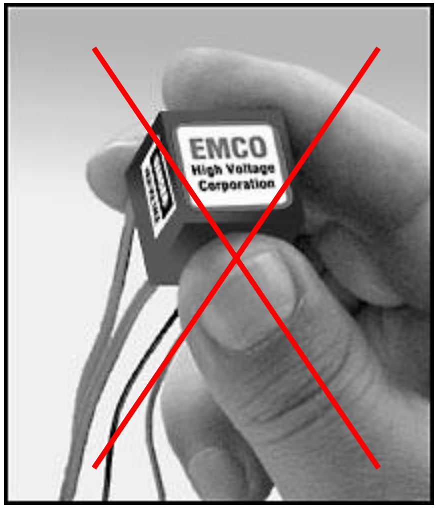
Development of μHV (miniature HV supplies) at Nikhef

Henk Boterenbrood, Harry van der Graaf, Henk Groenstege, Ruud Kluit, Fred Hartjes and Jaap Kuijt

RD51 Collaboration workshop
Freiburg, 25 May 2010

Why developing HV power supplies?

- Getting a HV supply that is dedicated for gaseous detectors
  - Fast trip in sub μA region
  - Accurate current measurement in nA region
  - Small unit, not too expensive
  - Fast remote control
  - Gently ramping to target voltage



- In addition, for large scale HEP experiments, one would like having these units close to the detectors in the hot region
  - Non-magnetic
  - Minimal mass
  - Radhard
  - Low noise emittance

Developing two designs

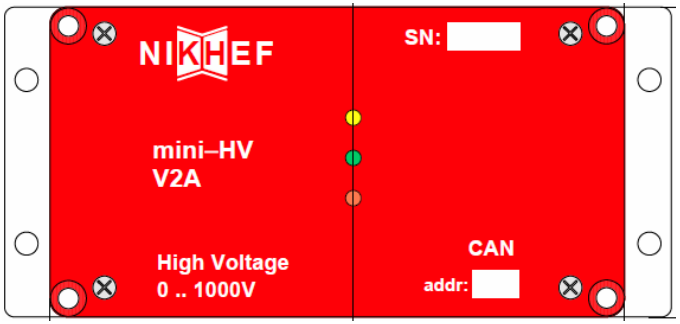
1. **Mini HV** for use in the lab, testbeams etc
   - Practical in use, relatively small, not completely antimagnetic
     - But **NO** inductors, transformers

2. **Micro HV** for use near the detectors in a big experiment
   - Very low mass, non-magnetic, radhard (until 1000 Mrad/ 10^7 Gy)

- Presently we are developing **mini HV**

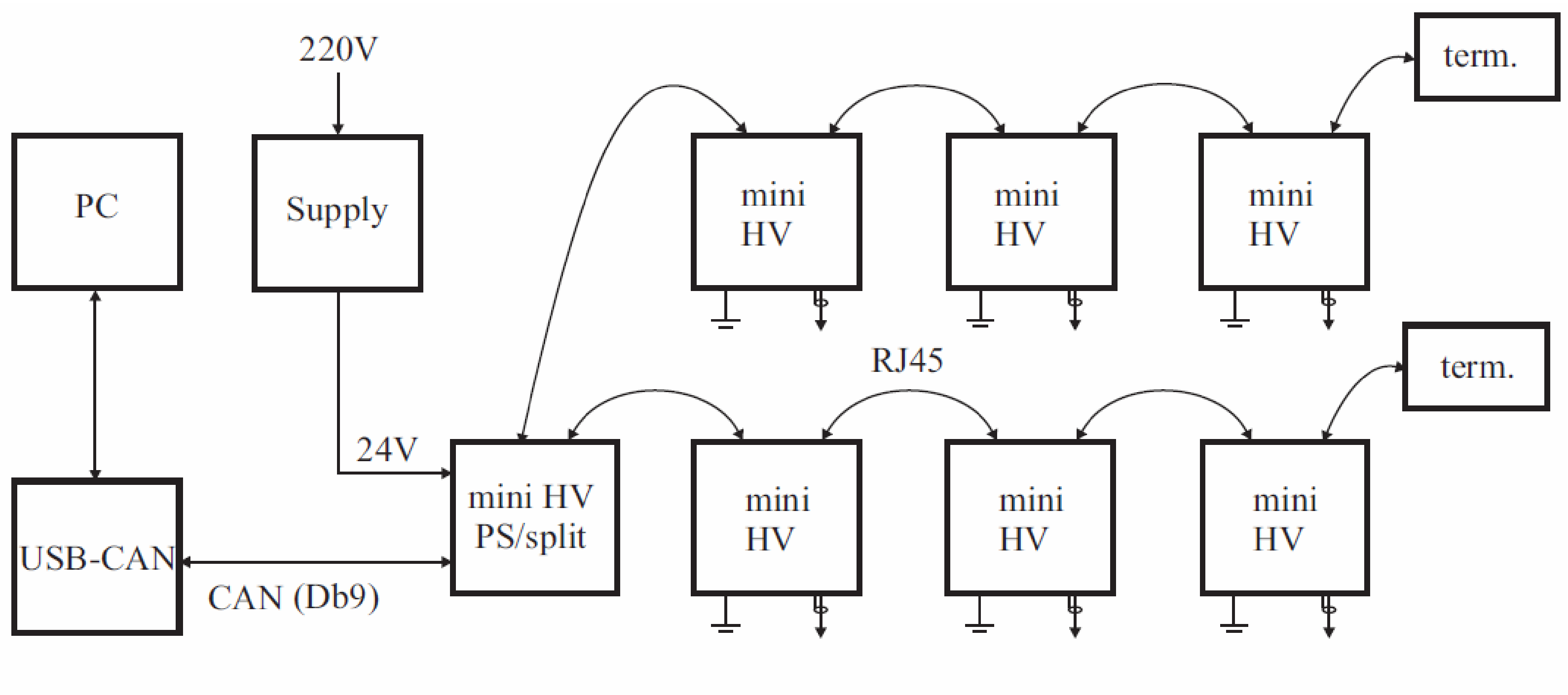
Preliminary specs of mini HV, version 2

- Output ~ -3 to -1000V @ 1.8 µA max
  - Steps of 73.6 mV
- Ripple 2 mV p-p @ 1 µA expected
- Ramping: initially linear, followed by exponential approach to target voltage
  - Linear part adjustable in units of 73.6 mV/s
- Current measurement in 56 pA units
- Communication by CANopen protocol
- Single RJ45 cable for CAN communication and supply
  - Can be daisy chained
- Cast aluminium box 112 x 60 mm, 31 mm high
  - SHV out



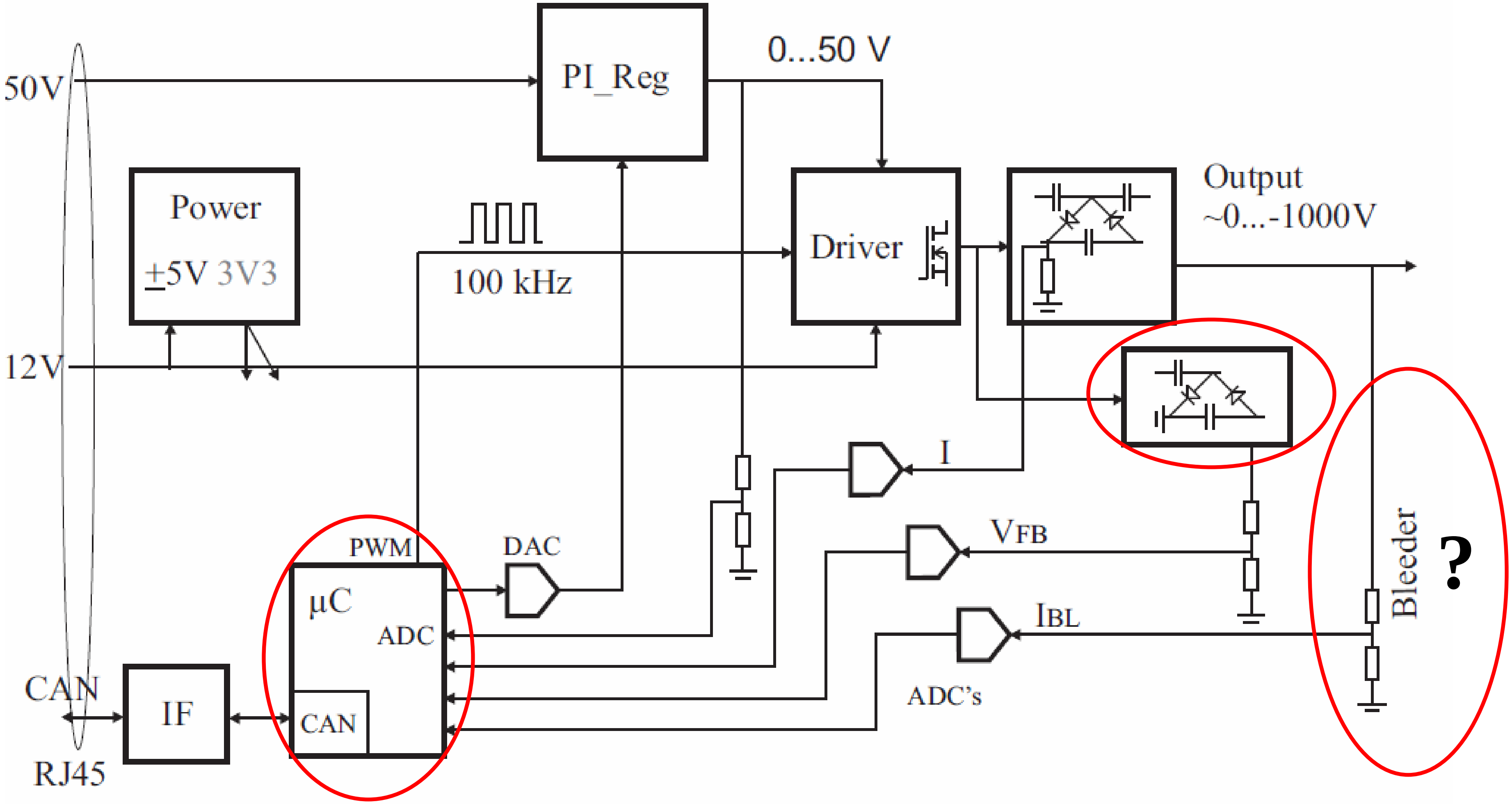
CANopen communication to multiple mini HVs

- Single RJ45 cable to supply everything



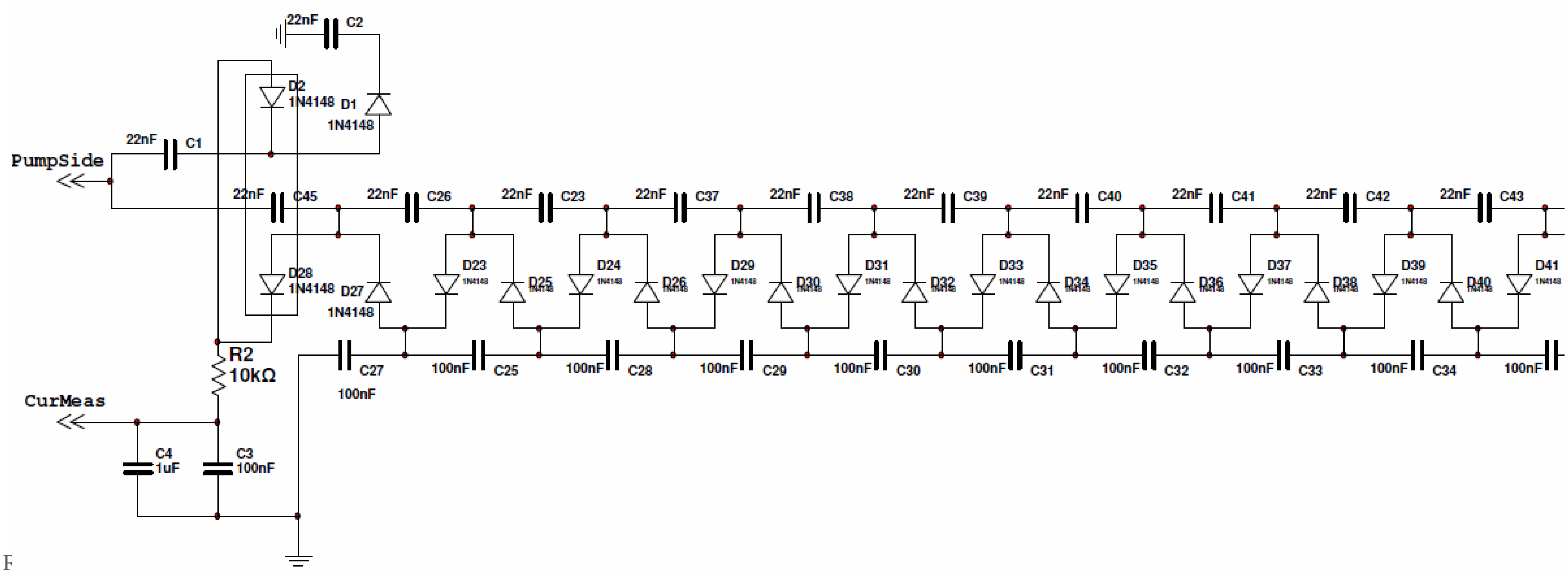
Block diagram of single mini HV unit

- Chop frequency may be modified
- Trip by CAN logic processor, depending on voltage ramp
  - E.g. Trip 5 nA @ ramp 1V/s
- Voltage feedback from dummy diode circuit



Cockcroft-Walton circuit

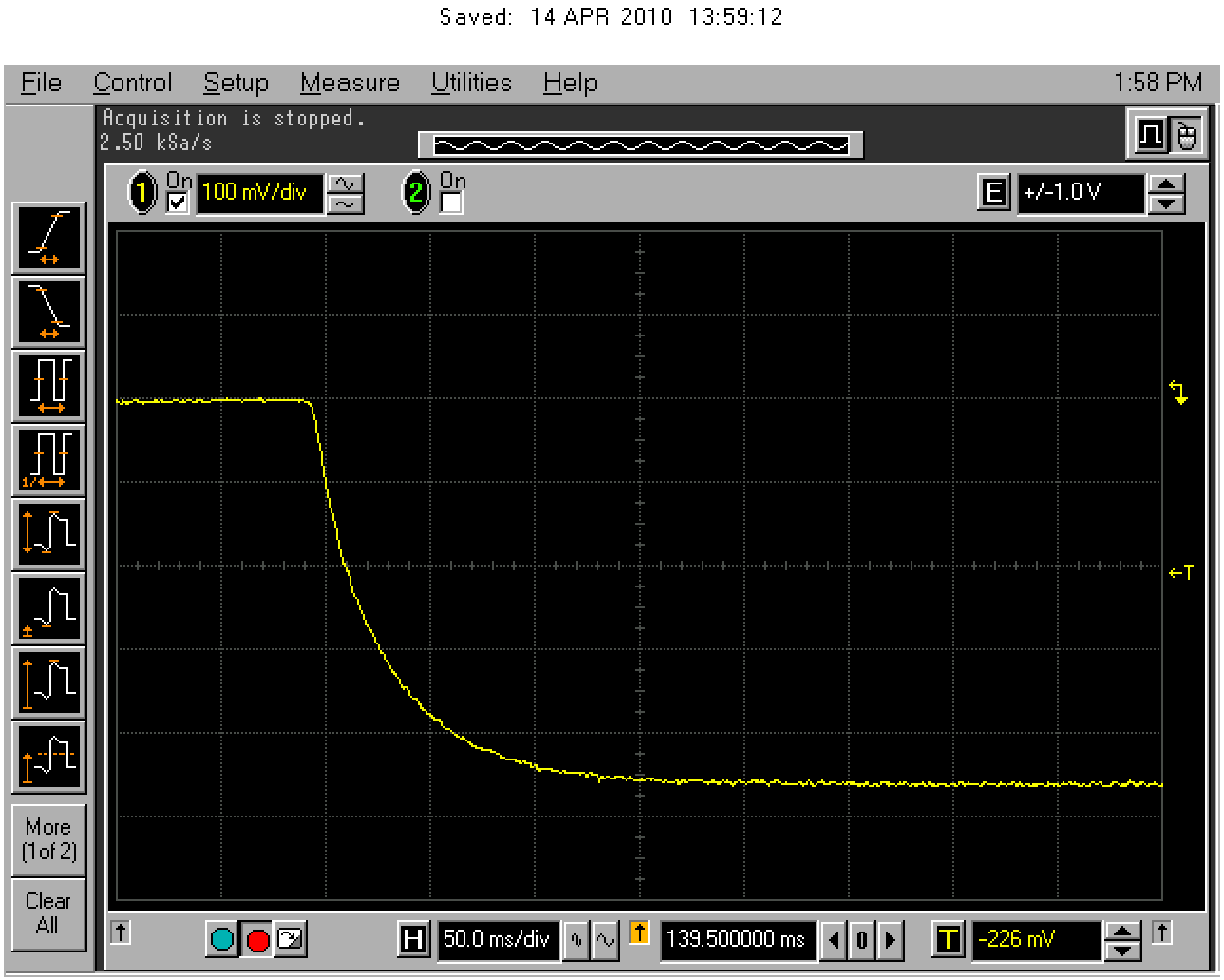
- In principle no feedback at end of diode chain, only from first diode circuit
- Advantages
  - Accurate measurement of output current in nA region
  - Sensitive trip possible
- Disadvantage
  - Regulation less direct, depending on diode characteristics
- Output capacitance ~ 5 nF



F

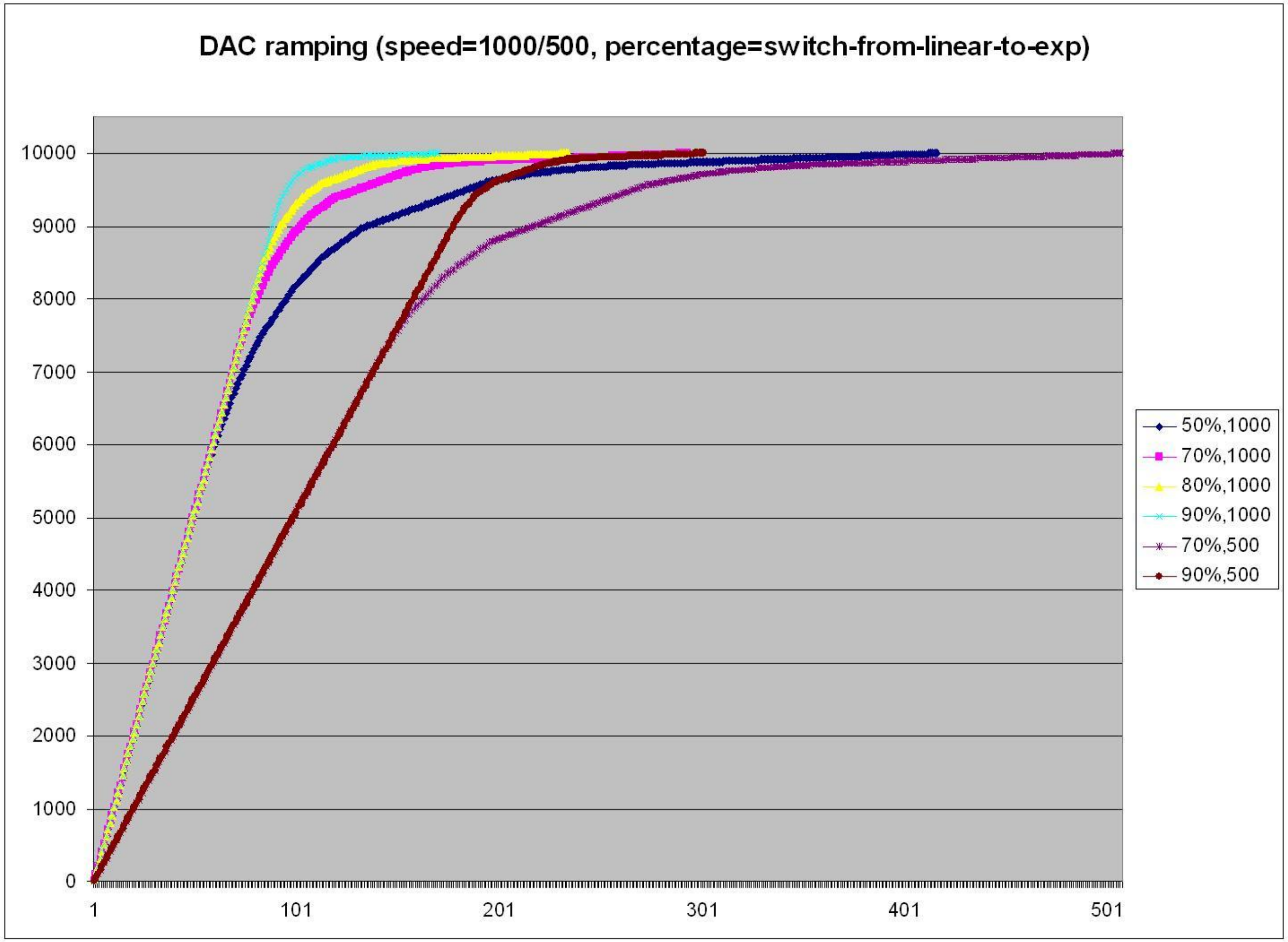
Fast ramping possible

- Measured rise time without slope adjustment ~ 100 ms (from 0 to -480V)
  - No overshoot



Simulation of smooth ramping

- Linear rise adjustable in steps of -73.6 mV/s
- Followed by exponential approach to target voltage
- Slope parameters controlled by CANopen commands
  - Linear slope
  - Start exponential part



CANopen Object Dictionary prepared

MicroHV software v0.1 3-Feb-2009

MicroHV

CANopen application software
for the
'Micro' High-Voltage Powersupply Controller

Henk Boterenbrood
NIKHEF, Amsterdam
3 February 2010

Version 0.1

Manufacturer-Specific Profile Area *(continued…)*

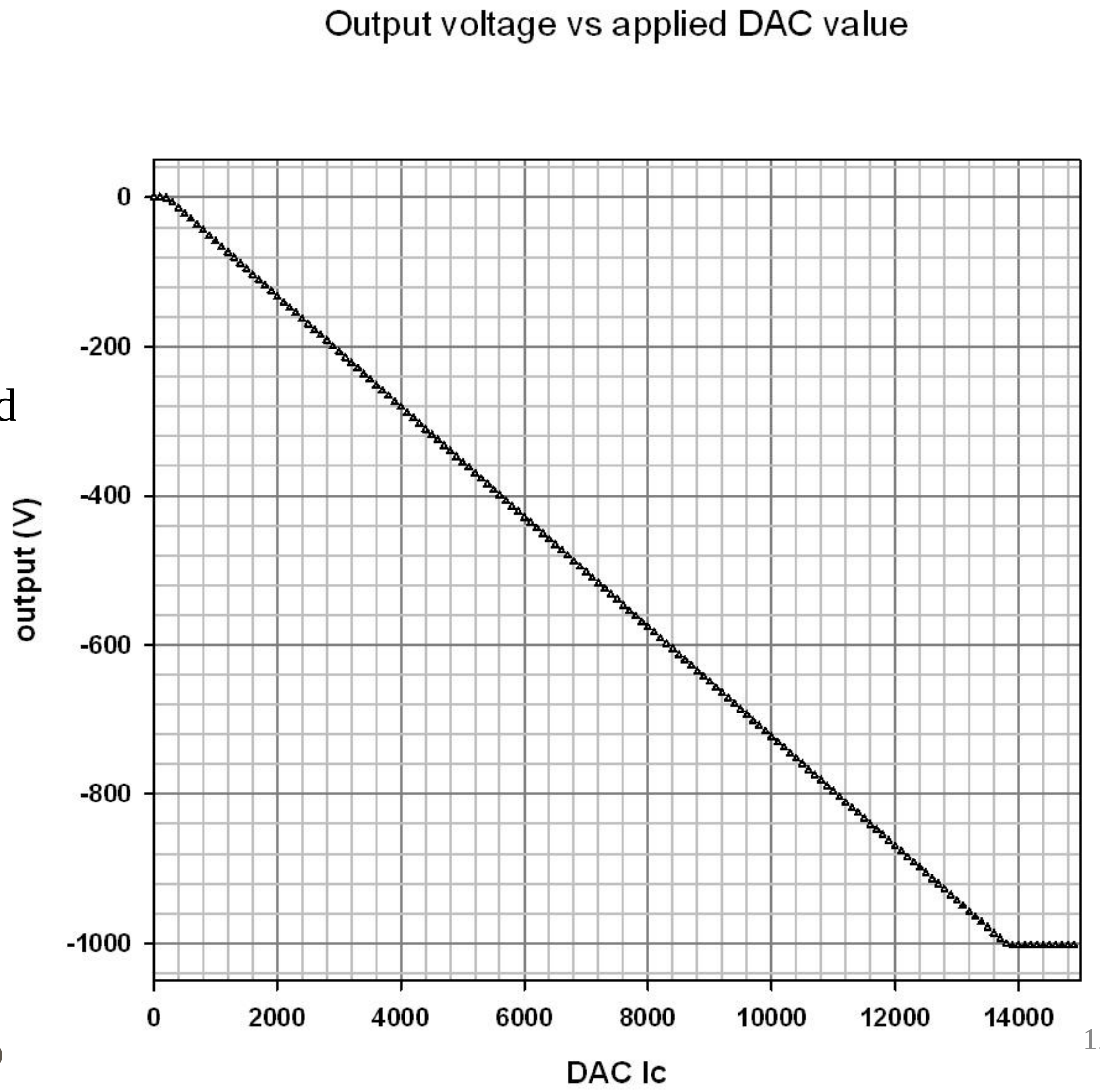
Index (hex)	Sub Index	Name	Data/ Object	Attr	Default	Comment
2500		DAC configuration	Record			
	0	Number of entries	U8	RO	2	
*	1	SPI SCLK signal high period (opto-coupler delay)	U8	RW	10	in µs, 10 ≤ value ≤ 255
*	2	Ramp speed	U16	RW	0	If != 0 ramp speed is taken into account; in DAC-counts per sec
	3	Ramping pause/continue	Bool	RW		Ramping in progress or not (read), pause/continue ramping (write)
*	4	Percentage to switch from linear to exponential ramp-ing	U8	RW	90	The percentage of the requested DAC end-value at which up-ramping (not down) switches from linear to exponential, taking the set ramp speed into account
2600		PWM configuration	Record			PWM waveforms on AT90CAN64 outputs OC3B/C
	0	Number of entries	U8	RO	4	
*	1	Start at power-up	Bool	RW	0	Start at power-up or not
*	2	Frequency	U8	RW	3	1 = 25KHz, 2 = 50KHz, 3 = 100KHz, 4 = 200KHz
*	3	Gap size	U8	RW	1	Gap between waveforms positive pulses, in units of system clock period (4 MHz, i.e. 250 ns)
	4	PWM stop/start	Bool	RW	0	PWM running or not (read), start or stop the PWM (write)

Test results of two prototypes of mini HV version 1

- **Note: version 2 (in development) may have different performance**

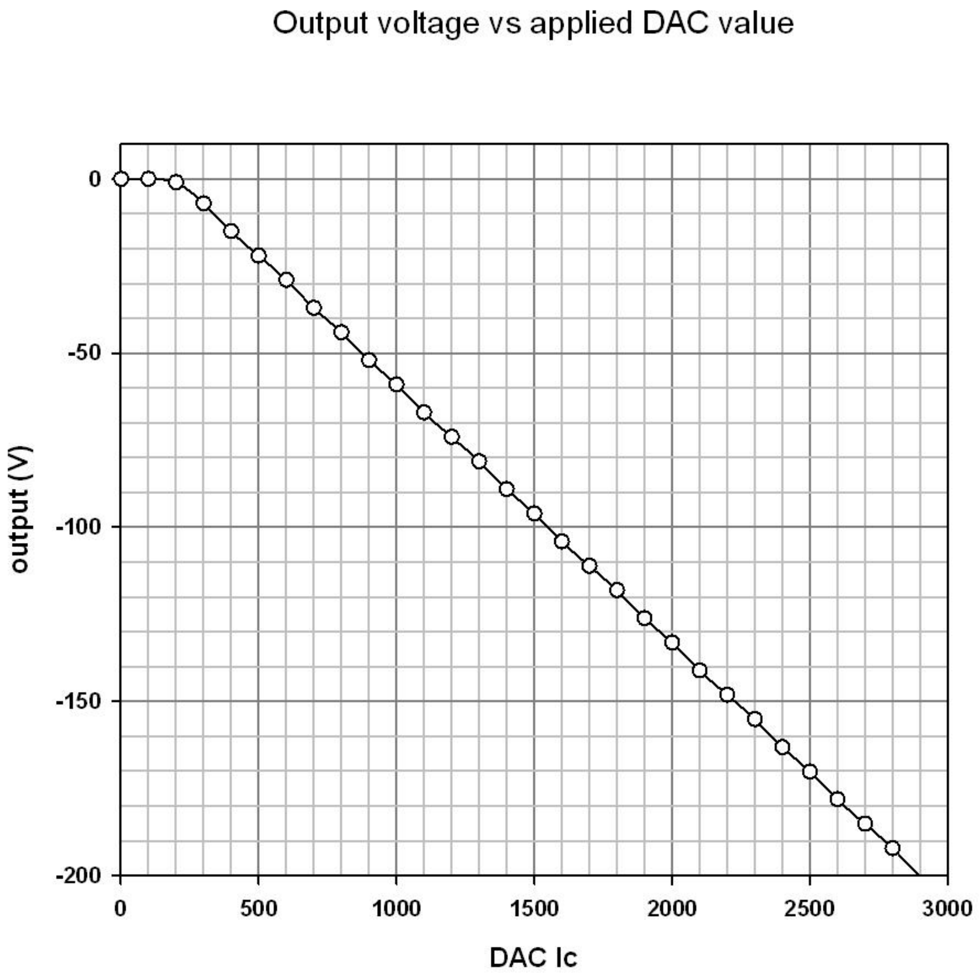
Output voltage vs DAC value

- Unit 1.2
- Good linear behaviour over full range
- Voltage can be regulated in steps of 73.6 mV



Detail at low voltage

- Starting from ~ -3V on

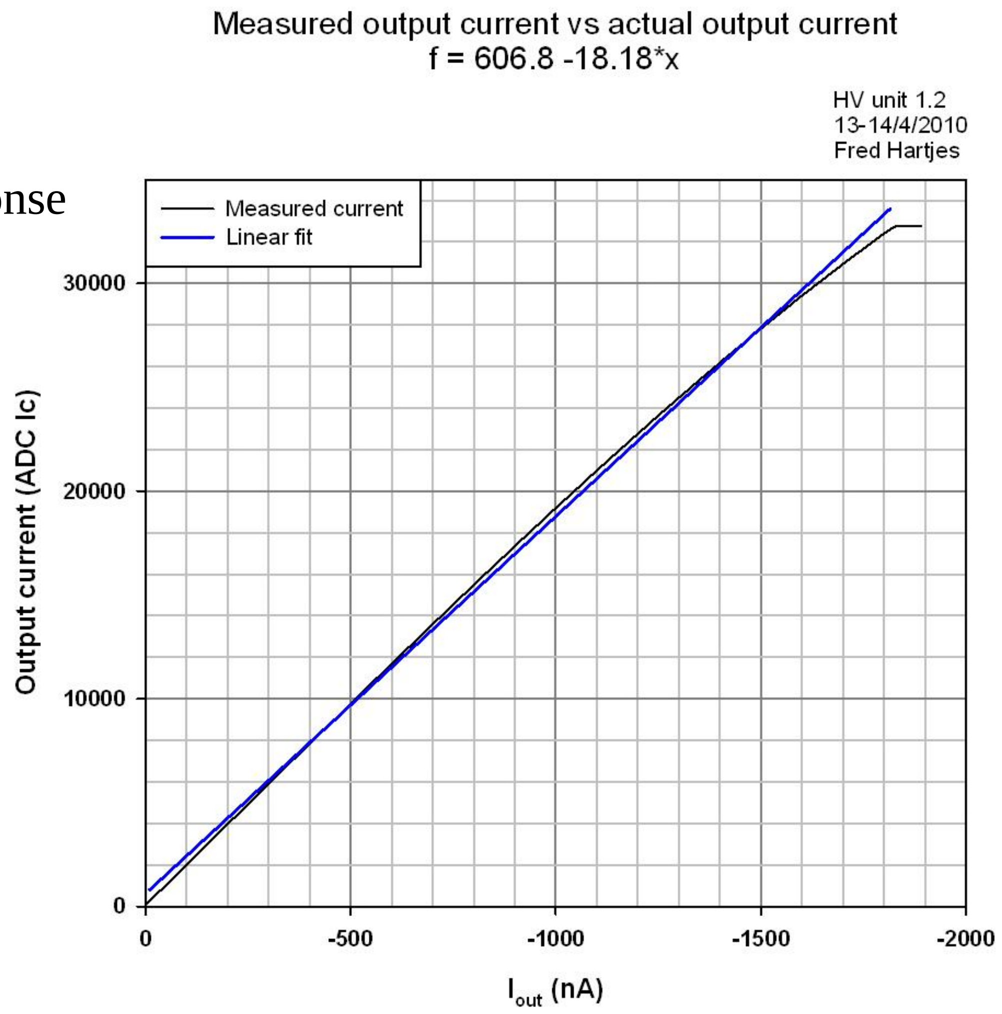


Current measurement

- Unit 1.2

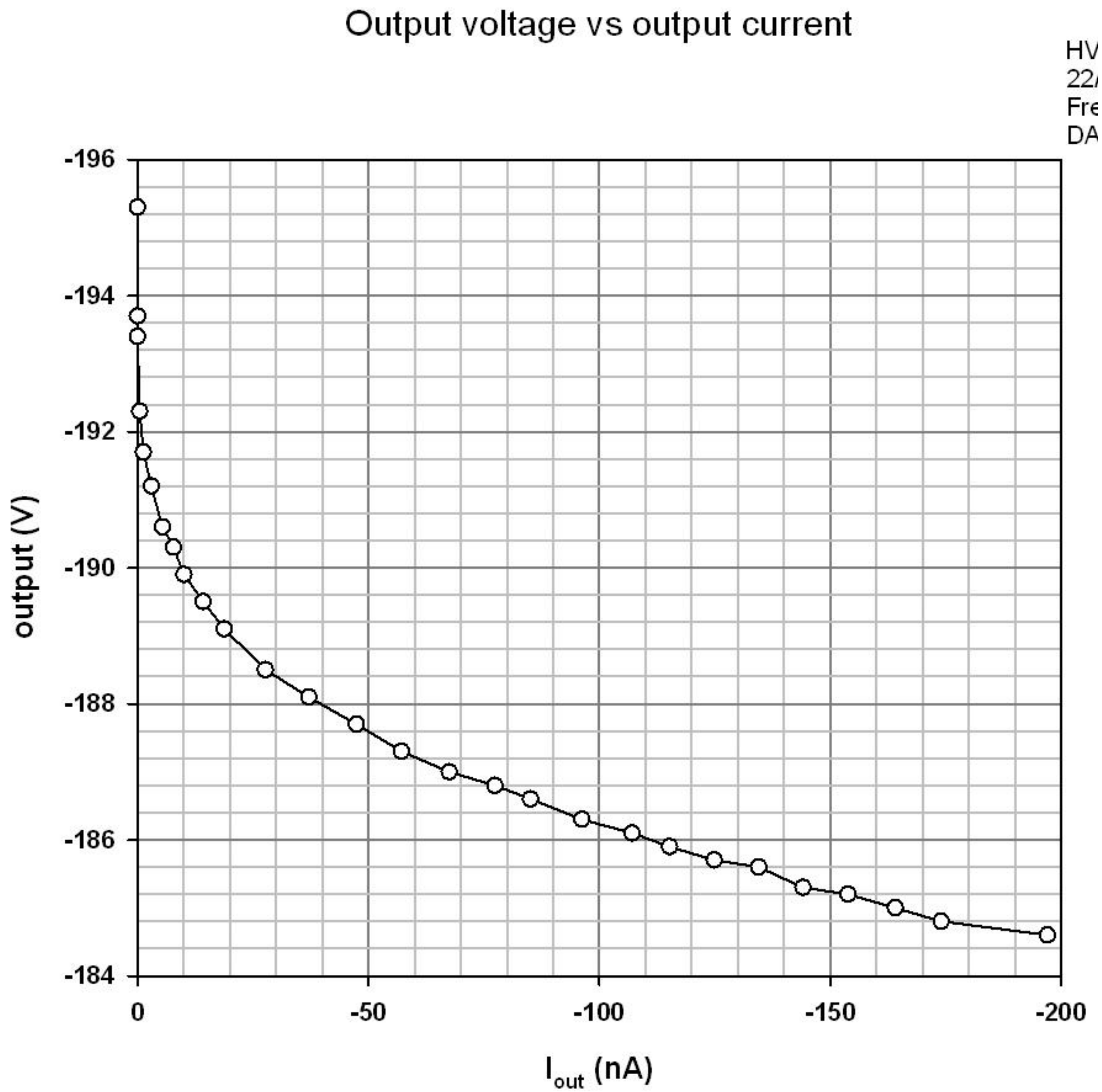
- Steps of ~ 56 pA
- Certain deviation from linear response

- RMS ~ 50 pA
  - Measured at -500 V and 500 nA



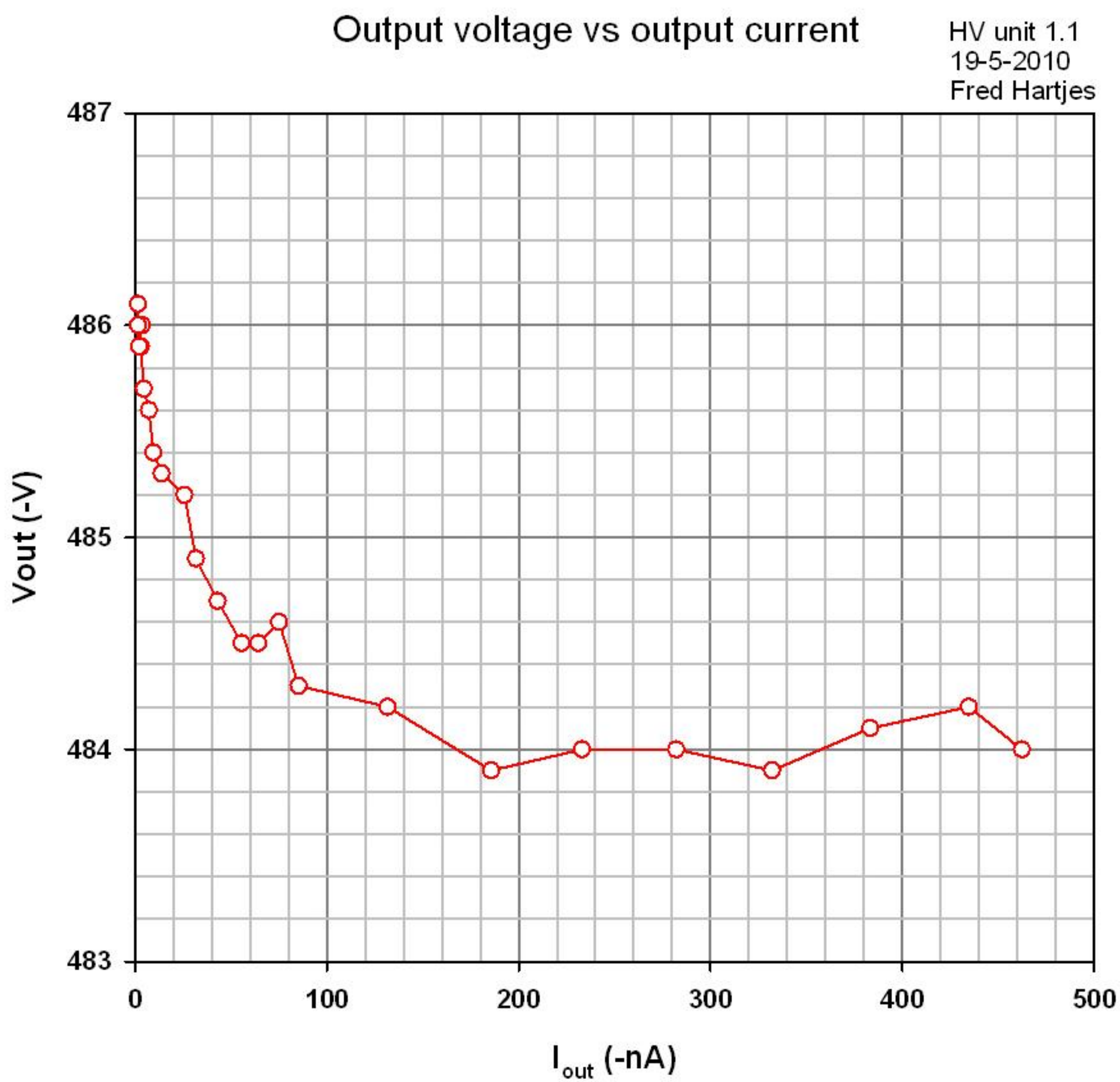
Voltage regulation

- Unit 1.2
- Output impedance ~ 10 MΩ for currents > 200 nA
- ~ 10V higher output voltage for currents in few nA range compared to 200 nA
  - Using two different types of diodes
  - => Mismatch of diode characteristics

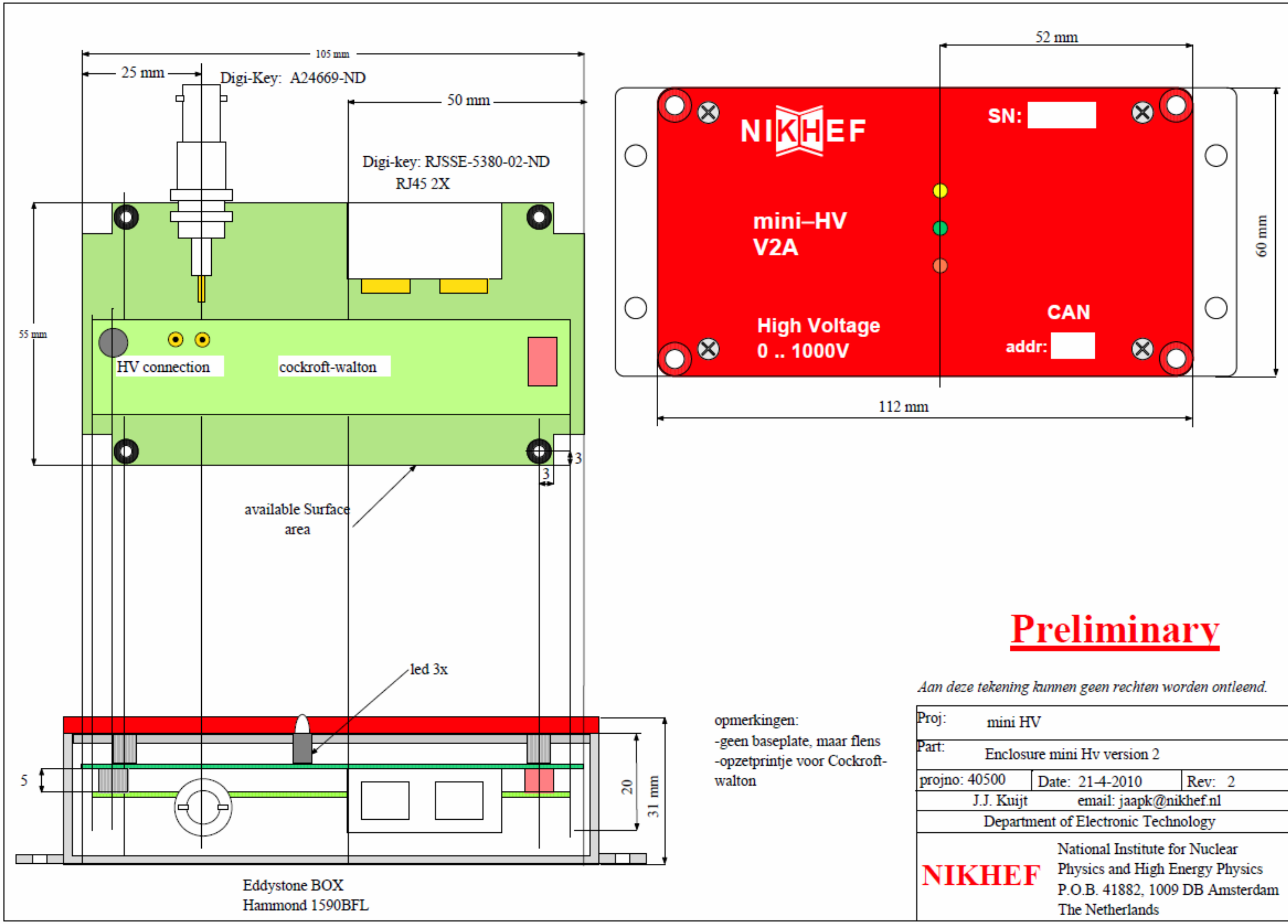


Voltage regulation for Unit 1.1

- Basically no mismatch of diode characteristics
  - => output impedance zero for currents > 150 nA
  - => ~ 2V higher output voltage for currents in few nA range
- Remaining inaccuracy might be partly cured
  - by adding bleeder resistors like 50 GΩ per cascade stage
  - Making correction in CAN processor
- Alternative: voltage feedback
  - But resistor may be less stable
  - Regulation pretty slow



Assembly in cast aluminium box



Planned time schedule mini HV unit

- Version 1 ready
  - 2 prototypes (-500 and -1000V
  - Not suited for series production
- Version 2 in development
  - Schematic to be finished
  - Layout PCB to be made
  - Production and assembly PCB
  - Assembly HV box
- Starting with producing **5** prototypes
  - Planned to be ready mid October
  - Production setup for 25 units

Conclusions

- Global design for mini HV now settled
  - But still quite some detailing to be done

- Stabilize voltage
  - By individual calibration curve
  - By using voltage feedback from bleeder resistor

- Could start in autumn with some series production (~20 units)

- We might consider also more outputs
  - Like for GEM grids, omitting resistor chain
  - => bit larger housing

- Plan starting producing series of 20 in October 2010