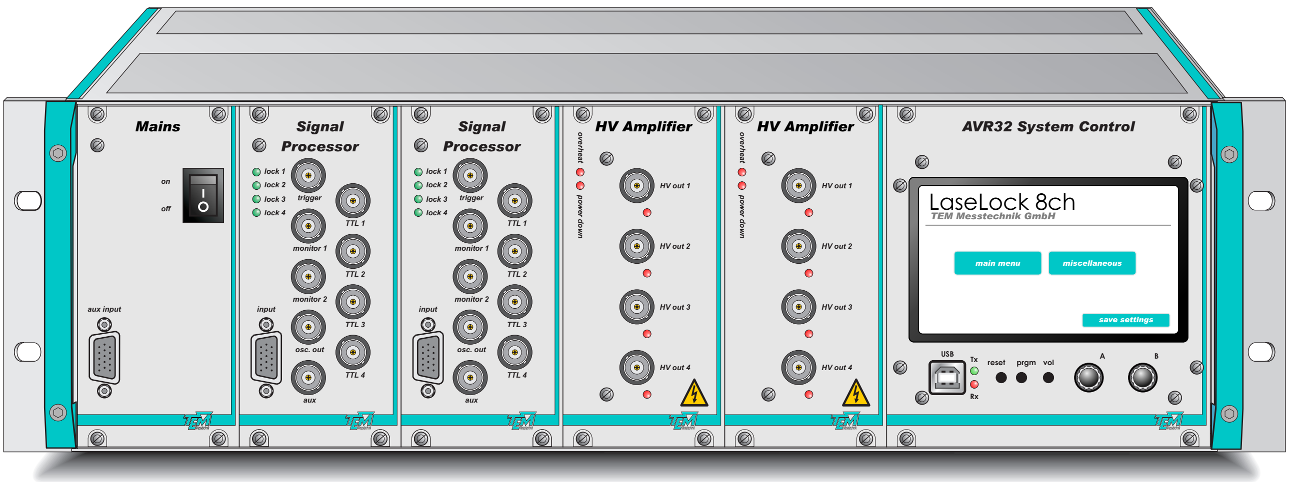
LaseLock 8ch Manual

TEM Messtechnik GmbH

February 6, 2017



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1 Product description

1.1 Principle of operation

By the help of *LaseLock 8ch* electronics, tunable lasers (like diode lasers, dye lasers or Ti:Sapphire lasers) can be stabilized in their frequency. For this, particularly optical resonators (Fabry-Prot cavities) and atomic absorption or fluorescence lines serve as references. Vice versa, also optical resonators can be stabilized towards a given laser frequency by means of mechanical actuators (e.g. piezo actuators, stepping motors). Two different methods can be applied: Side-of-fringe stabilization or top-of-fringe stabilization. Moreover, *LaseLock 8ch* can be adapted to many other regulation tasks in the laboratory.

1.1.1 Side-of-fringe stabilization

Side-of-fringe stabilization is used if a discriminator signal can be derived directly from the measurement signal, e.g. by subtraction of a fixed set value.

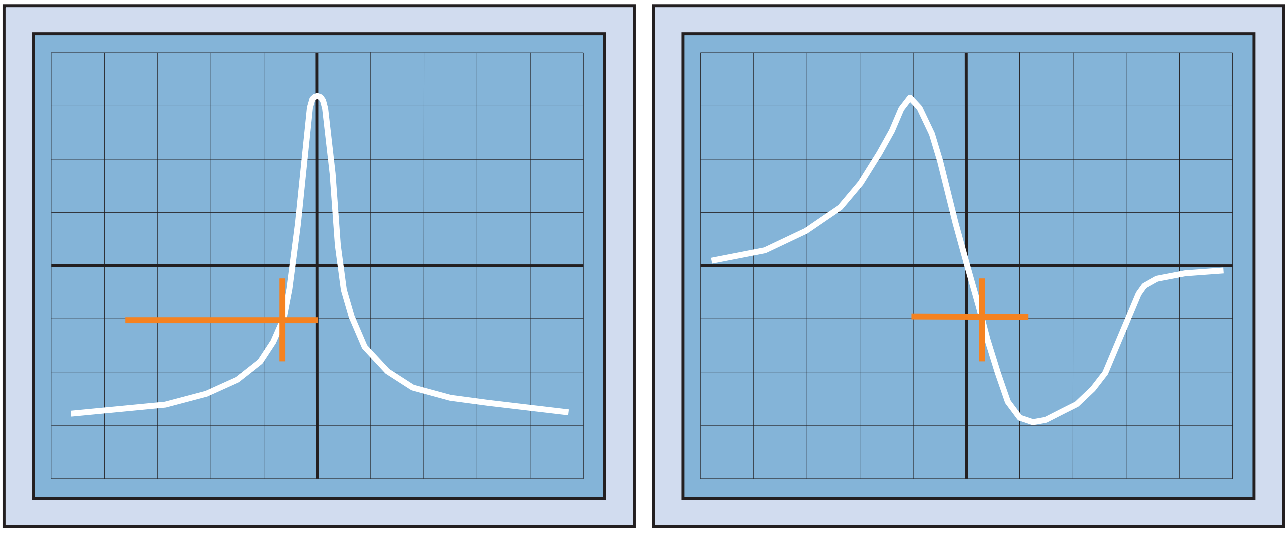


Figure 1: Side-of-fringe stabilization

1.1.2 Top-of-fringe stabilization

In contrast, top-of-fringe stabilization uses a modulation technique and phase-synchronous detection (PSD). For this, the laser frequency (or another physical dimension like the resonator length) is modulated (dithered), a detector signal is multiplied (mixed) with the modulation signal, and the multiplied signal is averaged by a low pass filter. The resulting lock-in signal represents the first derivative of the measured signal with respect to the laser frequency (or the respective varied physical dimension). Even higher order derivatives can be generated by mixing with multiples of the modulation frequency. This can be used directly for physical examinations, because in most cases it contains less disturbing signal parts (noise, offsets) than the directly measured signal does.

The zero-crossing of the derivative represents a maximum (or minimum) of the detected structure. For stabilization of a laser or resonator towards such an extremum, the lock-in signal is processed by a regulator, which generates a suitable control signal that is fed back (either directly, or for piezo actuators via a high-voltage amplifier) to the frequency-determining element of the laser (or resonator). In this way the control loop is closed and the laser (or resonator) is locked actively to the maximum (or minimum).

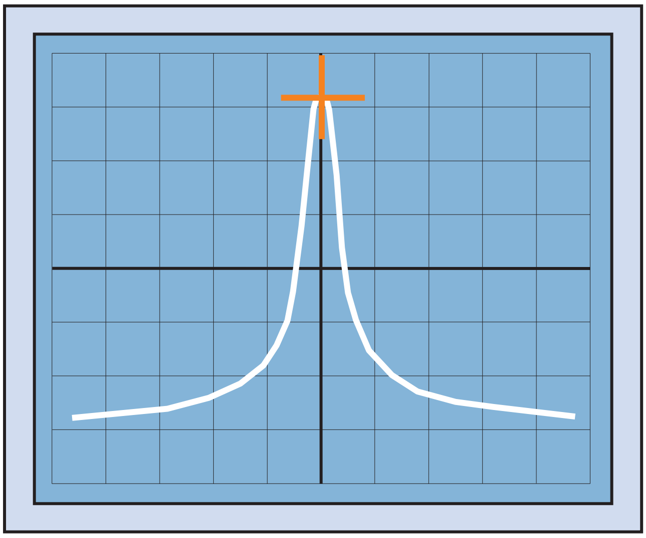


Figure 2: Top-of-fringe stabilization

1.2 Functional components

LaseLock 8ch combines all components required or beneficial for this purpose in a user-friendly compact device. Each channel of the *LaseLock 8ch* contains the following sections:

- Input section (incl. generation of difference and/or normalization signal)
- Optional: sine generator (in addition cosine generator for quadrature detection)
- Optional: phase-synchronous detection, lock-in amplifier with adjustable phase and a second order high pass filter
- PID regulator, adapted especially to resonant systems like piezo driven optical components
- Low Pass Filter (second order Butterworth filter)
- Optional: additional regulator (integrator) for motorized components
- Scan generator, for adjustment or supervision of the physical system
- Optional: drivers, on choice as high-voltage amplifier for piezo actuators, as power amplifier for magnetic or thermic actuators, current / temperature controllers for diode lasers, or stepping motor drivers

The *LaseLock 8ch* block diagram is shown in Figure 3, which gives a first overview on the function blocks, the relation of the function blocks to each other, the switching options, as well as the inputs and outputs of *LaseLock 8ch*.

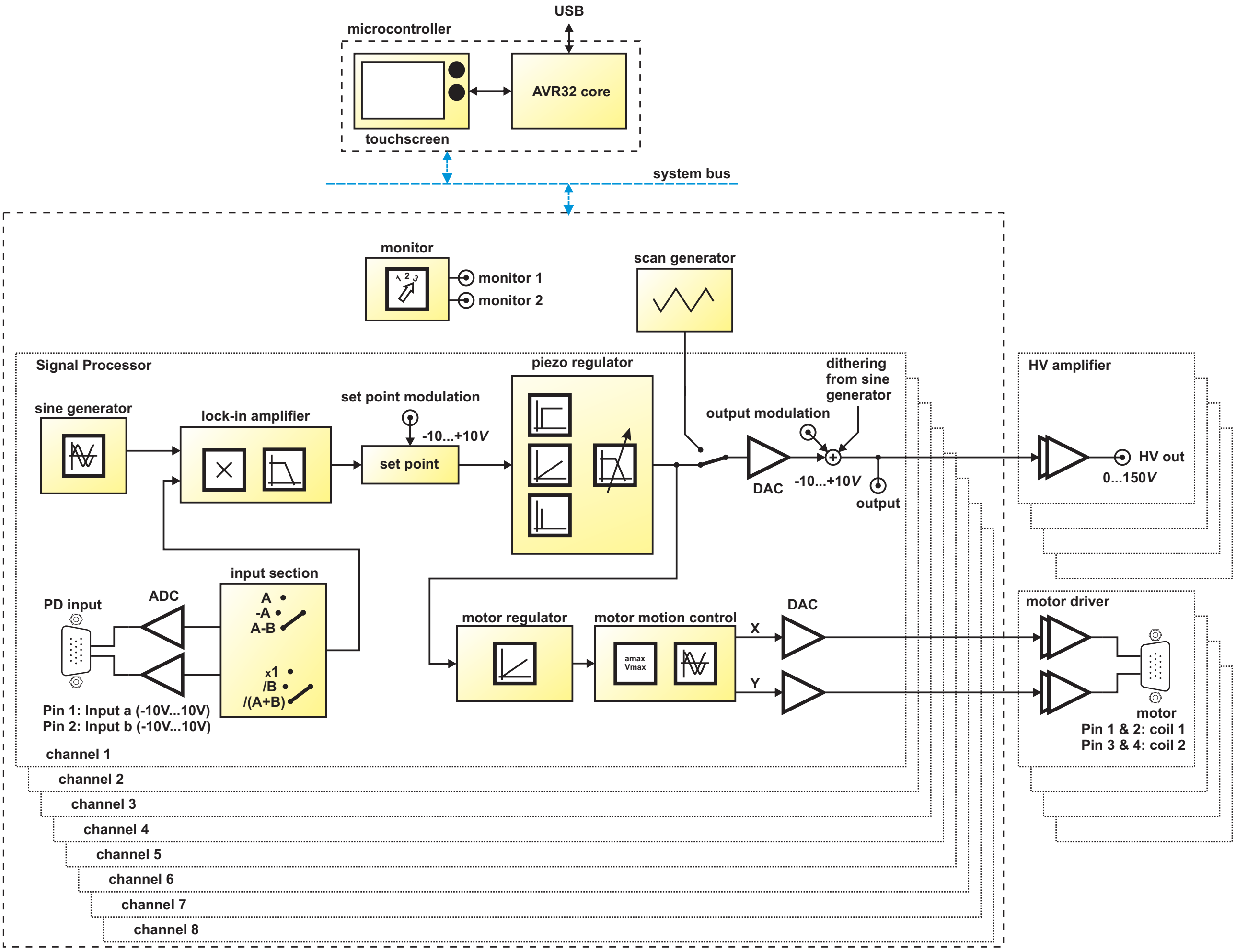


Figure 3: Schematic block diagram of *LaseLock 8ch* device

2 Safety Instructions

Before operating the *LaseLock 8ch*, please read this user guide carefully in order to avoid any damage of the device or connected equipment as well as any injury to persons.

CAUTION! The *LaseLock 8ch* device is intended for laboratory use only. The *LaseLock 8ch* device should be operated by trained personnel.

CAUTION! The *LaseLock 8ch* device is used with lasers emitting visible or invisible radiation. Do not stare into the laser beam! Take precautions to avoid exposure of direct or reflected laser radiation.

CAUTION! The user is responsible for keeping the legal rules concerning laser safety that apply in their country. In Germany, this is the "Unfallverhtungsvorschrift BGV B2" of the "Berufsgenossenschaft der Feinmechanik und Elektrotechnik".

CAUTION! Use only the supplied power adapter and plugs or the corresponding ones for your country, as only this guarantees safe operation and grounding of the device.

CAUTION! The *LaseLock 8ch* is intended for indoor operation with a temperature range of $+5°C$ to $+45°C$. Do not subject to heat, direct sunlight or the influence of other electric devices. Protect from humidity, dust, aggressive liquids and vapors.

CAUTION! The *LaseLock 8ch* should be opened by trained technical personnel only. Before opening the housing, the device must be disconnected from the supply voltage, for example by pulling the power plug.
Please keep this manual within easy reach to refer to if needed. Give your *LaseLock 8ch* to third parties only with this manual.

3 Brief description of the control elements

3.1 Front / rear panel elements

3.1.1 Power switch and fuse holder / Module: Mains

LaseLock 8ch is equipped with both primary and secondary power switches. Turning off the rear side switch disconnects the device from the lines on the primary side. This ensures zero power consumption and is recommended when the *LaseLock 8ch* is out of use for a longer period. The switch at the front panel switches the power supply on the secondary side. Before connecting *LaseLock 8ch* to the mains, we recommend to switch off both power switches.

After making the connections, turn on the main switch on the rear side first. Turn on the secondary power switch on the front panel. The green LED on the switch will indicate that the device is powered-up. Last, take your individual settings for the system parameters. In daily use, *LaseLock 8ch* is switched on and off by the front side switch.

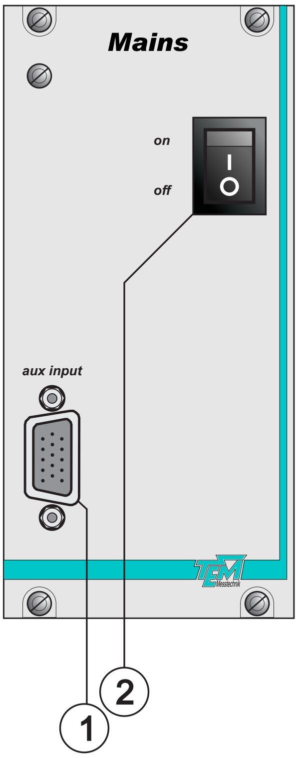


Figure 4: Module: Mains

Nr.	Description
-	Primary power switch and fuse holder (on the rear side)
1	Auxiliary signal input HD-15 connector (aux input)
2	Secondary power switch

3.1.2 Module: AVR32 System Control

The module AVR32 System Control contains an AVR based 32-bit microcontroller. The microcontroller acts as an arbitrator between the user (PC or user interface) and the FPGA. The main purpose of the microcontroller is to receive the user defined data and, if required, convert it and send it to the FPGA over the system bus.

The microcontroller can communicate to a PC via USB. The configuration and control of the microcontroller is done from a PC by sending simple commands via the communication interface. For a description of the commands see chapter 8. The commands can be sent to the microcontroller either line-based with a universal communication tool (like HyperTerminal) or more user-friendly and application-oriented with the help of the *LaseLock 8ch* application software Kangoo running on a PC.

The microcontroller also manages the user interface with colored touchscreen on the front panel. All important parameters can be controlled using menu navigation.

Figure 5: Module: AVR32 System Control

Nr.	Description
1	USB connector
2	Data transmit (green) / data receive (red) LEDs
3	Reset button
4	Program mode button
5	Volume trim
6	Multijog A
7	Multijog B
8	TFT touchscreen

3.1.3 Module: Signal Processor

The device contains an FPGA chip (field programmable gate array) connected to several ADCs and DACs for input and output of analog signals. The FPGA handles the entire signal processing, like:

- Input trimming and normalization
- PID control loop and filtering
- Motor motion control
- Monitor signal selection
- Logic operations
- Other arithmetical operations

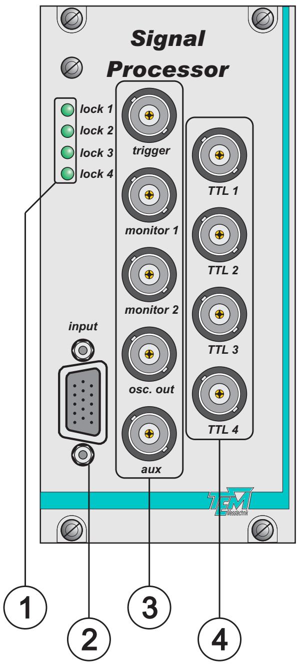


Figure 6: Module: Signal Processor

Nr.	Description
1	Status LEDs (lock 1...4). Turn on whenever the error signal of all enabled regulators is within a small range.
2	Signal input HD-15 connector (input)
3	BNC plugs: TTL trigger output BNC plug, Monitor 1, Monitor 2, oscillator output, auxiliary plug
4	TTL 1 ... 4 trigger input BNC plugs (internal pull-up to +5V)

3.1.4 Module: HV Amplifier

The HV Amplifier module contains four channel high voltage amplifier driving piezo actuators. The HV amplifier is of “class A” type and very robust against stray signals.

The standard actuators are piezo stacks with a driving voltage of 0...150 Volts. Thus the mid position is given by a driving voltage of approximately 75 Volts.

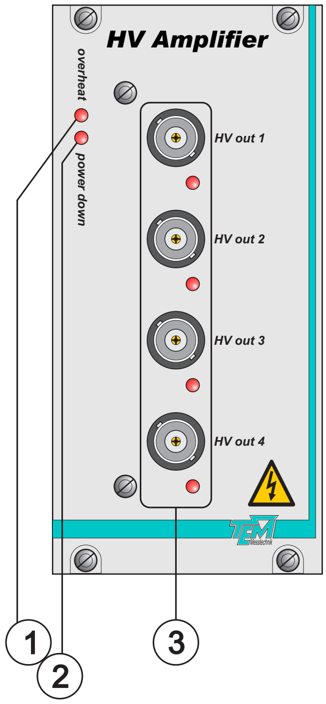


Figure 7: Module: HV Amplifier

Nr.	Description
1	“overheat” red LED: if the HV amp stage is overheated, this red LED is on, and the output voltage is switched off
2	“power down” red LED: this LED is on, when the amplifier voltage is disabled due to overheating or overcurrent
3	HV output BNC plugs (HV out 1...4) for e.g. piezo actuators

3.1.5 Module: Motor Driver

The Motor Driver module contains current drivers for up to four micro stepping motors.

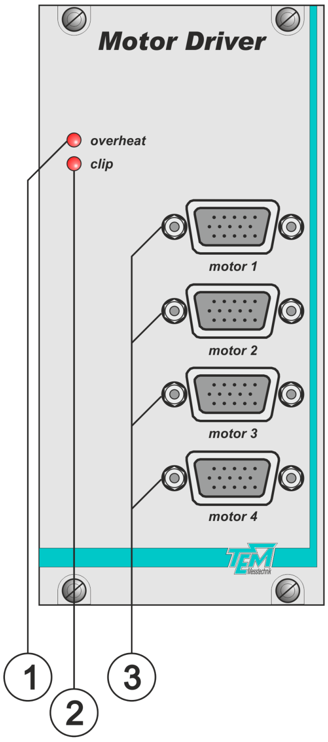


Figure 8: Module: HV Amplifier

Nr.	Description
1	Status LED "overheat". If the device is overheated, this red LED is on, and the output current is switched off
2	Status LED "clip". If the device is not able to drive the required output current, this red LED is on.
3	HD-15 connectors (motor 1...4) for the micro stepping motors

3.2 Touch screen

3.2.1 Home screen

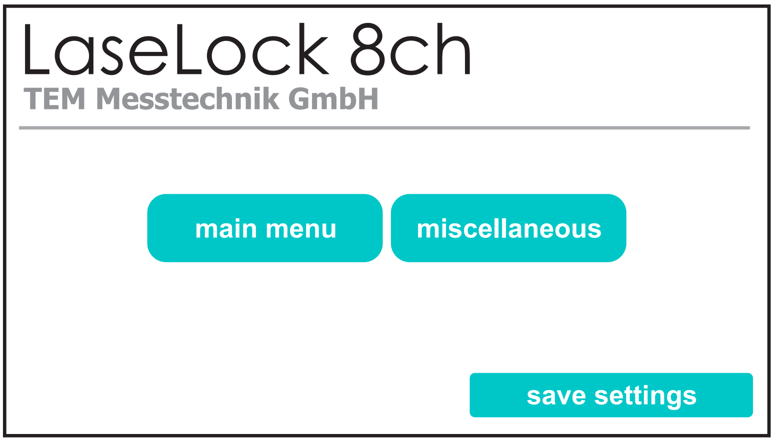


Figure 9: Home screen

The home screen of the device is shown in Figure 9 and contains following objects:

- "main menu" button enters the device menu and allows access to all parameters.
- "miscellaneous" button allows access to other general parameters of the device.
- "save settings" button allows quick saving of the parameters.

3.2.2 Regulator Settings

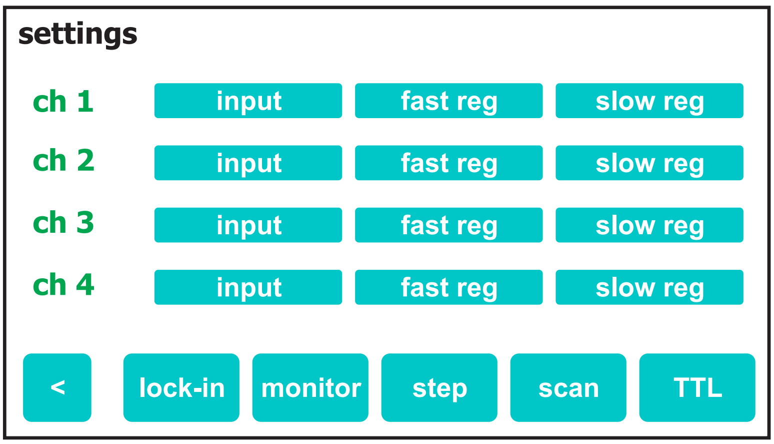


Figure 10: Main menu

The main menu of the device allows access to all parameters for every regulating channel. Furthermore other settings like lock-in amplifier, scan generator, monitor and TTL trigger settings can be accessed here.

3.2.3 Regulator Status

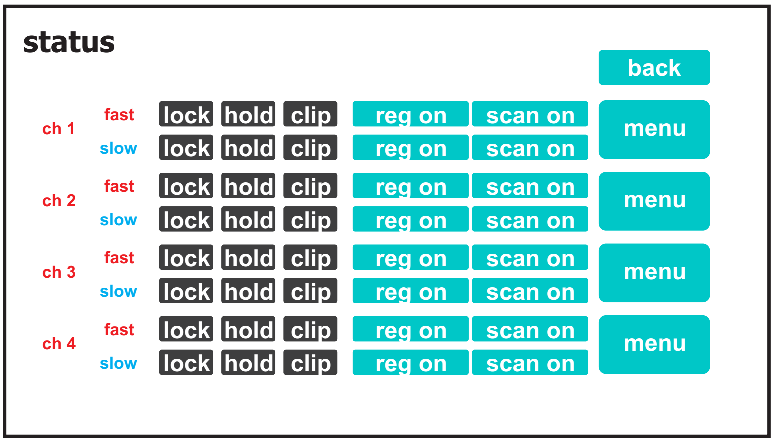


Figure 11: Status screen

The status screen is shown in Figure 11. It contains important regulator status flags and allows quick access to parameters “RegOnOff” and “ScanOnOff”. Furthermore a detailed menu can be accessed by pressing menu for more settings.

3.2.4 Display settings

To adjust display settings like LED backlight brightness or screensaver settings go to (*miscellaneous* → *display settings*)

Backlight brightness
The brightness of the LED backlight can be adjusted in 10 steps e.g. to avoid bright display illumination in dark rooms.

Screensaver
When displaying a static image for long periods of time the LCD displays can create a permanent ghost-like image. A static picture burns into the display and degrades the image quality. To prevent this burn-in effect the display becomes white after an adjusable delay time. You can return to the menu by touching the display.

4 LaseLock 8ch Getting started

4.1 Overview of Getting started

The following sections describe how to take *LaseLock 8ch* into operation from the beginning, step by step. These chapters can be used for becoming acquainted with *LaseLock 8ch*, as well as for function testing of the device. It is strongly recommended to read through chapter 3 first. A detailed description will follow later in this manual. Please start with the device disconnected and switched off.

4.2 Installation of the PC visualization software "Kangoo"

Even though the *LaseLock 8ch* device can work completely as a stand-alone device, it is very helpful and strongly recommended to use "Kangoo" for visualization and set up of parameters.

Please refer to the separate chapter on installation of the Kangoo software to your computer.

4.3 Connection of the device to main power supply

Use the cables which came with the device. If you want to use cable extenders, please contact TEM about which cables can be used.

All TEM cases and racks have an IEC power socket at the rear. Use the delivered power cord (European, German, US) for connection to the main power supply. If country-specific cables are required use high quality power cords, fitting to the local power supply outlets.

IMPORTANT! Do not use dimmed or switching power supply lines (used in UPS [Uninterrupted Power Supply] units.) They may damage the transformers or the power supply circuits.

NOTE! The power supply automatically adapts to local main power supplies of 100...120 VAC, 220...240 VAC.

4.4 Switch the device on

1. Turn on the main switch on the rear side

2. Turn on the secondary power switch on the front side (module: Mains)

3. The device will be ready to use after a short acoustical signal

4.5 Connection to PC

Please refer to the separate chapter on installation of the USB driver to your computer.

For communication over USB connect the USB plug by means of a standard USB (A-B) cable. (Please avoid cables longer than three meters, especially if strong electromagnetic fields are present in your environment). The device will appear as "TEM uC Virtual Com Port" in the device manager of your computer.

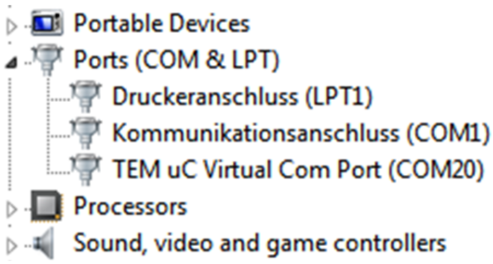


Figure 12: COM Port in the device manager

Click to "check!" in the COM Parameters windows to search for available COM ports. The COM number should appear in the drop down list next to the button on the left. The port settings like baud rate, data bits und parity settings are important for "real" COM ports e.g. RS-232. They will be ignored by the virtual COM port.

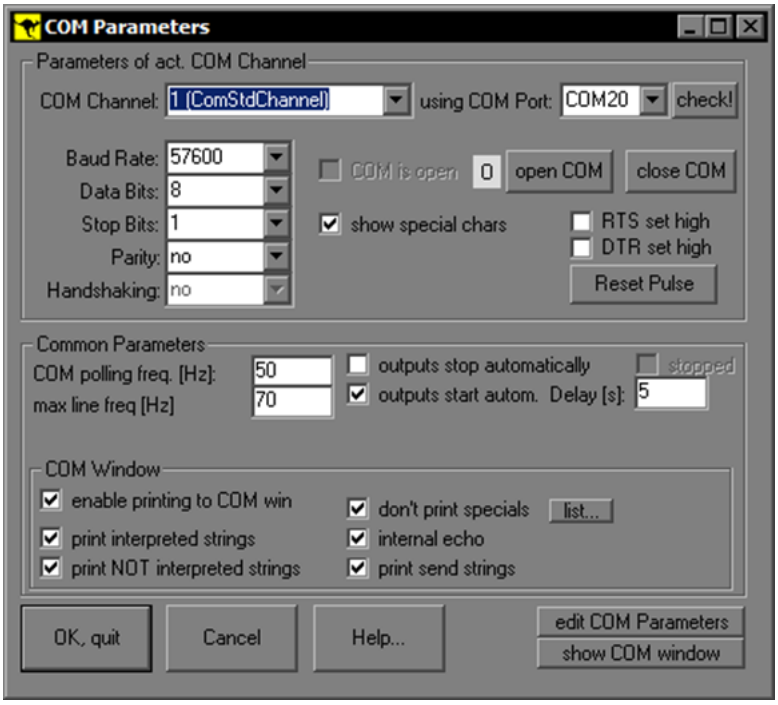


Figure 13: COM port settings

To test the communication go to the COM-Terminal window and press ‘ENTER‘. The device should answer with "no command...".

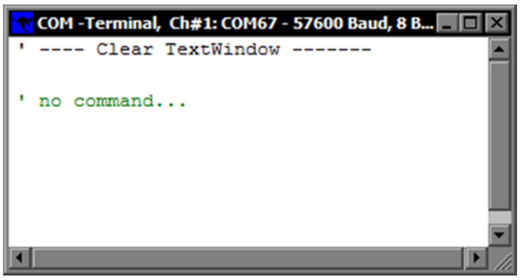


Figure 14: COM Terminal window

4.6 Taking the input section into operation (simple mode)

In the following sections, the setup of a simple control loop with one channel is described. If you are not sure about the initial settings of your LaseLock, just type the command vardefault in the PC terminal window or enter *menu* → *misc.* → *restore factory settings*. This will reset all internal parameters to factory settings.

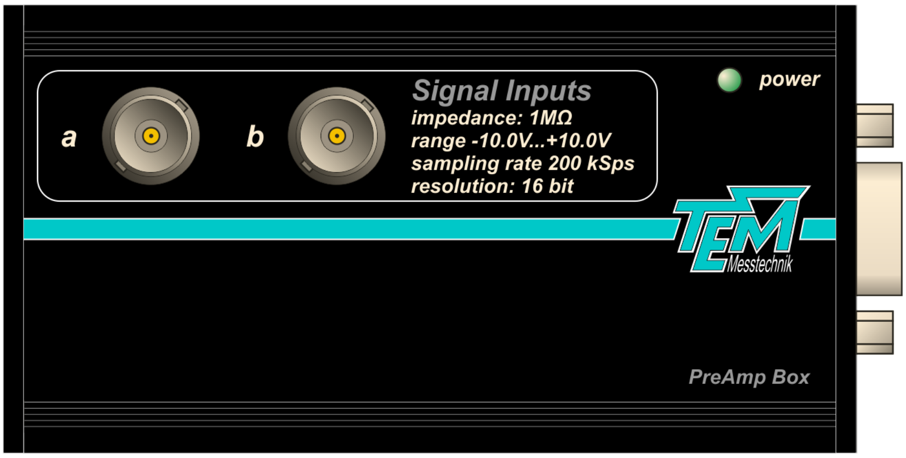


Figure 15: PreAmp Box for input signals

1. Connect the signal sources (e.g. Photo Diode Receiver) to the BNC connectors "a" and "b" of the PreAmp Box shown in the Figure 15. The amplitude of the signals at input a and input b should be in the range of ten volts (-9...9V). Signal amplitudes up to +/-15V will not damage the device. Unused inputs must be short-circuited to the shield or closed with a 50Ω resistor. All inputs have an input impedance of 1MΩ.

2. Connect an oscilloscope to the BNC jacks "monitor 1, 2" on the front panel.

3. Choose the input signal for monitor line nr. 1 either by PC control (Kangoo) or by the touch panel menu: *menu* → *monitor* → *monitor1* → *input A1 raw*. Leave this menu by pressing "<".

4. Choose the and the output signal for monitor line nr. 2 in a similar way: *menu* → *monitor* → *monitor2* → *output 1*.

4.7 Taking the output section and scan generator into operation

1. Connect your system (laser, Fabry-Prot cavity, SHG ring cavity, ...) to the output BNC jack of the *LaseLock 8ch* (Module "Output"). When using the HV amp option, you will find the amplified signals provided on separate BNC jacks on the module "HV Amplifier". Please check that your system complies with the output voltage range of *LaseLock 8ch*!

2. Choose an appropriate scan frequency for your system: *menu* → *scan* → *scan frequency*, then turn the knob.

Remark: By turning the wheel while it is pressed you can select the digit you want to change. The curser marks the actual digit which can be changed by the help of the wheel.
Leave this menu by pressing "<".

3. Switch on the scan generator for output 1: *menu* → *scan* → *couple to piezo reg* → *couple to piezo reg 1*. A triangular signal will now show up on the oscilloscope, representing the scanned output signal.

4. The monitor channel 1 on the scope should now show the reaction of the scanned system (i.e. fringes from a Fabry-Pérot cavity).

5. Enter the *menu* → *scan* → *scan offset piezo* → *scan offset piezo 1* to adjust the output offset. This will shift up and down the scan ramp.

6. Enter the *menu* → *scan* → *scan width piezo* → *scan width piezo 1* to adjust the output range. This will influence the scan amplitude. Please note that the scan range also defines the output voltage range that later on can be addressed by the regulator. It is displayed as percentage of the full output voltage range.

7. Now change the oscilloscope display to normalized signals: Set the monitor channel 1 to the combined and normalized input signal: *menu* → *monitor* → *monitor1* → *Norm input 1*. Later in this manual we describe how to configure complicated arithmetic operations on the two input signals. Here, Norm input 1 is simply equal to input signal a. Set the monitor channel 2 to Reg out 1: *menu* → *monitor* → *monitor 2* → *Reg out 1*. This will scale the output range to +/-10V on the oscilloscope, independent from the true output range. It is recommended to switch your scope to XY-Mode, as this will display the output signal in X and the input signal in Y direction.

8. Now you can play with "offset" and "width" as in 5. and 6., in order to get familiar with the display.

4.8 Taking the lock-in amplifier into operation

You may skip this section if you plan a side-of-fringe lock.

1. Set the monitor 1 to "Error 1".

2. Check that the input signal on the oscilloscope is not distorted. Otherwise reduce the scan frequency or increase the cut-off frequency of the low pass filter in the input section: *menu* → *(ch1) input* → *input cut off*.

3. Choose an appropriate dither (modulation) frequency for your system (*menu* → *lock-in* → *osc. frequency*).

4. Increase the dither amplitude (*menu* → *(ch1) piezo reg* → *piezo output* → *dither. ampl.*), until the fringes on the oscilloscope broaden.

5. Switch to the demodulated signal (derivative) by choosing first harmonic demodulation (*menu → (ch1) input → lock-in harmonic*, then adjust the parameter to "1").

6. Now, the derivative signal should show up as filtered signal on the oscilloscope. Please note that the time constant of the lock-in amplifier is determined by the cut off frequency of the input filter (see 2.).

7. Adjust the demodulation phase (*menu → (ch1) piezo reg → piezo output → phase shift*) then adjust the phase in a way that the lock-in signal gets its maximum amplitude.

8. Increase the input filter gain (*menu → (ch1) input → input filter gain*) to get the derivative in the same voltage range as the input signal.

4.9 Taking the PID regulator into operation

1. Set the monitor 1 to "Error 1".

2. Adjust the parameter "Set Point" (*menu → (ch1) piezo reg → settings → set point*) to the required regulation value. This value should be as near as possible to the middle of the scan/regulating area, i.e. in the center of the scan ramp.

3. Select the appropriate regulator sign (*menu → (ch1) piezo reg → settings → sign → positive or negative*). When set to "positive" LaseLock will regulate to a positive edge of the error signal.

4. Stop the scan (*menu → (ch1) piezo reg → scan on/off*). The scan will stop at the middle of the output range (0V on the oscilloscope).

5. Switch on the PID loop (*menu → (ch1) piezo reg → reg on/off*). However, the regulator will not do anything yet!

6. As a final step, increase the I coefficient (and after that, the P and the D), until you get a stable lock. Details for a good PID adjustment are given later in this manual: *menu → (ch1) piezo reg → settings → I gain (P gain, D gain)*.

4.10 Taking the motor regulator into operation

The motor regulator can be used to control a slow servo actuator with a higher working range, in order to keep the piezo in its center position.

1. While the piezo regulator is active, carefully move the motor by changing the motor output offset (*menu → (ch1) motor reg → motor output → offset*). The piezo regulator will compensate for this movement, thus changing its output voltage (X channel on the oscilloscope).

2. Press to "here is zero!" in the motor output menu. This will define the actual motor position as center of its working range.

3. To choose the right regulator sign observe the moving of the piezo regulator output while turning the motor offset. When you move the offset in the positive direction and the piezo regulator output moves in the negative (to the left) choose negative regulator sign. *menu → (ch1) motor reg → settings → reg sign*
4. As a final step, increase the I coefficient of the motor regulator. As long as the piezo voltage is within a window of 30...70% the motors a kept still, in order to avoid mechanical noise. The windows size can be adjusted here: *menu → (ch1) motor reg → settings → error threshold*

4.11 Saving the settings

In order to keep the new settings you made, press "save settings" on the home screen before power down.

5 Detailed Description

5.1 Description of the functional blocks

5.1.1 Overview

The *LaseLock 8ch* block diagram is shown in Figure 16 which gives a first overview of the inputs and outputs of *LaseLock 8ch*.

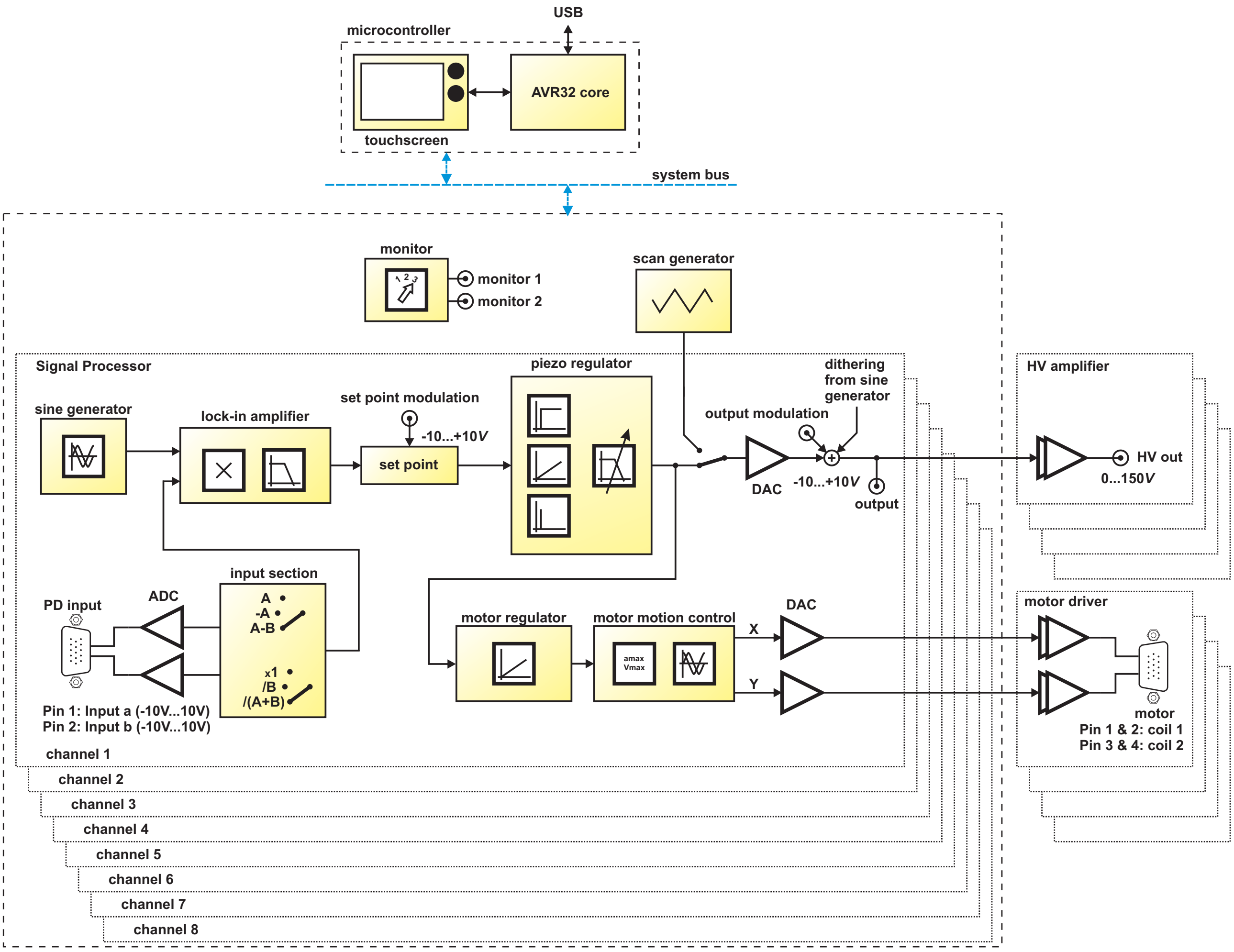


Figure 16: Schematic block diagram of *LaseLock 8ch* device

5.1.2 Input section

There are two input signals at the "PD input" HD-15 connector Input a (pin 1) and Input b (pin 2). In the following, these signals are referred to as raw signals.

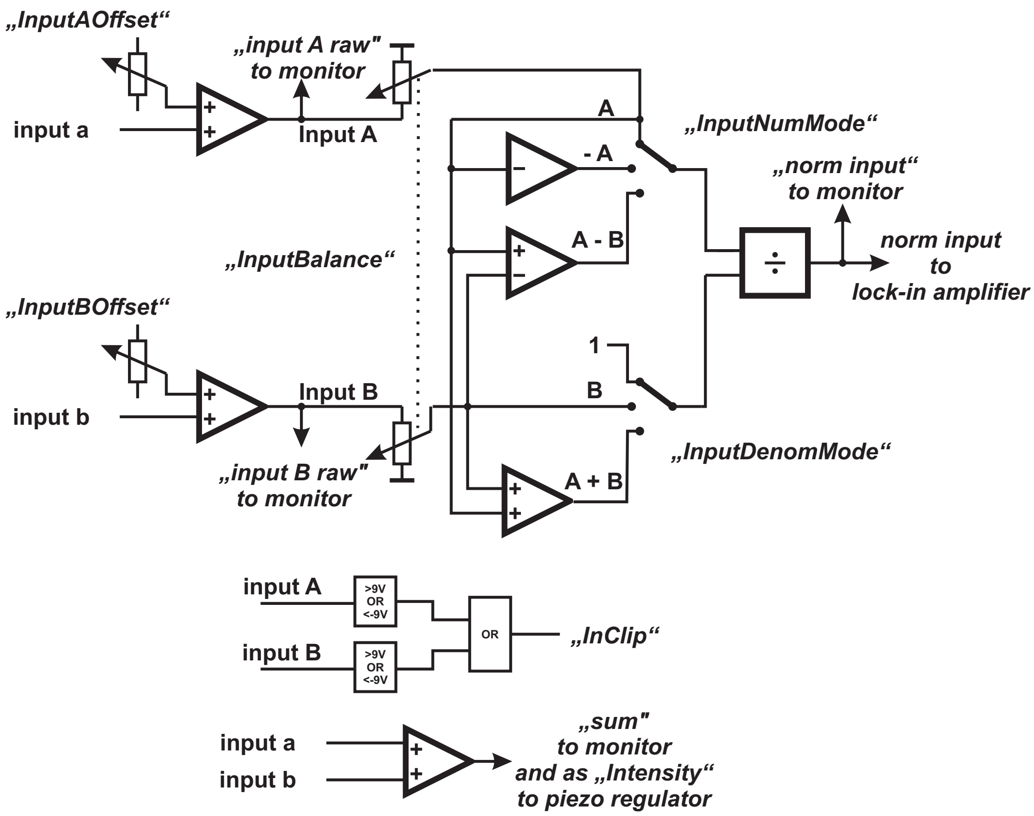


Figure 17: Block diagram of the input section (simple mode)

The offset value for each raw input signal can be trimmed independently by the parameters "InputAOffset" and "InputBOffset".

The actual regulator input signals are obtained from the raw signals by linear combination and/or division. This process is referred to as normalization. The user can define the combination by the help of following parameters:

- "InputNumMode" (a, -a, a-b) sign and/or difference of the input signals
- "InputDenomMode" (1, b, a+b) denominator for the normalization
- "InputBalance" (-0.8...0.8) balance value between input a and input b

The parameter "InputDivisionGain" defines the binary gain of the division, which determines the dynamic range of the division. It is necessary to adjust this correctly, because the signals are digitally processed and are therefore subject to a limited numerical resolution. Make sure to adjust this parameter in a way that the normalized signal is as large as possible without clipping.

5.1.3 Lock-in amplifier section

The lock-in amplifier section allows a phase-sensitive detection of the input signal and thus its differentiation with respect to a dithered parameter. This section consists of a quadrature (sine and cosine) signal generator for the dither signal, and two independent product mixers that perform the amplitude and phase detection.

The quadrature signal generator in combination with a pair of mixers offers the advantage that the phase shift of the input signal can be detected directly, so that the phase can be adjusted easier. Alternatively, the second mixer can calculate the derivative of an independent input signal.

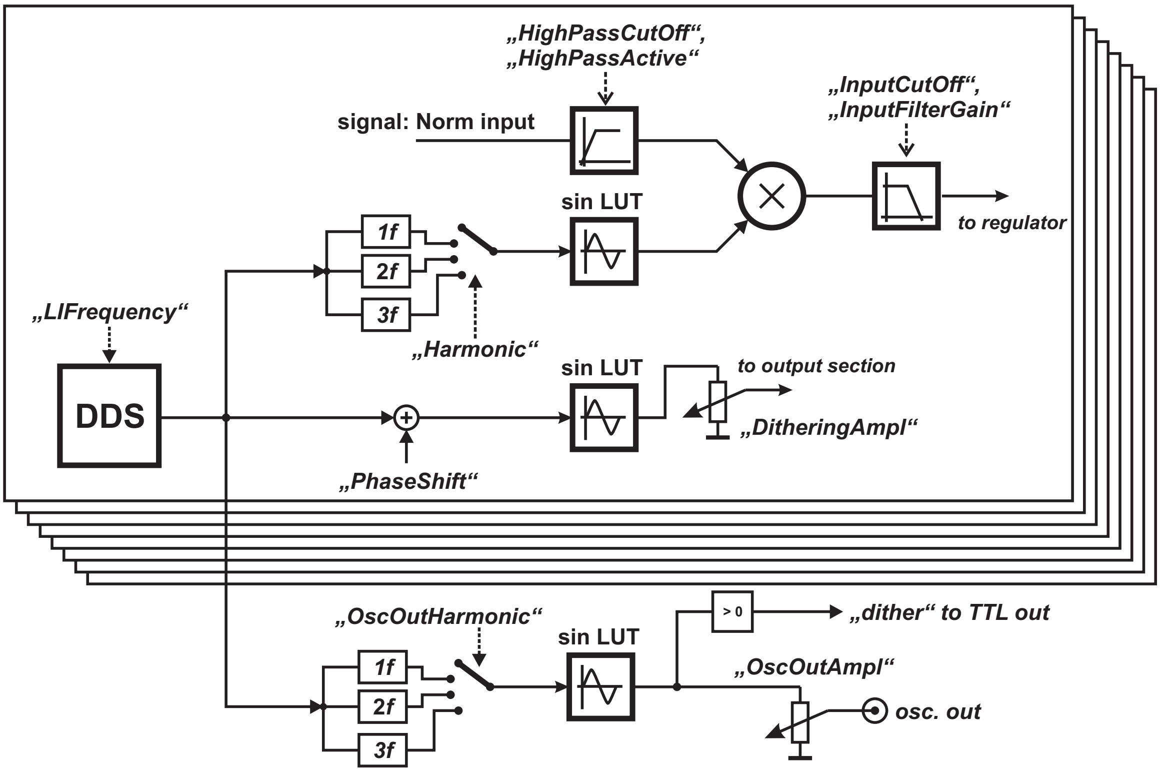


Figure 18: Block diagram of the lock-in amplifier section

In usual phase-sensitive detection, the high pass filtered input signal is multiplied with the dither signal and then low-pass filtered. However, *LaseLock 8ch* offers the possibility to multiply with the frequency-doubled or frequency-tripled dither signal by selecting the "Harmonic" parameter. Setting this parameter to 0 disables the phase-sensitive detection, thus forwarding the unchanged input signal to the low-pass filter.

The parameter "DitheringAmpl" defines the amplitude of the dither signal that appears at the output.

The frequency of the quadrature signal generator can be adjusted by the help of the parameter "LIFrequency".

The cut-off frequency of the low pass Butterworth filters at the mixer output can be adjusted by the parameter "InputCutOff". This filter can be used for demodulation or bandwidth reduction.

The dither signal is also aplied on the BNC plug "osc. out" (Module "Mains") for external demodulation. The harmonic and the signal amplitude can be adjusted by the help of the parameters "OscOutHarmonic" and "OscOutAmpl".

5.1.4 Set point

The difference of the actual regulator input signal to an arbitrarily chosen "set point" value serves as "error signal" for the regulator loop. The set point is given by the parameter "RegSetPoint". The parameter "RegSign" selects the sign of the error signal.

The parameter "Locked" indicates that the error signal of the activated regulator is within a small range around zero (defined by the parameter "LockThreshold").

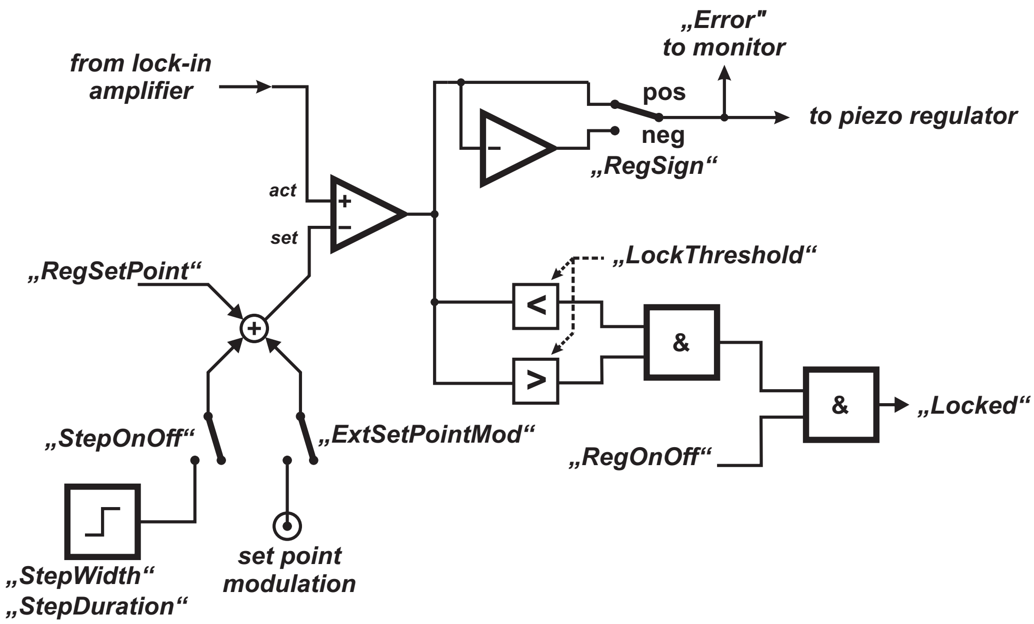


Figure 19: Block diagram of the set point section

In addition, the internal set point value can be modulated. By enabling the parameter ExtSetPointMod the voltage at the corresponding BNC plug set point modulation on the aux input module will be added.

To observe the step response of the regulator and set up the regulator gains, a square signal can be added to the set point value by enabling StepOnOff parameter. The amplitude and the cycle time of the square signal can be defined by the following parameters:

- "StepAmpl": the peek-to-peek amplitude of the signal.
- "StepDuration": cycle duration of the signal in milliseconds.

Please refer to chapter 6 for a description how to adjust the PID values. Do not forget to disable "StepOnOff" once you have finished the PID adjustment.

5.1.5 Regulator section

The regulator section includes two regulators and controls the main servo loop functionality. The "error" signal enters the piezo regulator section.

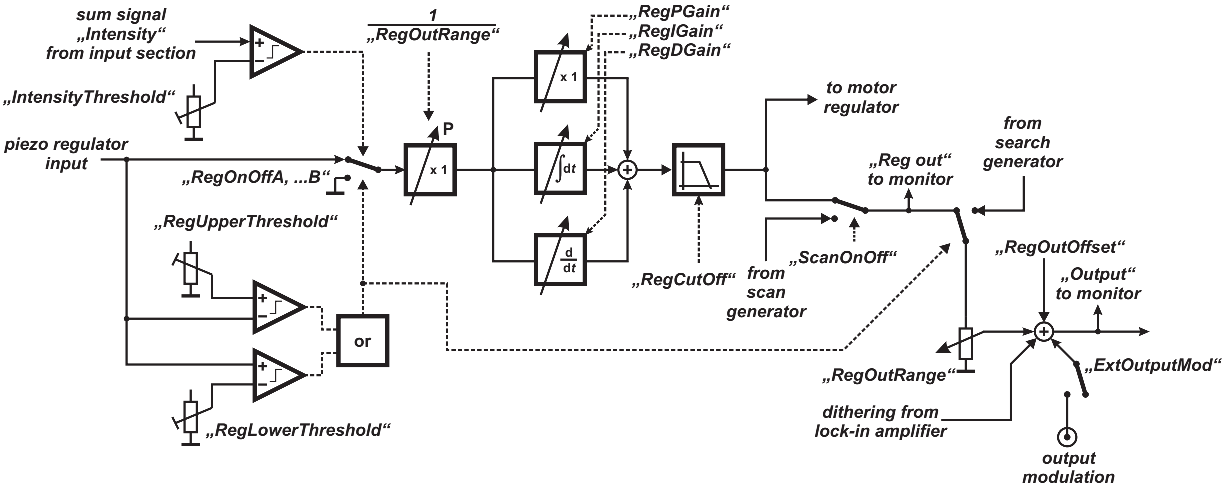


Figure 20: Block diagram of the piezo regulator section

Output range

The parameters "RegOutOffset" and "RegOutRange" define the operating range of the regulator, i .e. the voltage range of the output that can be addressed by the regulator output.

Relock

If the regulator output is driven to either limit of the operating range, the control logic will take a user-programmable action, which is selected by the parameter "RegRelockMode".
You can choose following relock modes:

- Stop: regulator holds the output value
- Relock: regulator jumps to the opposite relock value
- Left relock: regulator jumps always to the left relock value
- Right relock: regulator jumps always to the right relock value

"RegRelockValue" defines the relock range as a percentage of the operating range.

Reset

The parameter "RegOffMode" defines the behavior of the regulator output after disabling. You can choose the following modes:

- Hold: regulator holds the last output value
- Reset: regulator jumps to the user defined reset value defined by "RegResetValueA"

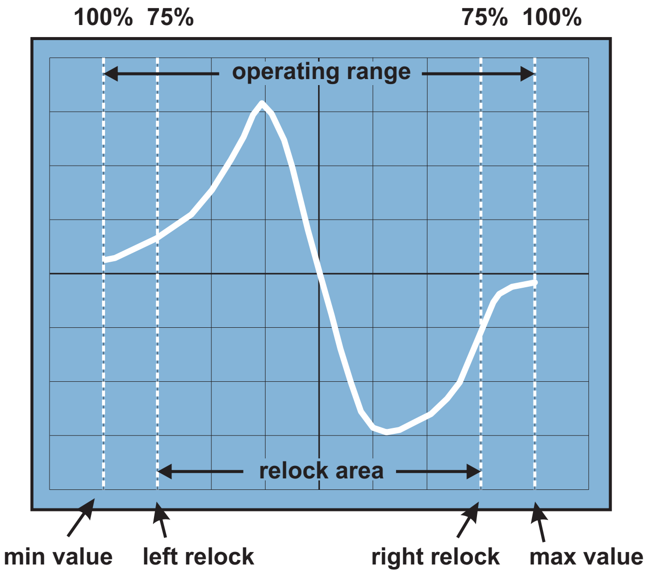


Figure 21: Display of the input signal vs. the output signal, which is applied to the controlled system. Explanation of the operating range and the relock range (example: relock = 75%)

Search logic

The search logic distinguishes valid from invalid regulation ranges: A user-selected normalized input signal is compared to a voltage window given by the parameters "RegUpperThreshold" and "RegLowerThreshold". If the input signal is outside the window bounds for a time greater than "SearchTimeOut", a user-programmable action is taken, depending on the parameter "RegSearchMode". You can choose the following search modes:

- "off": The servo loop remains closed if the signal is out of window
- "search": The servo loop is opened and a search scan starts at the present regulator output voltage
- "left relock & search": The servo loop is opened and the regulator output is set to the left relock value and then starts searching
- "right relock & search": The servo loop is opened and the regulator output is set to the right relock value and then starts searching

During a search scan, a triangle voltage is passed to the regulator output in order to "search" for a valid region. The rise time of the output voltage during the search scan is adjustable by the parameter "RegSearchSpeed".

As soon as the input signal enters the window again, *LaseLock 8ch* closes the loop.

Hold

In order to prevent irregular loop behavior upon loss of laser power, a intensity signal (sum of input a and b) is compared to a threshold value “IntensityThreshold”. If the intensity is below the threshold, the servo loop is opened while regulator output is “frozen” at the actual integrator value without starting a search scan. This function can be used to stop the regulator when the laser intensity drops.

If the criterion signal becomes greater than the threshold value for a time defined by the parameter LowIntensTimeOut, the servo loop is closed again.

Piezo Regulator
The piezo regulator is represented by the PID elements the low pass filter. The second order Butterworth filter (selectable as a low pass or a high pass) limits the bandwidth of the servo loop if necessary. This is important when regulating systems that tend to resonate (e.g. piezo-mechanical set-ups). It is therefore recommended to set the cutoff frequency to a value well below the resonance frequency of the set-up. This in turn allows increasing the D coefficient of the regulator, which is required for tightly locking inert actuators. The filtered error signal is amplified (P-coefficient), integrated (I-coefficient) and differentiated (D-coefficient), adjustable by the parameters “P-, I-, D-Gain”. To keep a constant loop gain, the regulator input is multiplied with the inverse value of the output range.

Motor Regulator
A motor regulator can be used to control a slow servo actuator (e.g. micro stepping motor) with a larger control range. This regulator uses the output value of the piezo regulator as error signal. In this combination the piezo regulator is always working, because they have a higher resolution. They will work with rather high speed. However, the piezos have a limited small stroke. Even rather small drifts will drive the piezos to their limits. The additional motor regulator will keep the selected piezo regulator output in their mid-position. If the piezos remain in their mid-positions the motorized actors will keep in rest to achieve less noise by moving. The parameter “MRegErrorThreshold” defines the piezo output value when the motor servos will start working.

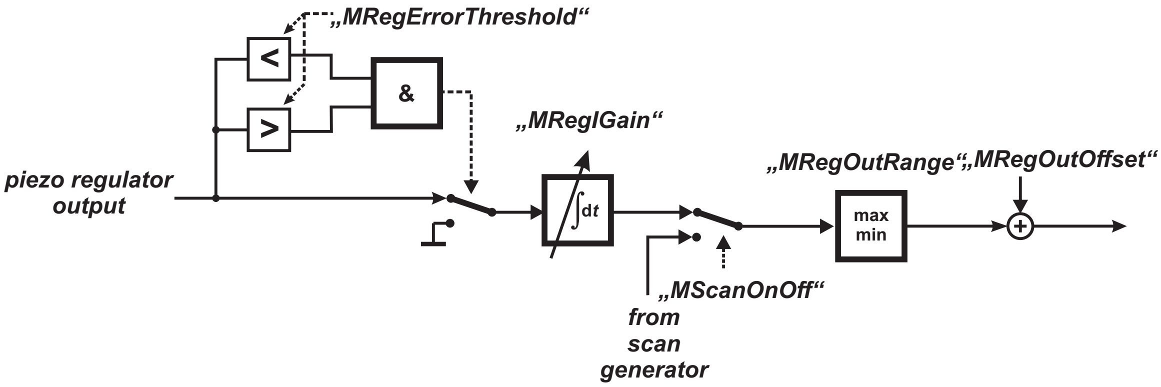


Figure 22: Block diagram of the motor regulator section

5.1.6 Scan generator

The built-in scan generator generates a signal with triangular or saw tooth waveform. The scan signal can be used e.g. for identifying the search area for atomic resonances, or for system alignment.

Each regulator output can be individually coupled to the scan generator by enabling the parameter "ScanOnOff". To avoid jumps the scan generator will be coupled first when the scan signal crosses regulator output.

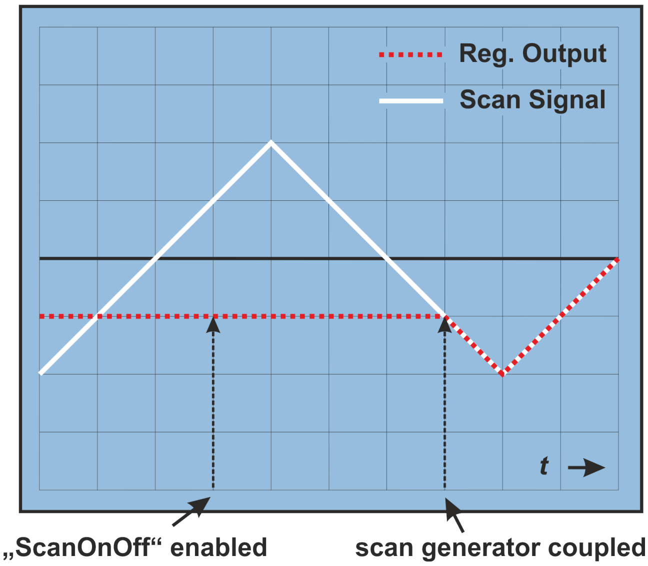


Figure 23: Scan on behavior

After disabling of the parameter "ScanOnOff" the scan generator will remain coupled to the output the signal crosses zero.

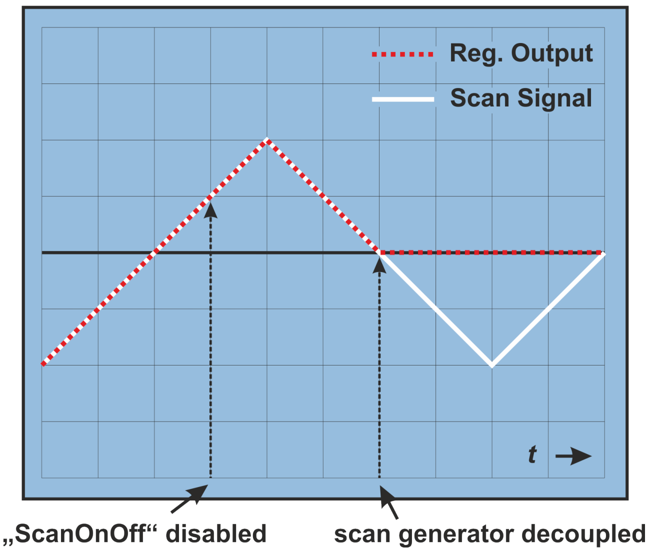


Figure 24: Scan off behavior

The frequency of the scan signal can be defined using the "ScanFrequency" parameter in a range of 0.1...5000 Hz.

5.1.7 Monitor section

The oscilloscope connectors monitor 1 and monitor 2 give access to internal signals depending on the selection in the menu section MonitorSelect1 and MonitorSelect2. Here you can choose between the following signals:

- Input A raw (raw signal on input A, incl. offset)
- Input B raw (raw signal on input B, incl. offset)
- Norm input (normalized signal)
- Sum (sum signal or input a and input b without offsets)
- Error (difference between the set point and the regulator input signal)
- Reg out (output signal of the PID regulator)
- Output (output signal)

5.2 Connection to PC

Please refer to the separate chapter on installation of the USB driver to your computer.

For communication over USB connect the USB plug by means of a standard USB (A-B) cable. (Please avoid cables longer than three meters, especially if strong electromagnetic fields are present in your environment). The device will appear as "TEM uC Virtual Com Port" in the device manager of your computer.

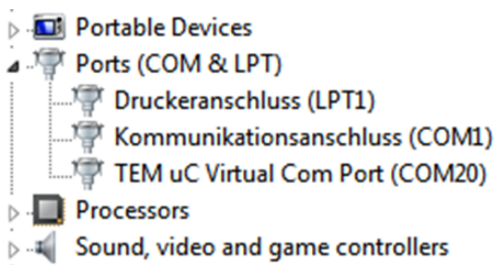


Figure 25: COM Port in the device manager

Click to "check!" in the COM Parameters windows to search for available COM ports. The COM number should appear in the drop down list next to the button on the left. The port settings like baud rate, data bits und parity settings are important for "real" COM ports e.g. RS-232. They will be ignored by the virtual COM port.
To test the communication go to the COM-Terminal window and press 'ENTER'. The device should answer with "no command...".

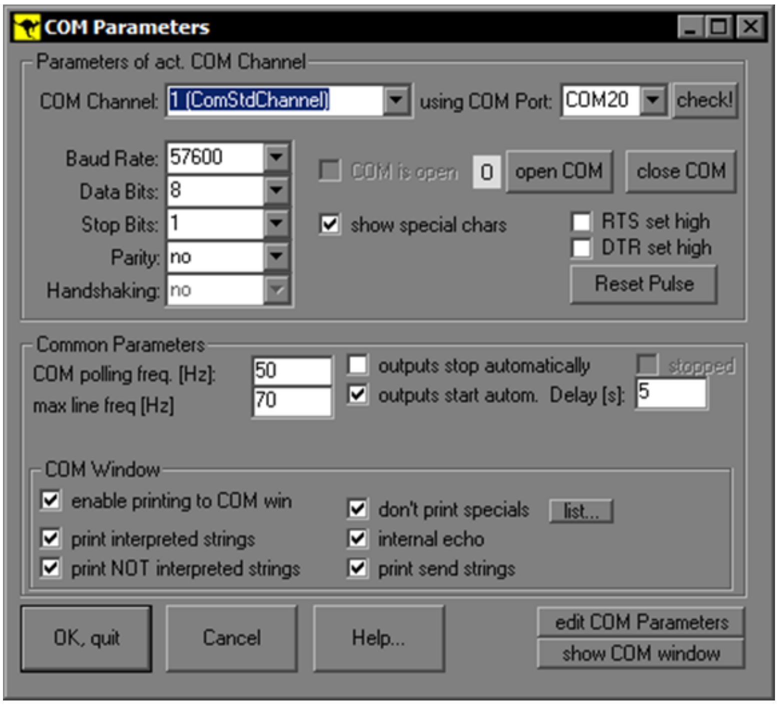


Figure 26: COM port settings

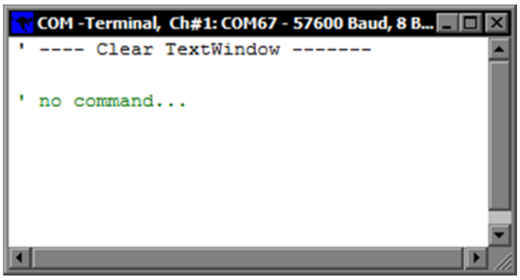


Figure 27: COM Terminal window

5.2.1 Using Kangoo "LaseLock 8ch digital" standard configuration

When you have installed and started the Kangoo Software, you will be greeted by a welcome screen which lets you choose the Main Menu Configuration (the Kangoo software can handle a large variety of different hardware modules). Please choose LaseLock Multichannel.

The basic configuration will look as follows:

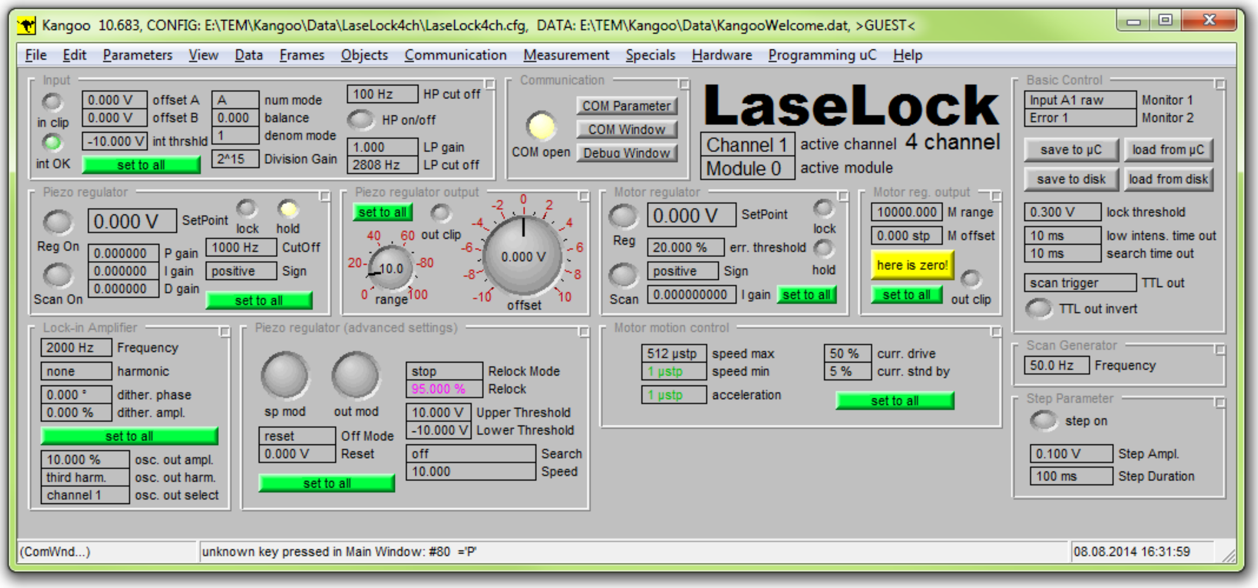
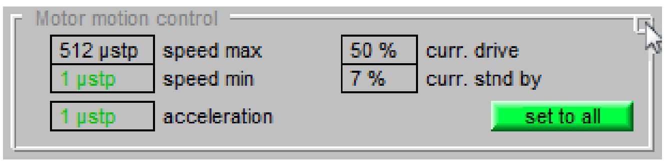
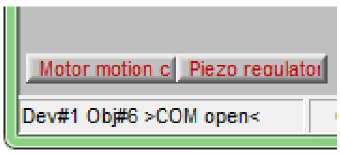


Figure 28: LaseLock digital standard configuration

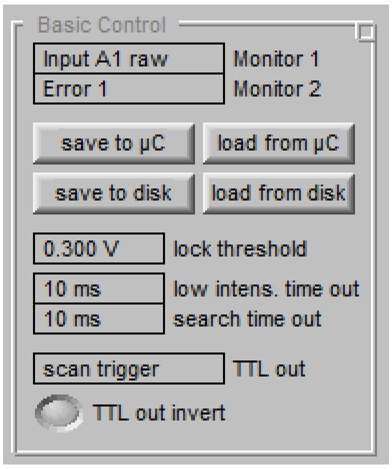
The interaction between the user and the program is (apart from the menu line) mainly realized by "buttons" and "devices". They allow visualization and control of the microcontroller based device.

The configurations are normally separated into sections for more clearness and convenience. Some sections contain parameters, which are not needed all the time, just for setting once, or which are used seldom. By clicking the upper right "close" button the section window will be shrunk to a small button at the bottom line of the user screen. The section window can be re-sized by clicking to the shrunk button.



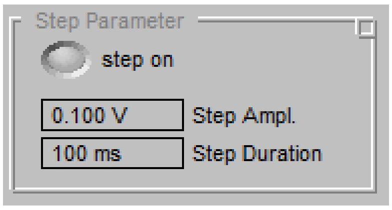


Section: “Basic Control”



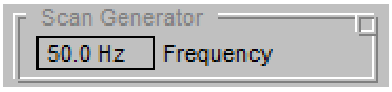
Monitor 1 / 2	Monitor signal selection
save to μC / load from μC	These two buttons save or load all current settings in the microcontrollers non-volatile memory. These saved values are loaded automatically at startup.
save to disk / load from disk	These two buttons save or load all current settings in the hard disk of your computer.
low intens. time out	Defines the time the intensity should be above the threshold value to reactivate the regulator
relock time out	Defines the time the input signal should be outside the window defined by the upper and the low threshold to hold the regulator start to search for valid lock point
TTL out	Signal selection on TTL out BNC plug
TTL out invert	Allows invertion of the TTL out level

Section: “Step Parameters”



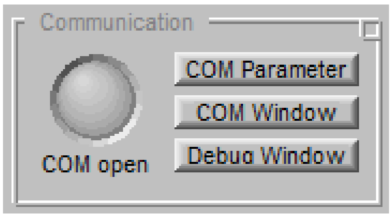
step Duration	Defines the cycle duration of the square signal
step Ampl.	Defines the peek-to-peek amplitude of the square signal
step on	Enables / disables the addition of the step signal to the set point value

Section: "Scan generator"



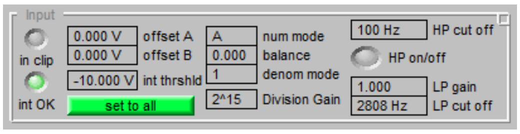
frequency	Defines the frequency of the scan signal

Section: "Communication"



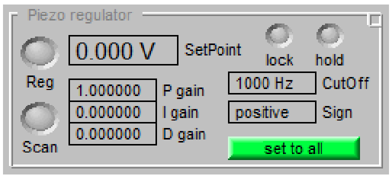
open	Opens / closes the active communication port
COM parameter	Displays the COM port parameter window
COM window	Displays the communication window. The user can watch the communication between Kangoo and the microcontroller. Additionally, commands and requests can be typed manually at the COM window.
debug window	Displays the debug window. The user is provided with feedback about all processes of the Kangoo software.

Section: "Input"



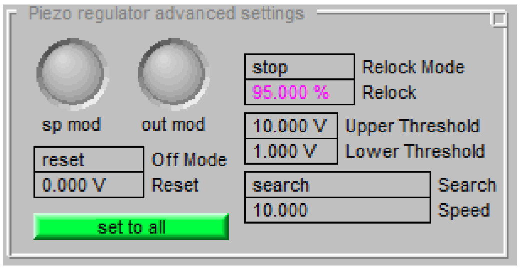
Offset a, b	Defines the offset value for each input signal
In clip	Input signal to large
Int OK	Intensity is below threshold
Int threshlod	Defines the minimal intensity value
Num. mode	Mode selection for the numerator
Balance	Defines the gain ratio of the input signal
Denom. mode	Mode selection for the denominator
Division gain	Defines the binary gain value for the division
HP cut off	Defines the cut-off frequency of the high pass filter
HP on/off	Activates / deactivates the high pass filter
LP cut off	Defines the cut-off frequency of the low pass filter
LP gain	Defines the gain value of the low pass filter
Set to all	Parses the input parameters of the current channel to all other channels

Section: "Piezo regulator"



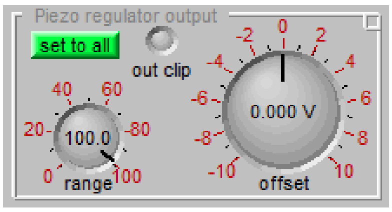
lock	regulator is locked
hold	regulator holds
Reg	Enables / disables the regulator
Scan	Couples / decouples the scan generator to the regulator output
SetPoint	Defines the internal set point value in V
sign	Regulator input sign selection
P, I, D gain	Define the gain values of the regulator
CutOff	Defines the cutoff frequency of the low pass filter
Set to all	Parses the piezo regulator parameters of the current channel to all other channels

Section: "Piezo reg. (advanced settings)"



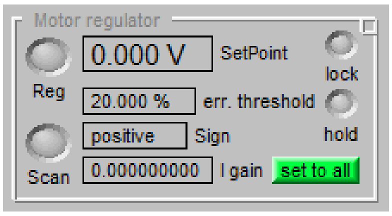
sp mod	Enables / disables set point modulation from BNC plug
out mod	Enables / disables output modulation from BNC plug
relock Mode	Mode selection by crossing the limits of the operating area
reset Mode	Mode selection by disabling the regulator
relock	Defines the relock value in %
reset	Defines the reset value in V
upper threshold	Defines upper threshold fot the search criterion in V
lower threshold	Defines lower threshold fot the search criterion in V
search	Defines search behavior
search speed	Defines search speed
Set to all	Parses the piezo advanced regulator parameters of the current channel to all other channels

Section: "Piezo reg. output"



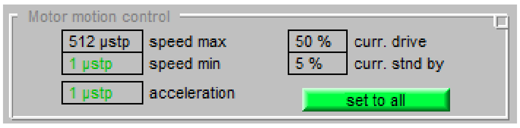
range	Defines the output range value in %
offset	Defines the output offset value in V
Out clip	Regulator output clips
Set to all	Parses the piezo regulator output parameters of the current channel to all other channels

Section: "Motor regulator"



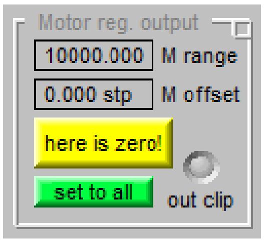
lock	Motor regulator is locked
hold	Motor regulator holds
Reg	Enables / disables the motor regulator
Scan	Couples / decouples the scan generator to the motor regulator output
SetPoint	Defines the internal set point value in V
Err. threshold	Defines the error threshold value
sign	Regulator input sign selection
I gain	Define the integrator gain values of the motor regulator
Set to all	Parses the motor regulator parameters of the current channel to all other channels

Section: "Motor motion control"



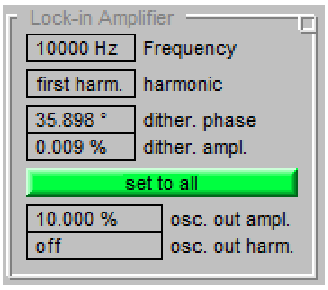
Speed max	Defines the maximum speed of the motor
Speed min	Defines the minimum speed of the motor
acceleration	Defines the acceleration value of the motor
Curr. drive	Defines the current percentage when the motor is moving
Curr. Stnd by	Defines the current percentage when the motor is keeps in rest
Set to all	Parses the motor motion control parameters of the current channel to all other channels

Section: "Motor reg. output"



M range	Defines the output range value
M offset	Defines the output offset value
Out clip	Motor regulator output clips
Here is zero!	Defines the actual position as zero position
Set to all	Parses the piezo regulator output parameters of the current channel to all other channels

Section: "Lock-in amplifier"



frequency	Defines the frequency of the dither signal
harmonic	Defines the harmonic for the lock-in amplifier
dither. phase	Defines the phase shift of the dither signal
dither. phase	Defines the amplitude of the dither signal
Set to all	Parses the lock-in amplifier parameters of the current channel to all other channels
osc. out ampl.	Defines the amplitude of the oscillator output
osc. out harm.	Defines the harmonic of the oscillator output

5.2.2 Connection to oscilloscope

Optionally: connect an oscilloscope to the monitor outputs "monitor 1" and "monitor 2" for observation of several internal signals. Use the setting menu or Kangoo to select the monitor signals.

6 Empirical adjustment of the PID regulator

6.1 Introduction

What is a regulator? A regulator is a means to drive some actuator in such a way that some relevant physical measure ("control variable") equals (or comes close to) an arbitrary value ("set value"). In other words, the difference between the set value and the actual value of the control variable (the "error value") is to be minimized. To this end, the regulator mainly consists of a means to calculate (digitally) the difference between the input signal and the user-selected set value, and one or more amplifiers with different characteristics. In case of the PID regulator, three amplifiers are present:

- The output signal of the proportional (P) amplifier is proportional to the error signal.
- The output of the integrating (I) amplifier is the integral of the error signal over the time.
- The output of the differentiating (D) amplifier is the derivative of the error signal with respect to the time.

The output signal of the regulator (the "actuating value") is the weighted sum of the three amplifier output signals. Optimizing the regulator means to adjust the weights of the three contributions in a manner that the error resulting from an external disturbance is as small as possible. As the regulator, the actuator (here: the laser) and the sensor (here: an FPI, a spectroscopy setup or similar) form a loop ("servo loop"), the system might be excited to stable oscillations of the signals. The condition for this unwanted effect is that the total loop gain is greater than 1 for frequencies, for which the loop delay equals a phase shift of 180°. Thus, the optimization of the PID-contributions remains a trade-off between low gains in the critical frequency ranges (leading to large residuals error values) and high gains (leading to unstable or oscillating states).

6.2 Finding the operation point

Before switching the regulator on, make sure that there is at least one operating point within the output voltage range of the regulator. (The operating point is a value of the regulator output for which the error signal crosses zero. This can be found by help of the scan function: Watch the error signal whilst scanning the laser, and adjust the output offset and the output range so that at least on zero-crossing is well within the scan range.) Then switch the scan off. Turn the trim pots for P-, I- and D-Gain to their minimum. Then switch on the regulator on ("RegOnOff") while watching the error signal on the oscilloscope. Increase the P-Gain until the error signal converges (slowly) to zero. (If it diverges away from zero, the feedback sign is wrong change it). When the error signal is about zero, the system has reached the operating point.

6.3 Optimization of the step response

In order to appraise the regulation quality, a reproducible disturbance needs to be induced. (It can be superimposed either to the set value (set point modulation) or to the output voltage (output modulation).) Enable the “RegStepOnOff” parameter. *LaseLock 8ch* then adds a rectangular voltage with user defined amplitude and cycle duration to the set point.

The error signal exhibits step-shaped disturbances that creep towards zero after each step. (The creeping is an effect of the integrating amplifier.) Increase the P contribution. The steps will turn into impulses (needles). Increase either P or the total gain until you observe an overshoot of the error signal by about 30% of the step size. Increase I until the error signal reaches the zero as soon as possible after each step.

6.4 Adjusting the differential (D) contribution

When regulating inert systems (as are present in most cases), a D contribution helps to damp the overshoot of the error signal that occurs with PI regulation. The D contribution can be explained as a measure for the amount of energy that needs to be placed in the system in order to compensate the disturbance. Care has to be taken when regulating resonant systems (e.g. spring-mass-systems, such as piezo-mounted mirrors): The differentiation provide frequency proportional gain (i.e. high gain for high frequencies) with a 90° phase shift for all frequencies. As the resonance of the system also provides high gain at a phase shift of 90°, the oscillation condition is easily met. To avoid this, a low-pass filter is required, that reduces the gain at the critical frequency, thus allowing a large D contribution in the low-frequency range.

The adjustment of the filter cut-off frequency and the D contribution is a trade-off again: Choosing cutoff frequency low (compared to the resonance frequency), thus reducing the regulation bandwidth, allows to increase the gain, thus leading to better regulation in the remaining frequency range.

If you work with a non-resonant system (as is the case e.g. with temperature regulation of a thermal mass), just increase the D gain until the overshoot disappears (or at least reaches a minimum value).

If you work with a resonant system, increase the D contribution, until you observe a large overshoot or even oscillations. Decrease cut-off frequency of the low-pass filter at the PID input (parameter “RegCutOff”), until the overshoot or oscillation disappears. Repeat the last two steps until further decreasing of the cutoff frequency has no significant effect. Decrease the D gain until the overshoot disappears (or at least reaches a minimum value).

6.5 Fine adjustment

The regulator is now adjusted very close to its optimum. You can now play with the P, I and D gain as well as the overall gain, and see if the step response gets somewhat better. But keep in mind that an overshoot indicates potential instability.

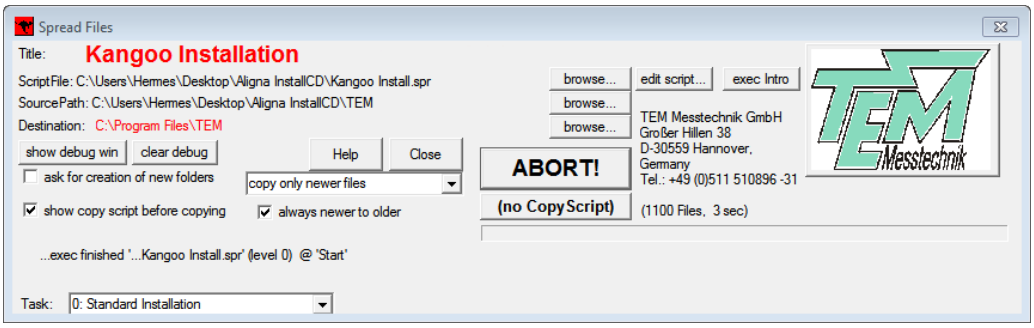
Do not allow more than few percent overshoot.

7 Software Installation

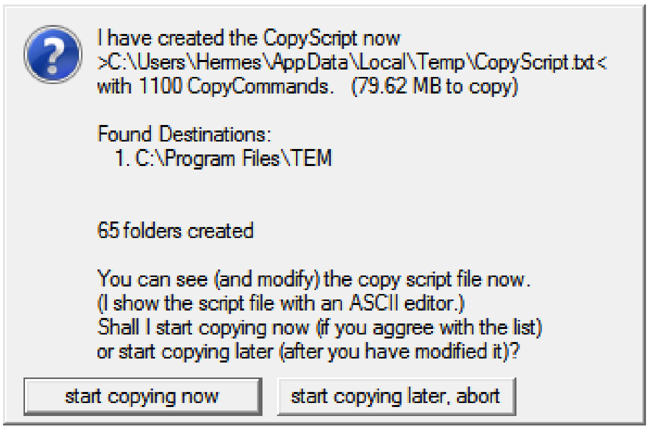
7.1 Installation of the Kangoo Software

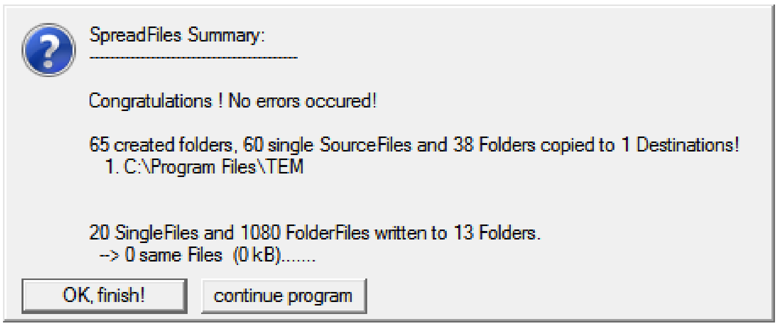
To install the Kangoo software, start the program Install.exe in the root directory of the installation CD. The installer will show a welcome screen with several options.

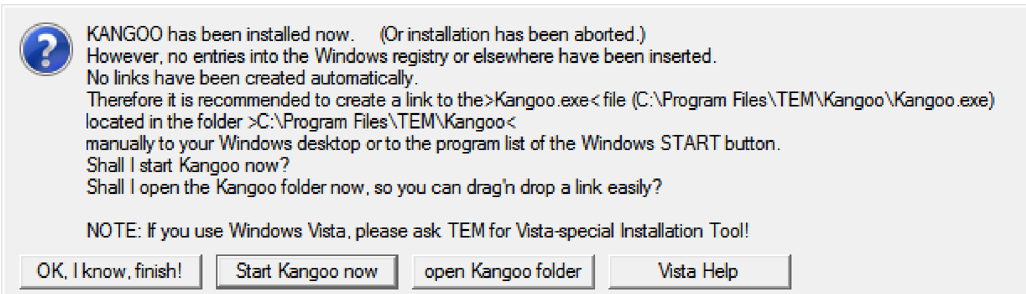
The default options should work fine, with the possible exception of the section "Destination Path", where the destination directory is specified. The standard directory is "TEM" in the "Program Files" folder. On Windows Visa or Windows 7 systems, please avoid the "Program Files" folder and choose and a different path, for example "C:/TEM". The button "OK, install now!" starts copying all required files from the source path to the destination path. During the installation procedure, the installation program checks all required files.



The program then creates a list of file copy commands. When this list is complete, you can check the list and start the copy procedure.







7.2 Installing the USB Drivers

Typically, when the USB connection between the micro-controller and a PC is first made, Windows will open the Found New Hardware Wizard. Here, choose to install drivers from a user-specified location. The necessary driver file is located in the directory "TEM/Service/USB Driver" in the Kangoo installation directory (or on the install CD). The Hardware Wizard will now finish the installation and no further configuration will be necessary.
Once the installation is complete, Windows will assign a COM-port. To find out which COM-port has been assigned, check for a new entry in the section "Ports (COM & LPT)" of the device manager.

7.3 Upgrading the Firmware

Please contact TEM Messtechnik for details about firmware upgrades.

8 Communication interface

8.1 Communication syntax

The communication with the micro-controller is based on plain text ASCII commands and variable assignments. Commands can be:

- entered in the COM window of *Kangoo* or another terminal such as Microsoft HyperTerminal
- sent by application programs such as *Kangoo* or LabView by programmed "Devices" or "Virtual Instruments"
- sent by user-written programs, using languages like VB (Microsoft Visual Basic), C/C++, Delphi, etc. with help of COM procedures.

The command language is **not** case-sensitive, but using upper-case letters may increase readability. Please note the following points on micro-controller commands:

Each command line ends with a "Carriage Return" ($\langle CR \rangle$, "Enter", ASCII 13).
Example: `VarSave`$\langle CR \rangle$

The micro-controller differentiates between commands and variable assignments. If the command-line contains an equal sign, it is interpreted as a variable assignment:
Example: `CutOff= 1000`$\langle CR \rangle$
sets the cut-off frequency to a value of 1000.

Entering a variable assignment without value queries the variable's current value
Example: `CutOff=`$\langle CR \rangle$
returns the current cut-off frequency.

8.2 List of firmware variables

The actually defined variables can be requested by means of the interface command "VarDump".

Variable	Default	Min	Max	Unit / Scale	Comment
SerialNumber	-	-	-	-	Serial number of the device
LCDBrightness	100	0	100	%	Brightness of the LCD screen
ScanFrequency	100	1	100000	1/10Hz	Frequency of the scan signal
StepAmpl	1000	0	10000	mV	peek-to-peek amplitude of the square signal
StepDuration	20ms	10	1s	μs	cycle duration of the square signal
LockThreshold	300	0	10000	mV	Defines the maximal error value at which the regulating loop is considered as "locked"

LowIntensTimeOut	10	0	1000	ms	Defines the time the intensity should be above the threshold value to reactivate the regulator
SearchTimeOut	10	0	1000	ms	Defines the time the input signal should be outside the window defined by the upper and the lower threshold to hold the regulator start to search for valid lock point
LIFrequency	5000	1	10000	Hz	Defines the frequency of the oscillator/dither signal
OcsOutAmpl	5000	0	100000	%	Defines the signal amplitude for the oscillator output
OcsOutHarm	0	0	3	%	Defines the harmonic for the oscillator output
TTLOutSelect	0	0	2	-	Signal selection at the "TTL out" BNC plug [0: off, 1: scan trigger, 2: dither]
TTLOutInvert	0	0	1	-	Inverts the signal at the "TTL out" BNC plug
MonitorSelect1, MonitorSelect2	0, 0	0	31	-	Signal selection at the "monitor 1" and "monitor 2" BNC plug [0: Input A1 raw, 1: Input B1 raw, 2: Sum 1, 3: Norm input 1, 4: Error 1, 5: Reg out 1, 6: Output 1, 8: Input A2 raw, 9: Input B2 raw, 10: Sum 2, 11: Norm input 2, 12: Error 2, 13: Reg out 2, 14: Output 2, 16: Input A3 raw, 17: Input B3 raw, 18: Sum 3, 19: Norm input 3, 20: Error 3, 21: Reg out 3, 22: Output 3,24: Input A4 raw, 25: Input B4 raw, 26: Sum 4, 27: Norm input 4, 28: Error 4, 29: Reg out 4, 30: Output 4]

The variables in the following table are present four times for each channel in the signal processing module. The channel number (1,2,3,4) is defined by the number after the name of the variable. The module number (0,1) is defined by the number in the brackets. For example: RegSetPoint3(0) defined the set point value of the third channel on module 0 - leftmost module).

Input variables					
Variable	**Default**	**Min**	**Max**	**Unit / Scale**	**Comment**
InputAOffset	0	-1000	1000	mV	offset value for input a
InputBOffset	0	-1000	1000	mV	offset value for input b
InputNumMode	0	0	1	-	Numerator mode (simple mode) [0: a, 1: -a, 2: a-b]
InputDenomMode	0	0	1	-	Denominator mode (simple mode) [0: 1, 1: b, 2: a+b]
InputBalance	0	-800	+800	10-3	Input gain ratio
InputDivisionGain	$0(2^{15})$	$0(2^{15})$	$15(2^{0})$	-	Binary division gain [2^{15}...2^{0}]
IntensityThreshold	-10000	-10000	10000	mV	Minimum value for intensity signal (sum of input a and input b)
IntensityOK	-	0	1	-	Flag: Intensity is below the threshold
InClip	-	0	1	-	Flag: one of the input signal is above 9V

HighPassCutOff	100	100	20000	Hz	Cut off frequency for the high pass filter
HighPassActive	0	0	1	-	High pass filter enabling/disabling [0: disable, 1: enable]
InputCutOff	100000	50	100000	Hz	Cut off frequency for the input low pass filter
InputFilterGain	1000	0	100000	(10^{-3})	Gain value for the input low pass filter
LIHarmonic	0	0	3	-	Lock-in harmonic selection
Piezo regulator variables					
Variable	**Default**	**Min**	**Max**	**Unit / Scale**	**Comment**
RegSign	0	0	1	-	Sign of the error signal [0: positive; 1: negative]
RegOnOff	0	0	1	-	Regulator enabling/disabling [0: disable, 1: enable]
RegSetPoint	0	-10000	10000	mV	Set point value
ScanOnOff	0	0	1	-	Coupling the regulator output to scan generator [0: disabled, 1: enabled]
StepOnOff	0	0	1	-	Adding a square signal to the set point [0: disabled, 1: enabled]
Locked	-	0	1	-	Regulator is locked
Hold	-	0	1	-	Regulator holds
ExtSetPointMod	0	0	1	-	Enables set point modulation from the BNC plug [0: disabled, 1: enabled]
RegCutOff	100000	50	100000	Hz	Filter cut off frequency
RegPgain	0	0	10^7	10^{-6}	Gain value of the proportional (P) amplifier
RegIgain	0	0	10^6	10^{-6}	Gain value of the integrating (I) amplifier
RegDgain	0	0	10^7	10^{-6}	Gain value of the differentiating (D) amplifier
OutputOffset	0	-10000	10000	mV	Output offset value
Output	-	-10000	10000	mV	Actual output value
RegOutRange	10000	1000	100000	‰	Output range value
RegOffMode	-	0	0	1	Regulator reset mode selection [0: hold, 1: reset]
OutClip	0	0	1	-	Regulator output clipped
RegResetValue	0	-10000	10000	mV	Regulator reset value
RegRelockMode	0	0	3	-	Regulator relock mode selection [0: stop, 1: relock, 2: left relock, 3: right relock]
RegRelockValue	95000	0	95000	‰	Regulator relock value
RegStepOnOff	0	0	1	-	Adding a square signal to the set point [0: disabled, 1: enabled]
ExtOutputMod	0	0	1	-	Enables output modulation from the BNC plug [0: disabled, 1: enabled]
RegUpperThreshold	1000	-1000	1000	mV	Upper threshold for the input signal
RegLowerThreshold	-1000	-1000	1000	mV	Lower threshold for the input signal
RegSearchSpeed	10000	0	1^{-6}	-	Search speed
RegSearchMode	0	0	3	-	Search mode [0: off, 1: search, 2: left relock & search, 3: right relock & search]
Motor regulator variables					
Variable	**Default**	**Min**	**Max**	**Unit / Scale**	**Comment**
MRegErrorThreshold	20000	0	100000	‰	Error threshold value of the motor regulator input
MRegSign	0	0	1	-	Sign of the error signal [0: positive; 1: negative]

MRegOnOff	0	0	1	-	Regulator enabling/disabling [0: disable, 1: enable]
MRegSetPoint	0	-1000	1000	mV	Set point value
MScanOnOff	0	0	1	-	Coupling the regulator output to scan generator [0: disabled, 1: enabled]
MLocked	-	0	1	-	Regulator is locked
MHold	-	0	1	-	Regulator holds
MRegIgain	0	0	10^6	10^{-9}	Gain value of the integrating (I) amplifier
MOutputOffset	0	-10000	10000	mV	Output offset value
MRegOutRange	10000	1000	100000	‰	Output range value
MOutput	-	-10000	10000	mV	Actual motor position
Motor motion variable					
Variable	**Default**	**Min**	**Max**	**Unit / Scale**	**Comment**
MSpeedMax	100	1	1023	μsteps	Maximal motor speed
MSpeedMin	1	1	1023	μsteps	Minimal motor speed
MAccel	1	1	1023	μsteps	Motor acceleration value
MCurrentDrive	50000	0	100000	‰	Defines the current percentage when the motor is moving
MCurrentSndBy	10000	0	100000	‰	Defines the current percentage when the motor keeps in rest

8.3 List of commands

Entering a command with a parameter value sets the value of the parameter to the corresponding value. A blank separator (space) has to be used between command and the parameter:

Example: `SetToAll 8 2`<CR>

A typical command set of the LaseLock digital is listed in the following table:

command	**arg. 1**	**arg. 2**	**comment**
FPGAread	address	-	requests a value from FPGA
FPGAwrite	address	data	sends a value to FPGA
FPGAtest	-	-	testing communication with the FPGA board
VarSave	-	-	saves all parameters to the microcontroller‘s non-volatile memory
VarLoad	-	-	loads all parameters from the microcontroller‘s non-volatile memory
VarDefault	-	-	loads default parameters
VarDump	-	-	prints all parameters
Hello	-	-	testing communication. Microcontroller answers with "Here I am"
uCtype	-	-	prints the used microcontroller type
Sound	-	-	plays a short peep tone

SetToAll	Parameter section: -1: all; 1: input parameters; 2: piezo regulator; 4: piezo advanced settings; 8: piezo output; 16: motor regulator; 32: motor motion paramters; 64: motor output; 128: lock-in settings	Channel (1...4)	Passes the parameter section of chosen channel to all other channels

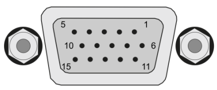
9 Connectors and Electrical Specifications

9.1 Mains Power Cable

Use the included power supply cable that provides proper grounding contact. The system may be delivered with country-specific mains power cables.

9.2 HD-15 Connector

NOTICE: Only use the cable delivered with your system. Using standard cables like those that are used for personal computers can lead to malfunction or damage of electronic components. Many available cables have internal connections (common shielding of R, G, B) or some pins are not connected.



Hd15 Socket

Pin	**Input (Signal Processor)**	**ch 1...4 (HD15 adapter, PDR-HC)**	**Motor Driver**	**Aux Input (Mains)**
1	input a (ch1)	signal a, P	Coil 1 +	aux in 1
2	input b (ch1)	signal b, S	Coil 1 -	aux in 2
3	input a (ch2)	n.c.	Coil 2 +	aux in 3
4	input b (ch2)	n.c.	Coil 2 -	aux in 4
5	analog ground	analog ground	n.c.	n.c.
6	+15V supply			
7	-15V supply			
8	system ground			
9	n.c.	n.c.	n.c.	n.c.
10	n.c.	n.c.	n.c.	n.c.
11	input a (ch3)	n.c.	Coil 3 +	aux in 5
12	input b (ch3)	n.c.	Coil 3 -	aux in 6
13	input a (ch4)	n.c.	Coil 4 +	aux in 7
14	input b (ch4)	n.c.	Coil 4 -	aux in 8
15	n.c.	n.c.	n.c.	n.c.

10 Delivery Content

Your *LaseLock 8ch* system consists of the following components:

- *LaseLock 8ch* control unit
- *LaseLock 8ch* user manual
- PreAmp box or other signal receiver box, e.g. PDR-HC (1 per channel)
- 4-to-1 HD15 adapter
- HD-15 cable (1 per channel + 1)
- Kangoo software CD-ROM or USB flash drive
- 1x USB cable
- 1x power supply cable

It is recommended to keep the packaging material for future storage and transportation. Please check the contents of your delivery for completeness.

11 Customer Service

In case of service needs, general questions, need of repair or warranty claims you will get quick and effective support at:

TEM Messtechnik GmbH
Grosser Hillen 38
D-30559 Hannover
Germany

Tel: +49 (0)511 51 08 96 -30
Fax: +49 (0)511 51 08 96 -38

E-mail: `mailto:info@TEM-messtechnik.de`
URL: `http://www.TEM-Messtechnik.de`

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