Development of miniHV at Nikhef

Small HV modules for laboratory use

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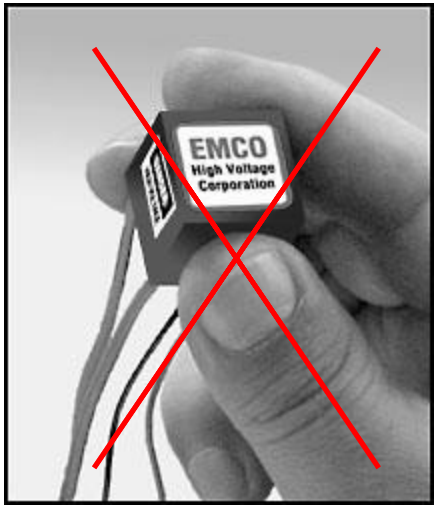
6th RD51 Collaboration workshop
Bari, 9 October 2010

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 **miniHV**

Preliminary specs of miniHV, version 2

Based on prototype studies, to be updated with final version

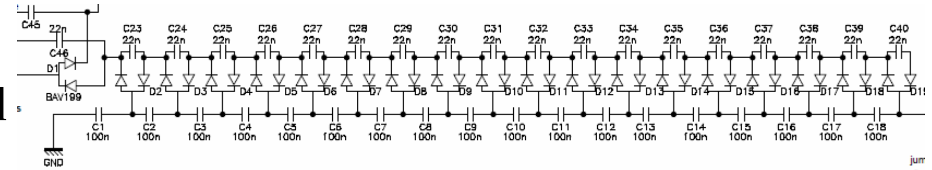
- Output ~ -3 to -1000V @ $\geq$ 1.8 μA
  - Steps of -73.6 mV
- Standard negative output
  - **Positive** output in principle possible using same PCBs
- Ripple 2 mV p-p @ 1 μA expected
- **Ramping**
  - Completely controlled by local microprocessor
  - Initially linear, followed by exponential approach to target voltage
  - Linear part adjustable in units of 73.6 mV/s
- Containing probably few magnetic parts from electronics
  - But no magnetic transformers etc, so is **expected to operate in magnetic field**

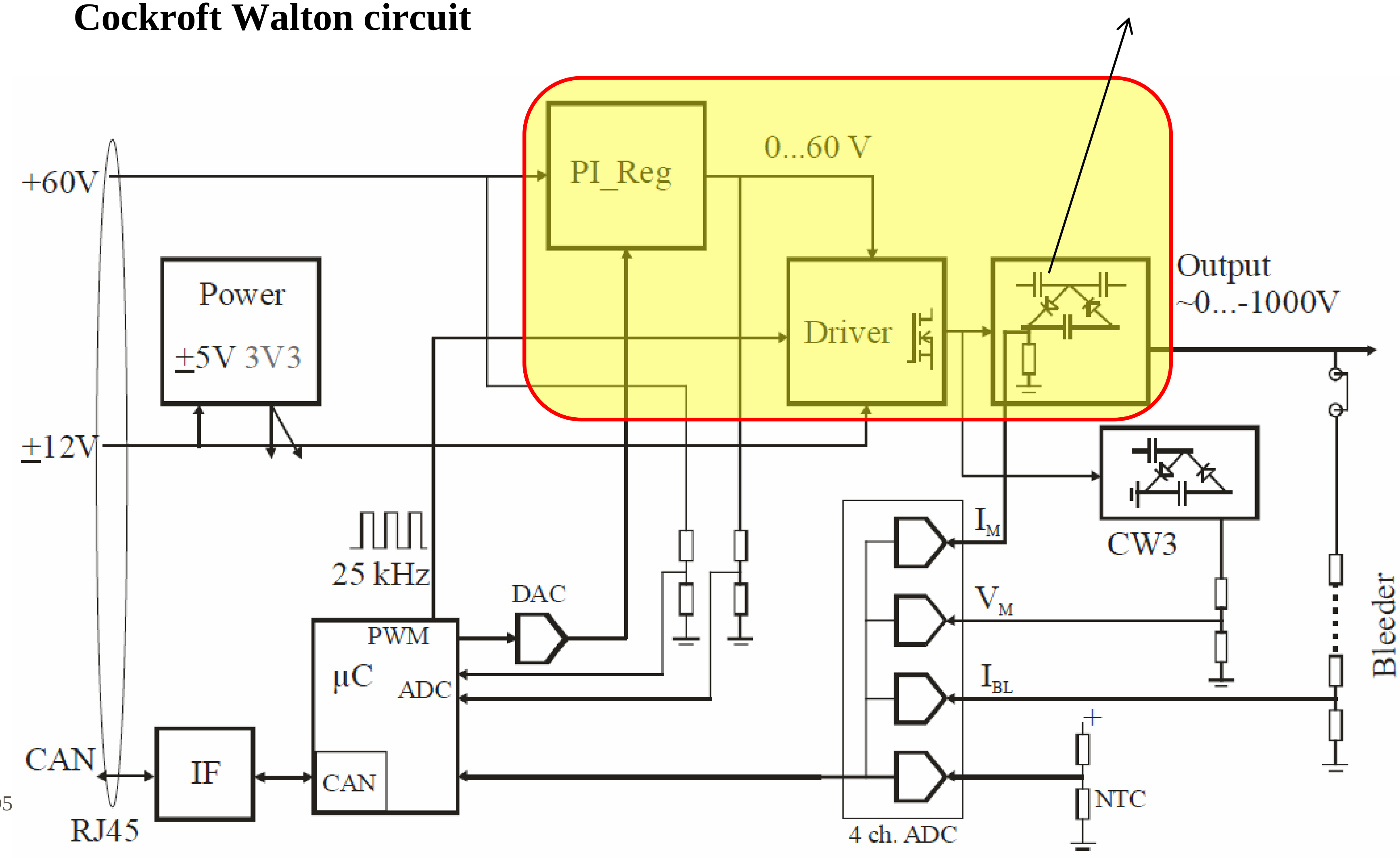
Preliminary specs of mini HV, version 2

- Current measurement by 24 bit ADC
  - => high dynamic range
- Communication by **CANopen** protocol
- Single RJ45 cable for CAN communication **and supply**
  - May be easily daisy chained
- Cast aluminium box 110 x 82 mm, 45 mm high
  - SHV out
- Presently no low ohmic bleeding circuit foreseen
  - => residual HV may remain hours after switching off

High voltage generation

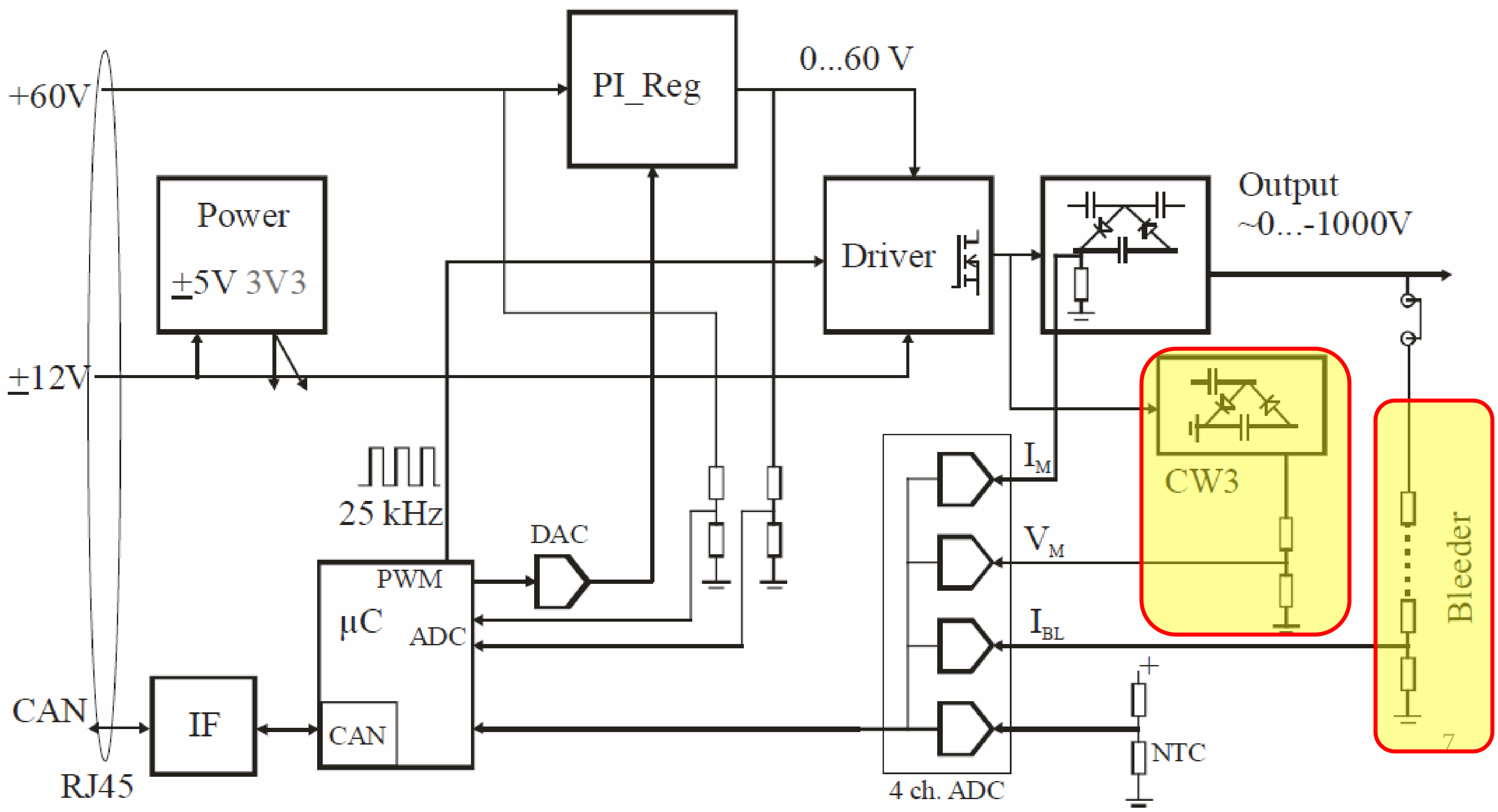
- 60 V input voltage regulated and chopped
- High voltage (N x V_{in}) generated by **Cockroft Walton circuit**





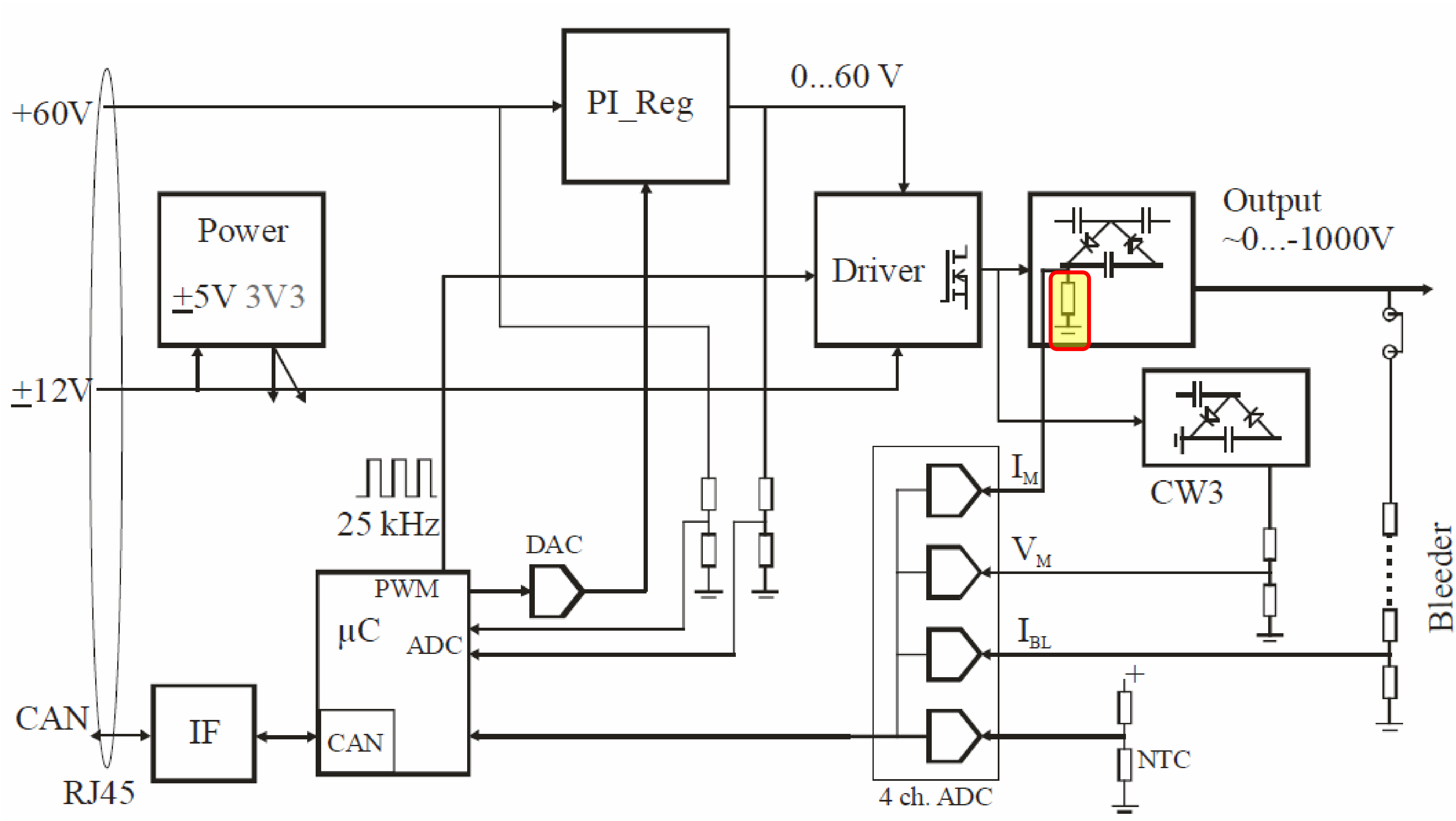
Voltage regulation

- Regulation by analogue input voltage (0 – 60V)
- Voltage feedback
  - Via single Cockroft Walton circuit
  - Current compensation by local microprocessor
- (Maybe via chain of 36 resistors of 5 GΩ (180 GΩ) into 100 MΩ)



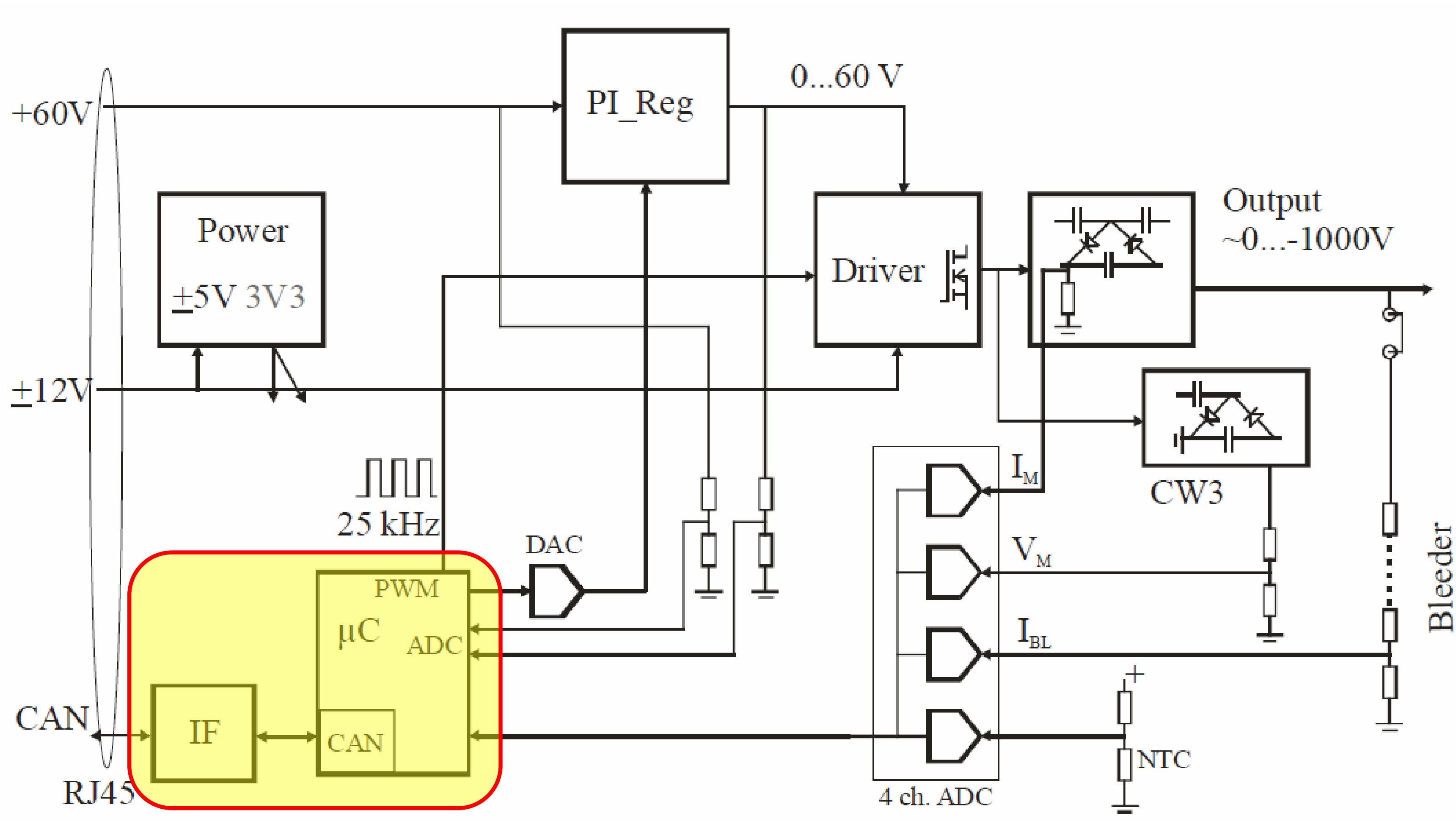
Output current measurement

- Output current measured as the return current of the Cockroft Walton circuit



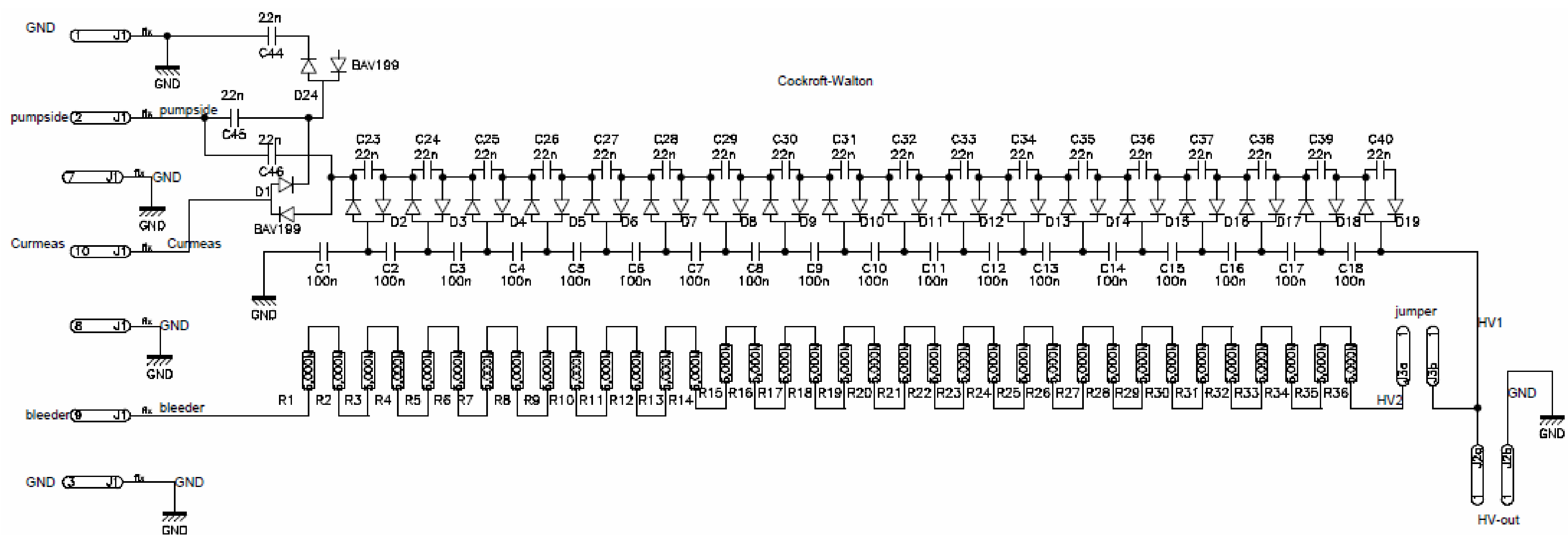
Remote control

Via **CANopen** protocol



Cockcroft-Walton circuit

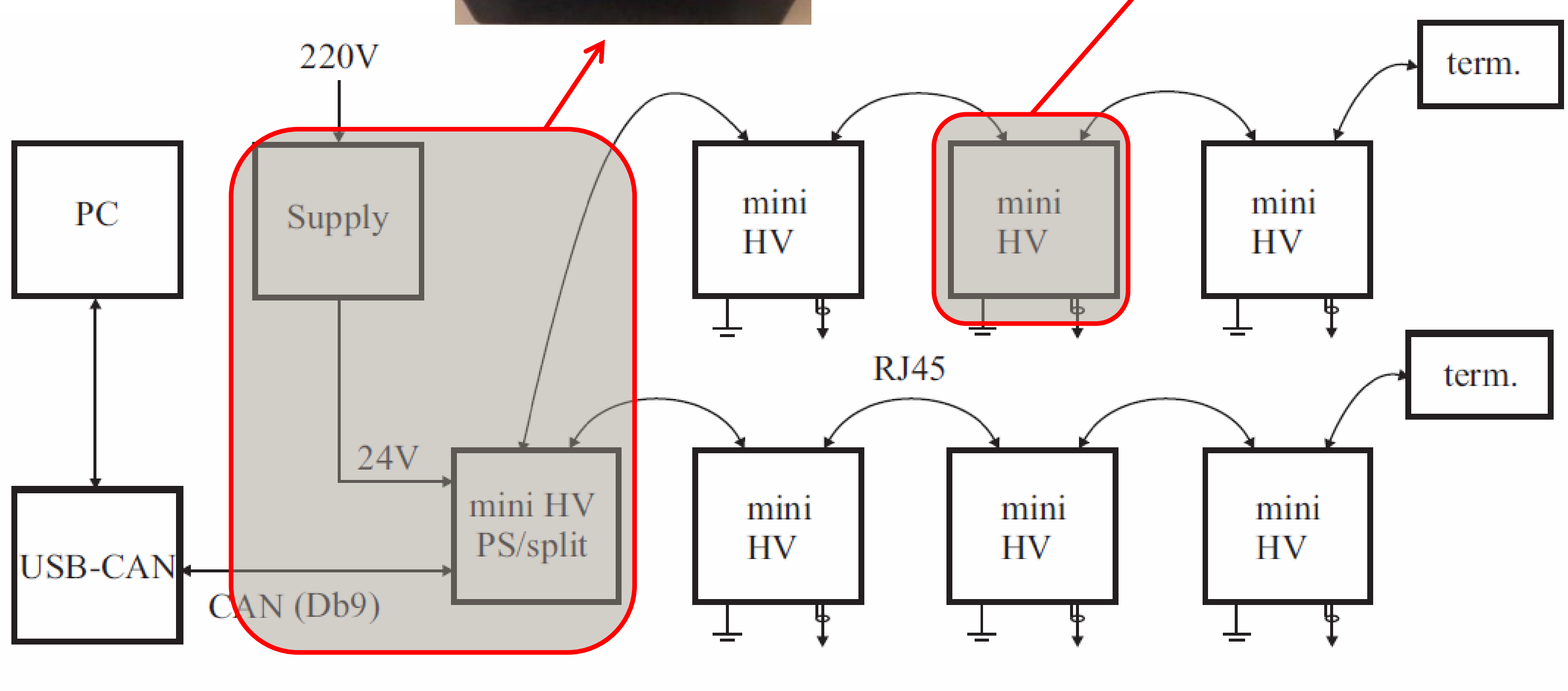
- In principle no feedback at end of diode chain, only from idle diode circuit
  - Regulation less direct, depending on diode characteristics
- Output capacitance ~ 5 nF
- Bleeder resistance if switched on: 36 x 5 GΩ = 180 GΩ
  - Bleeder current ~ 5 nA



Fred Hartjes

CANopen communication to multiple mini HVs

- Two RJ45 cables to supply up to 8 miniHV units



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

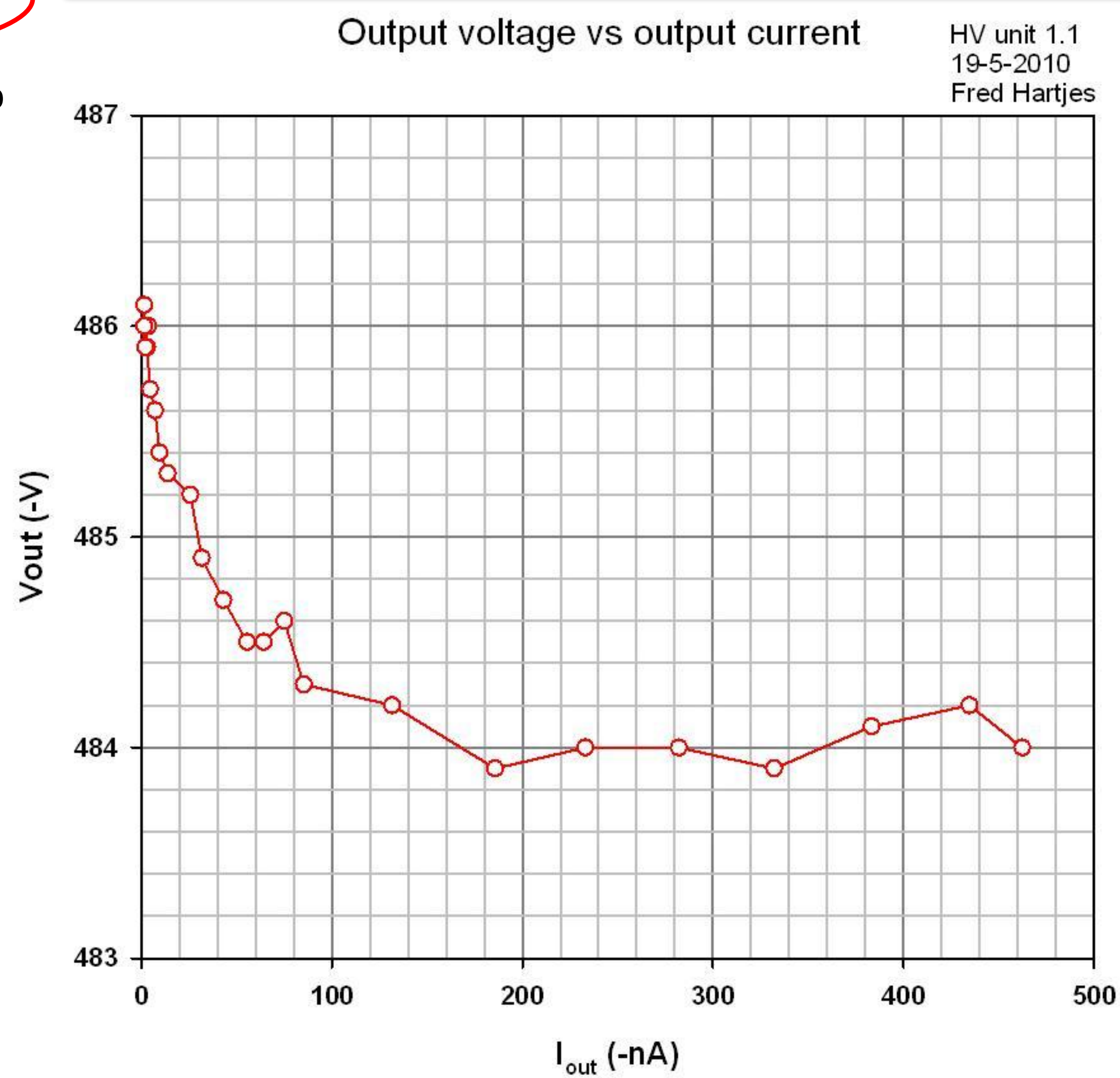
Manufacturer-Specific Profile Area *(continued…)*

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, $10 \le value \le 255$
*	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)

Voltage regulation for prototype version 1.1

- Basically no mismatch of diode characteristics
  - => output impedance zero fo currents > 150 nA
  - => ~ 2V higher output voltage for currents in few nA range
- Remaining inaccuracy might be cured by making simple correction in CAN processor
  - Simple exponential fit
- Alternative: voltage feedback
  - By adding bleeder resistors like 5 GΩ per cascade stage
  - But resistors in GΩ range may be less stable
  - Regulation pretty slow

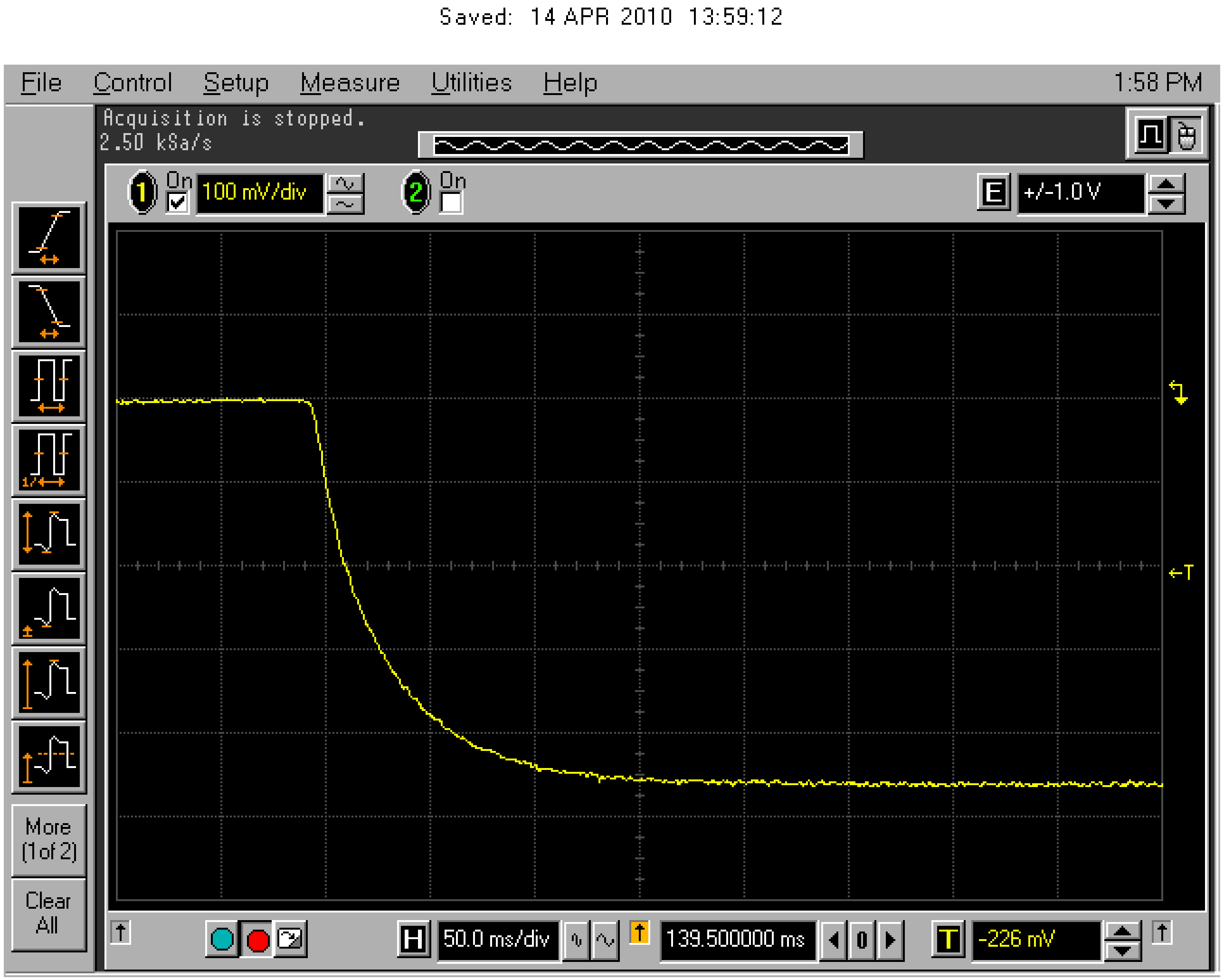
Version 2 may have different performance



Rapid ramping possible

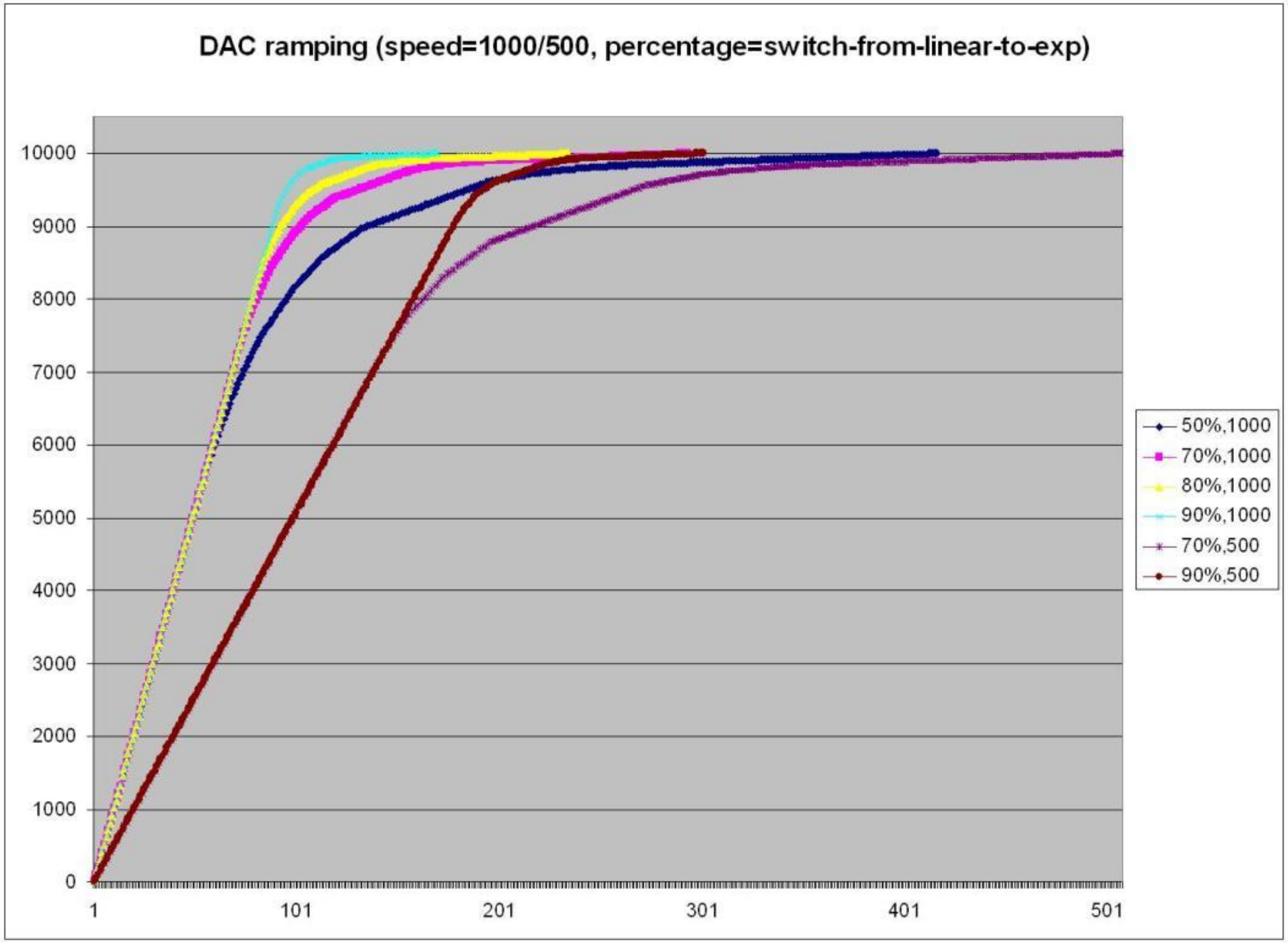
Version 2 may have different performance

- Measured rise time without slope adjustment ~ 100 ms (from 0 to -480V)
  - No overshoot
- But normally gentle software controlled ramping will be applied



Simulation of smooth ramping

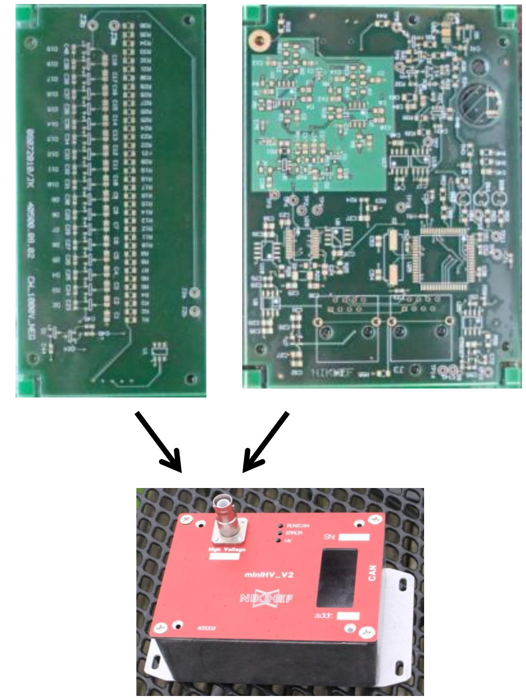
- Linear rise adjustable in steps of -73.6 mV/s
- Followed by exponential approach to target voltage
- Slope parameters controlled by CANopen commands
  - **Linear slope**
  - **Start** exponential part
- Presently not yet working (software bug)



Planned time schedule miniHV version 2

- ☑ Version 1 evaluated
  - 2 prototypes (-500 and -1000V)
  - Not suited for series production
- ◆ Version 2 being produced for 5 units
  - ☑ Schematic to be finished
  - ☑ Layout PCB to be made
  - ☑ Production PCB
  - Assembly PCBs (ready mid October)
  - Assembly miniHV and power units
  - **Evaluation and small modifications until end 2010**

  - Components including PCBs available for 25 miniHV units



MiniHV version 2 will be available for other groups in RD51

- Price not yet known
- Delivery may be spring 2011, but we cannot make promises at this stage

Send me an email if you're interested

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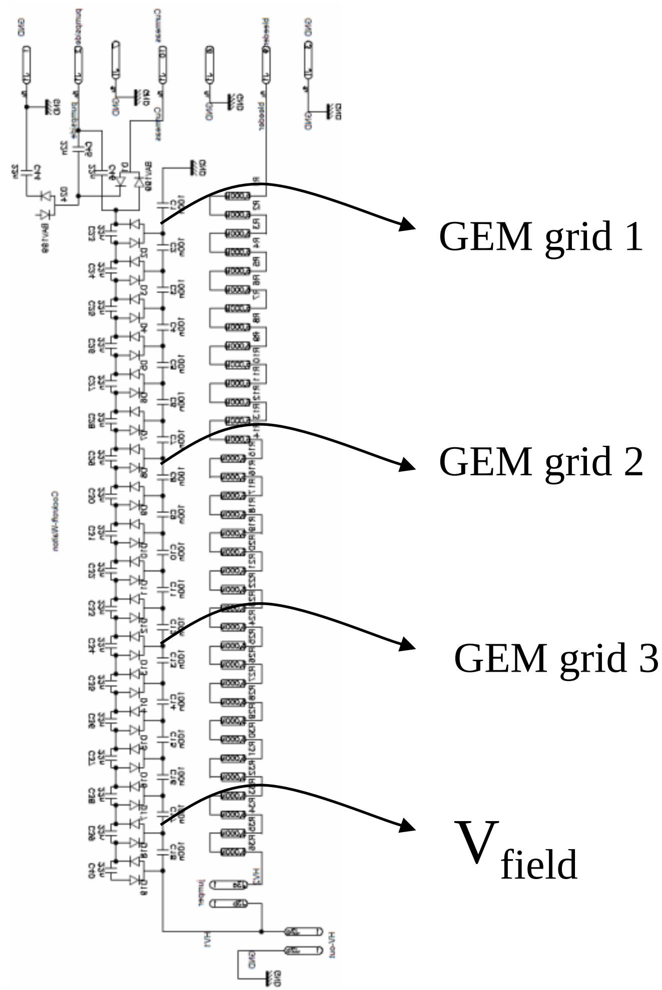
Ideas for other miniHV modules

1. **-2000 V version**

2. **Single MiniHV** with ~ 7 outputs (-6000 V?) from Cockroft Walton circuit for **triple GEM**
   - Regulating GEM voltages by selecting the desired CW stage
     - steps of ~ 50V
   - But whole chain may be finely tuned

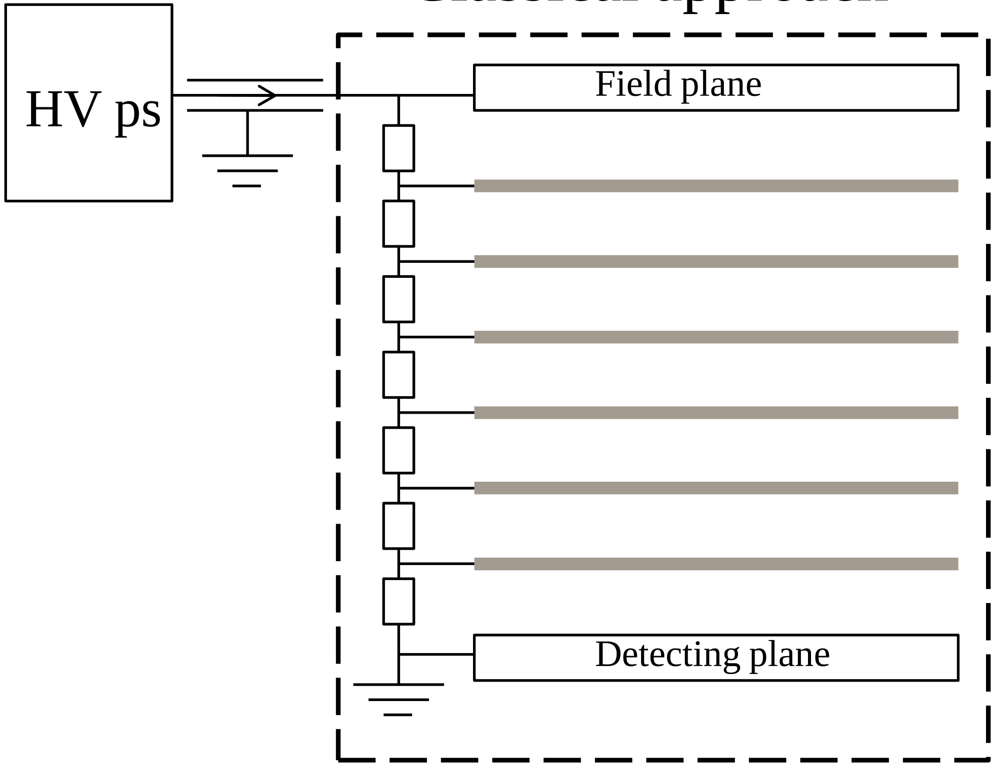
- Advantage
  - Getting rid of voltage divider chains or multiple cascaded HV units
  - Low trip levels possible (nA region)
    - No current from voltage divider chain



Filed cage for large TPCs

- Large TPC (1 m) requires very high voltage and low driftfield gas (CF4 mixtures)
  - Field shaping strips to define proper drift field
- Substantial HV needed
  - **50 kV or more**
  - Difficult cable and connection
- Voltage on field shaping strips supplied by resistor chain
  - **=> substantial HV current**
  - => risk on HV operation
  - => no low trip level possible

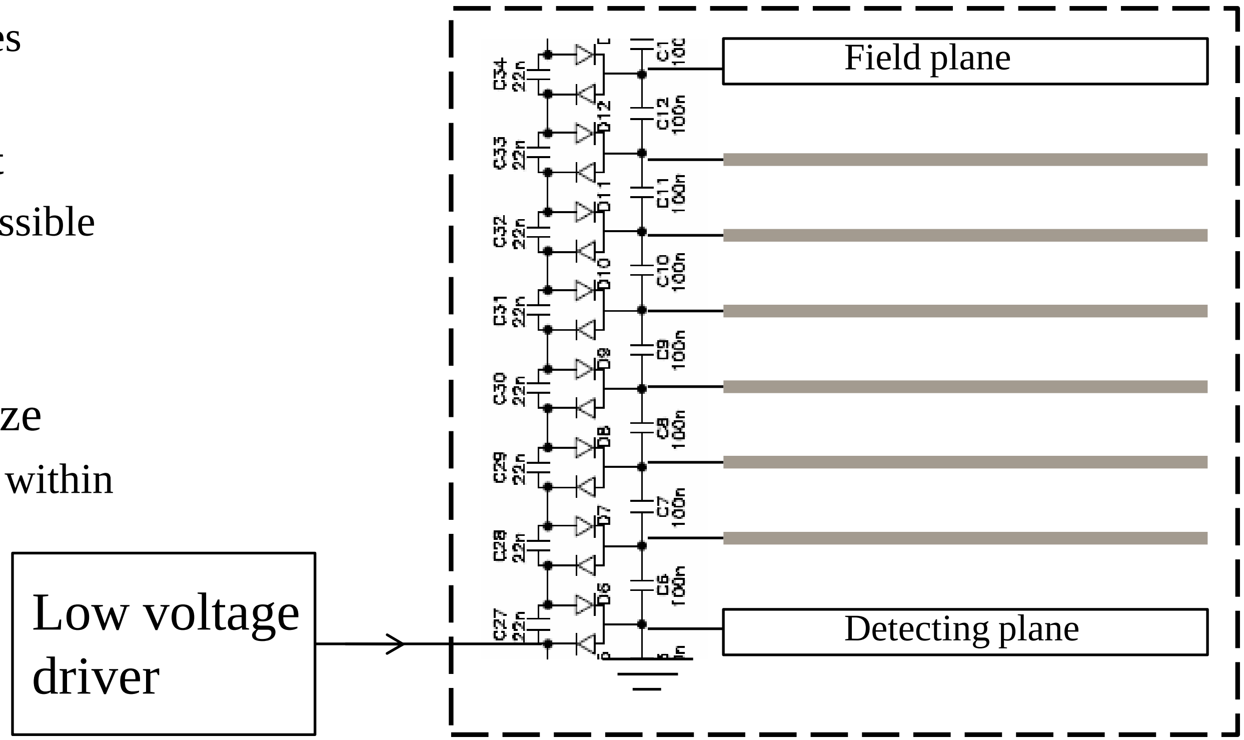
Classical approach



Integrating Cockroft Walton technology

- Cockroft-Walton chain integrated in field cage
  - No external HV lines
  - Only LV driver
  - **No bleeder current**
  - => low trip level possible
- HVs in 100 kV region relatively easy to realize
  - Everything remains within the cage structure
- Need some discharge circuitry
  - Relay + resistor to get rid of the residual HV after switching off

Integrated Cockroft-Walton



Conclusions

- Mini HV version 2 (-1000V) now completely designed
  - Production bit delayed (delivery components, assembly firm)
- Evaluation of first prototypes version 2 starting mid October
- Plan starting producing series of 20 pcs in January 2011
- Possible future developments
  - **More outputs and higher voltage**
    - GEM grids, omitting resistor chain
    - => bit larger housing
  - Cockroft Walton integrated in field cage of drifter