Programmable Digital Pulse Controller for Fast High-Voltage Switches

Firmware Version 1-00

User Manual

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Contents

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Technical Data

Characteristics

- control of 5 independent fast high-voltage switches
- resolution: 5 ns coarse, 0.5 ns fine
- internal trigger
    - period: 100 µs .. 10 ms
    - resolution: 10 ns
- trigger output:
    - connector: BNC
    - signal level: TTL, log. 0: 0..0.4 V, log. 1: 2.4..5.0 V
    - output impedance: 50 Ω
    - resolution: 10 ns
- interlock: 4 independent loops, selectable per software
- memory data space: 256 KB
- maximum number of stored measurements: 100
- maximum number of stored voltage settings: 100
- maximum number of stored timing settings: 100
- maximum number of stored trigger settings: 100

Human Interface

- monochrome LCD display 128x64 pixel
    - pixel size: 0.5 mm
    - pixel color: yellow, background: blue
    - background illumination: white LED
- keypad: 5 keys: 4x direction + 1x "enter"
- rotary encoder: 24 positions per revolution, integrated press button
- press button for amplifier activation
- optional external shutdown button via the interlock loop

Digital Interface

- USB interface according to USB 2.0 standard
    - connector: USB plug type B
    - data transfer rate: up to 12 MBit/s (*Full Speed*)
    - effective data transfer rate: >100 kBit/s

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Description

General

The pulse controller produces control signals and supply voltages for up to 5 fast high-voltage switches. The switches are placed at a board located in a vacuum chamber. The connection between the pulse controller and the vacuum board is made by two dedicates cables - one for the control signals and one for the high voltages.

The signal output is triggered by an internal trigger signal. Its period can be adjusted to any value between 100 µs and 10 ms with a resolution of 10 ns. The control signals for the switches are generated from the internal trigger signal and several clock signals. The pulse duration can be set to values from 20 ns to 10 µs, the pulse can start up to 10 µs before or after the trigger pulse, the resolution is 0.5 ns. Some channels can be coupled together so that they produce synchronous signals.

The device outputs a trigger pulse with a TTL level at a BNC socket located at the front panel. The start and the end of the trigger pulse can be set to any value within the period of the internal clock with a resolution of 10 ns. The trigger output can be inverted or disabled.

The high voltages determining the non-zero potentials of the switch outputs are obtained in 5 high-voltage amplifiers. The voltages can be set to values of 750 V maximum with a resolution of 0.1 V. The outputs are continuously monitored and, in case of any discrepancy, the device is deactivated. This can happen if the outputs are overloaded, the shutdown protects the hardware from secondary damages.

The device monitors several interlock loops, which disable the outputs of the attached switches if any of the loops is opened. The terminals of the interlock loops are located at the device's output connectors and at two BNC sockets at device front and rear panels. The terminals at the output connectors are fed by output cables to the vacuum board with the switches where they are short connected if the board operates properly. Thus, the device output is disabled if one of the output cables is disconnected or broken, or if the vacuum board does not respond properly. The terminals at the BNC sockets can be connected to a vacuum controller or other supervising device that opens the contacts in emergency states. The function of each particular interlock

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loop can be disabled if it is not used. If all four interlock loops are disabled, the device can be activated regardless of the interlock state.

The pulse controller is fitted with several temperature sensors, which scan the temperature of the internal heatsinks and some integrated circuits. The measured temperatures are used to control two fans, which actively cool the device. The fan function is monitored and a warning light (red LED "Failure") is activated, if the fans do not operate at the desired speed. On such failures, the operation of the device is still possible but an overheating may occur. The pulse controller is disabled first if the device overheats or if any temperature sensor fails.

The pulse controller is equipped with a USB data interface that allows to transfer measurement and settings data to or from the device and remotely control it. The USB data interface is galvanically connected to the device case. When making a connection to a host computer, a large ground loop is created that can influence the device performance. If the host computer should be permanently connected to the device, it is advisable to check the influence of the USB connection on the output signal. Optionally, a USB isolator can be used if the connection negatively influences the signal quality.

Control and Indication Elements

All control elements of the device are located on the front panel (see Fig. 1).

The rocker switch "Power" turns the device on or off. If the device is powered on, the LCD is activated and its backlight is turned on. Manufacturer logo is shown and, after a short hardware initialization, the device enters its idle state where it waits for user commands (see Fig. 2).

If the device is activated, the high-voltage supply and the control signals of the switches are turned on. This state is signalized by the green LED " Activated".

The yellow LED "Interlock" shows the state of the interlock loops. It lights if the selected interlock loops are closed. When any of the selected loops is opened, the LED "Interlock" is off and the device cannot be activated. If it is active, an opened interlock loop shuts the hardware down.

The red LED "Failure" lights if any failure occurs. This may be a device overheating or a too low device temperature[†], a failure of the supply voltages or of the fans. Only the fan failure does not prevent the device from operation, on all other failures, the device cannot be activated. The reason of the failure can be found out by inspecting the dialog boxes for device monitoring (see section "Device Monitoring"). If a fan failed, the device continues to operate, you should, however, replace the defective fan as soon as possible to prevent overheating. The temperature thresholds for the fan operation and for overheating can be adjusted (see section "Device Setup"). If an overheating event occurs, check these thresholds and adjust them if necessary.

[†] The device cannot be activated at temperatures below 10°C because of a possible moisture condensation.
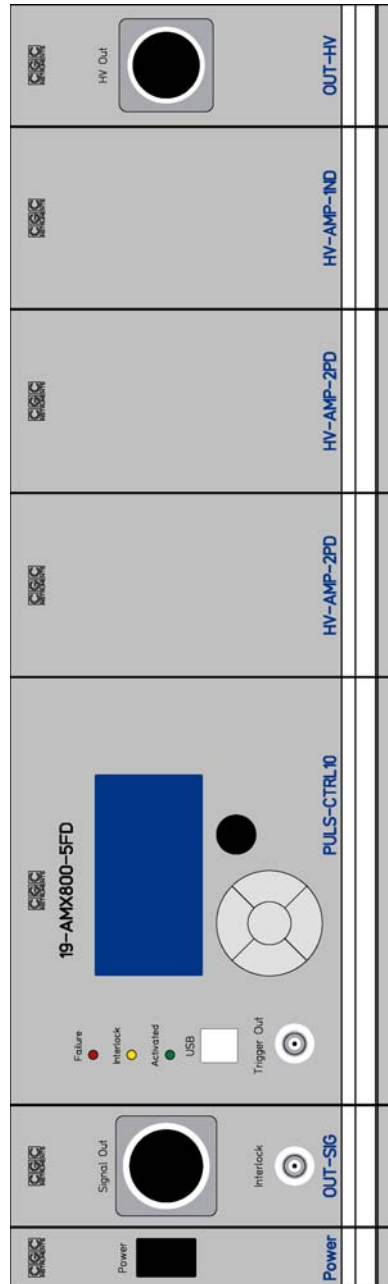
Fig. 1. Front panel of the pulse controller.

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Device Function

The pulse controller generates control signals and supply voltages for the high-voltage switches according the setting stored in controller's non-volatile memory. The control signals drive the high-voltage switches, they switch between ground and the corresponding supply voltage provided by the pulse controller.

The control signals are generated by an FPGA (*Field Programmable Gate Array*) and by subsequent high-resolution delay lines. The FPGA is equipped with a non-volatile memory in that all settings are stored. The FPGA also controls all device components and monitors the crucial device parameters. It shuts down the pulse controller on any failure. The user interface and most of the control logic is realized by a microcontroller connected to the FPGA. The microcontroller serves the human interface (see section "Human Interface"), controls the USB data interface, and executes several monitoring tasks. The microcontroller's firmware realizes a user-friendly graphical interface. The device is controlled by the help of menus and dialog boxes, they provide an intuitive device control.

The setting defining the output parameters are grouped in three sets: trigger settings (see section "Trigger Management"), timing settings (see section "Timing Management"), and voltage (see section "Voltage Management") settings. They describe the function of the trigger, the timing of the switches, and the output voltages, respectively. Sets of these settings are stored as measurement settings (see section "Measurement Management"). Thus, a measurement setting is a data set completely describing the output signals.

Several measurement settings can use the same trigger, timing, or voltage settings. Thus, you may setup, for instance, only one trigger setting that matched your experimental needs and use this setting in all measurement settings. Different measurement settings can differ in timing or voltage settings only. It is also advisable to create test setting of every art for tuning purposes so that it is not necessary to modify the settings that were already created and tuned for optimum parameters.

To control the signal output, a special dialog box is available (see section "Experiment Control"). You can select a particular measurement and start, stop, or tune the signal output.

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The firmware also provides a set of dialog boxes for monitoring the device parameters (see section "Device Monitoring"). Next, the firmware automatically manages several processes that permanently supervise the device and control the attached switches. For instance, the supply voltages and temperatures of the semiconductor power devices are continuously checked and the device is deactivated if necessary.

Using the USB interface, settings data can be uploaded from or downloaded to the device and stored in its non-volatile memory (see sections "Software Utilities" and "Backing Up and Restoring the Data").

The USB interface can also be used to remotely control the device (see section "Utility RemoteControl"). A part of the remote controller is a hardcopy utility that copies the current display contents via USB to a bitmap file at the host computer. The USB interface can also be used to upgrade the firmware. For a detailed description, see the section "Utility FlashLoader").

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Quick Setup Guide

The device is delivered with cleared non-volatile memory. This means that there are neither measurements nor other settings installed and set up. To prepare the device for a measurement, you have to create and set up these settings. To do so, follow the next steps:

- Create and setup at least one trigger setting as described in the section "Trigger Management": Press the middle key "enter" and start the trigger management by selecting the menu item "Manage ► Triggers". Create a new trigger setting by selecting the menu item "New ► Current". Setup the desired parameters; it is also advisable to setup the settings name. Save the trigger setting by selecting the menu item "Save", then close the setting management. For details see section "Trigger Management".

- Create and setup at least one timing setting as described in the section "Timing Management": Press the middle key "enter" and start the timing management by selecting the menu item "Manage ► Timings". The timing management is very similar to the abovementioned management of trigger settings.

- Create and setup at least one voltage setting as described in the section "Voltage Management": Press the middle key "enter" and start the voltage management by selecting the menu item "Manage ► Voltages". The voltage management is very similar to the abovementioned management of trigger settings.

- Create and setup at least one measurement setting as described in the section "Measurement Management": Press the middle key "enter" and start the measurement management by selecting the menu item "Manage ► Measurements". Also the measurement management is very similar to the abovementioned management of trigger settings. As components of the measurement setting, use one of the trigger, timing, and voltage settings that you have created before: Select the corresponding data set and press the middle key "enter" - this opens the management of the corresponding setting. Use the encoder to select the desired settings, then close the setting management by the selecting the menu item "Select".

- Press the middle key "enter" and start the experiment control by selecting the menu item "Experiment". Choose a measurement by selecting the menu item "Select". Launch the measurement by selecting the menu item "Run". If necessary, check the output signals with an oscilloscope connected to the monitor outputs. Stop the meas-

urement by selecting the menu item "Stop". For details see section "Experiment Control".

If you encounter problems, read carefully the corresponding section in this manual. If the measurement cannot be launched, check the device parameters by opening the dialog boxes for monitoring (see section "Device Monitoring").

Backing Up and Restoring the Data

The data stored in the device's non-volatile memory can be backed up or restored. The data includes the measurement (see section "Measurement Management"), trigger (see section "Trigger Management"), timing (see section "Timing Management"), and voltage (see section "Voltage Management") as well as device (see section "Device Setup") settings. This means that a restore procedure rolls back the device exactly to the state it was in at the backup time. Thus, if any tuning of the settings are planned, it is advisable to create a backup before with which the original state can be restored.

To perform a data backup, locate the program `PulseLoader.exe` in the directory "Program" of the enclosed software package. To back up the system memory into a data file `Memory.txt`, execute the following command in a Windows™ command shell[‡]:

```
PulseLoader 6 -y MemoryData.txt -t
```

This command downloads the memory data from the device connected to the virtual port COM6 into the file `Memory.txt`.

To restore the data, execute the following command:

```
PulseLoader 6 -Y MemoryData.txt -t
```

This command uploads the memory data from the file `Memory.txt` to the device connected to the virtual port COM6.

[‡] Select "Run" in the start menu of Windows™ and type "cmd". Then change the directory to that with the program files using the command "cd". Finally, execute the given command by copy & pasting and pressing "Enter". A better and more comfortable alternative to the Windows™ command shell are utilities like "File Commander/W" or "File and archive manager (FAR)". Please use the search utilities to find out how to obtain these applications.

Human Interface

The device is equipped with a graphic liquid crystal display (LCD), a set of keys (keypad) and a rotary encoder. The keys are arranged in a circle symbolizing the key function: There are four direction keys ("left", "right", "up", and "down") and a middle key for confirmation or selection ("enter").

The keys are used for menu navigation, for selecting dialog items, or for changing various values. The function of the keypad in every device state is symbolized on the LCD immediately above the keypad. A text describes the function of the middle key, alternatively just the symbol "⏎" is displayed showing that the middle key can be used. Similarly, arrows show which of the keys has an influence on the operation in the current state. When a menu is active, the vertical direction keys are used to change the current selection. The right direction key as well the middle key opens a submenu, provided it is available. The left direction key closes the submenu or the main menu if there was no opened submenu. The middle key selects the menu item and launches the corresponding action.

The rotary encoder is used to change numerical values or select items. The function of the encoder is symbolized in every device state on the LCD immediately above the encoder knob. In most situations, the encoder uses an enhanced speed control. This enables you to set precisely any desired value or rapidly make large changes, since the value steps are proportional to the rotational speed of the encoder. You can change the corresponding value in small steps when you rotate the encoder slowly or make large changes when you spin the encoder knob rapidly. To set large numbers, the encoder speed can be further increased by pressing the direction key "left". If this feature is available, the left arrow is shown above the keys. In some situations, the encoder's push button is used to confirm the selected value or to switch the encoder function. In such cases, the symbol "▣" is shown on the LCD above the encoder knob.

Main Program Menu

When the device starts, the initialization takes place and the manufac-turer logo is shown for couple of seconds. Then, the device enters the idle state (see Fig. 2). The lower right corner shows the uptime, i.e. the time elapsed from the last device start.
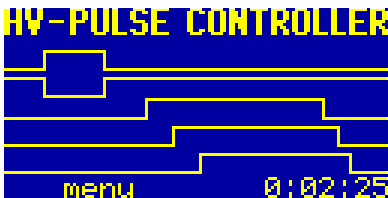
Fig. 2. Program display in device idle state.

By pressing the middle key "enter", the main menu can be accessed (see Fig. 3). You can start a measurement (menu item "Experiment", see also section "Experiment Control"), manage the device configura-tion (submenu "Manage", see also section "Device Management"), setup the device settings (submenu "Setup", see also section "Device Setup"), monitor the device function (submenu "Monitor", see also section "Device Monitoring"), view the device state (submenu "View", see also section "Device State"), or manage the system settings (submenu "Adjustment").

You can save the current system settings (menu item "Adjustment ► Save"), load the settings back (menu item "Adjustment ► Load"), or reset them to default values (menu item "Adjustment ► Reset"). The system settings are saved automatically to a non-volatile memory when the device powers down and are loaded back when the device starts. You may save the settings using the main menu prior to the next device shutdown if you have made changes that you wish to keep permanently. When you choose to load the settings back, the settings will be reloaded and the last saved state will be restored, i.e. the settings will be set to the state immediately before the last shut-down or after the last startup, or to the state when you saved the set-tings. Further, you may reset the settings to their default values. This is advisable if you wish to restore the original device state. Note that the settings reset does not influence the measurement settings and data. If you wish to also clear this data, start the corresponding man-

Fig. 3. Main program menu.
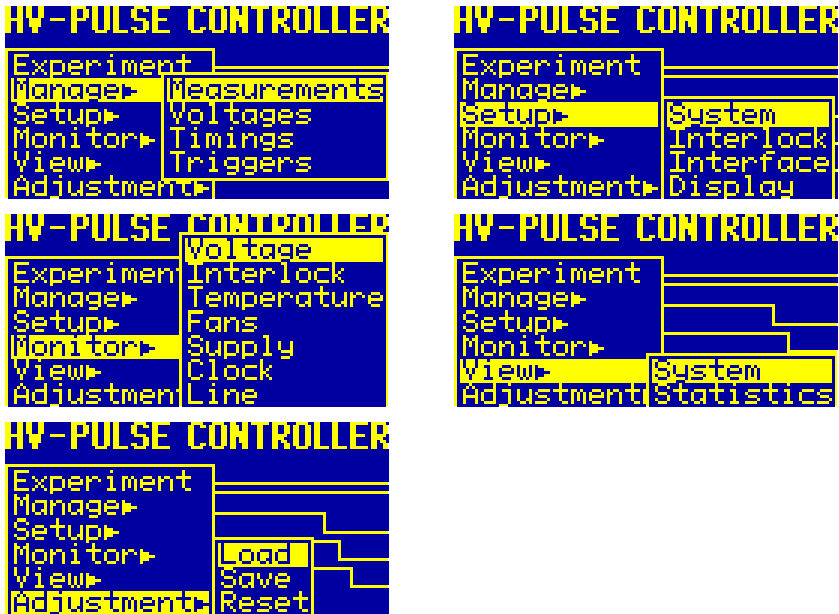The figure shows the different submenus of the main program menu.

agement (see section "Device Management") and clear the data in the corresponding dialog box.

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Device Setup

System Preferences

The dialog box "System Preferences" (see Fig. 4) shows the current system settings and enables you to change them.
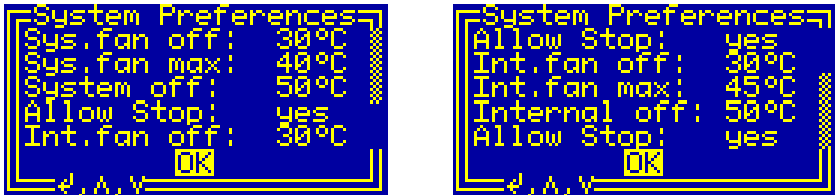
Fig. 4. Dialog box "System Preferences".
Two different views of the dialog box that correspond to different positions of the scroll bar located at the right side.

Use the vertical direction keys to change the currently selected item. The selected item is highlighted by inverting the displayed characters. By pressing the middle key "enter", the settings can by modified or the dialog box can be closed (see the selection shown in Fig. 4). The numerical values can be modified by the rotary encoder.

The values "Sys.fan off" and "Sys.fan max" as well as "Int.fan off" and "Int.fan max" define the temperature thresholds for the fan controller. The first ones correspond to the system fan at the rear panel, the second ones to the internal fan in the controller module. If the temperature measured by the attached sensors is lower than the lower threshold "Sys.fan off" or "Int.fan off", respectively, the fan rotates at its minimum speed, it rotates at its maximum speed if the measured temperature reaches the upper threshold "Sys.fan max" or "Int.fan max", respectively.

The fan can be turned off if the corresponding item "Allow Stop" is set to "yes". The hysteresis is 1°C, i.e. the fan starts to rotate if the temperature exceeds the lower threshold but stops at a temperature lower by 1°C.

The function of the fans can be checked using the dialog box "Fan Monitor" (see section "Fan Monitor").

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If the temperature exceeds the shutdown threshold "System off" or "Internal off", respectively, the device is deactivated and overheating is signalized. The device can be activated again once the temperature has decreased below the shutdown threshold, the hysteresis is 1°C.

The threshold values can be changed using the rotary encoder. The minimum settable value is 20°C, the maximum is 60°C. The differences between the values must be at least 1°C.

Interlock Setup

The dialog box "Interlock Setup" (see Fig. 5) shows the current interlock settings and enables you to change them.
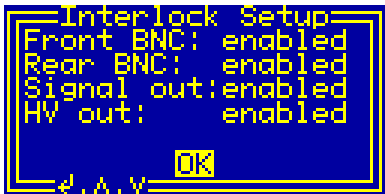
Fig. 5. Setting the interlock function in the dialog box "Interlock Setup".

Use the vertical direction keys to change the currently selected item. The selected item is highlighted by inverting the displayed characters. By pressing the middle key "enter", the settings can by modified or the dialog box can be closed (see the selection shown in Fig. 5).

If the selected value is enabled, the state of the corresponding interlock loop is evaluated. The interlock loop is closed and the device can be activated, if all enabled loops are closed. The state of the interlock loop is signalized by the yellow LED "Interlock", the state of each particular loop can be displayed in the dialog box "Interlock Monitor" (see section "Interlock Monitor"). Note that if all loops are disabled, the LED "Interlock" lights permanently and the device can be enabled independently on the state of the interlock loops.

The contacts of the loops "Front BNC" and "Rear BNC" are located in the BNC sockets at the front and rear panel, respectively. The particular loop can be closed by shorting the BNC socket, i.e. by connecting its signal to ground. The contacts of the loops "Signal out" and "HV out" are located in the signal and high-voltage connectors, respectively. These loops supervise the state of the corresponding cable, the loop "Signal out" also supervises the state of the vacuum electronics. Thus, these interlock loops should be disabled for testing purposes only. Under normal operation, they should be permanently enabled.

Interface Setup

The dialog box "Interface Setup" (see Fig. 6) shows the current setting of the USB interface and allows you to change it.

Fig. 6. Dialog box "Interface Setup".

Use the vertical direction keys to change the currently selected item. The selected item is highlighted by inverting the displayed characters. The settings can by modified by pressing the middle key "enter". Furthermore, the dialog box can be closed using the middle key "enter" (see the selection shown in Fig. 6).

Fig. 7. Enabling the USB interface in the dialog box "Interface Setup".

The value "USB port" determines whether the USB interface is active or not (see Fig. 7). By pressing the middle key "enter", the value can be toggled between "active" or "idle" and "off". If the interface state is "off", the interface is disabled and no communication is possible. The remaining interface states indicate that the interface is enabled. If the displayed state is "active", the interface is activated and a communication can be launched. If the displayed state is "idle", the interface is activated but does not communicate, i.e. there is no connection to a remote host. If a cable connects the device with a functioning remote host, the state changes to "active".

The communication state of the USB interface is shown as the item "comm.", it indicates the state of the handshake lines of the interface.

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The communication state changes between "active" and "idle" depending on the communication activity on the interface. The communication state is "idle" if you do not access the device and it changes to "active" if you start a communication software on the remote host.

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Display Setup

The dialog box "Display Setup" (see Fig. 8) shows the current settings of the display controller and allows you to change them.
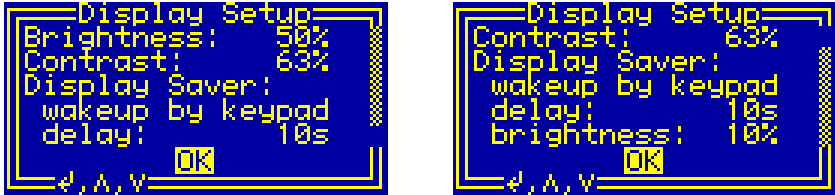
Fig. 8. Dialog box "Display Setup".

Use the vertical direction keys to change the currently selected item. The selected item is highlighted by inverting the displayed characters. The settings can by modified by pressing the middle key "enter". Furthermore, also using the middle key "enter", the dialog box can be closed (see the selection shown in Fig. 8).
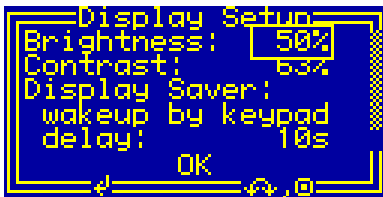
Fig. 9. Setting the brightness in the dialog box "Display Setup".

The value "Brightness" shows the luminosity of the display, it can be changed by pressing the middle key "enter" and spinning the encoder (see Fig. 9). Note that the lifetime of the display is inversely proportional to the brightness, thus you should chose the lowest possible value that provides a sufficient luminosity.

Fig. 10. Setting the contrast in the dialog box "Display Setup".

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The value "Contrast" determines the display contrast, it can be changed by pressing the middle key "enter" and spinning the encoder (see Fig. 10). By changing this value, the readability of the display for a certain view angle can be optimized.

Fig. 11. Setting the display saver in the dialog box "Display Setup".

The value "Display Saver" determines the functionality of the display saver, it can be changed by pressing the middle key "enter" (see Fig. 11). If disabled, the display is permanently lit up with the luminosity given by the value "Brightness" (see Fig. 9). In both remaining cases, the luminosity is reduced after a predefined inactivity time in order to increase the display lifetime. If "wakeup by keypad" is selected, the display saver is stopped by pressing any key or operating the encoder. The luminosity given by the value "Brightness" is restored and the device is ready for further operation. If "wakeup by all" is selected, the display saver is also stopped by pressing a virtual key using the remote controller (see Fig. 42 and the corresponding text).
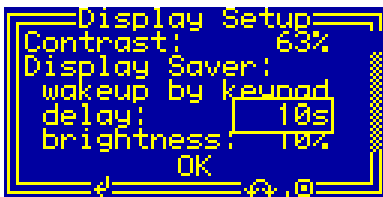
Fig. 12. Setting the display saver delay in the dialog box "Display Setup".

The value "delay" defines the delay of the display saver, it can be changed by pressing the middle key "enter" and spinning the encoder (see Fig. 12). The delay is the inactivity time required to launch the display saver, the allowable values are between 3 and 9999 seconds. Be sure that you set the delay to a sufficiently high value that will not disturb normal operation. On the other hand, a too large value will

completely prevent the display saver from launching, thus a compromise has be found for practical usage.
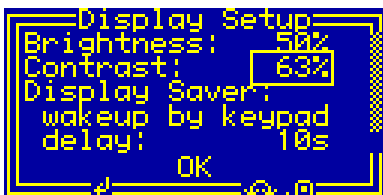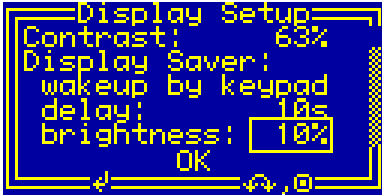

Fig. 13. Setting the display saver brightness in the dialog box "Display Setup".

The value "brightness" determines the luminosity of the display when the display saver is active, it can be changed by pressing the middle key "enter" and spinning the encoder (see Fig. 13). The brightness should be set to lowest possible value that provides a minimum luminosity indicating that the device is still running.

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Device Monitoring

To monitor the function of the device, several dialog boxes are available. You can use them to check the function of the device if you encounter any problem, for instance, if the red LED "Failure" lights.

Voltage Monitor

The dialog box "Voltage Monitor" (see Fig. 14) shows the current values of the high voltages supplying the fast switches.
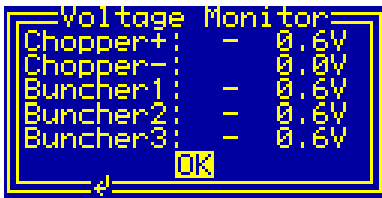
Fig. 14. Dialog box "Voltage Monitor".

Under normal conditions when the device is activated, the voltages "Chopper+" and "Buncher1-3" have positive, the voltage "Chopper-" negative values. If the device is deactivated and the high voltages disabled, also small voltages with an opposite polarity may be shown.

The voltage at each channel may rise up to 750 V. Any higher voltage or a voltage larger than about 1 V present also if the device is deactivated indicates a malfunction. In such case, try to locate the failure. Disconnect the output cables, disable the corresponding interlock loops the dialog box "Interlock Setup" (see section "Interlock Setup"), and start the measurement (see section "Experiment Control") again. If the issue persists, contact the manufacturer.

The values are measured about 4 times per second. The microcontroller checks them continuously and deactivates the device if the voltages differ from their set values. This may happen when the outputs are overloaded or when one of the power supplies overheats.

If you aim to manipulate the output cables, the connectors, or the vacuum hardware, use the dialog box "Voltage Monitor" to check the high voltages. Be sure that you open the connectors or touch the vacuum hardware only if the high voltages have decreased to values that are not lethal.

Interlock Monitor

The dialog box "Interlock Monitor" (see Fig. 15) shows the state of the interlock loops.
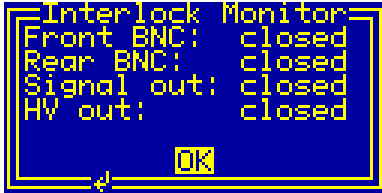
Fig. 15. Dialog box "Interlock Monitor".

For the assignments, consult the dialog box "Interlock Setup" (see section "Interlock Setup"). The possible states are "open" and "closed", they directly correspond to the state of each particular loop.

Note that the dialog box "Interlock Monitor" shows the real state of the particular loop, independently on that if it is enabled or not. If a certain interlock loop cannot be closed, you may consider to deactivate it in the dialog box "Interlock Setup".

Temperature Monitor

The dialog box "Temperature Monitor" (see Fig. 16) shows the temperatures measured in different parts of the device.
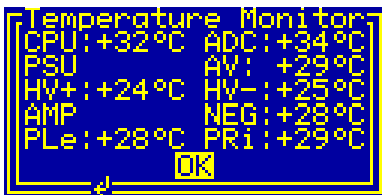
Fig. 16. Dialog box "Temperature Monitor".

The value "CPU" is the chip temperature of the controller CPU. Under normal conditions, it approaches values around 30°C.

The value "ADC" is the chip temperature of an analog-to-digital converter (ADC) located in the proximity of the delay lines. This temperature is used to control the internal device fan (see sections "System

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Preferences" and "Fan Monitor" for more details). Under normal conditions, the value stabilizes at about 35°C.

The values "PSU" are the heatsink temperature of the device's power supplies. The value "AV" indicates the temperature of the analog power supply of ±15 V, the "HV+" of the positive high-voltage power supply of +770 V, and the "HV-" of the negative high-voltage power supply of -770 V, respectively. Under normal conditions, these temperature approaches values around 30°C.

The values "AMP" are the heatsink temperature of the amplifiers producing the adjustable supply voltages for the fast switches. The value "NEG" indicates the temperature of the negative amplifier HV-AMP-1ND, the "PLe" and the "PRi" of the left and right positive amplifier HV-AMP-2PD, respectively. Under normal conditions, these temperature approaches values around 30°C.

The values are measured about once per second. The microcontroller checks the values continuously, controls the fans, and deactivates the device if the temperature rises above the allowed values (see sections "System Preferences" and "Fan Monitor" for more details). The microcontroller is also able to discover failures such as a disconnected or shorted sensor; any failure causes an immediate deactivation of the device.

Fan Monitor

The dialog box "Fan Monitor" (see Fig. 17) shows the state of the fans located in the device.

Fig. 17. Dialog box "Fan Monitor".

The values "Rear" and "Internal" show the rotational speed of the respective fan. The first one is the system fan located at the rear panel, the second one is the internal fan located in the controller module. The rotational speed is shown in revolutions per second (rpm).

The values "state" indicate the state of the fans. The values shown may be either "running" if the fan is running properly, "stopped" if the fan is halted, or "failed" if the fans has failed and does not rotate. The state "failed" is shown for a short time after the fan start, this is a normal behavior since the fan needs several seconds to run up. If the failure persists for a longer time (about 10 s), the red LED "Failure" lights. Note that this does not prevent the device from operation but an overheating may occur sooner. You should, however, replace the defective fan as soon as possible to maintain proper device operation.

Supply Monitor

The dialog box "Supply Monitor" (see Fig. 18) shows the current values of the supply voltages of the device.
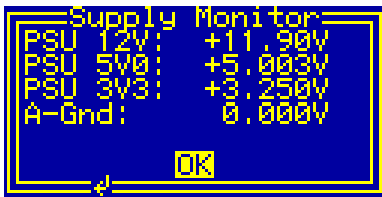
Fig. 18. Dialog box "Supply Monitor".

The value "PSU 12V" is the internal voltage supplying the fan and the vacuum electronics. The nominal value is 12 V.

The value "PSU 5V0" is the internal voltage supplying the digital circuits of the device incl. the LCD and the vacuum electronics. The nominal value is 5 V.

The value "PSU 3V3" is the internal voltage supplying the fast digital circuits. The nominal value is 3.3 V.

The value "A-Gnd" is the voltage at the analog ground. The analog ground is connected to the digital ground, i.e. also the protection earth (PE) by the vacuum electronics. Due to voltage drops in the connection cables, a nonzero voltage may be measured. However, voltages larger than 100 mV most probably indicate an issue with the cables or connectors.

The values are measured about 2 times per second. The microcontroller checks them continuously and deactivates the device if the

voltages differ from their nominal values. This may happen when the device is overloaded, the supply voltage is shorted, or when one of the power supplies overheats.

Clock Monitor

The dialog box "Clock Monitor" (see Fig. 19) shows the current frequencies of various clock signals used internally to control the device.
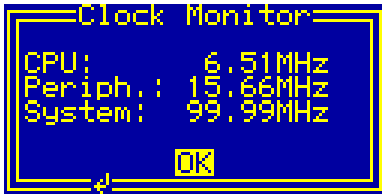
Fig. 19. Dialog box "Clock Monitor".

The value "CPU" is the frequency of the main microcontroller clock that controls the device. Since the microcontroller clock is dynamically changed according to the current load, this value may vary according to the number of active processes.

The value "Periph." is the frequency used to control the peripheral devices of the microcontroller. It is regulated by the microcontroller to a value of about 15.67 MHz.

The value "System" is the frequency of the main clock controlling the FPGA (*Field Programmable Gate Array*). It is gained by a PLL (*Phase Locking Loop*) circuitry. The PLL multiplies the frequency of a quartz oscillator and provides a DDR (*Dual Data Rate*) clock of nominally 100 MHz. This clock is internally used to create control signals for the switches with a resolution of 5 ns

The frequencies are measured as ratios between the particular frequency and the frequency of an auxiliary quartz oscillator running at 32.768 kHz. If this oscillator fails, all measured values are subjected to systematic deviations.

Line Monitor

The dialog box "Line Monitor" (see Fig. 20) shows the current state of the line input.
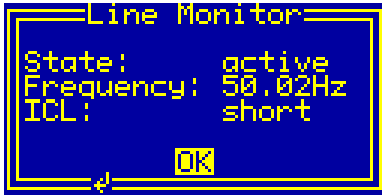
Fig. 20. Dialog box "Line Monitor".

The value "State" indicates the state of the line input. The value "active" is shown if the line voltage is present. If the line voltage is absent, the state changes to "down" but the device shuts down after a short time.

The value "Frequency" is the line frequency measured by the device. Dependent on the location, the nominal values are 50 or 60 Hz. Due to natural deviations, the line frequency may slightly differ from the nominal values.

The value "ICL" shows the state of the inrush current limiter (ICL). The ICL is activated when the device starts and the indicated ICL state is "active". After a few seconds when the charging current vanishes, the ICL is deactivated, i.e. shorted and the indicated ICL state is "short".

Device State

To inspect the device state, several dialog boxes are available.

System Information

The dialog box "System Information" (see Fig. 21) summarizes general information about the device. The text "ID" shows the product identification, "Product No." is the unique product serial number. The entries "HW version" and "FW version" designate the hardware and the firmware versions, "FW date" is the compilation date of the firmware. In case of any trouble with the device, please use these values when contacting the manufacturer.
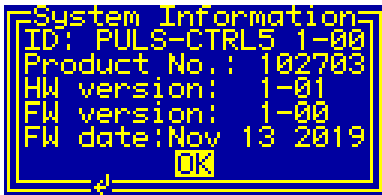
Fig. 21. Dialog box "System Information".

Statistics

The dialog box "Statistics" (see Fig. 22) shows information about the operation time of the device. The "Uptime" indicates the time elapsed since powering on the device or since the last firmware restart. The next line "Total" shows the total operation time of the device.
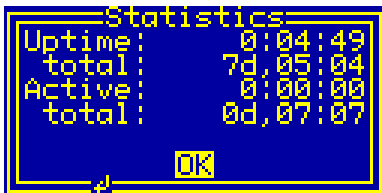
Fig. 22. Dialog box "Statistics".

The time "Active" displays the operation time of the switches and the high-voltage power supplies, which has elapsed since powering on

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the device or since the last firmware restart. The next line "Total" shows the total operation time of the switches and the high-voltage power supplies.

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Device Management

Several dialog boxes are available to manage the experiment settings. The experiment settings is summarized in a measurement (see section "Measurement Management"). A measurement consists of trigger (see section "Trigger Management"), timing (see section "Timing Management"), and voltage (see section "Voltage Management") settings.

Measurement Management

Using the dialog box "Measurement", you can setup and manage the measurement settings (see Fig. 23).
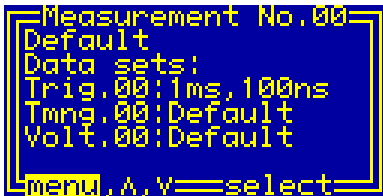
Fig. 23. Dialog box "Measurement".

To select a particular measurement, use the rotary encoder - this functionality is indicated by the label "select" above the encoder knob. The current measurement number is shown in the title bar of the dialog box. The next row displays the measurement name.
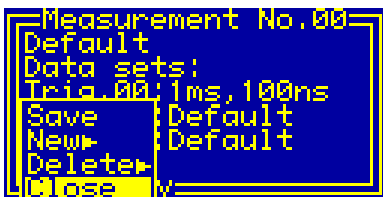
Fig. 24. Menu in the dialog box "Measurement".

Use the vertical direction keys to change the currently selected item in the dialog box. The selected item is highlighted by inverting the displayed characters. By pressing the middle key "enter", the settings can by modified or the dialog menu can be activated (see the selection shown in Fig. 23). The menu allows you to manage the meas-

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urements, save the current measurement, or close the dialog box (see Fig. 24).
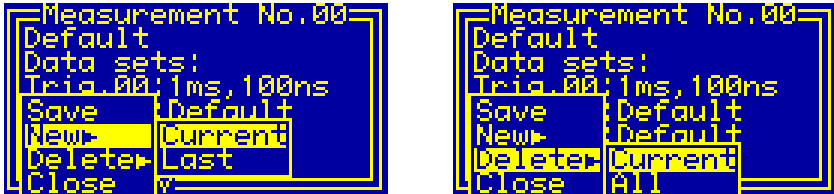
Fig. 25. Submenus in the dialog box "Measurement".

By selecting the menu items "Delete ► Current" or "Delete ► All" (see Fig. 25), specified measurements can be erased. The menu item "Delete ► Current" deletes the currently selected measurement; all measurements with higher numbers will be renumbered. The menu item "Delete ► All" deletes all available measurements. Each deletion must be confirmed in a separate message box. When deleting all measurements, two confirmations must be positively answered to allow the erasing. This measure prevents accidental deleting of the measurement data.

By selecting the menu items "New ► Current" or "New ► Last" (see Fig. 25), the specified measurement can be created. The menu item "New ► Current" creates a measurement with the number of the currently selected one; all measurements with higher numbers including the old current one will be renumbered. The menu item "New ► Last" attaches the new measurement at the end of the current list. The new measurement is created with default parameters, they have to be modified to the desired values.

By pressing the middle key "enter" when the measurement name is selected, a simple editor in the current dialog box is invoked (see Fig. 26). The name editor is controlled by the direction keys and by the rotary encoder. The horizontal direction keys select the current character, it is displayed inversely. The vertical direction keys or the encoder change the current character. The change occurs according to the ASCII character code, it may range from 32 (space) to 127 (copyright sign); for other codes, see the standard ASCII character table or check the LCD character set (see Tab. 2). By pressing the middle key "enter" or the encoder button, the editor will be closed and the changes saved.

Fig. 26. Measurement name editor in the dialog box "Measurement".

The rows below the label "Data sets" show the attached trigger, timing, and voltage settings.
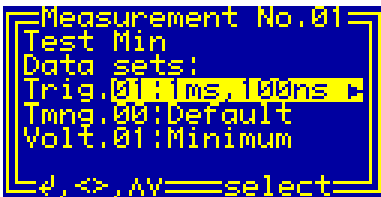
Fig. 27. Selecting trigger settings in the dialog box "Measurement".

The item "Trig" displays the number of the used trigger settings and, behind the colon, its name. If this item is selected, horizontal arrow keys may be used to inspect the settings name if it is longer than the LCD width (see Fig. 27). By pressing the middle key "enter", other trigger settings can be assigned to the selected measurement. A new dialog box will be opened that is similar to the dialog box "Trigger" (see Fig. 30). The only difference to the dialog in Fig. 30 is the presence of the last menu item "Select" (see Fig. 28) that assigns the selected trigger settings to the current measurement.

Fig. 28. Menu in the dialog box "Trigger" for selecting trigger settings.

Similar functionality is provided for the timing and voltage settings: Settings names longer than the LCD width can be displayed by using the horizontal arrow keys and other settings can be assigned to the selected measurement by pressing the middle key "enter".

If the measurement data has been changed, the title bar of the dialog box is highlighted (see Fig. 29). If you progress to another measure-ment or try to close the dialog box without having selected the menu item "Save", a dialog box appears that asks to confirm this action.
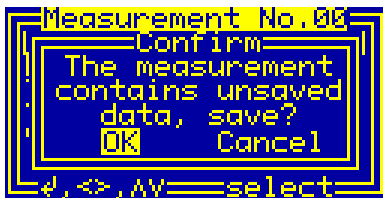
Fig. 29. Service of unsaved data in the dialog box "Measurement".

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Trigger Management

Using the dialog box "Trigger", you can setup and manage the trigger settings (see Fig. 30). These settings are a part of a measurement, i.e. experiment settings. They define the behavior of the internal trigger and the trigger output at the BNC socket at the controller module.

Fig. 30. Dialog box "Trigger".

The handling of the dialog box "Trigger" is similar to the dialog box "Measurement" (see section "Measurement Management"). The similarity concerns selecting items, editing the setting name, and creating or deleting settings.

The value "Period" defines the period of the internal trigger. The minimum value is 100 µs corresponding to a maximum repetition rate of 10 kHz. The maximum value is 10 ms corresponding to a minimum repetition rate of 100 Hz. The period can be adjusted with a precision of 10 ns, while the typical jitter over a 1-ms period is lower than 5 ns.

The value "Output" shows if the trigger output at the BNC socket is enabled or disabled. This setting does not influence the functionality of the internal trigger, this internal signal is active at any time. If the value "Output" is set to "disabled", the output level is a permanent logical 0, independent on the value "Polarity".

The values "Start" and "Stop" define the beginning and end of the trigger output at the BNC socket. The possible values range from negative to the positive half of the trigger period, while the minimum with of the trigger pulse is 10 ns. The values "Start" and "Stop" can be adjusted with a precision of 10 ns.

The value "Polarity" can be switched between "positive" and "negative". If the "positive" is selected, the trigger output at the BNC socket begins by a positive edge defined by the value "Start" and ends by a

negative edge defined by the value "Stop". If the "negative" is se-lected, the transitions occur at opposite edges.

Note that in any case, a TTL-compatible signal with positive voltages is produced at the trigger output, i.e. the signal switches between a logical 0 (0..0.4 V) and a logical 1 (2.4..5.0 V). The value "Polarity" just determines which of these both levels is the active one.

Timing Management

Using the dialog box "Timing", you can setup and manage the timing settings (see Fig. 31). These settings are a part of a measurement, i.e. experiment settings. They define the behavior of the control signals of the fast switches.
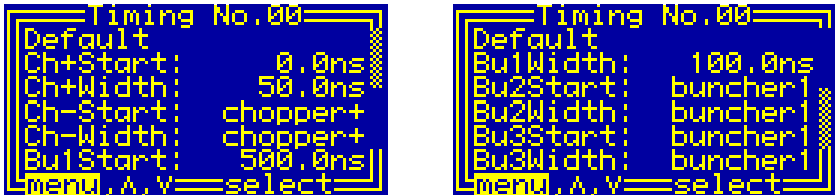
Fig. 31. Dialog box "Timing".

The handling of the dialog box "Timing" is similar to the dialog box "Measurement" (see section "Measurement Management"). The similarity concerns selecting items, editing the setting name, and creating or deleting settings.

The values "Start", i.e. "Ch±Start" or "Bu1-3Start" define the beginning of the output pulse. In case of the chopper pulses ("Ch+Start" or "Ch-Start"), these start by a transition to ground (0 V). Opposite to this, the buncher pulses ("Bu1Start" till "Bu3Start") start by a transition from ground. The position of the pulse start has to be between -10 µs and +10 µs.

The values "Width", i.e. "Ch±Width" or "Bu1-3Width" define the duration of the output pulse. The minimum pulse duration is 20 ns, the maximum is 10 µs.

The resolution of all timing values is 0.5 ns. The coarse resolution of 5 ns is provided by the FPGA, any finer resolution is provided by subsequent delay lines with an intrinsic resolution of 11 ps.

By pressing the middle key "enter", all items with the exception of "Ch+Width" and "Bu1Width" can be set to alternate values by a menu. This simplifies the settings if a time synchronized chopper and buncher control is desired or if a certain channel should not be pulsed.

Fig. 32 shows the menus for the items "Ch+Start" and "Bu1Start". The menu item "pulse" selects the numerical delay shown in Fig. 31, the delay value can be subsequently adjusted by the encoder. The menu

items "perm.high" and "perm.gnd" set the corresponding switch output to a permanent level, the pulse generator of the corresponding channel is disabled. If "perm.gnd" is selected, the switch output is grounded, if "perm.high" is chosen, the switch output is connected to its high voltage supply.
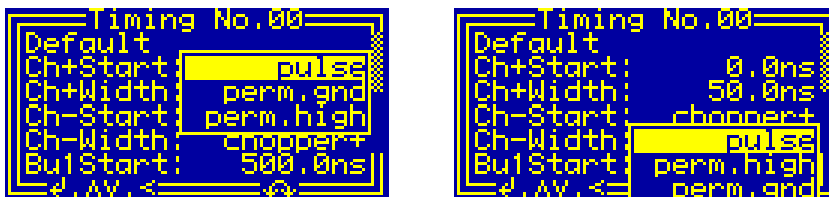
Fig. 32. Menus of the items "Ch+Start" (left) and "Bu1Start" (right) in the dialog box "Timing".

If "perm.high" or "perm.gnd" is selected, the corresponding value "Width" is not available more, thus cannot be modified (see Fig. 33).
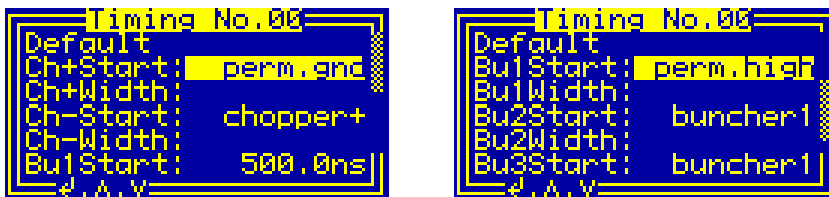
Fig. 33. Dialog box "Timing" if the items "Ch+Start" (left) and "Bu1Start" (right) are set to a permanent level.

The menus of the items "Ch-Start" and "Ch-Width" of the negative chopper channel are shown in Fig. 34. The pulse start can be set to a delay value (menu item "pulse"), to the same value as the positive chopper channel (menu item "Chopper+"), or to a permanent level (menu items "perm.high" and "perm.gnd"). For pulse width, only the first two menu items are available.

Note that if the pulse start of the negative chopper channel is set to the same value as the positive chopper channel (menu item "Chopper+") and the positive chopper channel is set to a permanent level, also this value is copied to the negative channel. This implies that the value "Ch-Width" is not available more and cannot be modified (see Fig. 33).

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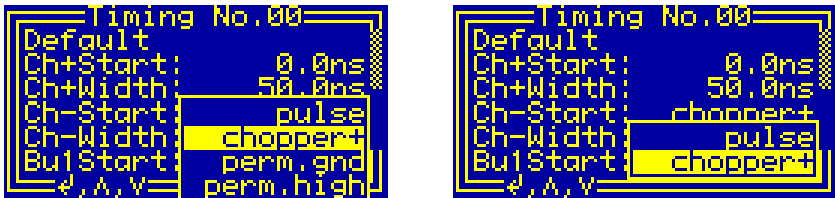
Fig. 34. Menus of the items "Ch-Start" (left) and "Ch-Width" (right) in the dialog box "Timing".

The menus of the items "Bu2-3Start" and "Bu2-3Width" of the buncher channels (see Fig. 35) are similar to the menus of the items "Ch-Start" and "Ch-Width" of the negative chopper channel (see Fig. 34). The pulse start can be set to a delay value (menu item "pulse"), to the same value as the first buncher channel (menu item "Buncher1"), or to a permanent level (menu items "perm.high" and "perm.gnd"). For pulse width, only the first two menu items are available. Also the values "Bu2-3Width" are not available and cannot be modified if the menu item "Buncher1" is selected (see Fig. 33).
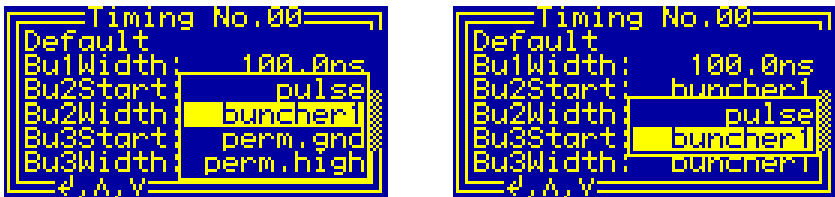
Fig. 35. Menus of the items "Bu2-3Start" (left) and "Bu2-3Width" (right) in the dialog box "Timing".

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Voltage Management

Using the dialog box "Voltage", you can setup and manage the voltage settings (see Fig. 31). These settings are a part of a measurement, i.e. experiment settings. They define the behavior of the high voltages supplying the fast switches.

Fig. 36. Dialog box "Voltage".

The handling of the dialog box "Voltage" is similar to the dialog box "Measurement" (see section "Measurement Management"). The similarity concerns selecting items, editing the setting name, and creating or deleting settings.

The values "Chopper+" and "Buncher1-3" can be set to positive, the voltage "Chopper-" to negative values only. The available resolution is 0.1 V.

By pressing the middle key "enter", the value "Chopper-" of the negative chopper channel can be set to a value "-Chop.+", i.e. the voltage of the positive chopper channel. This simplifies the settings if a symmetrical chopper control is desired.

Similarly to that, the values "Buncher2" and "Buncher3" of the buncher channels can be switched to a value "Bunch.1" by pressing the middle key "enter". This setting implies that the corresponding value defaults to the value of the first buncher channel. This simplifies the settings if all buncher channels should be run with the same voltage.

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Experiment Control

The pulse generation is controlled by the dialog box "Experiment Control" (see Fig. 37).
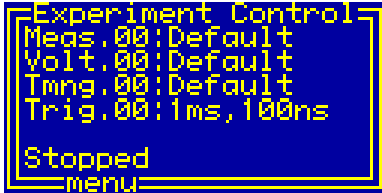
Fig. 37. Dialog box "Experiment Control".

The text "Meas.NN" is the name of the selected measurement, the two numerals NN in the measurement label ("00" in Fig. 37) stand for the measurement number (see also section "Measurement Management"), "Volt.NN", "Tmng.NN", and "Trig.NN" are the names of the corresponding voltage (see section "Voltage Management"), timing (see section "Timing Management"), and trigger (see section "Trigger Management") settings, respectively. Also here, the two numerals NN in the respective label stand for the settings number.

The text "Stopped" in the bottom line shows the device status, it changes according to the measurement phase or due to a possible failure (see Tab. 1).

Fig. 38. Start menu of the dialog box "Experiment Control" in the idle state.

By pressing the middle key "enter", the menu can be accessed. The menu structure changes according to the device state. After opening the dialog box "Experiment Control", i.e. when the pulse generator is stopped, the menu allows you to select a measurement, to launch it, or to close the dialog box (see Fig. 38). The device monitoring can be started from a submenu (for details see section "Device Monitoring").

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The function of this submenu is identical to the submenu "Monitor" of the main menu (see Fig. 3). The device monitoring is accessible from all menus regardless of the device state.
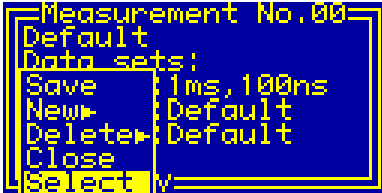
Fig. 39. Menu in the dialog box "Measurement" for selecting measurements.

The menu item "Select" opens a new dialog box that allows you to choose a measurement. This dialog box is similar to the dialog box "Measurement" (see Fig. 23). The only difference to the dialog in Fig. 23 is the presence of the last menu item "Select" (see Fig. 39) that selects the current measurement.
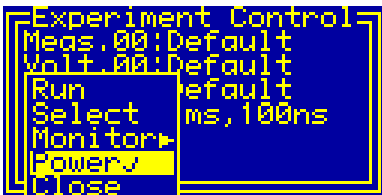
Fig. 40. Menu point in the dialog box "Measurement" for turning on/off the high voltage.

The menu item "Power" can be used to turn the high-voltage supply on or off (see Fig. 40). The high voltage is activated automatically if a measurement is launched and remains activated if the measurement is stopped. You may turn it off manually by the menu item "Power". Note that the high voltage is deactivated when the dialog box "Experiment Control" is closed.

The menu item "Run" launches the selected measurement. The high voltage is activated automatically, the status changes to "Waiting for Hi-Volt" and the device waits until the output voltages stabilize. Then, the control signals for the fast switches are activated and the state changes to "Running".

In the active state, the menu changes (see Fig. 41). The menu item "Stop" stops the running measurement. First, the control signals for

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the fast switches are deactivated and the high voltage is turned off, the status changes to "Waiting for shutoff". If the output voltages reach values below 10 V, the state changes to "Stopped". When this shutoff has finished, the device enters the idle state, i.e. the same state as before the measurement was started (see Fig. 37). Note that the high-voltage supply remains active, this is indicated by the check box at the menu item "Power" (see Fig. 40).
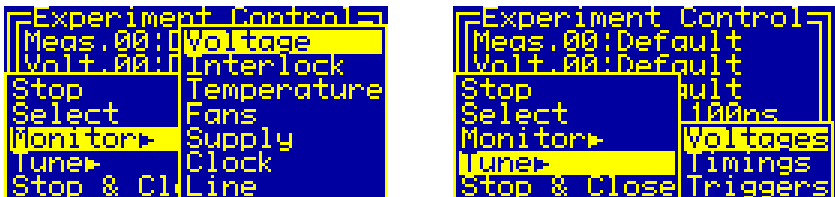
Fig. 41. Start menu of the dialog box "Experiment Control" in the active state.

The pulse generation may also be interrupted by a fault condition. This may be an opened interlock loop, overheating, output-voltage mismatch, or a supply-voltage fault. In such fault conditions, the complete device is deactivated, i.e. the control signals and the high voltages for the fast switches are turned off and the high-voltage supply is shut down. The bottom line shows the corresponding device status (see Tab. 1).

Tab. 1. Possible states of the pulse generator.

Text	Explanation
Stopped	the pulse generator is idle
Waiting for Hi-Volt	the device is waiting until the high voltages at the outputs reach their correct values
Running	high voltages and control signals for the fast switches are being generated
waiting for shutoff	pulse generation has been stopped, the device is turning off the high voltages and is waiting until the outputs reach safe values
!!Supply failure!!	one of the supply voltages was out of the allowable range, was overloaded, overheated, or is defective; the device was deactivated and the pulse generation stopped
!!Voltage failure!!	the device was deactivated due to mismatch of the output voltages, the outputs may be overloaded by short circuits - check the attached vacuum hardware
!Temperature fail!	the device is overheated or the temperature is too low for a safe operation
!!Interlock fail!!	the device could not be activated because the interlock loop is open, close it or manage its sensing
Activation failure!	the device could not be activated, the interlock loop may be open, the device may be overheated, one of the supply voltages is out of the allowable range
!Measurement empty!	the selected measurement or one of its components is not valid, select or create a new ones

Tab. 2. The LCD character set.

value	char	value	char	value	char	value	char
20h	space	38h	8	50h	P	68h	h
21h	!	39h	9	51h	Q	69h	i
22h	"	3Ah	:	52h	R	6Ah	j
23h	#	3Bh	;	53h	S	6Bh	k
24h	$	3Ch	<	54h	T	6Ch	l
25h	%	3Dh	=	55h	U	6Dh	m
26h	&	3Eh	>	56h	V	6Eh	n
27h	'	3Fh	?	57h	W	6Fh	o
28h	(	40h	@	58h	X	70h	p
29h	)	41h	A	59h	Y	71h	q
2Ah	*	42h	B	5Ah	Z	72h	r
2Bh	+	43h	C	5Bh	[	73h	s
2Ch	,	44h	D	5Ch	\	74h	t
2Dh	–	45h	E	5Dh	]	75h	u
2Eh	.	46h	F	5Eh	^	76h	v
2Fh	/	47h	G	5Fh	_	77h	w
30h	0	48h	H	60h	`	78h	x
31h	1	49h	I	61h	a	79h	y
32h	2	4Ah	J	62h	b	7Ah	z
33h	3	4Bh	K	63h	c	7Bh	{
34h	4	4Ch	L	64h	d	7Ch		
35h	5	4Dh	M	65h	e	7Dh	}
36h	6	4Eh	N	66h	f	7Eh	~
37h	7	4Fh	O	67h	g	7Fh	©

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Software Utilities

The software utilities can be found in the directory "Program" of the enclosed software package. Before using them, the virtual USB port driver must be installed (see sections "Driver Installation"). The utilities do not require any additional installation, you need only to copy them to a suitable directory on your computer. Before starting the utilities, you need to obtain the virtual port number, as described in the section "Driver Installation".

Utility PulseLoader

The PulseLoader is a simple Windows™ program that runs in text mode. It enables you to backup and restore data of the pulse controller. Launching the utility `PulseLoader.exe` without any parameters or with the parameter `-?` displays a simple help:

```
PulseLoader -?
```

To start the program without any error message, at least the number of the COM port must be given:

```
PulseLoader 6
```

This command starts the utility PulseLoader and assumes that the device is connected to the port COM6. On success, the utility reports the following message:

```
Press '?' for help
```

and waits for command input.

In case of any problem, check whether the port number matches the system settings (see sections "Driver Installation") and the connected device is powered on and working properly. If an error occurs, please consult the section "Error Codes". The tables 4 and 5 explain the possible error messages; they should help you to localize the reason for the software failure.

To check the communication, press the key 'p' to obtain the product identification text. The device should respond as follows:

```
Product identification: PULS-CTRL5 1-00
```

Tab. 3. Command line parameters of the program PulseLoader.

Parameter	Explanation
-y FileName	backup memory data into a text file with the name FileName
-Y FileName	restore memory data from a text file with the name FileName
-s, -S	get the device status
-k, -K	simulate the keypad
-d, -D	get the device firmware date
-v, -V	get the device firmware version
-p, -P	get the product identification text
-n, -N	get the product number
-u, -U	get the device uptime
-b, -B	get the device buffer status
-z, -Z	purge the communication
-t, -T	terminate the program
-q, -Q	quiet mode
-g	debug mode
-G	debug mode with output into Debug.txt
-?	show the online help

If the device responds properly, you may try other program commands. Press '?' to obtain the help listing of all available commands[§].

In practice, you may prefer to use the command line mode instead of the interactive mode. The former mode allows you, for instance, to save the complete commands in batch files for repeated usage.

Table 3 summarizes all allowable command line parameters of the program PulseLoader. The parameters are processed from left to

---

[§] Note that keyboard layouts different to the US one may cause issues when evaluating several characters. We recommend to switch to the US layout when using the utility PulseLoader in the interactive mode.

right. If an error in the command line is encountered, the program stops with an error text showing the allowed values of the parameters.

If the parameter -t is found, the program stops without processing any following parameter. If you do not specify the parameter -t at all, the program does not stop and enters the interactive mode after having processed the complete command line.

If you wish to specify a name parameter containing spaces or special characters, use the conventions valid for your operating system. In Windows™ systems, for instance, enclose the name in quotation marks.

The quiet program mode reduces the program text output, contrary to that, the debug mode provides a detailed output for error analysis.

Tips

To backup the complete device memory, execute the command:

```
PulseLoader 6 -y MemoryData.txt -t
```

The text file MemoryData.txt will contain the memory data in hexadecimal format. To restore the device memory, use the command:

```
PulseLoader 6 -Y MemoryData.txt -t
```

It restores the data immediately without any confirmation, thus be careful when executing it.

! **Attention:** The functions backup and restore can be conducted only if the device is idle (see Fig. 2). If a dialog box or a menu is open, the communication is stopped and the utility reports "Device not ready".

Note also that the backup and restore needs several minutes to finish.

Utility FlashLoader

The FlashLoader is a simple Windows™ program running in text mode. It enables you to upgrade the firmware of the pulse controller. You should perform the upgrade if you have received or downloaded a new firmware file from the device manufacturer. Launching the utility FlashLoader.exe without any parameters displays a simple help text with the expected syntax of the command line.

Before upgrading the firmware, you should first test the device and the communication by verifying the current firmware version. To do so, start the following command:

```
FlashLoader 6 Firmware.txt -v
```

where `Firmware.txt` is the file containing the current firmware and the number 6 indicates the port COM6 to which the device is connected. The program should produce the following output:

```
Code file R:Final.txt from 11/04/2019, 12:00:00
Flash Loader 1.12
Verifying code file Final.txt
Verifying finished at Tue, 11/05/2019, 15:00:00
100495 (1888Fh) bytes processed, 99584 (18500h)
bytes verified
Resetting the target
Program finished ok
```

During the verify procedure, a message box is displayed at the device display informing the user that the flash loader has been activated. When the verify finishes without any error, the device is restarted.

Note that the utility `FlashLoader.exe` cannot communicate with the device if it is not in the idle state (see Fig. 2).

! **Attention:** To be sure that the device cannot activate the attached switches when the FlashLoader is active, disconnect the output cables. Note that the utility stops all processes running at the microcontroller, thus the monitoring is not available and the device would not be deactivated if a critical situation arises.

If any error occurs, do not proceed with the firmware upgrade. If you cannot resolve the issues, contact the manufacturer. Note that even if the verify fails and the flash loader at the device remains active, it is safe to power the device off to restart it. However, a more safe and comfortable alternative to that is to execute the following command:

```
FlashLoader 6 -i -f
```

This prevents the utility at the host computer from initializing the flash loader utility at the microcontroller again and sends the reset command to the device.

If the verify has succeeded, you may start the firmware upgrade by entering the command:

```
FlashLoader 6 Firmware.txt
```

where `Firmware.txt` is the file with the new firmware. The program should produce the following output:

```
Code file R:Final.txt from 11/04/2019, 12:00:00
Flash Loader 1.12
Programming code file Final.txt
Programming finished at Tue, 11/05/2019, 15:00:00
100495 (1888Fh) bytes processed, 99584 (18500h)
bytes programmed
Resetting the target
Program finished ok
```

During the programming procedure, a message box is displayed at the device display. When the programming finishes, the device is restarted with the new firmware.

If an error occurs, the flash loader utility at the microcontroller may remain active. This is the case if the message box at the device display is still present and the device did not restart. In this case, you may retry the action with the command line parameter '-i':

```
FlashLoader 6 Firmware.txt -i
```

This will prevent the utility at the host computer from initializing the flash loader utility at the microcontroller again and it will just try to reprogram the file `Firmware.txt`. If the error persists, contact the manufacturer.

! **Attention:** You must not power down the device if the firmware upgrade did not succeed. Otherwise, the device will not operate properly or might even not restart at all. Did this happen, it would be necessary to reprogram the device in the factory.

If the current firmware is damaged so that the device is inoperable, you may try to start the flash loader utility at the microcontroller manually. Press, simultaneously, the horizontal direction keys (left and right) and power on the device. If this small part of the firmware is still working, the device's flash loader will start. Then, try to launch the utility FlashLoader with the command line parameter '-s':

```
FlashLoader 6 Firmware.txt -s
```

This does not start the flash loader utility at the microcontroller but will only try to reprogram the file `Firmware.txt`. If an error occurs that you cannot solve, contact the manufacturer.

Utility RemoteControl

The RemoteControl is a Windows™ GUI program that enables you to control the pulse controller remotely and obtain a hardcopy of the current LCD content.

To launching the utility, start the following command:

`RemoteControl 6`

The number 6 indicates the port COM6 to which the device is connected.
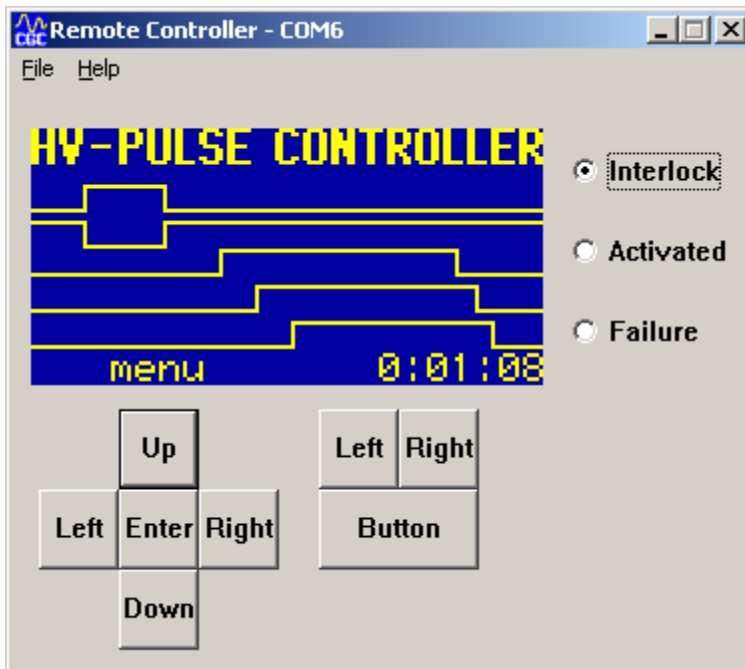

Fig. 42. Utility RemoteControl.

The program opens a dialog box that shows the current content of the device's LCD (see Fig. 42). The direction keys and the encoder can be simulated by clicking the corresponding buttons or using the keyboard shortcuts. For the detailed description of them, see the online help.

The right side of the program window shows the status of the device LEDs. This allows you to observe the LEDs without the necessity of a direct visual contact to the front panel of the device.

You may obtain a hardcopy at any time by selecting the menu item File ► Save Hardcopy. The program opens a dialog box to select the destination bitmap file. The hardcopy is performed immediately without waiting for any confirmation.

Note that the utility RemoteControl continuously transfers display data over the USB. Compared to the idle state, this leads to a higher load of the microcontroller controlling the device. Further, the utility prevents any other program from accessing the device via USB.

Error Codes

Tab. 4. Return values of the interface functions

Return value	Error message	Description
0	No error	The data transfer finished success-fully.
-2	Error opening the port	The port could not be opened. For the possible reasons, see Tab. 5.
-3	Error closing the port	The port could not be closed. For the possible reasons, see Tab. 5.
-4	Error purging the port	The port buffers could not be cleared.
-5	Error setting the port control lines	The port control lines could not be set.
-6	Error reading the port status lines	The port status lines could not be read.
-7	Error sending command	The data transfer to the device failed. For the possible reasons, see Tab. 5.
-8	Error sending data	
-9	Error sending termination character	
-10	Error receiving command	The data transfer from the device failed. For the possible reasons, see Tab. 5.
-11	Error receiving data	
-12	Error receiving termination character	
-13	Wrong command received	The device sent an unexpected re-sponse.
-14	Wrong argument received	
-15	Wrong argument passed to the function	One of the arguments passed to the function was out of the allow-able range.

Return value	Error message	Description
-100	Device not connected	The port status lines indicate that the device is not connected.
-101	Device not ready	The port status lines indicate that the device is not ready. The communication with the device is possible only if it does not execute any process. Terminate all dialog boxes and menus at the device and retry the operation.
-102	Device state could not be set to not ready	The device did not react properly. Try to reset the communication or restart the device by powering it off and on.
-400	Error opening the file for debugging output	The file for debugging output cannot be opened for writing. Check if you have permissions to perform this action or if the file exists and is opened by another application.
-401	Error closing the file for debugging output	The file for debugging output cannot be closed. Check if the access to the file is still possible.

Tab. 5. I/O errors

Return value	Error message	Description
0	No error	The data transfer finished successfully.
1	Port has not been opened yet	You attempted to use the communication channel before having opened it.
2	Cannot open the port	The specified port could not be opened. Either the port does not exist or it is being currently used by another program.
3	Cannot get the state of the port	The system could not get the state of the port.
4	Cannot set the state of the port	The system could not set the state of the port.
5	Cannot set the timeouts for the port	The system could not set the timeouts for the port.
6	Cannot clear the port	The system could not clear the port buffers.
7	Error reading data from the port	The system could not read data from the port. Most probably, no data is available because the device is either disconnected or does not respond.
8	Error writing data to the port	The system could not write data to the port.
9	Wrong data amount written to the port	The system could not write the proper data amount to the port.
10	Error setting the control lines of the port	The system could not set the state of the port control lines.
11	Error reading the status lines of the port	The system could not get the state of the port status lines.
12	Device is busy	The system could not access the device since menus or dialog boxes are active.

Driver Installation

Installation of the Virtual Port for the USB Interface

The virtual port driver is required for the operation of the device with a USB interface. If you use the operating system Windows™, please note the following:

- Please use the update function of the operating system at the host computer or download the most recent driver from the homepage of the manufacturer of the USB adapter. The drivers are located at the following address: http://www.ftdichip.com/Drivers/VCP.htm. Please choose the correct driver version according to your operating system.

- To install the driver, administrative rights are required.

- The installation is described in detail in the "Installation Guides" available at the abovementioned address. Please read this description carefully before starting the installation.

- After the installation, the number of the virtual port can be set. You can change the settings in the device manager by opening the settings of the device *USB Serial Port (COMx)*. To modify the settings, administrative rights are required. The settings are applied immediately, you do not need to reboot the PC to activate them.

The software can also be used at computers running the Linux operating system. You can run them using the Windows™ emulator wine (see http://www.winehq.org/).

Starting with Linux Kernel 3.0.0-19, all FTDI devices are already supported without the necessity of compiling additional kernel modules. For more details, consult the homepage of the manufacturer of the USB adapter: http://www.ftdichip.com/Drivers/VCP.htm.

The system has to be configured an the following way:

- Use, for instance, the program 'dmesg' to find out to which USB port the device is attached: Look for a line similar to "FTDI USB Serial Device converter now attached to ttyUSB0"

- Link the Linux device to the virtual COM port of wine:
  ```
  ln -s /dev/ttyUSB0 ~ /.wine/dosdevices/com3
  ```
  This assumes that the device is attached to ttyUSB0 and will be linked with COM3