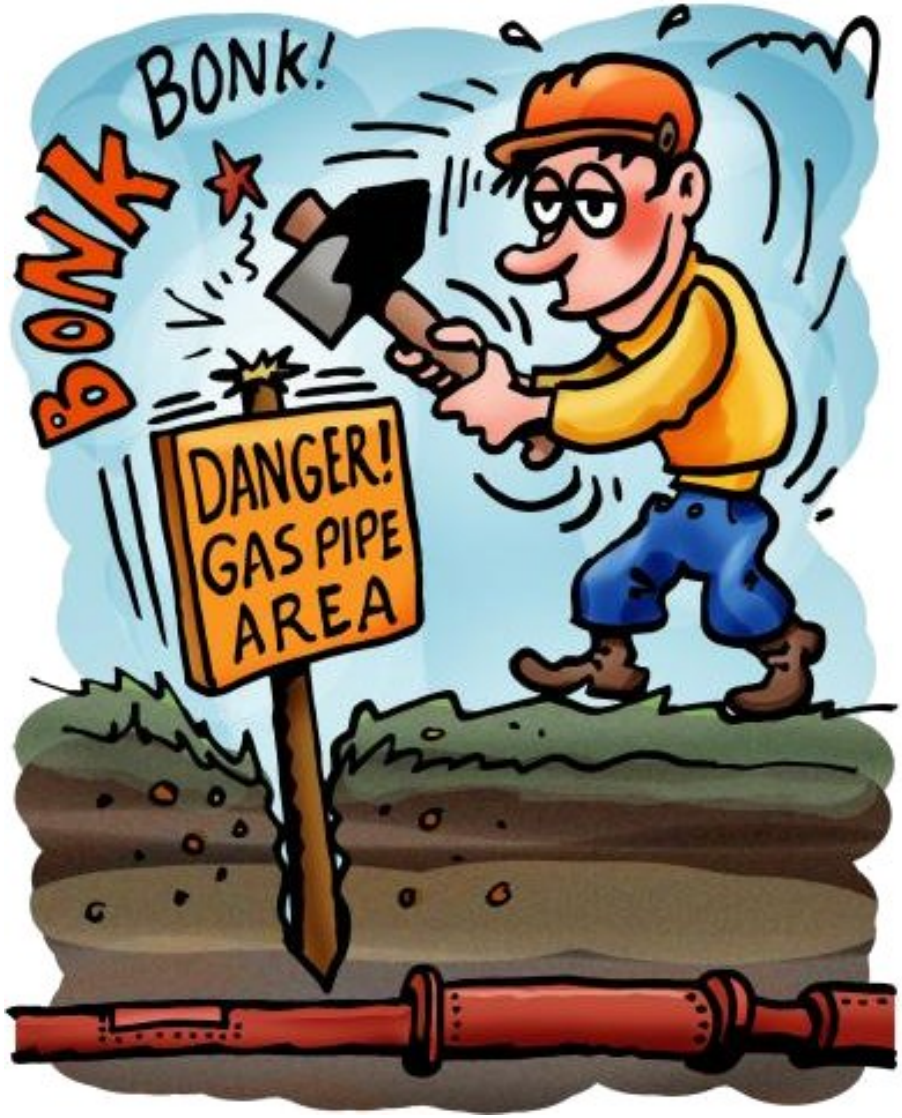
- hardware-concept & electronic-concept
- selection of analysis devices

current work:

- 3-D design of hardware / PCB creation
- hardware / electronic dimensionings
- control software

ToDo:

- build mechanical and electronic stuff
- programming of Firm-& Software
- various tests of the whole system



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There is much to do.
Let's do it!

Are there any questions?

Thank you for your attention.