Programmable Digital Waveform Generator for High-Voltage Power Amplifiers

Firmware Version 1-70

User Manual

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Table List

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Technical Data

Characteristics

- resolution: 16 bit
- data rate: 254 S/s..16.7 MS/s
- total memory size: 512 KW (= 512 KWords = 1 MB)
- memory space for waveform data: 508 KS (= 520192 samples)
- waveform size: variable from 2 S to 64 KS (= 65536 samples)
- burst size: 1..65,000 waveforms per run
- maximum number of stored waveforms: 100
- maximum number of stored measurements: 100
- trigger: manual/external
- trigger delay: 0 ms..6.5 s, settable with a precision of 0.1 ms
- smart triggering for selecting the measurement for the next output
- external synchronization

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 waveform generator can produce preferably harmonic signals or a combination of them in a frequency region of up to several kHz. The signal output can be synchronized with external instruments via the trigger and synchronization inputs. The digital trigger signal at the trigger input starts the signal generation. The device requires a signal with TTL, 5V-CMOS, or 3V-CMOS levels, the trigger slope is selectable. The digital synchronization signal can be used instead of the internal clock base to control the waveform generation. This ensures a signal output synchronous with the external clock source over virtually any time period. To reduce the risk of ground loops, the trigger and synchronization inputs are galvanically isolated from the device, the trigger signal can be optionally supplied using an optical cable.

The device monitors an interlock loop that disables and shorts the output of the attached power amplifier if it is opened. The terminals of the interlock loop are located at the amplifier's output connector. They are typically fed by the output cable to the actuator where they are either short connected or wired to a security push button or switch with a breaking contact. The output is disabled if the output cable is disconnected or broken, or if the security push button or switch is activated.

The device is also equipped with a circuitry that scans the temperature measured by an external Pt1000 sensor. This sensor is typically located at the actuator, the attached power amplifier is disabled if the sensor temperature exceeds a preset value. This ensures a secure operation of the actuator and prevents its overloading.

The power amplifier and its power supplies are typically cooled by a heatsink located at the rear panel of the device. The heatsink is actively cooled by several temperature-controlled fans. The waveform generator unit monitors the heatsink temperature and the fan function. The attached power amplifier is disabled if the heatsink threatens to overheat or if any temperature sensor fails. Further, the device activates a warning light (typically a red LED) if the fans do not operate at the desired speed.

The waveform generator is equipped with a USB data interface that allows you to transfer waveform, measurement, and settings data to

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or from the device. 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, carefully check the influence of the USB connection on the output signal.

Control and Indication Elements

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

The "On/Off" push button activates or deactivates the attached amplifier. When deactivated, the power supply of the amplifier is turned off and each output terminal is shorted by resistors to ground. When activated, the power supply is turned on, the LED "Amplifier Activated" lights green.

The LED "Interlock" shows the state of the interlock loop. It lights yellow, if the interlock loop is closed. When the loop is opened, the LED "Interlock" is off and the amplifier cannot be activated.

The LED "Fan Failure" lights red if one of the fans fails. The device continues to operate, you should, however, replace the fan as soon as possible. You can locate the defective fan by a dialog box (see Fig. 47 and the corresponding text).

The LED "Amplifier Overheated" lights red if one of the power semiconductor devices of the amplifier or of the power supply units reaches the critical temperature. When the LED lights, the amplifier cannot be activated. The temperature threshold is internally set, you cannot change it. You can monitor the current temperatures by a dialog box (see Fig. 46 and the corresponding text). In case of overheating, you can locate the device part that caused the temperature rise in a dialog box (see Fig. 47 and the corresponding text).

The LED "Actor Overheated" lights red if the temperature sensor at the actuator reaches the critical temperature. When the LED lights, the amplifier cannot be activated. The sensor can be deactivated and the temperature threshold can be modified by a dialog box (see Fig. 35 and the corresponding text). You can monitor the current actuator temperature by a dialog box (see Fig. 46 and the corresponding text).

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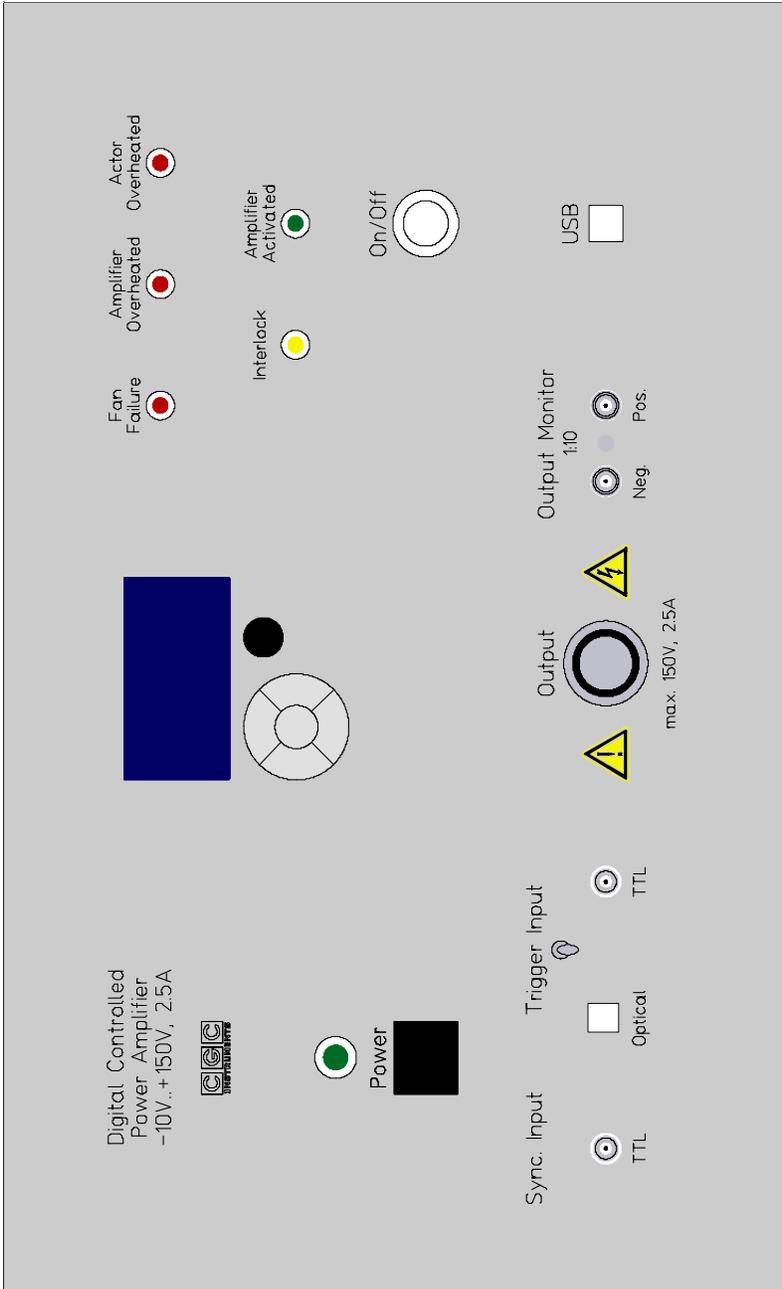
Fig. 1. Typical front panel of a power amplifier with integrated waveform generator DAFG–1.

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Generator Function

The waveform generator generates and manages the waveform signals. The waveform generator directly drives the input of the attached power amplifier, it also monitors the amplifier's operation state, as well as the state of the power supplies, the actuator temperature and the interlock loop.

The waveforms are generated by a 16-bit digital-to-analog converter (DAC) from data samples stored in a non-volatile memory. The waveform generation is controlled by an FPGA (*Field Programmable Gate Array*). The FPGA also monitors the crucial device parameters and shuts down the attached amplifier if necessary. 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.

Using the USB interface, waveforms, measurements, and settings data can be uploaded to the device and stored in its non-volatile memory (see section "Up- and Downloading Waveforms"). Waveforms are sets of data samples; they do not contain any direct information about the frequency, the amplitude, or other device parameters. You can visualize and manage them using the waveform manager (see section "Waveform Management").

To output a waveform signal, you have to create a measurement. The measurement is a set of settings completely describing the waveform signal. It defines, for instance, which waveform data, which frequency, and which amplitude should be used to create an output signal. The measurement data is stored together with the waveform data in the non-volatile memory. The measurements can be managed by several dialog boxes (see section "Measurement Management").

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

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 su-

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pervise the device and control the attached amplifier. For instance, the supply voltages and temperatures of the semiconductor power devices, as well as the actuator temperature, are continuously checked and the amplifier is deactivated if necessary.

Each waveform can have a size of up to 64 KS (65536 samples), the non-volatile memory, with its total size of 512 KW (= 524288 words of 16 bits = 1 MB), provides a space for 508 KS (= 520192 samples) of waveform data. This means that up to 7 waveforms with the maximum size of 64 KS can be stored simultaneously. The remaining 4 KW (8 KB) of the non-volatile memory are used to store the waveform and the measurement parameters as well as the system settings.

The USB interface can be used to remotely control the device and to manage the waveforms. Further, a hardcopy utility is available 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 "Software Utilities").

Smart Triggering

Smart triggering is a special trigger mode that allows controlling the generator remotely via trigger pulses. The smart triggering mode can be enabled, disabled, and adjusted in the dialog box "System Preferences" (see Fig. 26, Fig. 27, Fig. 28, Fig. 29, and Fig. 30). If disabled, the trigger input behaves conventionally, i.e. a trigger event occurs if a specified signal slope at the trigger input is detected. To set up the trigger slope, read the description of the dialog boxes "Measurement" (see Fig. 19) and "System Preferences" (see Fig. 25).

If the smart triggering mode is enabled, the device evaluates the duration of the pulses at the trigger input. The pulse duration is the length of a pulse at the trigger input that ends with the slope specified by the device defaults set in the dialog box "System Preferences" (see Fig. 25).

If the detected pulse duration is shorter than the trigger threshold specified in the dialog box "System Preferences" (see Fig. 27), the pulse is evaluated as a trigger event. The waveform generation starts with the slope specified by the device defaults set in the dialog box "System Preferences" (see Fig. 25). I.e., if the device default value is the falling slope, the duration of positive pulses will be measured and

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the waveform generation will be initiated at the end of this short positive pulse.

Longer pulses do not generate a trigger event but are used to switch between different measurements or execute any control task. The measurement number is calculated from the following expression:

$$MeasurementNumber = \left[\frac{PulseDuration - TriggerThreshold}{TriggerStep} \right], (1)$$

where the brackets [] denote the integer part of the enclosed argument. If the measurement number points to a valid measurement, the measurement data is loaded and the measurement is activated. I.e. if the amplifier was not active, it will be activated upon the reception of the first data pulse. The activation procedure equals to the startup done after selecting the menu item "Run" in the dialog box "Experiment Control" (see Fig. 37 and the corresponding text). Note that, dependent on the device state, the startup may take up to several seconds. When the startup has finished, the selected measurement can be started by a next short trigger pulse.

Note that longer pulses corresponding to measurement numbers above 99, i.e. above the maximum allowable measurement number cannot point to a valid measurement and are ignored per default.

Let us assume the following example: *TriggerThreshold* = 100 μs and *TriggerStep* = 10 μs (see Fig. 27 and Fig. 28). In this case, the device can be triggered by pulses shorter than 100 μs. A reception of a pulse with a duration of 100..110 μs starts the measurement number 0, a pulse duration of 110..120 μs starts the measurement number 1, etc.

If stopping is allowed in the dialog box "System Preferences" (see Fig. 29), the smart triggering accepts also pulses corresponding to measurement numbers between 100 and 200. Such pulses stop the running waveform output and switch to a measurement with the number according to formula (1) lowered by 100. I.e. a pulse corresponding to measurement number 105 switches to the measurement number 5. Pulses corresponding to measurement numbers above 199 have a special meaning since they cannot start any valid measurement. The pulse corresponding to the measurement number 200 has a special stopping function, it switches to the current measurement (see below). Other pulses are ignored per default.

The stopping procedure equals to halting the waveform output by selecting the menu item "Halt" in the dialog box "Experiment Control"

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(see section "Experiment Control"), i.e. stops the waveform output at the end of the particular waveform. If the waveform output is inactive, the stopping does not take place and the device just switches to the new measurement. The stopping takes place regardless on the validity of the target measurement, i.e. any pulse corresponding to a measurement number between 100 and 200 stops the current waveform output. If the measurement number does not point to a valid measurement, the running waveform output is stopped but the device does not load any new measurement data. Thus, the next short trigger pulse will start the old measurement again. Since the pulse corresponding to the measurement number 200 cannot point to any valid measurement, it just stops the running waveform output but never switches to a new measurement. If no waveform output is active, it starts the last valid measurement.

If smart trigger blocking is allowed in the dialog box "System Preferences" (see Fig. 30), the smart triggering accepts also pulses corresponding to measurement numbers of 201 and 202. If blocking is enabled, the device blocks all smart trigger pulses per default when the dialog box "Experiment Control" (see section "Experiment Control") is started. Thus, the device accepts only the abovementioned pulses: the pulse corresponding to the measurement number of 201 allows the reception of all other smart trigger pulses, the pulse corresponding to the measurement number of 202 blocks it again. This means that the device must receive the pulse corresponding to the measurement number of 201 to enable the control via smart triggering. If smart trigger blocking is disabled in the dialog box "System Preferences" (see Fig. 30), the device can be controlled via smart triggering independently on the reception of the pulses corresponding to measurement numbers of 201 and 202.

Pulses corresponding to measurement numbers above 202 are ignored in the present firmware version. They are reserved for future enhancements of the device functionality.

The smart trigger pulses are continuously evaluated during the device operation. If the waveform output is active, the received measurement number is stored and the new measurement will be loaded if the current waveform output finishes. If the waveform output has already finished, the new measurement will be loaded immediately. Please note that the device may require a time period of several ms for evaluating the pulse duration and for loading the new measurement data. In order to shorten the dead time, the pulses for switching to a new meas-

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urement should be sent already during the last active waveform output. The device loads the new measurement directly after the waveform output has finished and is immediately ready to receive the trigger pulse for the next waveform output.

Please note that after having changed the DAC frequency (see the dialog box "Clock" in Fig. 44) due to a measurement switching, the device may need time to stabilize the new frequency. The time necessary for the stabilization depends on the required frequency precision and, if critical, must be determined experimentally. The time constant of the corresponding filter is, however, rather short and the new frequency should be adjusted with a sufficient precision already within 1 ms.

The measurement-specific setting of the trigger slope in the dialog box "Measurement" (see Fig. 19) does not have any influence on the function of the smart triggering. The measurement active at the measurement start, however, must not be set up for manual triggering if the smart triggering mode should be used. The manual triggering disables the trigger input, thus prevents the device from evaluating the duration of trigger pulses. Measurements set up for manual triggering are typically suited for diagnostic purposes and can be started by the menu only. Nevertheless, if the device switches to a measurement with pre-set manual triggering, the smart trigger operation will not be disturbed. The measurement will be triggered externally and the trigger pulses will be evaluated for smart triggering.

Tip: Create an auxiliary measurement number 0 with any associated waveform and set the trigger in the dialog box "Measurement" to "default" (see Fig. 19). Use this measurement as a starting measurement for smart triggering and finish every measurement sequence by switching to this measurement. This procedure guarantees that the smart triggering mode will be operating with any trigger settings of other measurements and that the setup necessary for a new measurement sequence will be minimized. The user will just need to select the menu item "Experiment" to open the dialog box "Experiment Control" (see Fig. 36) and send a smart trigger pulse to launch a measurement.

External Synchronization

To achieve a perfect synchronization of the signal output with an external time base, the synchronization input can be used. The input ac-

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cepts typically TTL or sinusoidal signals with a frequency in the region between 5 and 20 MHz. If the external synchronization is enabled in the dialog box "System Preferences" (see Fig. 31), the device uses the external signal at the synchronization input to generate the sampling frequency $f_{sampling}$ for the waveform output. In this case, the external signal replaces the internal time base of 20 MHz. The sampling frequency $f_{sampling}$ is generated by a PLL (*Phase Locking Loop*) circuitry. The PLL multiplies and divides the frequency of the time base $f_{timebase}$ to get the desired sampling frequency $f_{sampling}$. The output frequency of the PLL circuitry is given by the following expression:

$$f_{PLL} = \frac{M}{512}\, f_{timebase}, \tag{2}$$

where M is an integer number. The divider M has to be chosen such that the PLL frequency f_{PLL} fulfills the following condition:

$$25\text{ MHz} < f_{PLL} \leq 50\text{ MHz}. \tag{3}$$

Inserting the expression (2) we get:

$$25\text{ MHz} < \frac{M}{512}\, f_{timebase} \leq 50\text{ MHz}. \tag{4}$$

The sampling frequency $f_{sampling}$ is generated by additional frequency division of the PLL frequency f_{PLL}:

$$f_{sampling} = \frac{f_{PLL}}{3 \cdot 2^N} = \frac{M}{3 \cdot 512 \cdot 2^N}\, f_{timebase}, \tag{5}$$

where the exponent N is again an integer number that must not be negative.

The resulting signal frequency is given by the size of the waveform:

$$f_{signal} = \frac{f_{sampling}}{N_{sample}}, \tag{6}$$

where N_{sample} is the size of the waveform, i.e. the number of data samples in the waveform (see also the dialog box "Timing Setup" in Fig. 15 and the corresponding text). Combining the abovementioned formulas, the following expression for the signal frequency f_{signal} can be obtained:

$$f_{signal} = \frac{M}{3 \cdot 2^{N+9} \cdot N_{sample}}\, f_{timebase}. \tag{7}$$

This expression implies that you need to adjust the waveform size if you wish to set the signal frequency precisely to a certain value.

Note that the signal frequency f_{signal} designates the repetition rate of the whole waveform. If the waveform consists of several periods of a particular signal, the frequency of the output signal increases accordingly:

$$f_{output} = N_{period} \cdot f_{signal}, \tag{8}$$

where N_{period} is the number of signal periods within the waveform (value "Periods" in Fig. 7 and Fig. 15).

Example:

We assume that the device is externally synchronized with a frequency of $f_{timebase}$ = 10 MHz and should generate a signal with a frequency of f_{signal} = 100 Hz. According to the formula (7), the following equation must be fulfilled:

$$100\ \text{Hz} = \frac{M}{3 \cdot 2^{N+9} \cdot N_{sample}}\ 10\ \text{MHz}. \tag{9}$$

This implies:

$$2^{N+4} \cdot 3 \cdot N_{sample} = 5^5 \cdot M. \tag{10}$$

This equation can be fulfilled, for instance, with the waveform size of $N_{sample} = 2^2 \cdot 5^6 = 62500$:

$$2^{N+6} \cdot 3 \cdot 5 = M. \tag{11}$$

The condition (4) reads:

$$25\ \text{MHz} < \frac{M}{512}\ 10\ \text{MHz} \le 50\ \text{MHz}, \tag{12}$$

which implies:

$$1280 < M \le 2560. \tag{13}$$

Considering this condition, the equation (11) can be fulfilled with N = 1 and M = 1920. Using these parameters, the PLL frequency f_{PLL}, the sampling frequency $f_{sampling}$, and finally the resulting signal frequency can be calculated from the formulas (2), (5), and (7):

$$f_{PLL} = \frac{M}{512}\ f_{timebase} = \frac{1920}{512}\ 10\ \text{MHz} = 37.5\text{MHz},$$

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$$f_{sampling} = \frac{M}{3 \cdot 512 \cdot 2^N} \, f_{timebase} = \frac{1920}{3 \cdot 512 \cdot 2^1} \, 10 \text{ MHz} = 6.25 \text{MHz},$$

$$f_{signal} = \frac{M}{3 \cdot 2^{N+9} \cdot N_{sample}} \, f_{timebase} = \frac{1920}{3 \cdot 2^{1+9} \cdot 62500} \, 10 \text{ MHz} = 100 \text{Hz}.$$

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Quick Setup Guide

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

- Upload the waveforms as described in the section "Up- and Downloading Waveforms".

- Press the middle key "enter" and start the waveform management by selecting the menu item "Manage ► Waveforms" and check the uploaded waveforms. Then close the waveform management. For details see section "Waveform Management".

- Press the middle key "enter" and start the measurement management by selecting the menu item "Manage ► Measurements". Create a new measurement by selecting the menu item "New ► Current". Select the desired waveform and setup the measurement parameters. Save the measurement by selecting the menu item "Save", then close the measurement management. For details see section "Measurement Management".

- 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". Check the output signals with an oscilloscope connected to the monitor outputs. Stop the measurement 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").

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Up- and Downloading Waveforms

The waveform data can be transferred into/from the device via the USB interface. To establish communication with a host computer, you need to install the port driver for USB (see section "Driver Installation"). When the installation is finished, copy the software from the directory "Program" of the enclosed software package to a suitable directory of your computer. Locate the program `WaveManager.exe` and the port settings file `COM.ini`. Edit the file `COM.ini` as described in the section "Functionality of the Software Interface" to set the virtual port number. Launch the program `WaveManager.exe`; it should start without any error message. If the communication port cannot be opened, check the port settings in the file `COM.ini`. The port number must match the system settings (see section "Driver Installation") and the remaining parameters should be as follows:

```
BaudRate:       230400
ByteSize:       8
StopBits:       1
Parity:         even
```

If you discover any discrepancies, correct them in the configuration file `COM.ini`. Note that wrong port settings will prevent the device from communicating with the host computer. Please also consider that the host computer can communicate with the device only if the device is in the idle state (see Fig. 2). You must close all opened dialog boxes or menus to enable communication.

In case of other communication errors, please consult the section "Functionality of the Software Interface". The tables 4 and 5 explain the possible error messages; they should help you to localize the reason for the software failure.

If the port can be opened and the device responds properly, the program starts without any error message. It opens a list of waveforms that have already been uploaded to the device. To obtain detailed information about the device, select the menu item "Device ► Information..." or press "Ctrl+N". This opens a dialog box with a summary of the device parameters.

To upload a new waveform, first open the corresponding file by selecting the menu item "File ► Open..." or by pressing "Ctrl+O". This opens a dialog box for selecting the data file. You may open ASCII

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files containing floating point data or data in hexadecimal format (for more details, see section "Utility WaveLoader"). If the file has the proper format, it will be read and displayed in a new window. Now you can upload the waveform to the device by selecting the menu item "Device ► Upload Waveform" or by pressing "Insert". This opens a dialog box in which you should enter the waveform name and the period value (for more details, see section "Waveform Management"). After closing the dialog, the upload starts. The waveform is uploaded at the position selected in the waveform list; the number of the selected waveform and of all subsequent waveforms is increased by one. If no waveform is selected, the new waveform is appended at the end. If you have already selected a waveform in the list and wish to deselect it again, just refresh the list by selecting the menu item "Device ► Get/Refresh Waveform List" or by pressing "F5".

By double clicking on an item in the waveform list, pressing "Enter", or selecting the menu item "Device ► Download Waveform", a particular waveform can be downloaded. A new window opens and the waveform is displayed in it. When the download finishes, you may save the waveform into a file or compare its data with a waveform file. To compare the waveform data, select the menu item "File ► Compare With..." or press "Ctrl+C". Like when opening a file, this opens a dialog box for selecting the data file; the expected file format is the same as when opening a file. When the compare finishes, a message box pops up and informs you about the comparison result. To save the waveform data, select the menu item "File ► Save As..." or press "Ctrl+S". This also opens a similar dialog box for selecting the data file. You may save the data as an ASCII file containing floating point data (extension .csv) or data in hexadecimal format (extension .hex).

By selecting the menu item "Device ► Delete Waveform" or by pressing "Delete", the selected waveform can be deleted. The program requires a confirmation before a waveform will be deleted. It is advisable to download the waveform before deleting it. The window with the deleted waveform remains available, you can upload the waveform data to the device again or save it into a file.

By selecting the menu item "Device ► Modify Waveform" or by pressing "F2", the selected waveform can be edited. A new dialog box opens, you can modify there the waveform name and the period value. By selecting the menu item "Device ► Replace Waveform Data", new data for the selected waveform can be uploaded. This menu item is accessible only, if you have previously opened a wave-

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form file and selected a waveform in the list that has the same number of data points like the opened waveform. The function uploads the new data and replaces the old one. Note that there is no undo function, the old waveform data is lost at the time when the command is being executed.

In case of a communication error, you may try to select the menu item "Device ► Communication purge" or press "Ctrl+P" to repair the communication channel. The communication buffers will be cleared and the communication should be enabled again.

The program uses and requires a multithreading version of Microsoft Windows™ that can run 32-bit applications. The multithreading environment ensures the program functionality in every situation. You may download or upload waveforms while loading or saving the waveform data and manipulating the program windows. There is, however, only one communication channel available. Thus, when the program communicates with the device, no other concurrent communication process is possible. In such cases, the corresponding menu items are disabled and cannot be selected until the communication has finished. To prevent data corruption, you are also not allowed to close the program when the communication is active.

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.

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Main Program Menu

When the device starts, the initialization takes place and the manufacturer 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 configuration (submenu "Manage", see also section "Device Management"), monitor the device function (submenu "Monitor", see also section "Device Monitoring"), 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 shutdown or after the last startup, or to the state when you saved the settings. 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 influences neither the waveform data nor the measurement settings. If you wish to also clear this data, start the waveform or the measurement management (see sections "Waveform Management" and "Measurement Management") and clear the data in the corresponding dialog box.

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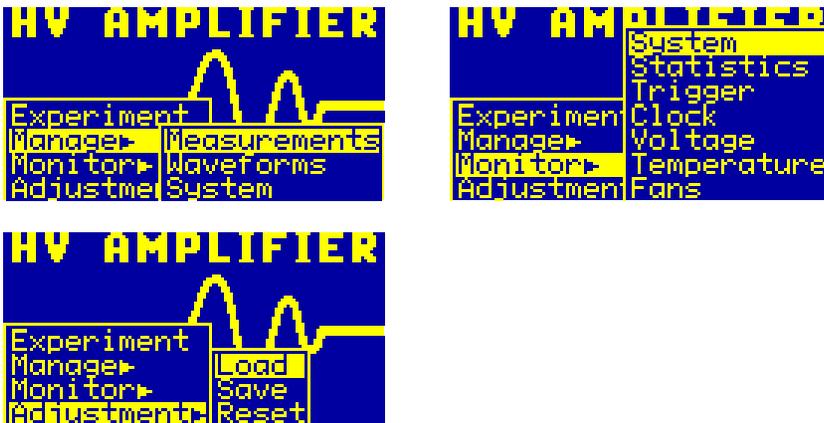
Fig. 3. Main program menu.
The figure shows the different submenus of the main program menu.

Device Management

Several dialog boxes are available to control the device settings and to setup waveforms and measurements.

Waveform Management

Using the dialog box "Waveform", you can visualize and manage the waveforms (see Fig. 4).
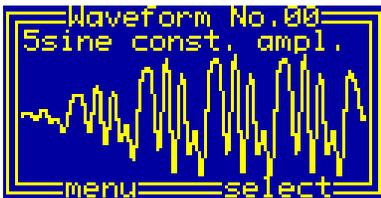
Fig. 4. Dialog box "Waveform".

To select a particular waveform, use the rotary encoder. The current waveform number is shown in the title bar of the dialog box. The next row displays the waveform name. In the main part of the dialog box, the waveform is drawn. For longer waveforms, the drawing may take several seconds. However, the drawing runs as a background process, it does not block the operation of the device.

Fig. 5. Menu in the dialog box "Waveform".

By pressing the middle key "enter", the menu can be accessed (see Fig. 5). You can select one of the waveform functions or close the dialog box. The functions "Detail" and "Zoom" open new dialog boxes, the menu item "Edit Name" invokes a simple editor in the current dialog box (see Fig. 6).

Fig. 6. Waveform name editor in the dialog box "Waveform".

The waveform 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.

The dialog box "Waveform Detail" displays the detailed information about the current waveform (see Fig. 7).

Fig. 7. Dialog box "Waveform Detail".

The title and the next row are identical to those of the main "Waveform" dialog box (see Fig. 4). The value "Samples" shows the number of waveform samples decreased by one. Thus, the waveform shown in Fig. 7 consists of 16,000 samples. The value is shown in decimal (the first value) and in hexadecimal format (the second value terminated by 'h').

The value "Periods" is the number of signal periods within the waveform. This auxiliary value should help you to set up the waveform timing, however, it does not influence the waveform output in any way.

You should set the value to a number that best characterizes your waveform.

The values "Maximum" and "Minimum" show the extremes of the waveform data. The values are shown as percent values (the first values terminated by '%') and in hexadecimal format (the second values terminated by 'h'). The hexadecimal values correspond to the real 16-bit waveform data, the absolute minimum equals 0000h, the absolute maximum is FFFFh. The percent values are related to these extremes. For longer waveforms, the calculation of the extreme values may take up to about one second. However, the calculation runs as a background process, it does not block the operation of the device.

Using the dialog box "Waveform Zoom", you can visually inspect the selected waveform in detail (see Fig. 8).

Fig. 8. Dialog box "Waveform Zoom".

Similarly to the main "Waveform" dialog box (see Fig. 4), the title bar shows the current waveform number. The next row displays the currently used waveform scale. The first two numbers are the horizontal limits of the drawing, the second two numbers the vertical limits. The values are shown in hexadecimal format.

Using the horizontal direction keys, you can change the horizontal resolution, the vertical direction keys change the vertical resolution: The keys "left" and "up" increase the resolution, the keys "right" and "down" decrease it. When the resolution is being changed, the new display limits are obtained such that the display center does not move. This is, however, not possible when the resolution is being decreased and one of the new display limits would exceed the allowable values, i.e. the waveform size. In this case, the drawing limits are shifted accordingly while maintaining the desired scale.

Using the rotary encoder, the current view can be shifted. By pressing the encoder button, you can change the shift direction between hori-

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zontal and vertical. The default direction is horizontal as shown in Fig. 8.

The menu of the dialog box is accessible by pressing the middle key "enter" (see Fig. 9). Using the menu, you can modify the drawing scale or close the dialog box and return to the main dialog box "Waveform" (see Fig. 4).

Fig. 9. Menu in the dialog box "Waveform Zoom".

Selecting the menu item "Full scale", the drawing resets to the initial state using the full scales in both directions. You can set the full scale for each direction separately by selecting the menu items "Vertical ► Full" or "Horizontal ► Full", respectively. By contrast, the menu items "Vertical ► Max" or "Horizontal ► Max", select the maximum possible resolution in the particular direction. If the maximum resolution is chosen, one display pixel step corresponds exactly to one data step, i.e. no waveform details can be lost by the drawing. Due to the limited display resolution, however, only a rather small part of the waveform can be drawn using the maximum resolution. Thus, in practice, lower resolutions are more suitable.

By selecting the menu item "Vertical ► Fit", an optimum vertical scale is calculated and the waveform is redisplayed using the new scale. This procedure requires about twice the time to stabilize the drawing compared to a normal operation. Be sure that you select this menu item after the waveform drawing with the currently selected horizontal resolution has completed, otherwise the proper scaling data are not available and the function fails.

If you choose the menu item "Vertical ► Auto", the automatic optimization of the vertical scale is applied permanently. This takes more time but provides the best results when inspecting a waveform in detail. When the horizontal resolution or the horizontal position change, the waveform extremes are obtained while drawing the waveform. When the drawing finishes, the optimum scale is obtained and the

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waveform is redrawn. These processes run in background, thus do not block the device in any way. You can shift the waveform or change the display scale without having to wait for the drawing to finish.

Please note that it does not make sense to move the waveform vertically or to change the vertical resolution if the automatic optimization of the vertical scale is active. After the device has drawn the waveform using the new display limits, the waveform will be redrawn again with the original optimum scale so that the final drawing does not change at all.

The recommended procedure for waveform inspection is as follows: Increase the horizontal resolution such that you can see the details that you are searching for. Turn on the automatic optimization of the vertical scale and use the rotary encoder to move through the waveform. If you shifted the waveform by about one half of the display width, wait a moment until the drawing stabilizes. Repeat this procedure for the whole waveform or for the part that you are inspecting.

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Measurement Management

Using the dialog box "Measurement", you can setup and manage the measurements (see Fig. 10).
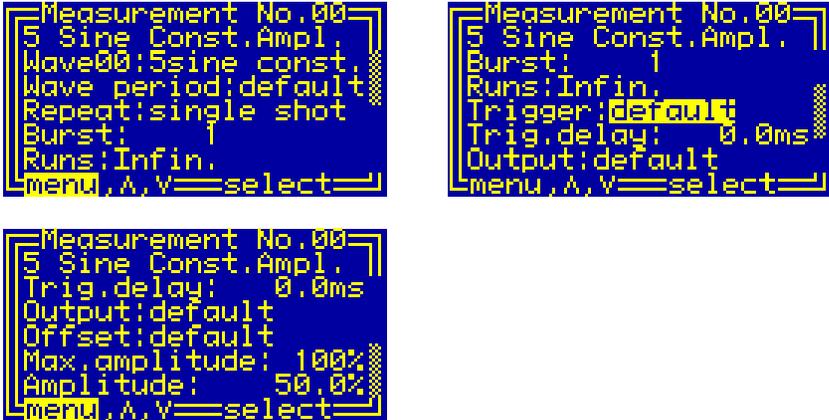
Fig. 10. Dialog box "Measurement".
Three different views on the dialog box that correspond to different positions of the scroll bar located at the right side.

To select a particular measurement, use the rotary encoder. The current measurement number is shown in the title bar of the dialog box. The next row displays the measurement name.

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. 10). The menu allows you to manage the measurements, save the current measurement, or close the dialog box (see Fig. 11). Please note that the changes made to a measurement will be lost if you progress to another measurement or close the dialog box without having selected the menu item "Save".

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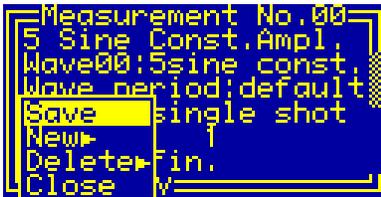
Fig. 11. Menu in the dialog box "Measurement".

By selecting the menu items "Delete ► Current" or "Delete ► All", measurements can be erased. The menu item "Delete ► Current" deletes the currently selected measurement; all measurements with higher numbers are 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 pressing the middle key "enter" when the measurement name is selected, a simple editor in the current dialog box is invoked (see Fig. 12). The function of the editor equals the waveform name editor (see Fig. 6 and the corresponding text).
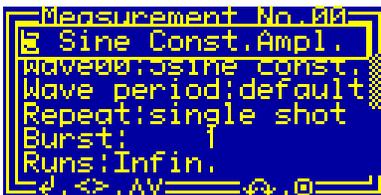
Fig. 12. Measurement name editor in the dialog box "Measurement".

When the waveform name is selected, press the middle key "enter" to change the waveform assigned to the measurement. A new dialog box will be opened that is similar to the dialog box "Waveform" (see Fig. 4). The only difference to the dialog in Fig. 4 is the presence of the last menu item "Select" (see Fig. 13) that assigns the selected waveform to the current measurement.

Fig. 13. Menu in the dialog box "Waveform" for selecting waveforms.

The value "Wave period" shows the currently set waveform duration, it can be changed by a menu using the direction keys (see Fig. 14). You can select the default value (see Fig. 24 and the corresponding text) or setup any other waveform duration. When the menu item "setup" is selected, a new dialog box opens (see Fig. 15).
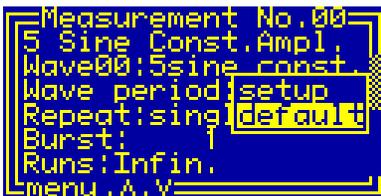
Fig. 14. Setting the waveform duration in the dialog box "Measurement".

The dialog box "Timing Setup" (see Fig. 15) allows you to set the waveform duration; it is displayed as the value "Wave period". Use the rotary encoder to change the value or press the middle key "enter" to close the dialog and save the settings.

Fig. 15. Dialog box "Timing Setup".

The values "Fsignal" and "Fsampl." show the signal and sampling fre-quencies, respectively. The signal frequency is obtained from the

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waveform duration and from the value "Periods" that is a part of the waveform definition (see Fig. 7):

$$Fsignal = Periods / Wave\ period. \hspace{2cm} (14)$$

Similarly, the sampling frequency is calculated from the waveform duration and from the waveform size "Samples":

$$Fsampl = Samples / Wave\ period. \hspace{2cm} (15)$$

The values displayed in the dialog box are the real signal and sampling frequencies that will be used for the waveform output. The shown sampling frequency *Fsampl* is obtained from the properties of the internal time base. This circuit is able to multiply the internal quartz clock by certain rational numbers only, thus the sampling frequency and, consequently, all other timing parameters may slightly differ from the desired value. If the external synchronization is active (see Fig. 31), the applied synchronization frequency also determines the sampling frequency. For more details, see section "External Synchronization".

Note that you cannot exit the dialog box "Timing Setup" without saving the data. You can, however, discard the changes of the settings in the main dialog box "Measurement".

The value "Repeat" in the dialog box "Measurement" displays the operation mode of the waveform generator, it can be changed by a menu using the direction keys (see Fig. 16). If "single shot" is selected, the generator produces one waveform or one waveform burst (see Fig. 17) per trigger and waits for the next trigger. If "continuous" is selected, the generator produces the waveform repeatedly, once it has been triggered.
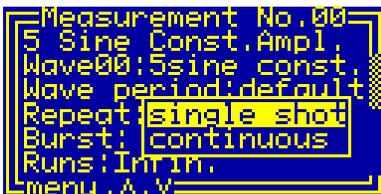
Fig. 16. Setting the waveform repeating in the dialog box "Measurement".

The value "Burst" shows how many times the selected waveform is output after one trigger event, i.e. defines the burst size. The value

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can be changed by the rotary encoder (see Fig. 17). To set large numbers, press the direction key "left" - the value will change one hundred times faster. The minimum value is 1 repetition of the wave-form, the maximum is 65,000 repetitions. The value can be selected on devices with the hardware version 1-10 and later only, with earlier hardware versions, the burst function is not available.
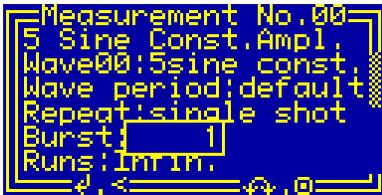
Fig. 17. Setting the burst size in the dialog box "Measurement".

Note that if the "continuous" mode of the waveform generator is se-lected (see Fig. 16), the burst size has not a direct influence on the signal output. Independently on the burst size, the device outputs a continuous train of waveforms.
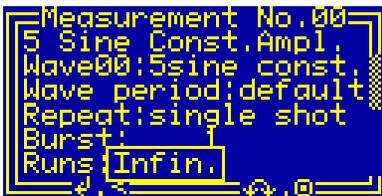
Fig. 18. Setting the number of waveform repetitions in the dialog box "Measurement".

The value "Runs" shows how many waveforms will be output until the generator stops the waveform generation. The value can be changed by the rotary encoder (see Fig. 18). To set large numbers, press the direction key "left" - the value will change one hundred times faster. The minimum allowable value is 1 run, the maximum is 999,999 runs. The minimum settable value of 0 has a special meaning: If selected, the text "Infin." instead of the numerical value is shown (see Fig. 18). This setting implies an infinite number of runs. On devices with the hardware version 1-10 and later, the generator will not stop at all; the output must be interrupted by selecting the menu item "Stop" from the dialog menu (see also section "Experiment Control"). On devices with earlier hardware versions, the generator stops after 4,294,967,295

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runs. Thus, when generating a continuous sine waveform with the frequency of 1 kHz, the total signal duration is limited to about 50 days.

Please note that the product of the values "Burst" and "Runs" must fit into a 32-bit number, i.e. must not exceed 4,294,967,295. When you have finished the setting of these values, the device corrects the settings automatically to match this requirement. If the value "Runs" is set to "Infin.", there are no limitations and an unlimited number of runs can be output.

Fig. 19. Setting the trigger slope in the dialog box "Measurement".

The value "Trigger" shows the trigger slope, it can be changed by a menu using the direction keys (see Fig. 19). You can select between rising and falling slopes, use the device default value (see Fig. 25 and the corresponding text), or set the manual triggering. When the manual triggering is selected, the waveform generation can be started by a menu item only, the external trigger input is disabled. In other cases, an external signal with the appropriate polarity at the trigger input launches the waveform generation, however, a manual triggering by a menu item is still available. If smart triggering is enabled, the device default value (see the dialog box "System Preferences" in Fig. 25) will be used instead of this measurement-specific setting, except that manual triggering is selected (see section "Smart Triggering").

The value "Trig.delay" shows the delay between the trigger event and the beginning of the waveform output. The value can be changed by
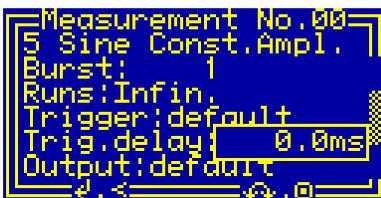
Fig. 20. Setting the trigger delay in the dialog box "Measurement".

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the rotary encoder (see Fig. 20). To set large numbers, press the direction key "left" - the value will change one hundred times faster. The minimum allowable value is 0 ms, the maximum is 6.5 s. The value can be set with a precision of 0.1 ms. The value can be selected on devices with the hardware version 1-10 and later only, with earlier hardware versions, the delay function is not available.
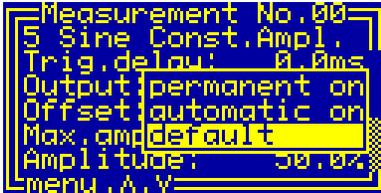

Fig. 21. Setting the amplifier activation in the dialog box "Measurement".

The values "Output" and "Offset" show the amplifier settings, they can be changed by a menu using the direction keys (see Fig. 21). You can select between "permanent on" and "automatic on", or select the default value (see Fig. 33 and the corresponding text). If the value "Output" is effectively set to "permanent on" and a measurement finishes, the amplifier remains active until it is turned off. It needs to be manually deactivated by the push button on the front panel. If the value "Output" is effectively set to "automatic on", the device automatically activates the amplifier at the beginning of the measurement and deactivates it when the measurement finishes. This mode reduces the power consumption and the heat production of the device, but increases the duration of the startup and shutdown procedures. If the value "Offset" is effectively set to "permanent on", the amplifier generates the offset voltage immediately when it is activated. If the value "Offset" is effectively set to "automatic on", the amplifier starts to generate the offset voltage at the beginning of the measurement and turns the offset voltage off when the measurement finishes. This option can be applied only if the value "Output" is set to "permanent on" or to "default", otherwise the item is not selectable and the value is set to "automatic on".

The values "Max. amplitude" and "Amplitude" show the settings of the output signal amplitude, they can be changed by the rotary encoder (see Fig. 22). The value "Max. amplitude" defines the maximum allowable signal amplitude, the output signal is in any case limited to this value. The value "Amplitude" is used as the starting signal ampli-

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tude when the dialog box "Measurement Control" is opened (see Fig. 36 and section "Experiment Control"). The signal amplitude can be changed during the waveform generation, it can, however, not exceed the value "Max. amplitude". The value "Max. amplitude" may not be smaller than the value "Amplitude". The device corrects the settings automatically to match this requirement.

Fig. 22. Setting the output signal amplitude in the dialog box "Measurement".

Note that when smart triggering is used, the waveform output starts with the amplitude defined by the value "Amplitude". Since user interference is not intended during smart triggering, you should setup the value "Amplitude" to a value that you intend to use for the respective output. If you aim to generate a waveform with different amplitudes by smart triggering, you have to setup a dedicated measurement for each parameter set. For more information, see sections "Measurement Management" and "Smart Triggering".

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System Preferences

The dialog box "System Preferences" (see Fig. 23) shows the current system settings and enables you to change them. Some of the settings can be used as default values for setting up a measurement. You can modify all measurements using these defaults in a single step by changing the system settings.
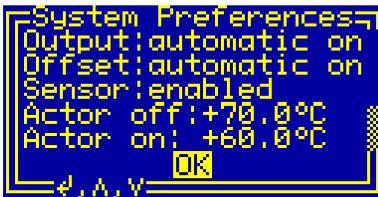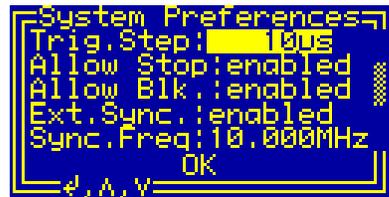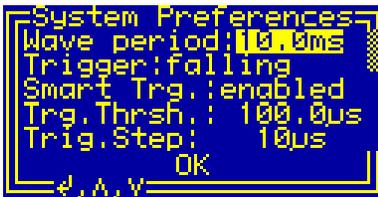
Fig. 23. Dialog box "System Preferences".
Three different views of the dialog box that correspond to different positions of the scroll bar located at the right side.

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. 23).

The value "Wave period" shows the default waveform duration, it can be changed using the rotary encoder (see Fig. 24). The minimum
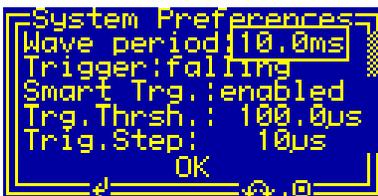
Fig. 24. Setting the waveform duration in the dialog box "System Preferences".

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value is 0.4 ms (i.e. 2.5 kHz), the maximum 999 s. The value is used as device default for the waveform duration. You can set the wave-form duration to "default" in the dialog box "Measurement" (see Fig. 14), the device will use the device default value set in this dialog.
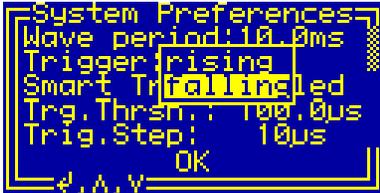
Fig. 25. Setting the trigger slope in the dialog box "System Preferences".

The value "Trigger" shows the default trigger slope, it can be changed by a menu using the direction keys (see Fig. 25). You can select be-tween rising and falling slopes. The value is used as device default for the trigger slope. You can set the trigger slope for a measurement to "default" in the dialog box "Measurement" (see Fig. 19), the device will use the device default value set in this dialog. If smart triggering is en-abled, the value will be used instead of the measurement-specific set-ting (see section "Smart Triggering").
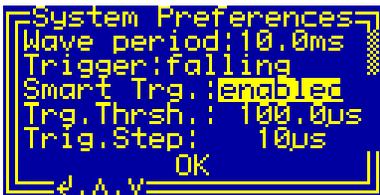
Fig. 26. Setting the smart triggering in the dialog box "System Preferences".

The value "Smart Trg." shows the state of the smart triggering, it can be changed by pressing the middle key "enter" (see Fig. 26). The value can be selected and enabled on devices with the hardware ver-sion 1-10 and later only, with earlier hardware versions, the smart triggering is not available. For more details, see section "Smart Trig-gering".

The value "Trg.Thrsh." shows the trigger threshold for the smart trig-gering, it can be changed using the rotary encoder (see Fig. 27). The minimum value is 0.1 µs, the maximum 6.5 ms. The value can be set

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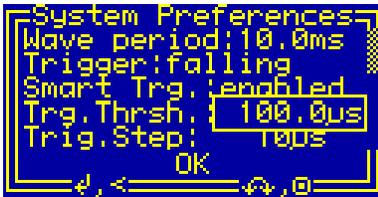
Fig. 27. Setting the trigger threshold for smart triggering in the dialog box "System Preferences".

with a precision of 0.1 µs. The value can be selected only if the smart triggering is enabled (see Fig. 26). For more details, see section "Smart Triggering".

The value "Trig.Step" shows the trigger step for the smart triggering, it can be changed using the rotary encoder (see Fig. 28). The minimum value is 1 µs, the maximum 65 ms. The value can be set with a precision of 1 µs. The value can be selected only if the smart triggering is enabled (see Fig. 26). For more details, see section "Smart Triggering".
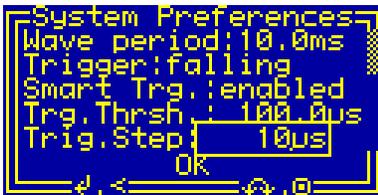
Fig. 28. Setting the trigger step for smart triggering in the dialog box "System Preferences".

The value "Allow Stop" shows the stopping ability of the smart triggering, it can be changed by pressing the middle key "enter" (see

Fig. 29. Setting the stopping feature for smart triggering in the dialog box "System Preferences".

Fig. 29). The value can be selected only if the smart triggering is enabled (see Fig. 26). For more details, see section "Smart Triggering".

Fig. 30. Setting the blocking feature for smart triggering in the dialog box "System Preferences".

The value "Allow Blk." shows the blocking ability of the smart triggering, it can be changed by pressing the middle key "enter" (see Fig. 30). The value can be selected only if the smart triggering is enabled (see Fig. 26). For more details, see section "Smart Triggering".

Fig. 31. Setting the external synchronization in the dialog box "System Preferences".

The value "Ext.Sync." shows the state of the external synchronization, it can be changed by pressing the middle key "enter" (see Fig. 31). The value can be selected and enabled only if the external synchronization is implemented. For more details, see section "External Synchronization".
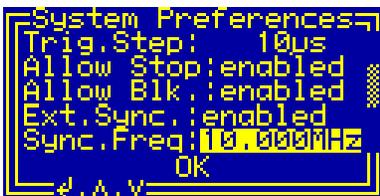
Fig. 32. Setting the frequency of the external synchronization in the dialog box "System Preferences".

The value "Sync.Freq" shows the expected frequency at the external synchronization input, it can be changed using the rotary encoder (see Fig. 32). The value can be selected only if the external synchronization is enabled (see Fig. 31). For more details, see section "External Synchronization".
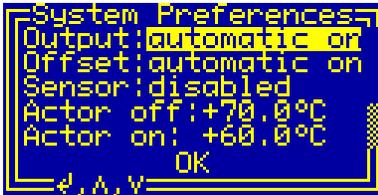
Fig. 33. Setting the amplifier activation in the dialog box "System Preferences".

The values "Output" and "Offset" show the default amplifier settings, they can be changed by a menu using the direction keys (see Fig. 33). You can select between "permanent on" and "automatic on". If the "Output" is set to "permanent on" and a measurement finishes, the amplifier remains active until it is turned off. It needs to be manually deactivated by the push button on the front panel. If the "Output" is set to "automatic on", the device automatically activates the amplifier at the beginning of the measurement and deactivates it when the measurement finishes. If the "Offset" is set to "permanent on", the amplifier generates the offset voltage immediately when it is activated. If the "Offset" is set to "automatic on", the amplifier starts to generate the offset voltage at the beginning of the measurement and turns the offset voltage off when the measurement finishes. This option can be applied only if the "Output" is set to "permanent on", otherwise the item is not selectable and the value is set to "automatic on". The values from the dialog box are used as device defaults for the amplifier settings. You can set the "Output" and the "Offset" for a measurement
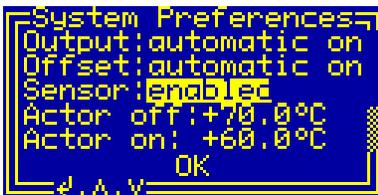
Fig. 34. Enabling the actuator temperature sensor in the dialog box "System Preferences".

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to "default" in the dialog box "Measurement" (see Fig. 21), the device will use the device default values set in this dialog.

The value "Sensor" enables the temperature sensor at the actuator, it can be changed by pressing the middle key "enter" (see Fig. 34). If the sensor is disabled, its response will not be monitored and the attached amplifier will not be disabled if the actuator overheats.
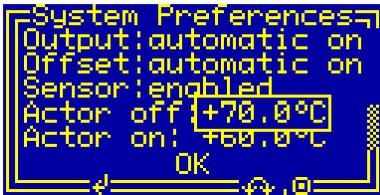
Fig. 35. Setting the allowable actuator temperatures in the dialog box "System Preferences".

The values "Actor off" and "Actor on" show the thresholds of the actuator temperature. The values can be selected only if the actuator temperature sensor is enabled (see Fig. 34). If the actuator becomes warmer than the value "Actor off", the attached amplifier will be deactivated and its output will be shorted so that the actuator will not be loaded any more, and thus should cool down. The amplifier can be activated again, if the actuator temperature has decreased below the value "Actor on". If the sensor is disabled, the attached amplifier will not be disabled at any actuator temperature. The values can be changed using the rotary encoder (see Fig. 35). The minimum settable value is 30°C, the maximum is 99.9°C. The difference between the values must be larger than 1°C, the values are automatically corrected to meet these requirements. You should set the values according to the data sheet of the actuator. Note that a too high operation temperature of the actuator may shorten its lifetime of even lead to its permanent destruction.

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Experiment Control

The waveform generation is controlled by the dialog box "Experiment Control" (see Fig. 36).
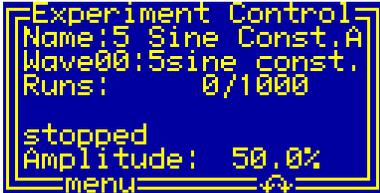
Fig. 36. Dialog box "Experiment Control".

The text "Name" is the name of the selected measurement (see also Fig. 12), "WaveNN" is the name of the corresponding waveform, the two numerals NN in the waveform label ("00" in Fig. 36) stand for the waveform number (see Fig. 4). The values "Runs" show the number of waveforms that have been generated and the total number of waveforms that should be generated. The latter value is given by the measurement settings (see Fig. 18). The waveform generation stops if the left number reaches the value of the second number. The text "stopped" shows the device status, it changes according to the measurement phase or to a possible failure (see Tab. 1). The value "Amplitude" is the currently set output signal amplitude. Its initial and maximum values are determined by the corresponding measurement settings (see Fig. 22). The amplitude value can be set by the rotary encoder between 0% and the maximum allowed amplitude.

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 waveform generator is stopped, the menu allows you to select a measurement, to launch it, or to close the dialog box (see Fig. 37). The device monitoring can be started from a submenu (for details see section "Device Monitoring"). 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.
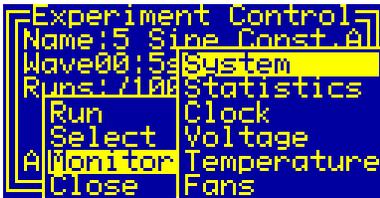
Fig. 37. Start menu of the dialog box "Experiment Control".

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. 10). The only difference to the dialog in Fig. 10 is the presence of the last menu item "Select" (see Fig. 38) that selects the current measurement.

Fig. 38. Menu in the dialog box "Measurement" for selecting measurements.

The menu item "Run" launches the selected measurement. If required, the amplifier and its output offset voltage will be activated (see Fig. 21 and the corresponding text). Next, the device waits for the trigger (see Fig. 39). If manual triggering is selected (see Fig. 19), the status changes to "waiting for start". The waveform output can be launched by the menu item "Start" that can be found in the dialog menu now. Note that the menu item "Start" is present in the dialog menu inde-pendently on the trigger source, i.e. it can be used to manually trigger
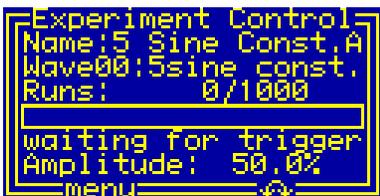
Fig. 39. Dialog box "Experiment Control" when the device is waiting for the trigger.

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a measurement even if you selected external triggering.

If the device has been triggered, the waveform output starts (see Fig. 40). The progress bar above the status text graphically indicates the time elapsed from the beginning of every particular waveform. Please note that due to the display delay, the real picture may appear blurred if the progress bar changes rapidly.

Depending on the settings, one waveform or a series of waveforms is generated until the device stops. The waveform generation may also be interrupted by a fault condition. This may be an opened interlock loop, amplifier or actuator overheating, or a supply voltage fault. The waveform output may be also halted by the menu item "Halt" or stopped by the menu item "Stop". If halted, the waveform output can be restored again by the menu item "Continue". If manual triggering is selected, the menu item "Continue" also triggers the device so that the waveform output is launched immediately. However, if external triggering is selected, the device waits for the next trigger before the waveform output is restarted.
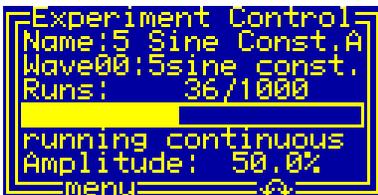
Fig. 40. Dialog box "Experiment Control" when the device is generating a waveform.

If the waveform generation stops, the amplifier and the output offset are deactivated if necessary. The deactivation does not happen, if the amplifier and the output offset are turned permanently on (see Fig. 21 and the corresponding text). When this shutdown has finished, the device enters the idle state, i.e. the same state as before the measurement was started (see Fig. 36).

The possible states of the waveform generator are summarized in Tab. 1. The table lists the texts that can be displayed in the status line of the dialog box "Experiment Control" and their explanations.

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Tab. 1. Possible states of the waveform generator.

Text	Explanation
`stopped`	the waveform generator is idle
`waiting for power`	the device is waiting until the power supply voltages reach their correct values
`waiting for offset`	the device is waiting until the output offset voltage stabilizes
`waiting for trigger`	the device is waiting for an external trigger
`waiting for start`	the device is waiting for a manual trigger, select the menu item "Start" to launch the waveform generation
`waiting for stop`	the output has been interrupted by selecting the menu item "Stop", the device is waiting until the current run finishes
`waiting for shutoff`	waveform generation has finished, the device is turning off the offset and is waiting until the output voltages reach safe values
`waiting for pw.down`	the offset has been turned off, the device is shutting off the power supply and is waiting until the power supply voltages reach safe values
`running single`	single waveform is being generated
`running continuous`	waveforms are being generated continuously
`halted`	waveform generation is halted, select the menu item "Continue" to restart the waveform generation
`!!supply failure!!`	one of the supply voltages was out of the allowable range since the power supply was turned off, overloaded, overheated, or is defective; the amplifier was deactivated and the waveform generation stopped

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Text	Explanation
`activation failure!`	the device could not be activated, the interlock loop may be open, the amplifier or the actuator may be overheated
`frequency failure!`	the required sampling frequency is out of the allowable range, check and correct the measurement settings
`measurement empty!`	the selected measurement is not valid, select or create a new one

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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.

Information

The dialog box "Information" (see Fig. 41) 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.
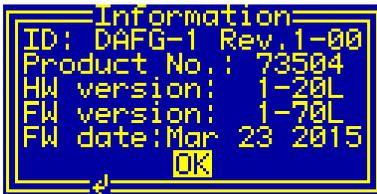
Fig. 41. Dialog box "Information".

The suffixes of the version numbers indicate the voltage version of the attached amplifier: The character 'L' stands for the low-voltage (output 150 V), 'H' for the high-voltage (output 1100 V) version, respectively. The voltage thresholds for monitoring the power supply differ according to the detected voltage version (see Fig. 45).

Statistics

The dialog box "Statistics" (see Fig. 42) 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.

The time "Amplifier" displays the operation time of the amplifier elapsed since powering on the device or since the last firmware restart. The next line "Total" shows the total operation time of the amplifier.

Fig. 42. Dialog box "Statistics".

Trigger

The dialog box "Trigger" (see Fig. 43) shows the state of the trigger engine. The value "Input" indicates the signal level on the trigger input. The possible values are "L" and "H" reflecting the low and high logic levels, respectively.

Fig. 43. Dialog box "Trigger".

The values "Smart Trigger" show the state of the smart triggering. The "State" displays the present state, the possible values are "not avail.", "disabled", "enabled", or "blocked". The state "not avail." is displayed if the smart triggering is not supported by the hardware. The value reads "disabled" if the smart triggering is disabled in the dialog box "System Preferences" (see Fig. 26). If smart triggering is enabled, the value may change between "enabled" and "blocked". The state is "blocked" if smart trigger blocking is enabled in the dialog box "System Preferences" (see Fig. 30) and an enable pulse has not been received yet. The state is "enabled" if smart trigger blocking is disabled or an enable pulse has been received. For more details, see section "Smart Triggering".

The value "Last" shows the duration of the last received trigger pulse. "Index" displays the index of the corresponding measurement, i.e. the measurement number according to formula (1). The value may be "-",

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if no pulse has been received yet, or "trigger", if a trigger event has been detected, i.e. a short trigger pulse received (for more details, see section "Smart Triggering").

Clock

The dialog box "Clock" (see Fig. 44) shows the current frequencies of various clock signals used internally to control the device. 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.

Fig. 44. Dialog box "Clock".

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 clock controlling the FPGA (*Field Programmable Gate Array*). The FPGA is responsible for the waveform generation and for activating the amplifier, its clock is gained from the main quartz oscillator.

The value "DAC int" is the frequency of the clock controlling the DAC (*Digital Analog Converter*) generating the waveforms. The clock is exactly three-times higher than the waveform sampling rate, it is gained by a PLL (*Phase Locking Loop*) circuitry. The PLL multiplies and divides the frequency of the main quartz oscillator or the external synchronization source to get the desired DAC clock. The label may read "DAC int" or "DAC ext" depending on the selected clock source. If the device displays the label "DAC ext", the external synchronization is enabled in the dialog box "System Preferences" (see Fig. 31), the label "DAC int" indicates the internal synchronization by the quartz oscillator. Note that if the external synchronization is enabled but no clock

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source is connected, the device does not work properly. The wave-form generator cannot be launched, i.e. cannot be triggered, and the dialog box "Clock" does not update the value "DAC ext".

The value "DMA" is the frequency of the clock controlling the DMA (*Direct Memory Access*) circuit used to move waveform data when a waveform is being inserted or deleted. The clock is gained by a PLL circuitry, the clock frequency is set to 80 MHz if the DMA is active or, to reduce EMI (*Electro-Magnetic Interference*), to 1.6 MHz if DMA is not used.

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.

Voltage Monitor

The dialog box "Voltage Monitor" (see Fig. 45) shows the current values of the supply voltages of the device.
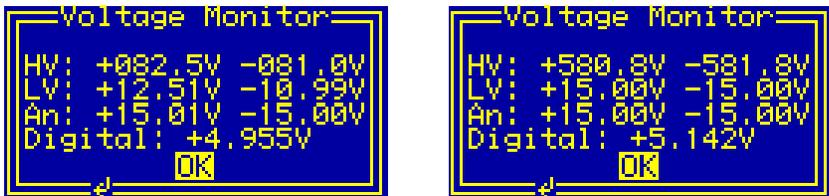
Fig. 45. Dialog box "Voltage Monitor".
Two voltage versions are depicted: low-voltage (left) and high-voltage (right).

The values "HV" are the positive and negative high voltages supplying the amplifier. If the amplifier is inactive, the voltages are near zero. They rise to about 80 V (low-voltage version) or 580 V (high-voltage version) if the amplifier is activated.

The values "LV" are the positive and negative low voltages supplying the amplifier. If the amplifier is inactive, the voltages are near zero. They rise to about 12 V (low-voltage version) or 15 V (high-voltage version) if the amplifier is activated.

The values "An" are the positive and negative voltages supplying the analog circuits of the device. The nominal values are 15 V. The volt-

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ages are present independent of the amplifier state and the values are independent of the voltage version of the attached amplifier.

The value "Digital" is the voltage supplying the digital circuits of the device. The nominal value is 5 V. The voltage is present independent of the amplifier state and the value is independent of the voltage version of the attached amplifier.

The values are measured about 2.5-times per second. The microcontroller checks them continuously and deactivates the amplifier if the voltages differ from their nominal values. This may happen when the amplifier is overloaded or when one of the power supplies overheats.

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

Temperature Monitor

The dialog box "Temperature Monitor" (see Fig. 46) shows the measured temperatures of the device and of the connected actuator.
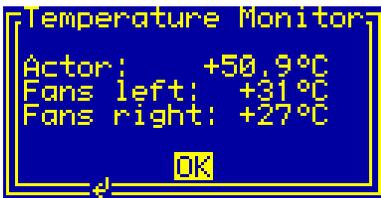
Fig. 46. Dialog box "Temperature Monitor".

The value "Actor" is the temperature measured using a Pt1000 sensor at the actuator. The sensor is connected via the output cable to the device. The microcontroller calculates the temperature from the sensor resistance using the simple linear formula:

$$R = 1\ k\Omega \cdot (1 + 0.00385 \cdot t\,/\,°C), \tag{16}$$

where R stands for the sensor resistance and t the sensor temperature.

The values "Fans left" and "Fans right" are the temperatures measured using 8 semiconductor sensors in the amplifier. The sensors are

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located directly at the 8 power semiconductor devices of the amplifier. The sensors are grouped into two groups with 4 sensors each. The measured value is the maximum temperature determined over the 4 sensors of each group. The sensors are also used to control the fans at the heatsink, each group controls one fan pair.

The values are measured about 2.5-times per second. The microcontroller checks the values continuously and deactivates the amplifier if the temperature rises above the allowed values. The microcontroller is also able to discover failures such as a disconnected or shorted sensor; any failure causes an immediate deactivation of the amplifier.

Fan Monitor

The dialog box "Fan Monitor" (see Fig. 47) shows the state of the fans located at the heatsink of the device.

Fig. 47. Dialog box "Fan Monitor".

The values "Fans left" and "Fans right" indicate the state of the fans. The values shown may be either "Ok" if the fans are running properly or "failure" if one of the fans has failed.

The values "Heatsink left" and "Heatsink right" show the temperatures of the sensors controlling the fans (for more details, see the section "Temperature Monitor"). The values shown may be either "Ok" or "hot" if the temperature exceeds the allowed limit.

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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	©

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" and "Up- and Downloading Waveforms"). The utilities do not require any additional installation, you need only to copy them to a suitable directory on your computer. If necessary, edit the file COM.ini to set the virtual port number, as described in the section "Functionality of the Software Interface".

Utility WaveLoader

The WaveLoader is a simple Windows program that runs in text mode. It is a text mode alternative to the GUI (Graphical User Interface) program WaveManager (see section "Up- and Downloading Waveforms"). Similarly to the WaveManager, the WaveLoader enables you to up/download the waveforms to/from the waveform generator. Launching the utility WaveLoader.exe without any parameters displays a simple help. To display a text with the expected syntax of the command line, start the program with the parameter -?:

```
WaveLoader -?
```

Regardless of the parameters, the program should start without any error message. In case of any problem, display the port settings by pressing the key 'i' and check whether the port number matches the system settings (see sections "Driver Installation" and "Up- and Downloading Waveforms").

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

```
Product identification: DAFG-1 Rev.1-00
```

If an error occurs, please consult the section "Functionality of the Software Interface". The tables 4 and 5 explain the possible error messages; they should help you to localize the reason for the software failure.

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

Finally, press 'W' to get the list of all uploaded waveforms. If no waveforms have been uploaded yet, the list should be empty. You may

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clear the waveforms by pressing the key 'E' or exit the program by pressing 'Esc'.

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. To list all uploaded waveforms, enter the following command:

```
WaveLoader -W -t
```

Similarly, the command:

```
WaveLoader -E -t
```

erases all waveforms, the command:

```
WaveLoader -e5 -t
```

erases the waveform number 5.

To upload a waveform, enter, for instance, the command:

```
WaveLoader -c0 5f-c.txt 5 "5sine const. ampl." -t
```

This creates a waveform with the number 0 from the file 5f-c.txt. The waveform parameter "Periods" will be set to 5, the name will be "5sine const. ampl." (for more details see section "Waveform Management").

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

Please note that the program does not request any user confirmation when manipulating the waveforms. Thus, use the list command

```
WaveLoader -W -t
```

prior to any of the waveform manipulations to ensure that you will delete or create waveforms with the proper number.

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

Tips

You can combine several command line parameters. For instance, the following command:

```
WaveLoader -W -e5 -W -t
```

lists all waveforms, erases the waveform number 5, and then lists all remaining waveforms.

To save the current device configuration, you may enter the command:

```
WaveLoader -q -W -t > WaveList.txt
```

It outputs the waveform listing into the file `WaveList.txt`. Using this file, you can restore the waveform parameters in case of any erroneous operation of the device or an operator failure.

To save all waveform data, you may create a batch file with the following contents:

```
WaveLoader -S0 0.txt -t
WaveLoader -S1 1.txt -t
...
```

By executing this file, the waveform data are saved in hexadecimal format in that they are stored in the non-volatile memory of the device.

To check the uploaded data, download the data to the host computer, for instance, by the command:

```
WaveLoader -s0 0.txt -t
```

The text file `0.txt` will contain the data in floating-point format. The data file may differ from the data originally uploaded, since the waveform samples are stored in the device using 16-bit precision.

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Tab. 3. Command line parameters of the program `WaveLoader`.

Parameter	Explanation
`-wN`	get the parameters of the waveform number `N`
`-W`	get the parameters of all waveforms
`-eN`	delete the waveform number `N`
`-E`	delete all waveforms
`-sN FileName`	save the data of the waveform number `N` into a text file with the name `FileName`, the data are in floating point format ranging from –1 to +1
`-SN FileName`	save the data of the waveform number `N` into a text file with the name `FileName`, the data are in 16-bit hexadecimal format
`-cN FileName P Name`	create the waveform number `N` from a text file with the name `FileName`, the parameter "Periods" will be `P`, the waveform name `Name`; the data are in floating point format ranging from –1 to +1
`-CN FileName P Name`	create the waveform number `N` from a text file with the name `FileName`, the parameter "Periods" will be `P`, the waveform name is `Name`; the data are in 16-bit hexadecimal format
`-mN P Name` `-MN P Name`	modify the waveform number `N`, the parameter "Periods" will be set to `P`, the waveform name will be set to `Name`
`-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

Parameter	Explanation
`-z, -Z`	purge the communication
`-i, -I`	display the port parameters read from the configuration file `COM.ini`
`-t, -T`	terminate the program
`-q, -Q`	quiet mode
`-g`	debug mode
`-G`	debug mode with output into `Debug.txt`
`-?`	show the online help

Utility FlashLoader

The FlashLoader is a simple Windows program running in text mode. It enables you to upgrade the firmware of the waveform generator. 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 Firmware.txt -v
```

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

```
Code file Firmware.txt from 06/30/2014, 12:00:00
Flash Loader 1.12
Verifying code file Firmware.txt
Verifying finished at Mon, 06/30/2014, 15:00:00
87576 (15618h) bytes processed, 87808 (15700h)
bytes verified
Resetting the target
Program finished ok
```

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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, the device is restarted.

! **Attention:** Never start the utility if the amplifier is active. The utility stops all processes running at the microcontroller, thus the monitoring is not available and the amplifier would not be deactivated if a critical situation arises. To be completely sure that the amplifier cannot be activated when the FlashLoader is active, open the interlock loop, for instance, by disconnecting the output cable.

If any error occurs, do not proceed with the firmware upgrade. To locate the reason for the error, follow the instructions described in the section "Up- and Downloading Waveforms".

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

```
FlashLoader Firmware.txt
```

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

```
Code file Firmware.txt from 06/30/2014, 12:00:00
Flash Loader 1.12
Programming code file Firmware.txt
Programming finished at Mon, 06/30/2014, 15:00:00
87576 (15618h) bytes processed, 87808 (15700h)
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 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 re-

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program 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. Should 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 and power on the device. If this small part of the firmware is still working, the flash loader will start. Then, try to launch the FlashLoader with the command line parameter '-s':

```
FlashLoader 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 HardCopy

The HardCopy is a simple Windows program running in text mode. It enables you to receive a copy of the display contents and to store it in a bitmap file. This may be useful for documentation purposes or for creating a bug report for the manufacturer. Launching the utility `HardCopy.exe` without any parameters displays a simple help text with the expected syntax of the command line.

To make a hardcopy of the current display contents, start the following command:

```
FlashLoader Image.bmp –v
```

where `Image.bmp` is the bitmap file that will be created by the utility. The utility starts and waits for the data from the device. You can interrupt it by pressing 'Esc' at the host computer keyboard. To activate the hardcopy, press, simultaneously, both vertical direction keys at the device's keypad. The device sends the hardcopy data, the utility receives it, stores, and terminates itself. If successfully finished, it should produce the following output:

```
Waiting for response, press Esc to break
Program finished successfully, bitmap file
Image.bmp created
```

If you encounter any error, follow the instructions described in the section "Up- and Downloading Waveforms".

Please note that the device may interpret the subsequently pressed direction keys and perform the corresponding action. Since the device does not use any combination of simultaneously pressed keys to control its operation, you may hold the last pressed key that opened the dialog box or menu that you wish to hardcopy. Then press one of the vertical direction keys without releasing the first key. Release the first key and press the second vertical direction key. This starts the hardcopy without invoking any other operation.

To make a hardcopy of the current display contents without waiting for the signal by the direction keys, start the following command:

```
FlashLoader Image.bmp -i
```

The device sends the hardcopy data immediately and reports:

```
Program finished successfully, bitmap file
Image.bmp created
```

Utility RemoteControl

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

To launching the utility, start the following command:

```
RemoteControl
```

The program opens a dialog box that shows the current content of the LCD at the test adapter (see Fig. 48). 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. This allows you to observe the status signals without the necessity of a direct visual contact to the front panel of the power amplifier.

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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.

Fig. 48. Utility RemoteControl.

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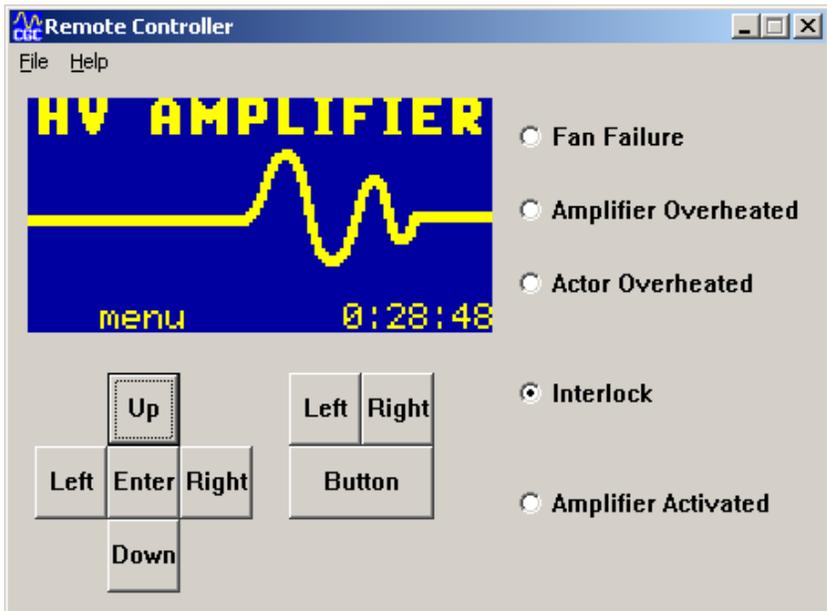
Driver Installation

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. The installation files are located in the directory "USB" of the enclosed software package. If you use the operating system Windows, please note the following:

- As an alternative to the drivers from the enclosed software package, you can 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 one of the pdf documents located in the abovementioned directory. 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*. 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 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 see the directory "USB" of the enclosed software package or 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"

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- 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
- Edit the configuration file `COM.ini` and set `PortNumber=3` (see also section "Functionality of the Software Interface")

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Software Interface

The software interface for the device consists of a 32-bit dynamic link library `COM-DAFG.dll`. It is located in the directory "Program" of the enclosed software package. The software interface is a stand-alone software package, it does not require any additional library or driver, except the virtual port driver (see section "Driver Installation").

The user functions in the dynamic link library `COM-DAFG.dll` can be called from any popular programming language. For the details, please consult the user manual of your compiler. The definition of the interface functions is located in the c-header file `COM-DAFG.h`. If your compiler cannot create an import library from the dynamic link library `COM-DAFG.dll`, please link the library `COM-DAFG.lib` instead of the dynamic link library to your project.

To simplify the integration in Pascal software packages, all functions of the software interface use Pascal calling conventions.

The sample program at the end of this section is written for the Borland C++ compiler. However, you should also be able to compile them with other C++ compilers without needing to change them.

Functionality of the Software Interface

The software interface controls one communication channel for the data transfer from/to the device. The communication channel must be opened before starting the communication. The open procedure uses the initialization file `COM.ini` to determine the virtual port parameters. It configures the used virtual serial port according to these parameters and clears the port buffers. You may need to change the virtual port number in the file `COM.ini` (item `PortNumber`) according your system settings. To do this, open the file with any ASCII editor, change the settings, and save the file.

The communication channel should be closed at the program end. If this fails to happen, the software interface does it automatically for you when the dynamic link library `COM-DAFG.dll` is unloaded from the system memory.

The return value of most interface functions contains a number describing the success of the particular operation. The return value is a signed 32-bit number (`int`). The last return value can be reloaded by

the function `COM_DAFG_State`. Table 4 summarizes the possible return values together with the error messages, which can also be obtained by the function `COM_DAFG_ErrorMessage`. If a data transfer failure has occurred, you can discover the reason by calling the functions `COM_DAFG_IO_State` and `COM_DAFG_IO_ErrorMessage`. The first one returns the last I/O error, the second one the corresponding error message (see Tab. 5.).

If you have trouble understanding the errors or establishing the communication, please contact the manufacturer of the device.

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Tab. 4. Return values of the interface functions

Return value	Error message	Description
0	No error	The data transfer finished success-fully.
-1	Error processing the `COM.ini` file	The initialization file either could not be opened or contains wrong en-tries. To obtain more details about the error, call the function `COM_DAFG_INI_ErrorMessage`.
-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.

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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.

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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	Port has already been opened	You attempted to open the communication channel that you have already opened.
3	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.
4	Cannot get the state of the port	The system could not get the state of the port.
5	Cannot set the state of the port	The system could not set the state of the port.
6	Cannot set the event mask for the port	The system could not set the event mask for the port.
7	Cannot set the timeouts for the port	The system could not set the timeouts for the port.
8	Cannot clear the port	The system could not clear the port buffers.
9	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.
10	Error writing data to the port	The system could not write data to the port.
11	Wrong data amount written to the port	The system could not write the proper data amount to the port.
12	Error setting the control lines of the port	The system could not set the state of the port control lines.
13	Error reading the status lines of the port	The system could not get the state of the port status lines.

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Communication Control

Function COM_DAFG_Open

```
int pascal COM_DAFG_Open();
```

Opens the communication channel and returns an error code according to Tab. 4.

You must call this function prior to any other communication function. If the function returns an error, no data communication is possible.

Function COM_DAFG_Close

```
int pascal COM_DAFG_Close();
```

Closes the communication channel and returns an error code according to Tab. 4.

You can use the function to free the port for another application.

If an application that has exclusively used the software interface COM-DAFG.dll finishes, the opened communication channel closes automatically. The programmer does not need to call the function COM_DAFG_Close explicitly.

Function COM_DAFG_Purge

```
int pascal COM_DAFG_Purge();
```

Clears the port data buffers and returns an error code according to Tab. 4.

The function can be used to repair a disturbed communication. In case of a user program crash, this function should be called to erase data incorrectly received from the device.

The function COM_DAFG_Purge is automatically called by the function COM_DAFG_Open.

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Function COM_DAFG_Buffer_State

```
int pascal COM_DAFG_Buffer_State
   (BOOL & empty);
```

Returns the state of the device's input data buffer in the variable `empty`. The return value is an error code according to Tab. 4.

When a large data amount should be transferred to the device, this function can be used to ensure that the input data buffer contains enough free space. If the return value of the variable `empty` is false, the input buffer is not empty and there is no guarantee that the device will be able to receive the data. This situation can occur if the device has just received a large amount of data and its processing has not yet finished. In such a case, the call to the function `COM_DAFG_Buffer_State` should be repeated after several milliseconds until the return value becomes `true`.

Function COM_DAFG_Device_Purge

```
int pascal COM_DAFG_Device_Purge
   (BOOL & empty);
```

Clears the device's output data buffer and returns the state of the device's input data buffer in the variable `empty` like the function `COM_DAFG_Buffer_State`. The return value is an error code according to Tab. 4.

The function can be used to repair a disturbed communication. If the device does not respond properly, the function `COM_DAFG_Device_Purge` should be called repeatedly until it returns the value `true` in the variable `empty`.

Waveform Management

Function COM_DAFG_DeleteWaveform

```
int pascal COM_DAFG_DeleteWaveform
   (WORD WaveformNumber);
```

Deletes the specified waveform and returns an error code according to Tab. 4.

The variable `WaveformNumber` specifies the waveform, its value must be between 0 and `COM_DAFG_WAVEFORM_NUMBER-1` (= 99). If the waveform does not exist, the function does not return any error.

Before calling this function, it is advisable to obtain the waveform parameters by calling the function `COM_DAFG_GetWaveform`. The success of the function can be also checked by the function `COM_DAFG_GetWaveform`.

Please note that the waveforms with numbers higher than `WaveformNumber` will be renumbered by this function - the numbers will be decremented to ensure a continuous waveform numbering. Further, the measurements using the specified waveform will become invalid since the waveform will not exist anymore.

Function COM_DAFG_CreateWaveform

```
int pascal COM_DAFG_CreateWaveform
   (WORD & WaveformNumber, WORD & Origin,
   WORD Size, double Periods, const char Name
   [COM_DAFG_WAVEFORM_NAME_SIZE+1]);
```

Creates a waveform with the specified number and returns an error code according to Tab. 4.

The `WaveformNumber` specifies the waveform number that should be created. The return value in this variable is the number of the waveform that has been created. For the allowed range of values for `WaveformNumber`, see the function `COM_DAFG_DeleteWaveform`. If a waveform with the specified number already exists, all waveforms with numbers higher or equal to this number will be renumbered to gain the space necessary for the new waveform. The new waveform will be inserted such that is becomes the specified number. Thus, the returned value equals to the value passed to the function. If the wave-

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form number points to the space, i.e. if the waveform with the specified number does not exist, the new waveform will be appended behind the last waveform. In this case, the number of the new waveform, i.e. the return value may differ from the specified one, that is from the value passed to the function. The easiest way to append a new waveform is to insert a waveform with the number `COM_DAFG_WAVEFORM_NUMBER-1` (= 99).

The variable `Size` specifies the size of the new waveform in samples. The value is equal to the real size decremented by one and it should not be zero. The waveform with the maximum allowable size of 64 KS (`COM_DAFG_MAX_WAVEFORM_SIZE` = 0x10000 = 65536) will be created with `Size` = 0xFFFF (65535).

The variable `Periods` specifies the number of signal periods within the waveform. This number is used when setting the device output timing to display the signal frequency. The value `Periods` does not have any direct influence on the waveform output; it is just an auxiliary number used for a user friendly frequency output. If the waveform consists of a combination of signals with several frequencies, the variable `Periods` should be set to the value that best characterizes the waveform.

The variable `Name` is a pointer to a null-terminated character string that specifies the waveform name. The maximum length of the waveform name is defined by the constant `COM_DAFG_WAVEFORM_NAME_SIZE` and equals 24 characters. The waveform name can be edited later in the device by a simple editor, however, to set it by calling the function `COM_DAFG_CreateWaveform` directly at the host computer is usually easier.

The variable `Origin` returns the address of the waveform data in the

Tab. 6. Error codes of the function COM_DAFG_CreateWaveform.

Error Code	Value	Explanation
`COM_DAFG_CRT_ERR_WAVE_NUM`	0xFFFE	no more free waveforms are available
`COM_DAFG_CRT_ERR_MEM_FULL`	0xFFFF	not enough memory space is available

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device memory. In most cases, you can ignore this value; it is intended for diagnostic purposes only. If the creation of the waveform fails, the variable `Origin` returns one of the error codes described in Tab. 6.

The function `COM_DAFG_CreateWaveform` creates the waveform only and does not setup its data. To set the waveform data, use the function `COM_DAFG_SetWaveformData`. Note: When appending a new waveform, ensure that you use the proper waveform number when calling the function `COM_DAFG_SetWaveformData`. You should use the return value in the variable `WaveformNumber` instead of the value originally passed in this variable to the function `COM_DAFG_CreateWaveform` (see above). In any case, it is advisable to repeatedly call the function `COM_DAFG_GetWaveform` in order to obtain the parameters of all valid waveforms before calling the abovementioned functions that manipulate the waveforms.

Function COM_DAFG_ModifyWaveform

```
int pascal COM_DAFG_ModifyWaveform
   (WORD WaveformNumber, WORD & Origin,
   WORD & Size, double Periods,
   const char Name
   [COM_DAFG_WAVEFORM_NAME_SIZE+1]);
```

Modifies a waveform with the specified number and returns an error code according to Tab. 4.

The function modifies the number of signal periods (variable `Periods`) and/or the waveform name (variable `Name`) and returns the parameters of the specified waveform in the remaining variables. For the description of the parameters, see the function `COM_DAFG_CreateWaveform`. If the specified waveform does not exist, the variable `Size` returns zero.

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Function COM_DAFG_GetWaveform

```
int pascal COM_DAFG_GetWaveform
   (WORD WaveformNumber, WORD & Origin,
   WORD & Size, double & Periods, char Name
   [COM_DAFG_WAVEFORM_NAME_SIZE+1]);
```

Obtains the waveform parameters and returns an error code according to Tab. 4.

For the description of the parameters, see the function `COM_DAFG_CreateWaveform`. If the waveform does not exist, the variable `Size` returns zero. Since the waveform numbers are continuous, the first waveform number returning `Size`=0 determines the origin of the free waveform space, i.e. there are no valid waveforms with higher numbers.

Function COM_DAFG_SetWaveformData

```
int pascal COM_DAFG_SetWaveformData
   (WORD WaveformNumber, WORD DataBase,
   WORD DataSize, WORD Data
   [COM_DAFG_MAX_WAVEFORM_BLOCK_SIZE]);
```

Sets the waveform data and returns an error code according to Tab. 4.

The `WaveformNumber` specifies the waveform number. For the allowed value range, see the function `COM_DAFG_DeleteWaveform`. The waveform with the specified number must already exist, otherwise an error occurs.

The variable `DataSize` specifies the number of samples that will be written. The maximum allowable value is given by the constant `COM_DAFG_MAX_WAVEFORM_BLOCK_SIZE` and equals 0x100 (256).

The variable `DataBase` specifies the offset of the data block with respect to the waveform origin. The offset is given in units of `COM_DAFG_MAX_WAVEFORM_BLOCK_SIZE` (0x100=256) samples.

The variable `Data` is a pointer to the buffer with the waveform data. The waveform data are unsigned 16-bit values (`WORD`), the data is coded as follows: The value `COM_DAFG_WAVEFORM_DATA_ZERO` (0x8000=32768) is the value corresponding to the zero output. The

value `COM_DAFG_WAVEFORM_DATA_SCALE` (0x7FFF=32767) is the waveform data scale corresponding to the unity signal. Thus, a signal value `X` normalized to unity can be converted into 16-bit values using the expression `Data` = `COM_DAFG_WAVEFORM_DATA_ZERO` + `X * COM_DAFG_WAVEFORM_DATA_SCALE`.

Note: To set the data of the whole waveform larger than `COM_DAFG_MAX_WAVEFORM_BLOCK_SIZE` (0x100=256) samples the function `COM_DAFG_SetWaveformData` must be called repeatedly. To set the data of a waveform with 64 KS, 256 calls to the function `COM_DAFG_SetWaveformData` are necessary.

Function COM_DAFG_GetWaveformData

```
int pascal COM_DAFG_GetWaveformData
   (WORD WaveformNumber, WORD DataBase,
   WORD & DataSize, WORD Data
   [COM_DAFG_MAX_WAVEFORM_BLOCK_SIZE]);
```

Gets the waveform data and returns an error code according to Tab. 4.

For the description of the parameters, see the function `COM_DAFG_SetWaveformData`. The value returned in the variable `DataSize` equals the number of data samples that have been read. It equals 0 if the waveform does not exist or if the `DataBase` points behind the waveform data. The normal return value equals `COM_DAFG_MAX_WAVEFORM_BLOCK_SIZE` (0x100=256), only for the last data segment, the value may be lover if the waveform size is not a multiple of `COM_DAFG_MAX_WAVEFORM_BLOCK_SIZE` (0x100=256).

Error Handling

Function COM_DAFG_State

```
int pascal COM_DAFG_State();
```

Returns the state of the software interface according to Tab. 4.

This function can be used to obtain the last return value of an interface function.

The function does not have any influence on the communication and can be called at any time.

Function COM_DAFG_ErrorMessage

```
const char * pascal COM_DAFG_ErrorMessage();
```

Returns the error message corresponding to the state of the software interface. The return value is a pointer to a null-terminated character string according to Tab. 4.

The function does not have any influence on the communication and can be called at any time.

Function COM_DAFG_IO_State

```
int pascal COM_DAFG_IO_State();
```

Returns the interface state of the serial port according to Tab. 5.

The function can be used to obtain the result of the last I/O operation at the port.

The function does not have any influence on the communication and can be called at any time.

Function COM_DAFG_IO_ErrorMessage

```
const char * pascal
   COM_DAFG_IO_ErrorMessage();
```

Returns the error message corresponding to the interface state of the serial port. The return value is a pointer to a null-terminated character string according to Tab. 5.

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The function does not have any influence on the communication and can be called at any time.

Function COM_DAFG_INI_ErrorMessage

```
const char * pascal
   COM_DAFG_INI_ErrorMessage();
```

Returns the error message corresponding to the COM.ini file error. The return value is a pointer to a null-terminated character string.

The function does not have any influence on the communication and can be called at any time.

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Various Functions

Function COM_DAFG_Version

```
WORD pascal COM_DAFG_Version();
```

Returns the version of the software interface (the dynamic link library `COM-DAFG.dll`).

The function should be used to check whether a software interface with the correct version is being used. The function should be called prior to any other function of the software interface.

The return value is an unsigned 16-bit integer (WORD). The higher byte contains the main version number, the lower byte the subversion, i.e. the version order within the main version. The identical main version number of two different libraries `COM-DAFG.dll` means that they implement the same functions. The difference in the subversion denotes that various corrections have been made to the interface functions. If the main version number is different, there is no guarantee that the library can be used. Mostly, the user software has to be recompiled or modified to match the new definition of the software interface.

Function COM_DAFG_GetIniParams

```
void pascal COM_DAFG_GetIniParams
   (char * Buffer);
```

Returns the parameters read from the `COM.ini` file. The parameter is a pointer to a buffer. The buffer must be large enough to store the null-terminated character string with the parameters.

Function COM_DAFG_GetUptime

```
int pascal COM_DAFG_GetUptime
   (DWORD & Seconds, WORD & Milliseconds);
```

Returns the device uptime in the variables `Seconds` and `Milliseconds`. The function return value is an error code according to Tab. 4.

The device uptime is the time elapsed from the last (re)start of the device. The function can be used, for instance, to see whether the device restarted unexpectedly.

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Function COM_DAFG_FW_Ver

```
int pascal COM_DAFG_FW_Ver (WORD & Version);
```

Returns the device's firmware version in the variable `Version`. The function return value is an error code according to Tab. 4.

The return value in the variable `Version` should be used to check whether the software interface is in an appropriate version.

The return value is similar to the return value of the function `COM_DAFG_Version`. It is an unsigned 16-bit integer (WORD) containing the main version and the subversion numbers. The software interface is compatible to the firmware if the main version numbers are identical.

Function COM_DAFG_FW_Date

```
int pascal COM_DAFG_FW_Date
   (char * DateString);
```

Returns the device's firmware date in the variable `DateString`. The function return value is an error code according to Tab. 4.

The return value in the variable `DateString` is a null-terminated character string with the firmware compilation date. The buffer passed to the function must be created before the function call, it must be at least 16 bytes long.

Function COM_DAFG_Prod_No

```
int pascal COM_DAFG_Prod_No (DWORD & Number);
```

Returns the device's product number in the variable `Number`. The function return value is an error code according to Tab. 4.

Function COM_DAFG_Prod_ID

```
int pascal COM_DAFG_Prod_ID
   (char * Identification);
```

Returns the device's product identification in the variable `Identification`. The function return value is an error code according to Tab. 4.

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The return value in the variable `Identification` is a null-terminated character string with the product identification. The buffer passed to the function must be created before the function call; it should be 81 bytes long.

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Sample Communication Program

```c
#include <stdio.h>
#include <windows.h>
#include "COM-DAFG.h"

int main()
    {
    // check the DLL version:
    if ((COM_DAFG_Version() & 0xFF00) != 0x0100)
        {
        printf ("Wrong DLL Version: expected 1.x, found %d.%02d\n",
            COM_DAFG_Version() / 0x100, COM_DAFG_Version() & 0xFF);
        return -1;
        }

    // open the port:
    if (COM_DAFG_Open())
        {
        // handle a possible error:
        printf ("%s\n", COM_DAFG_ErrorMessage());
        return 1;
        }

    // list waveforms and save them:
    for (WORD WaveNum = 0;
        WaveNum < COM_DAFG_WAVEFORM_NUMBER; WaveNum++)
        {
        // get the waveform parameters:
        WORD Origin, Size; double Periods;
        char Name [COM_DAFG_WAVEFORM_NAME_SIZE+1];
        if (COM_DAFG_GetWaveform (WaveNum, Origin, Size,
            Periods, Name))
            {
            // handle a possible error:
            printf ("%s\n", COM_DAFG_ErrorMessage());
            return 1;
            }

        // is the waveform empty?
        if (!Size)
            {
            if (WaveNum == 0)
                printf ("No waveforms found\n");
            break;
            }

        // print the waveform parameters:
        printf ("Waveform number %2hd: Size: %5d, "
            "Periods: %8.5lf, Name: %s\n", WaveNum, 1+Size,
            Periods, Name);
```

```
// generate the file name:
char FileName [0x10];
sprintf (FileName, "Wave%02hd.txt", WaveNum);

// open the file:
FILE * const DataFile = fopen (FileName, "wt");
if (DataFile == NULL)
    {
    // handle a possible error:
    printf ("Error opening the data file %s\n", FileName);
    return -1;
    }

printf ("Saving waveform %d into data file %s\n",
    WaveNum, FileName);
// loop for all data segments:
for (WORD Base = 0;
    Base <= Size/COM_DAFG_MAX_WAVEFORM_BLOCK_SIZE; Base++)
    {
    WORD DataSize;
    WORD Data [COM_DAFG_MAX_WAVEFORM_BLOCK_SIZE];
    // get a data segment:
    if (COM_DAFG_GetWaveformData (WaveNum, Base,
        DataSize, Data))
        // on error, retry the operation:
        if (COM_DAFG_GetWaveformData (WaveNum, Base,
            DataSize, Data))
            {
            // handle a possible error:
            printf ("%s\n", COM_DAFG_ErrorMessage());
            fclose (DataFile);
            return -1;
            }

    // loop for all data in the segment:
    for (int n = 0; n < DataSize; n++)
        // output the data:
        if (fprintf (DataFile, "%.6lf\n",
            double (Data[n]-COM_DAFG_WAVEFORM_DATA_ZERO) /
                COM_DAFG_WAVEFORM_DATA_SCALE) == EOF)
            {
            // handle a possible error:
            printf ("Error writing the data file %s\n",
                FileName);
            return -1;
            }
    }
```

```
    // close the file:
    if (fclose (DataFile) == EOF)
        {
        printf ("Error closing the data file %s\n",
            FileName);
        }
    }

//finish the program:
return 0;
}
```