

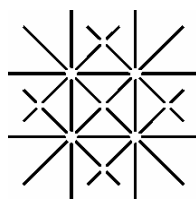
Piezo-Motor Controller (PMC)

SP 869

User's Manual

Physics Basel

Documentation Version 1.7, Mai 2006



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1. Safety Precautions

- The *Piezo-Motor Controller (PMC)* is designed for indoors dry laboratory use by qualified and authorized persons only.
- Read this manual carefully before installing and using the PMC; all the safety precautions must be respected!



- **ATTENTION:** During operation lethal voltages up to ± 400 V are present at the connector *HV_out[0..7]* (to piezo-motors) on the rear-panel of the *PMC*.
- **ATTENTION:** At the slip-stick piezo-motors and its interconnections lethal voltages up to ± 400 V are present during motion.
- For wiring the *HV_out[0..7]* connector to the slip-stick piezo-motors, shielded and isolated cables which are specified for this high voltage application must be used.
- Never connect or disconnect any cables during operation; make sure all cables are tightly connected and fixed by the bolts.
- Do not open the *PMC* main-housing since lethal voltages are present inside. Service and adjustments can be carried out only by the manufacturer.
- Don't cover the cooling slots at the bottom and on the rear-panel.
- Do not operate the *PMC* or the slip-stick piezo-motors in explosive atmospheres. The *PMC* does not provide any explosion protection from static discharges or arcing components.
- Always switch off and disconnect the mains cable of the *PMC* at least for two minutes before disconnecting/connecting the *HV_out[0..7]* connector or touching the slip-stick piezo-motors or the wiring cables.

2. Disclaimer

Physics Basel hereby disclaims all responsibility for personal injury, property damage, fine or penalty which results from misuse, not respecting the safety precautions, improper maintenance or improper application of this product.

Compliance with all applicable environment and personnel safety regulations is the sole responsibility of the user.

3. Key Specifications

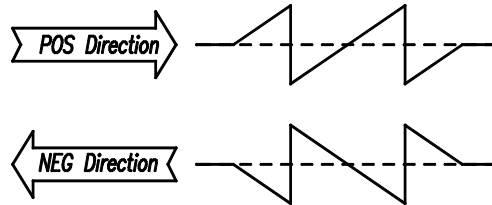
Channels:

Eight individual channels for forward and backward motion; only one channel can be activated at the same time. The channels are arranged in three groups: two groups with 3 axis and one group with 2 axis. Idle channels are short cut to *GND* via 47 Ohm resistors.

Output Voltage:

± 0 V ... ± 400 V saw-tooth with respect to common *GND* (minimum ± 20 V for proper waveform)

1 μ s back-jump (slip) rise/fall time (for load capacitance < 10 nF).



Stepping Frequency Range: ca. 1 Hz... 4'000 Hz (Load capacitance < 5 nF)
ca. 1 Hz... 2'000 Hz (Load capacitance < 10 nF)
ca. 1 Hz... 1'300 Hz (Load capacitance < 15 nF)

Load Capacitance Range: 0 nF... 15 nF

Hand-Control Unit:

- 6 push buttons for three axis ($\pm x$, $\pm y$, $\pm z$)
- Three position **group switch** (1, 2, 3)
- Two **potentiometers** for **frequency** and **voltage** adjustment
- Ergonomic housing for **one hand manipulation**
- Optical reflex photo sensor to activate the *Hand-Control Unit*
- 4 m cable length

Protection:

Overcurrent and **Overheat** (indicated by LED and beeper)

Mains Voltage:

85...264 VAC, 50 Hz / 60 Hz

Mains Fuse:

1.6 A slow blow, 5 mm x 20 mm

Power consumption, PFC:

70 W maximal, PFC according to **IEC/EN 61000-3-2**, Class A

Housing:

Desktop, Cooling-slots at bottom and rear-panel

Overall Size:

Width = 343 mm

Height = 95 mm

Depth = 310 mm (Without handles: 265 mm)

Weight:

ca. 4 kg

Additional Features:

- **Individual selectable polarity** for each channel
- **Passive air cooled** (no fans)
- **Status LEDs** on frontpanel
- Analog meter for **indication of the high voltage (HV)** on frontpanel
- **HV-output connector** 25 pin D-sub **compatible** with MSCU from the company *Omicron Nanotechnology GmbH*
- Audible step

4. Operation Conditions

- Indoors dry laboratories only!
- Ambient temperature between 5 °C (41 °F) and 40 °C (104 °F).
- Altitude up to 2'000 m (6'561 ft).
- Maximum relative humidity 80% for temperatures up to 31 °C (88 °F), decreases linearly to 50% at a temperature of 40 °C (104 °F).
- Pollution degree 1 (no pollution or only dry and non conductive pollution).

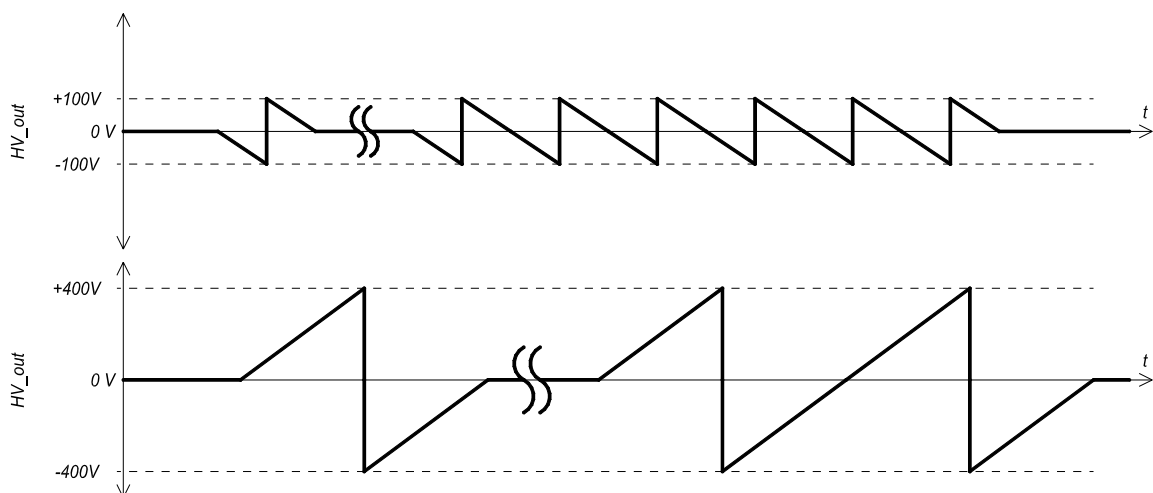
5. Introduction and Overview

The *Piezo-Motor Controller (PMC)* offers the flexible and robust operation of up to eight slip-stick piezo-motors. It allows a bidirectional movement in up to eight axis (channels), whereas only one axis can be driven at the same time.

The *PMC* can drive a wide range of piezo-motor-capacitances from zero up to 15 nF. For load capacitances smaller than 10 nF the sawtooth output voltage of the *PMC* has a fast back-jump (slip) rise/fall time of only 1 μ s. This leads to efficient and reliable operation of slip-stick piezo-motors.

The applied sawtooth high voltage (*HV*) can be varied in a wide range from zero (minimum ± 20 V for proper waveform) up to ± 400 V; the output voltage is referred to one common *GND* for all piezo-motors.

For flexible and precise positioning the continuous stepping frequency can be adjusted in a large range from about one step per second (1 Hz) up to 4'000 steps per second (4 kHz). The maximum stepping frequency depends on the total load capacitance connected to the *PMC*; it is given by the piezo-motor-capacitance plus the capacitance from the interconnection cable. For total load capacitances smaller than 5 nF the whole frequency range up to 4 kHz can be used, for 10 nF the maximum frequency is about 2 kHz, and for 15 nF the maximum frequency shrinks to about 1.3 kHz. *Fig. 1* shows two typical *HV* sawtooth output voltages with different parameters.



*Figure 1: Two different sawtooth HV output voltages (*HV_out*) with varied amplitudes, frequencies and slopes (directions). The upper waveform has an amplitude of ± 100 V and the slope (direction) is negative; the lower waveform shows a positive slope (direction) with the maximum amplitude of ± 400 V. In both diagrams the first part shows a single-step and the second part the continuous stepping mode.*

The *PMC* has only one *HV* sawtooth generator which is followed by an *HV* output channel selector where the sawtooth voltage is multiplexed (via eight relays) to the eight output channels. Non driven piezo-motors are short cut to *GND* via 47 Ohm resistors. If the *PMC* isn't used for longer than four seconds, the last used *HV* output channel is also deactivated; now the *PMC* is in the idle state. This means that all relays of the output channel multiplexer are switched off and so all piezo-motors are short cut to *GND* via 47 Ohm resistors.

The *PMC* can be manually operated by the remote *Hand-Control Unit (HCU)* or it can be easily controlled and monitored via the built-in *Computer-Control (CC)* interface. This is normally attached to a computer equipped with a digital (TTL) or mixed analog/digital interface-card. Under all conditions, the *HCU* has the highest priority and signals from the *CC* interface are immediately interrupted if the *HCU* gets activated. The *HCU* is activated by a finger of the operator which has to be placed at the bottom of the *HCU*; the presence of the finger is detected by an optical reflex photo sensor. The *HCU* is connected to the *PMC* via a four meter long flexible cable. To store the *HCU* in a save place it comes with a wall-mount holder.

When a push-button on the *HCU* is pressed a single-step is carried out immediately; if the same push-button remains pressed for longer than half a second the *PMC* switches to the continuous stepping mode with the selected frequency. Also during stepping it is allowed to vary the frequency as well as the voltage by the potentiometers on the frontpanel of the *HCU*.

The sawtooth polarity (*NORMAL* or *INVERTED*) of each *HV* output channel can be set individually by DIP-switches on the rear-panel. *NORMAL* means that a positive push button (e.g. +x) corresponds to a sawtooth with a positive slope and a negative push button (e.g. -x) to a negative-slope; if *INVERTED* is selected this relation is reversed. This option allows the user to adjust the *PMC* to his sense of wiring and motion of the piezo-motors.

For compatibility reasons the 25 pin D-sub *HV* output connector (*HV_out* to the piezo-motors) has the same pin assignment as the 'Micro Piezo Slide Control Unit (MSCU)' from the company *Omicron Nanotechnology GmbH*.

A fold-back current limitation is implemented in the *PMC* and allows a save operation over a wide stepping-frequency range. If the maximum *HV* output current of 25 mA at ± 400 V (12.5 mA at ± 200 V) is reached, the fold-back current limitation is activated and reduces the *HV* output voltage. Stepping is still allowed and the user has just to reduce the stepping frequency to leave this overcurrent condition. Overcurrent is indicated by the blinking red LED on the *PMC* (*Overcurrent*) as well as on the *Hand-Control Unit* (*Failure*); further an intermittent beeping is generated by the *PMC*. The *PMC* will not be damaged by this overcurrent condition and no fuse will blow.

If the device is forced to continuous ramping for a long time near its maximum output power (at the maximum frequency given by the load capacitance), it may overheat. If the *PMC* overheats it automatically stops ramping and disables the *HV* until it has cooled down again. During overheat the red warning LED on the *PMC* (*Overheat*) is turned on and the unit starts beeping. Further more, on the *Hand-Control Unit* the red LED (*Failure*) lights up. There is no damage to the *PMC* due to this overheating.

The *PMC* comes in a desktop housing with passive air cooling via slots at the bottom and on the rear-panel. The bumper-feet at the bottom allow a good air circulation inside the housing and they must not be removed. If the *PMC* has to be mounted in a 19"-rack, an optional rack-mount kit is available; nevertheless make sure that the cooling-slots at the bottom and on the rear-panel aren't covered.

6. Front-Panel

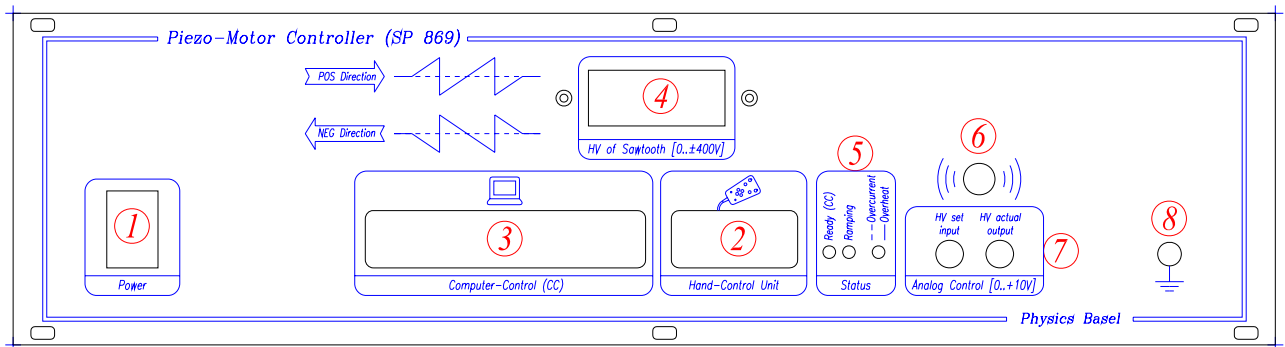


Figure 2: Front-panel top view of the Piezo-Motor Controller (not to scale).

The main elements to operate the *PMC* are arranged on the front-panel. A detailed description of all elements is given below (number corresponds to Fig. 2):

- (1) Main power switch. ON is also indicated by the white backlight of the analog meter (4)
- (2) Connection to the *Hand-Control Unit (HCU)*. Female D-sub 9 pin connector on *PMC*. Proprietary interface which can only be used for communication with the *HCU*. Before connecting/disconnecting the *HCU* switch off the main power switch.
- (3) Bidirectional digital *Computer-Control (CC)* Interface (TTL). Female D-sub 37 pin connector on *PMC*. See detailed description in chapter **Computer-Control**.
- (4) Analog meter for indication of the applied *HV* of the sawtooth. Only a rough reading (error about $\pm 20\%$). Scale 0... 10 => $\pm 0... \pm 400$ V sawtooth amplitude.
- (5) Status display: *Ready (CC)* = LED green, *Ramping* = LED yellow, *Overcurrent* = LED red blinking / *Overheat* = LED red continuous.
- (6) Piezo beeper for audible user information. A click for each piezo-motor step and a short beep if the *Hand-Control Unit* gets activated (finger at the bottom of the *HCU*). *Overcurrent* = intermittently beeping / *Overheat* = continuous beeping).
- (7) Analog input/output signals 0... +10 V (LEMO 00):
(Mating LEMO connectors: Crimp: FFS.00.250.CTCE31, Solder: FFA.00.CTAC29)

HV set input: The *HV* of the sawtooth ($\pm 0... \pm 400$ V) can be programmed by an analog input voltage from 0 V to +10 V. Input resistance is > 30 kOhm. This analog input control is only active if the TTL signal *AD_SEL* on the *Computer-Control* connector is high; otherwise the *HV* is digitally programmed.

HV actual output: Analog read-back output voltage in a range of 0 V to +10 V corresponding to the actual *HV* of the sawtooth ($\pm 0... \pm 400$ V). The connected device must have an input resistance of > 10 kOhm. This analog output is steadily working independent of the *AD_SEL* signal and of the *PMC*-control mode (by *HCU* or via the computer interface).

- (8) 4 mm banana-jack grounding connection to the housing of the *PMC*. The *PMC* housing is already grounded via the mains cord; there is no need to ground it by this 4 mm banana-jack connector.

- (3) Selection of the desired (*NORMAL/INVERTED*) sawtooth polarity for each of the eight HV-output channels (see Fig. 5). Programmed via the octal DIP switch (*Sawtooth Polarity*):

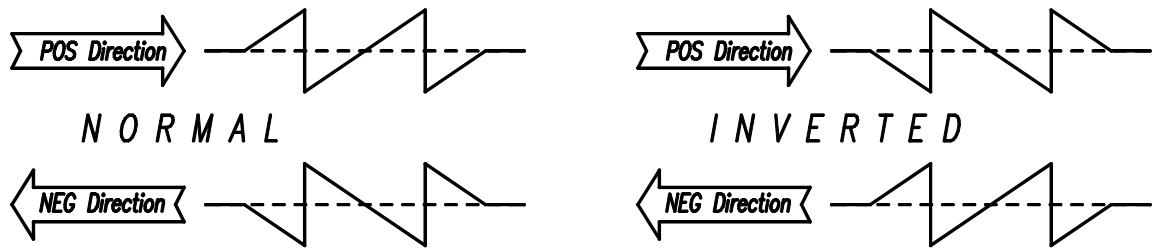
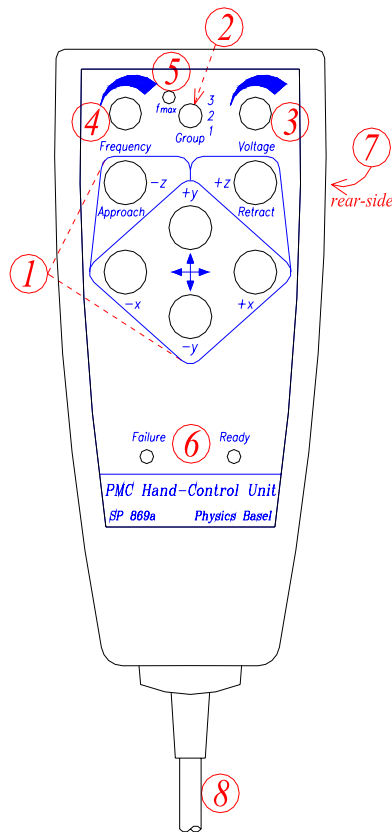


Figure 5: Shows the direction (POS or NEG) and the corresponding shape of the HV sawtooth for both the *NORMAL* and the *INVERTED* switch position. The mechanical movement of a piezo-motor can easily be reversed by switching the corresponding switch to the *INVERTED* position.

- (4) 4 mm banana-jack grounding connection to the housing of the *PMC*. The *PMC* housing is already grounded via the mains cord; there is no need to ground it by this 4 mm banana-jack connector.
- (5) Cooling slots. **Do not cover!**
- (6) Serial number of the *PMC*.

8. Hand-Control Unit (HCU) SP 869a

The *PMC Hand-Control Unit (HCU)* is connected to the *PMC* via a flexible four meter long cable. Make sure that the *PMC* is always switched off before connecting or disconnecting the *HCU*. To activate the *HCU* insert your forefinger inside the light shielding clip at its bottom. Then the optical reflex photo sensor will trigger and the green LED *Ready* on the *HCU* will be turned on. The top view of *HCU* is shown in *Fig. 6* and detailed description of the numbered elements is given below:



- (1) Six push-buttons for bidirectional movement in three axes ($\pm x$, $\pm y$, $\pm z$). A single step is carried out immediately after pressing one of the push-buttons; continuous stepping is reached by pressing the same button for longer than half a second.
- (2) To address the eight channels in total, three different groups (1, 2, 3) can be selected by a toggle switch. Group 1 and 2 provide three axes each ($\pm x1$, $\pm y1$, $\pm z1$ and $\pm x2$, $\pm y2$, $\pm z2$) and the group 3 provides two axes ($\pm x3$, $\pm y3$).
- (3) *Voltage* potentiometer to adjust (linearly) the amplitude of the sawtooth voltage in a range of ± 0 V... ± 400 V. A minimum and a maximum high voltage can be programmed by two pluggable resistors inside the *HCU*. At shipping these two resistors are zero which corresponds to the full amplitude range of ± 0 V... ± 400 V. Further details see the chapter **8.1 Disassembly of the *HCU* section A**).
- (4) *Frequency* potentiometer to adjust the repetition frequency nonlinear in the range of about 1 Hz up to the maximum frequency of normally 4 kHz. It can be reduced by the trimmer f_{\max} (5).

Figure 6: Top view of the *PMC Hand-Control Unit* (not to scale).

- (5) Trim-potentiometer to adjust the maximum repetition frequency (f_{\max}) from about 100 Hz (ccw) to max. 4 kHz (cw). At shipping the maximum repetition frequency of 4 kHz is adjusted.
- (6) LEDs to display the status of the *PMC* on the *HCU*. *Ready* = LED green: During *Ramping* the LED *Ready* is turned off. *Failure* = LED red: *Overcurrent* = Red LED is blinking, *Overheat* = red LED is continuously turned on.
- (7) Thru a drilling on the rear-side of the *HCU* the optical reflex photo sensor can detect objects outside its housing. To prevent from wrong switching due to ambient light or placing the *HCU* on a white table, the drilling is covered by a light shielding clip. Nevertheless, **strong direct light to the bottom of the *HCU* can unintentionally activate it.** If a finger covers the sensor-drilling at the bottom of the *HCU*, it gets activated. The green LED *Ready* on the *HCU* is turned on and the green LED *Ready* (CC) on the *PMC* is turned off. The sensitivity of the optical reflex sensor can be adjusted by a trimmer inside the *HCU*. Further details see the chapter **8.1 Disassembly the of the *HCU* section B**).
- (8) Robust and flexible four meter long interconnection cable to the *PMC*; the shielded cable has an outer diameter of 5 mm and a male 9 pin D-sub connector at its end.

8.1 Disassembly of the HCU

Before starting to disassemble the HCU, switch the PMC off and disconnect the cable from the PMC main unit!

Fig. 7 shows the sequence to open the HCU: First remove the gray and red caps on the adjusting knobs (*Frequency*, *Voltage*); then loose the two knob-screws below them to detract the knobs. Next unscrew the two hexagonally nuts of the potentiometer which were hidden by the two knobs (photo 2). Then remove the four outer screws on the rear-side of the HCU; do not unscrew the light shielding clip (photo 3). Now lift off the front-panel of the HCU to get access to the printed circuit board (photo 4). Fig. 8 shows a zoomed view to the elements which can be adjusted or replaced.

To reassemble the HCU follow the instructions above in reversed sequence.

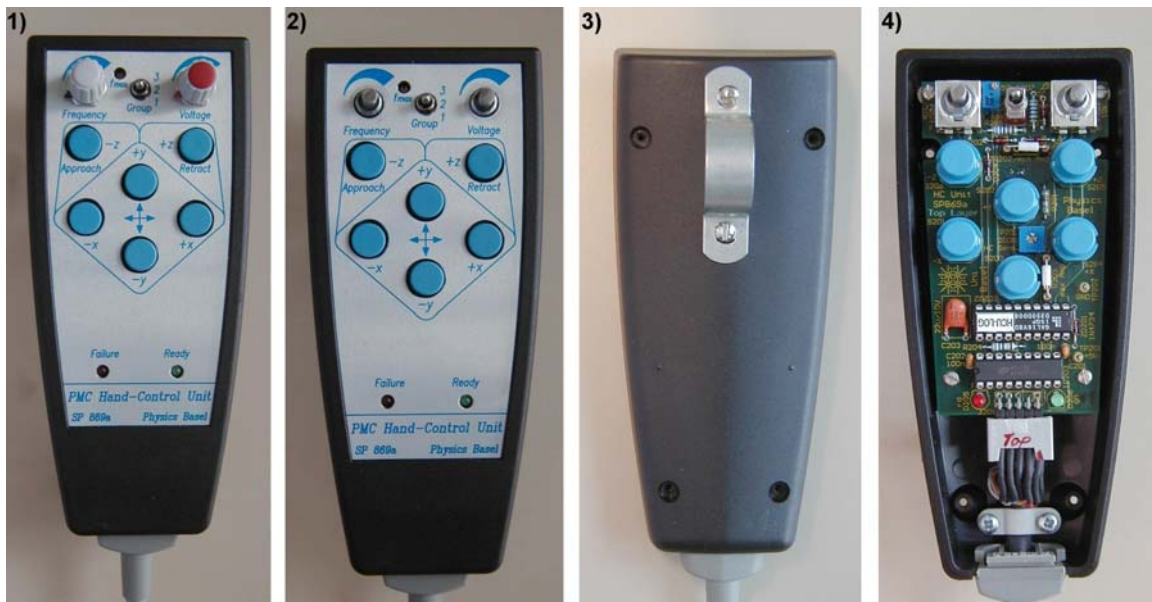


Figure 7: The sequence to open the HCU. First remove the two knobs of the potentiometers before removing the four screws at the bottom; do not unscrew the light shielding clip.

A) Adjusting the HV-Range of the HCU:

The range of the sawtooth high voltage (HV_{\min} to HV_{\max}), which is adjustable by the potentiometer on the HCU, can be hard-programmed by two pluggable resistors inside the HCU. At shipping these two resistors are zero, which gives the full possible amplitude range of $\pm 0 \text{ V} \dots \pm 400 \text{ V}$. Due to voltage restrictions given for example by the ceramic-material of the piezo-motors, it may be necessary to limit the possible voltage range. The values (in Ω) of these two range-resistors R_{\min} (sets HV_{\min}) and R_{\max} (sets HV_{\max}) are given by the following equations:

$$R_{\min} = 10k\Omega \frac{\left(\frac{400V}{HV_{\max}}\right)}{\left(\frac{400V}{HV_{\min}} - \frac{400V}{HV_{\max}}\right)}$$

$$R_{\max} = (10k\Omega + R_{\min}) \left(\frac{400V}{HV_{\max}} - 1\right)$$

HV_{\max} is the desired maximum peak sawtooth voltage. HV_{\min} is the desired minimum peak sawtooth output voltage; if a HV_{\min} of 0 V is demanded the resistor R_{\min} must be zero. The resistors are standard 0.5 W film resistors (1%, DIN0207) with a 10.16 mm folding.



By installing these two resistors only the sawtooth output voltage which can be adjusted by the HCU, is restricted. Via the computer interface still the full output voltage range of $\pm 0 \text{ V} \dots \pm 400 \text{ V}$ is programmable!

B) Adjusting the Optical Sensor Sensitivity:

The sensitivity of the optical reflex sensor (finger detection) can be adjusted by a trim-potentiometer inside the HCU (see Fig. 8). To increase its sensitivity turn the trim-potentiometer (*Optical Sensor Sensitivity*) clockwise. Normally a re-adjustment of the sensitivity is not necessary; if there are problems with the optical reflex sensor, first clean the drilling and the optics from outside the HCU.

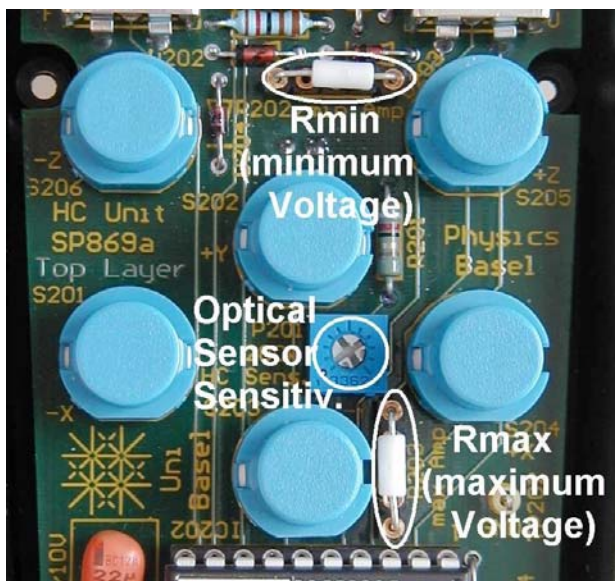


Figure 8: A zoomed view to the section of the HCU printed circuit board with the marked elements which can be adjusted or changed. The two white elements (R_{\min} , R_{\max}) are zero-Ohm resistors which are installed at shipping.

9. Computer-Control

The *PMC* has a built-in easy to use computer interface; it is based on parallel signals connected to a computer via the 37pin *Computer-Control (CC)* connector on the front-panel of the *PMC*. As mentioned before, the *Hand-Control Unit (HCU)* has the higher priority than signals from the *CC*-interface; signals coming from the *CC*-interface are immediately interrupted and ignored if the *HCU* gets activated.

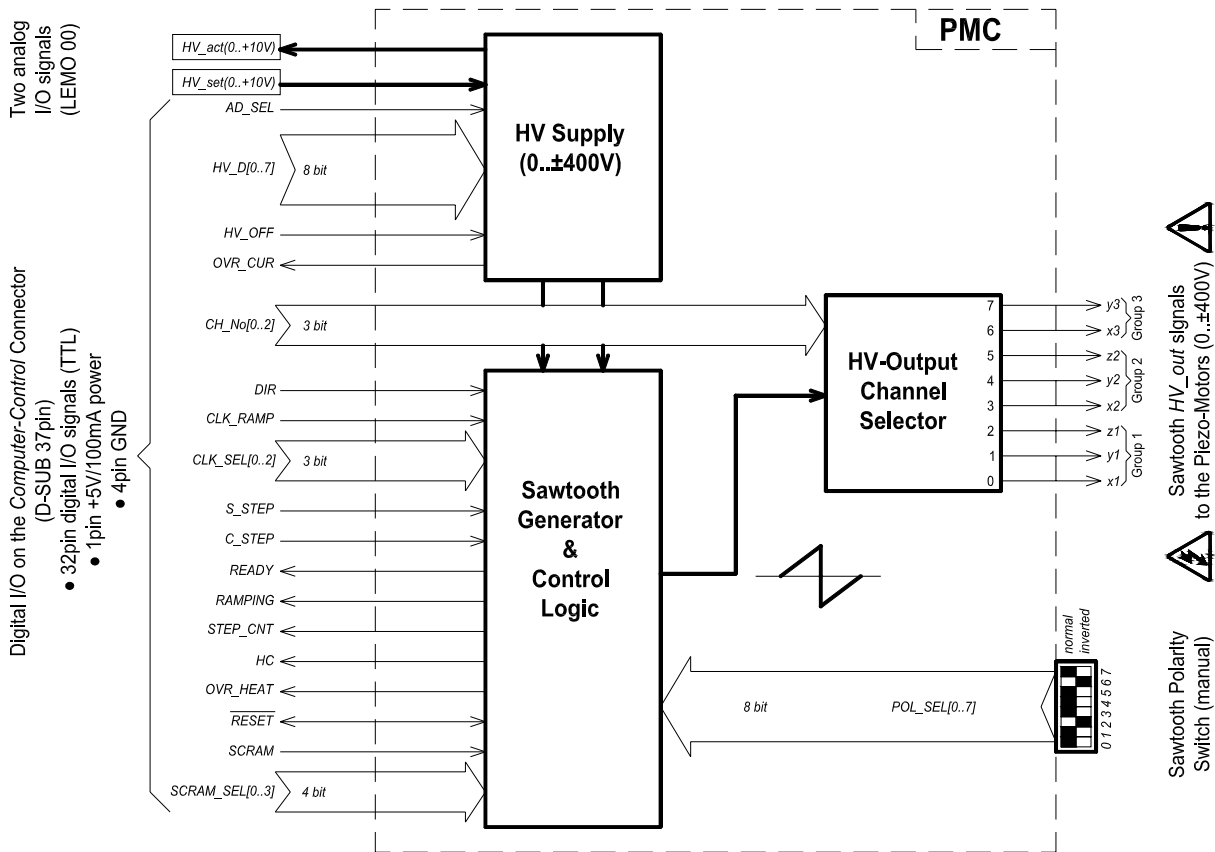


Figure 9: The simplified block diagram of the *PMC* and its interconnections to the outer world. The *Computer-Control* connections are located on the left side and its signals make interconnections to all of the three main blocks of the *PMC*.

Fig. 9 presents the simplified block diagram of the *PMC*. It shows how the simple computer interface works with bidirectional digital TTL signals, and if needed also with analog 0... +10 V signals.

Via the dedicated digital signals the desired sawtooth *HV* amplitude ($HV_D[0..7]$), the channel number ($CH_No[0..2]$), the moving direction (DIR) and the repetition frequency ($CLK_SEL[0..2]$) can be selected. A single step or continuous stepping of the selected piezo-motor can be started by activating the corresponding signal: S_STEP for a single step and C_STEP for continuous stepping. On the rising edge of one of these start signals (S_STEP or C_STEP) the following *CC*-data are registered: $CH_No[0..2]$, DIR , $SCRAM_SEL[0..3]$ and also the combination of the *Sawtooth Polarity* switch on the rear-panel. During stepping, changes of these parameters are completely ignored. To modify these parameters, the computer has first to deactivate the start signal (S_STEP or C_STEP), then alter the parameter(s), and then turn on one of the start signals again.

The exact mapping of the signals $CH_No[0..2]$, $SCRAM_SEL[0..3]$, DIR etc. is shown in Fig. 12; it gives a compressed overview of all digital I/O signals on the 37pin D-sub connector (*Computer-Control*).

With the **clock selection inputs** ($CLK_SEL[0..2]$) seven different preprogrammed repetition frequencies in the range of 15 Hz up to 1 kHz can be selected (the exact numbers can be found in the table of Fig. 12). For variable and own-specific repetition frequencies all clock selection inputs ($CLK_SEL[0..2]$) must be set to a high level (high if left unconnected). Now, the repetition frequency is given by an external applied TTL clock signal (CLK_RAMP) in a range from 0.. 4.096 MHz; the sawtooth repetition frequency is given by external clock frequency divided by 1'024.

The clock frequency as well as the HV amplitude (digital or analog) can be varied during stepping.

Fig. 10a shows a simplified timing diagram if the PMC is operated in the **single step mode**; the first step is in positive direction and the second one in negative direction. The single step is triggered by the rising edge of the S_STEP signal, the width of the S_STEP signal is unimportant.

The time delay (R_delay) between the rising edge of the start signal (S_STEP or C_STEP) and the beginning of the ramp at the HV_out is normally about 16 ms. This delay of 16 ms occurs when the PMC was idle, that means no channel-relay was active (after a pause of four seconds). If the same channel in the same direction was used shortly before (within about four seconds) the time delay is 0 ms; this is because there is no need to switch any relays. A time delay of about 24 ms is observed if the last used channel is still active (earlier than four seconds) and a change in the direction is demanded. The delay times are implemented to certainly start the ramping after the switching and bouncing of the channel relays (block HV-Output Channel Selector in Fig. 9).

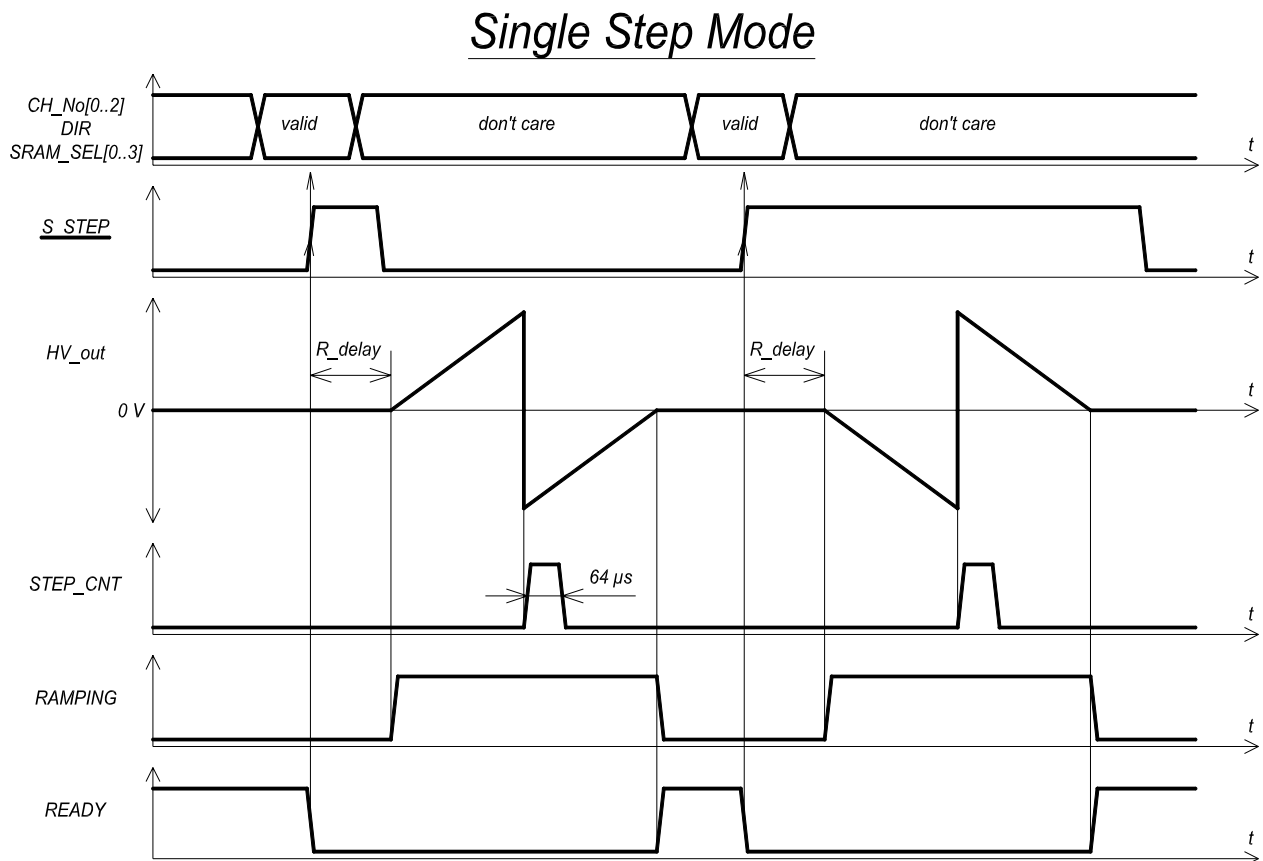


Figure 10a: Simplified timing diagram of the main signals if the PMC is computer-controlled in the single step mode (S_STEP). Notice that the data specified in the most top trace are stored on the rising edge of the S_STEP signal and are ignored thereafter.

The typical waveforms of the *PMC* operated via the computer interface in the **continuous stepping mode** (*C_STEP*) are given in the timing diagram of *Fig. 10b*. While the *C_STEP* signal is high a continuous sawtooth is generated with the selected frequency (*CLK_SEL[0..2]*). The relay time delay (*R_delay*) of 16 ms occurs only once, at the beginning when the selected channel-relay has to switch; other delays are possible under the circumstances explained above. When the *C_STEP* signals gets low the actual running cycle is properly terminated (until *HV_out* reaches 0 V again). The rising edge of the *READY* signal indicates that the *PMC* is ready to process the next instruction.

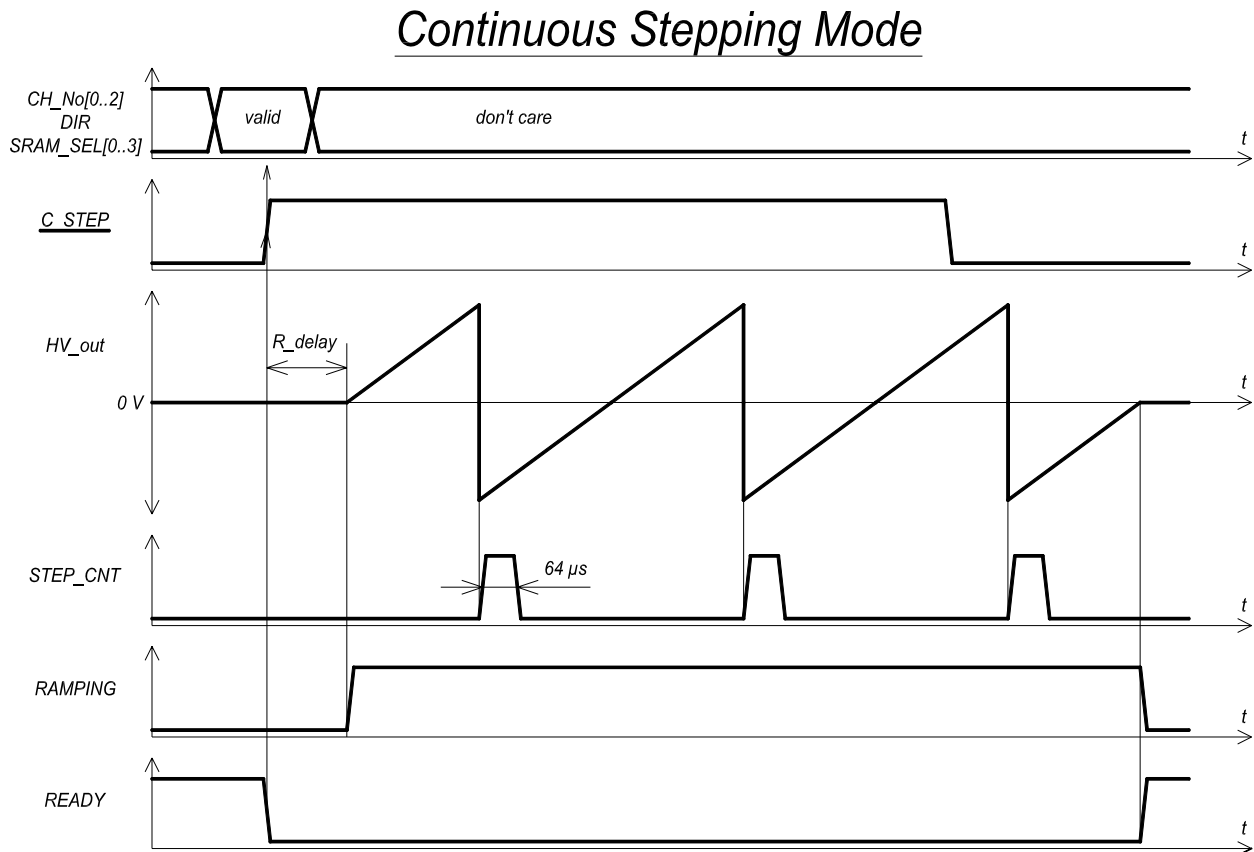


Figure 10b: Simplified timing diagram of the main signals if the *PMC* is computer-controlled in the continuous stepping mode (*C_STEP*). While the *C_STEP* signal is high, a continuous and seamless sawtooth is generated on the selected *HV* output channel. Data specified in the most top trace are stored on the rising edge of the *C_STEP* signal; those are ignored thereafter. To change the direction for example, one has to stop the ramping first and restart it with the inverted *DIR* signal.

The **status** of the *PMC* can be read-back via several status-signals (*READY*, *RAMPING*, *OVR_CUR*, *OVR_HEAT*, *HC*). The step-count output signal (*STEP_CNT*) releases a 64 μs long positive TTL pulse for each sawtooth step generated by the *PMC*; it can be used for counting the total number of steps. All status signals as well as the step-count output (*STEP_CNT*) are also available if the *PMC* is operated by the *Hand-Control Unit*. For more details see *Fig. 12*.

This **SCRAM** option is implemented to easily connect an external **approach security electronics**, which prevents the user from colliding with a sensitive object (e.g. a cantilever). If the user has approached too close to this object, the approach security electronics has to generate a TTL signal which can be wired to the *SCRAM* input of the *PMC*. Now the user is only allowed to retract from the sensitive object until he has reached a save distance again. The 'only allowed to retract' is realized by the exclusive channel and direction which can be operated when the *SCRAM* signal is high.

If the **SCRAM** input is activated (high level) the ramping stops immediately and all channels are blocked, except ONE channel in ONE direction. This blocking is active for the *Hand-Control Unit* as well as for the computer interface. The only enabled channel number is specified by the signals **SCRAM_SEL[0..2]**. This piezo-motor can be moved in the direction specified by the signal **SCRAM_SEL[3]**.

The sawtooth **HV amplitude** can be programmed either via an analog input signal from 0... +10 V (*HV set input*) or by an eight bit digital combination (**HV_D[0..7]**). If all 8 bits are low [00_{hex}] (low if left unconnected) the sawtooth high voltage is ±0 V and if all 8 bits are high [FF_{hex}] the HV is ±400 V. There is a linear relation between the digital number (**HV_D[0..7]**) and the actual HV; the resolution is about 1.57 V.

The **analog input control** is selected if the TTL signal **AD_SEL** on the *Computer-Control* connector is high (high if left unconnected). The analog HV actual output 0... +10 V (*HV actual output*) is permanently working independent of the signal **AD_SEL** and irrespective if the *PMC* is controlled by the *Hand-Control Unit* or via the computer interface.

A high TTL level at the input **HV_OFF** switches off the high voltage immediately and no ramping is allowed (by *HCU* as well as via computer control) while this input signal is high. If the **/RESET** pin is pulled down (low) the *PMC* is reset; since this signal is also internally activated (pulled down with an open collector or use a Schottky-Diode in series). Do not force the **/RESET** signal to a high TTL level.

Fig. 11 shows the **pin assignment of the Computer-Control** connector on the front-panel of the *PMC*. The connector also supplies +5 V with a maximum output current of 100 mA; this output voltage can be used to supply a small self-made interface electronics, if necessary. The +5 V supply and the **GND** (0 V) output pins are also foreseen for direct wiring the input control signals to a defined high (+5 V) or low level (**GND**).

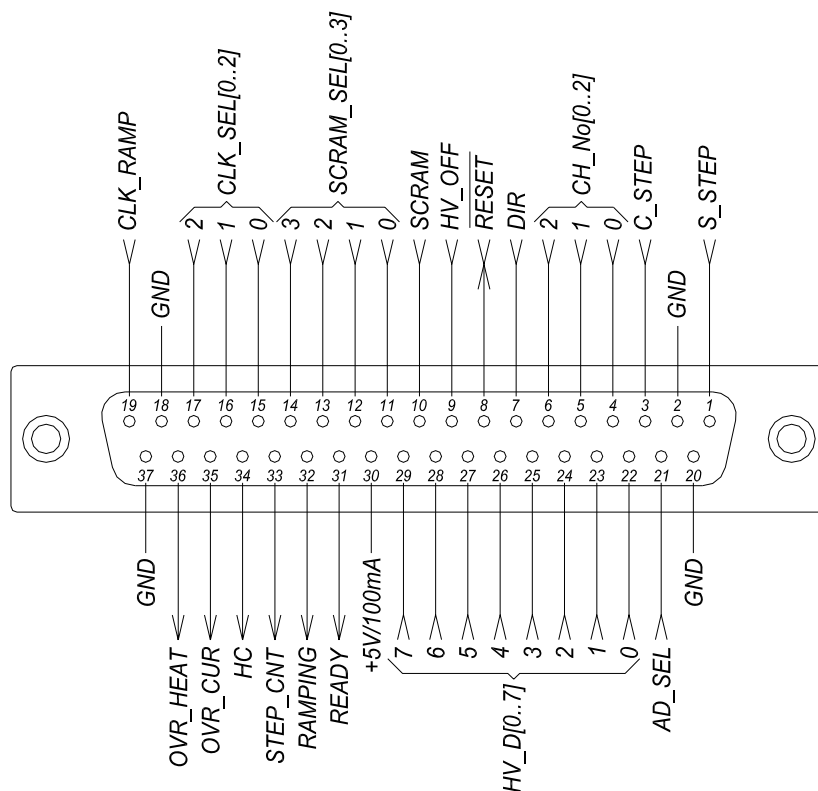


Figure 11: The pin assignment of the Computer-Control connector. On the *PMC* a female 37pin D-sub connector is mounted. 32 pins are used for digital TTL I/O signals; 4 pins are **GND** = 0 V (also connected to the *PMC* housing and to the shield of the D-sub connector); and one pin drives +5 V at a maximum 100 mA load current.

| PIN # of D- SUB37 | Signal Name | I/O to/from PMC | Input level if PIN left open | Description | Details (Bold = Default / Unconnected) |
|--------------------------------------|------------------------|--------------------------------|---|--|---|
| 1 | S_STEP | I | 0V = 0 | Single Step | A Single Step is generated on the rising edge. <i>The CH_No[0..2], DIR, SCRAM_SEL[0..3] and the Sawtooth Polarity switch are stored on the rising edge of S_STEP.</i> |
| 2 | GND | Power | | 0V / Housing PMC | |
| 3 | C_STEP | I | 0V = 0 | Continuous Steps | Continuous Steps are generated with the sawtooth frequency (f_saw) while C_STEP is HIGH. <i>The CH_No[0..2], DIR, SCRAM_SEL[0..3] and the Sawtooth Polarity switch are stored on the rising edge of C_STEP.</i> |
| 4 | CH_No[0] | I | 0V = 0 | Channel Number of HV_out (HV_out[0..7]) <i>Stored on the rising edge of S_STEP or C_STEP.</i> | 000: HV_out0 [x1] 001: HV_out1 [y1] 010: HV_out2 [z1] 011: HV_out3 [x2] 100: HV_out4 [y2] 101: HV_out5 [z2] 110: HV_out6 [x3] 111: HV_out7 [y3] |
| 5 | CH_No[1] | | | | |
| 6 | CH_No[2] | | | | |
| 7 | DIR | I | 0V = 0 | Direction (positive / negative sawtooth) <i>Stored on the rising edge of S_STEP or C_STEP.</i> | 0=POS / 1=NEG (Polarity = NORMAL) Depends also on the <u>Sawtooth Polarity switch</u> of the selected channel! |
| 8 | /RESET | I/O | 5V = 1 | Reset in/output | Open collector (pull down only, use an Open-Collector or a Schottky-Diode in series). Active LOW |
| 9 | HV_OFF | I | 0V = 0 | Switch HV off | HV is switched off fast and no ramping is allowed; also the Hand-Control is disabled. |
| 10 | SCRAM | I | 0V = 0 | SCRAM from external approach security electronics. | SCRAM switches HV_out off immediately. When SCRAM is HIGH, only ONE Channel in ONE Direction can be activated (specified by SCRAM_SEL[0..3]) |
| 11 | SCRAM_SEL[0] | I | 5V = 1 | SCRAM Channel Number of HV_out. Only the selected Channel Number is allowed when SCRAM is activated. <i>Stored on the rising edge of S_STEP or C_STEP.</i> | 111: Only HV_out7 allowed 110: Only HV_out6 allowed : 001: Only HV_out1 allowed 000: Only HV_out0 allowed |
| 12 | SCRAM_SEL[1] | | | | |
| 13 | SCRAM_SEL[2] | | | | |
| 14 | SCRAM_SEL[3] | I | 5V = 1 | SCRAM Direction (positive / negative sawtooth). <i>Stored on the rising edge of S_STEP or C_STEP.</i> | 0=POS / 1=NEG (Polarity = NORMAL) Depends also on the <u>Sawtooth Polarity switch</u> of the selected channel! |
| 15 | CLK_SEL[0] | I | 5V = 1 | Ramp clock source selection (variable f_saw via external CLK_RAMP or fixed f_saw from internal clock) | 111: f_saw = CLK_RAMP / 1024 110: f_saw = ca. 1kHz fix 101: f_saw = ca. 500Hz fix 100: f_saw = ca. 250Hz fix 011: f_saw = ca. 125Hz fix 010: f_saw = ca. 62.5Hz fix 001: f_saw = ca. 31.3Hz fix 000: f_saw = ca. 15.6Hz fix |
| 16 | CLK_SEL[1] | | | | |
| 17 | CLK_SEL[2] | | | | |
| 18 | GND | Power | | 0V /Housing PMC | |
| 19 | CLK_RAMP | I | 0V = 0 | External clock for the sawtooth | f_saw = CLK_RAMP(0..4MHz) / 1024 |
| 20 | GND | Power | | 0V / Housing PMC | |
| 21 | AD_SEL | I | 5V = 1 | Analog or Digital HV-set | 1=HV analog set / 0=HV digital set |

| | | | | | |
|----|------------------|-------|--------|--|--|
| 22 | <i>HV_D[0]</i> | | | | |
| 23 | <i>HV_D[1]</i> | | | | |
| 24 | <i>HV_D[2]</i> | | | | |
| 25 | <i>HV_D[3]</i> | | | | |
| 26 | <i>HV_D[4]</i> | | | | |
| 27 | <i>HV_D[5]</i> | | | | |
| 28 | <i>HV_D[6]</i> | | | | |
| 29 | <i>HV_D[7]</i> | | | | |
| | | I | 0V = 0 | 8bit digital HV-set value of the sawtooth output voltage | 0000'0000: HV = ±0V : 1000'0000: HV = ±200V 1000'0001: HV = ±201.6V : 1111'1111: HV = ±400V |
| 30 | +5V/100mA | Power | | +5V supply for external circuits | max. 100mA (internal 200mA multifuse) |
| 31 | READY | O | | PMC is ready for a step | Active HIGH |
| 32 | RAMPING | O | | PMC is ramping the HV_out | Active HIGH |
| 33 | STEP_CNT | O | | A 64 µs pulse is generated at the fast edge of sawtooth. | Pulse to count the number of steps (works also if Hand-Control Unit is active) |
| 34 | HC | O | | Hand-Control selected | 0=Computer-Control / 1=Hand-Control |
| 35 | OVR_CUR | O | | Overcurrent at the HV_out | Active HIGH Ramping (by HCU or S_STEP, C_STEP) is still possible. |
| 36 | OVR_HEAT | O | | Overheat of the PMC | Active HIGH Ramping is disabled and HV is switched off automatically. |
| 37 | GND | Power | | 0V / Housing PMC | |

Figure 12: The table with all I/O signals available on the Computer-Control connector. A short description and some details are also given; for better and deeper explanations see the chapter *Computer-Control*.

10. Functional Principle of the PMC Electronics

The block diagram presented in *Fig. 13* illustrates the entire inner life of the *PMC* inclusive the *Hand-Control Unit*. It shows the functional principle of the *PMC* electronics and its interaction with the controls and the analog and digital interface signals.

The complete *PMC* electronics is supplied by a 35 W switching power supply with a single output voltage of 12.7 V. All other voltages needed for the electronics (+5 V, ± 15 V), including also the variable bipolar high voltage (± 0 V... ± 400 V), are generated locally on the printed circuit board via DC/DC converters.

The positive (+ V_s , 0 V... +400 V) and the negative high voltage (- V_s , 0 V... -400 V) are produced by two high voltage DC/DC converters from the company *EMCO*. Two separate controller-circuits (*HV Supply Controllers*) perform the regulation and the current limitation of each of the two high voltage DC/DC converters. The set value of the high voltage is wired in parallel to both of the two *HV Supply Controllers*, resulting in a symmetrical bipolar high voltage (*HV*) in a range of ± 0 V... ± 400 V.

The bipolar *HV* supply is connected to the *HV-Power Stage* where the high voltage and high speed signals are generated and thereafter distributed via the *HV-Output Channel Selector* to the selected *HV* output channel (*HV_out[0..7]*).

The *HV-Power Stage* is a push-pull power stage formed by two high-speed, high-voltage n-channel MOS-FETs with two high power 22 Ohm resistors in series. These two resistors limit the maximum peak-current during the very fast discharge of the load capacitance.

The two gates of the power MOS-FETs are driven by two transformers which perform a galvanic isolation between the *HV* power stage and the driving circuit.

The following explanations are given for a positive sawtooth:

To generate the linear *HV* ramp, a 1 MHz square wave signal is amplitude modulated and then transmitted via the transformer to gate of the 'loading' MOS-FET (upper MOS-FET). Thus the capacitance at the *HV* output is continuously loaded by a vast series of small 1 MHz current pulses which result in a fine stepped linear *HV* ramp at the output. To enable that this principle works for different load capacitances and independent of the MOS-FET parameters, the linear ramp is generated by using a closed feedback loop. The amplitude modulation is steered by a *PI-Controller* which gets the actual value of the *HV* output via a *Voltage Divider* ($\div 200$). The sawtooth reference signal is generated by a *multiplying 10 bit DAC* connected to a *10 bit counter* located inside the *PMC-Chip*. The analog reference signal of the *multiplying DAC* is derived from the actual *HV* amplitude. This scheme leads to a sawtooth DAC output signal with an amplitude proportional to the adjusted *HV*.

When the linear ramp reaches its maximum positive output voltage (+ V_s), a fast back-jump has to discharge the loaded capacitance to the negative output voltage (- V_s) in a very short time (around 1 μ s). This is performed by an exactly timed discharge pulse feed to the gate of the 'discharge' MOS-FET (lower MOS-FET). After the fast discharge the *HV* output voltage is linearly ramped again towards the positive output voltage (+ V_s). A single steps as well as continuous stepping, start and stop with a piezo-motor output voltage (*HV_out*) of zero volt.

For a negative *HV* ramp (piezo-motor moves in opposite direction) the principle works in the same way but the functions of the MOS-FETs and some other circuits are swapped.

The complete sawtooth control logic, the relay logic and the computer interface are implemented inside the *PMC-Chip*. The *PMC-Chip* is a programmable CPLD from the company *ALTERA*.

Piezo Motor Controller (PMC) SP 869

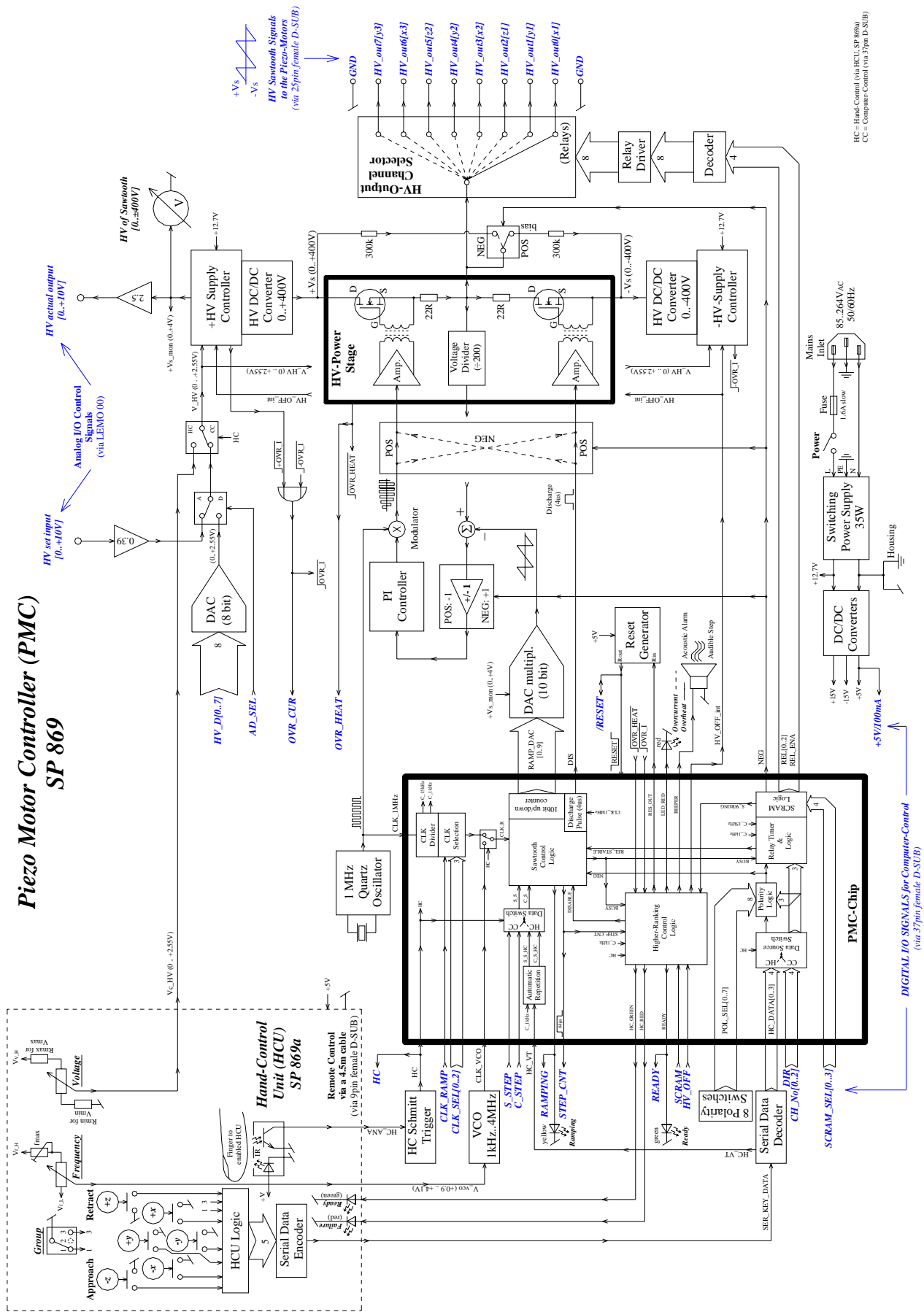


Figure 13: Block diagram of the complete PMC electronics inclusive the Hand-Control Unit. Nearly the complete logic of the PMC is implemented in the PMc-Chip, a programmable CPLD.