multichannel systems

(USB-) MEA-Systems Manual

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1 Important Information and Instructions

1.1 Operator's Obligations

The operator is obliged to allow only persons to work on the device, who

- are familiar with the safety at work and accident prevention regulations and have been instructed how to use the device;
- are professionally qualified or have specialist knowledge and training and have received instruction in the use of the device;
- have read and understood the chapter on safety and the warning instructions in this manual and confirmed this with their signature.

It must be monitored at regular intervals that the operating personnel are working safely.

Personnel still undergoing training may only work on the device under the supervision of an experienced person.

1.2 Guarantee and Liability

The *General conditions of sale and delivery* of **Multi Channel Systems** MCS GmbH always apply. The operator will receive these no later than on conclusion of the contract.

Multi Channel Systems MCS GmbH makes no guarantee as to the accuracy of any and all tests and data generated by the use of the device or the software. It is up to the user to use good laboratory practice to establish the validity of his findings.

Guarantee and liability claims in the event of injury or material damage are excluded when they are the result of one of the following.

- Improper use of the device.
- Improper installation, commissioning, operation or maintenance of the device.
- Operating the device when the safety and protective devices are defective and/or inoperable.
- Non-observance of the instructions in the manual with regard to transport, storage, installation, commissioning, operation or maintenance of the device.
- Unauthorized structural alterations to the device.
- Unauthorized modifications to the system settings.
- Inadequate monitoring of device components subject to wear.
- Improperly executed and unauthorized repairs.
- Unauthorized opening of the device or its components.
- Catastrophic events due to the effect of foreign bodies or acts of God.

1.3 Important Safety Advice

Warning: MEA-Systems include several instruments as individual components. Each instrument is shipped with a separate Manual. The information in the individual Manuals fully apply to the complete-System. This manual is only to be understood as an additional information. Read all Manuals thoroughly before setting up the system.

Warning: Obey always the rules of local regulations and laws. Only qualified personnel should be allowed to perform laboratory work. Work according to good laboratory practice to obtain best results and to minimize risks.

The product has been built to the state of the art and in accordance with recognized safety engineering rules. The device may only

- be used for its **intended purpose**;
- be used when in a **perfect condition**.
- Improper use could lead to serious, even fatal injuries to the user or third parties and damage to the device itself or other material damage.

Warning: The devices and the software are **not** intended for medical uses and **must not** be used on humans.

Malfunctions which could impair safety should be rectified immediately.

High Voltage

Electrical cords must be properly laid and installed. The length and quality of the cords must be in accordance with local provisions.

Only qualified technicians may work on the electrical system. It is essential that the accident prevention regulations and those of the employers' liability associations are observed.

- Each time before starting up, make sure that the **mains supply** agrees with the specifications of the products.
- Check the **power cords** for damage each time the site is changed. Damaged power cords should be replaced immediately and may never be reused.
- Check the **leads** for damage. Damaged leads should be replaced immediately and may never be reused.
- Do not try to insert anything sharp or metallic into the vents or the case of the products.
- Liquids may cause short circuits or other damage. Keep the devices and the power cords always **dry**. Do **not** handle it with wet hands.

2 Welcome to (USB-) MEA-Systems

2.1 Basic Components of (USB-) MEA-Systems

Multi Channel Systems MCS GmbH provides complete solutions for data acquisition, recording, stimulation, and perfusion from up to **256** channels, data analysis and export. The **MEA** (**microelectrode array**) product line is intended for extracellular electrophysiological recordings *in vitro*. Applications include whole-heart preparations; acute brain, heart, and retina slices, cultured slices, and dissociated neuronal or cardiomyocyte cell cultures.

In the following, all basic components that are part of all complete MEA-Systems are briefly described.

A microelectrode array MEA is an arrangement of usually **60 electrodes** (256 electrodes in 256MEA or 120 electrodes in MEA2100-120-Systems) that allows the simultaneous targeting of several sites for extracellular stimulation and recording. Cell lines or tissue slices are placed directly on the MEA, and can be cultivated for up to several months. Almost all excitable or spontaneously active cells and tissues can be used. The **temperature controller TC01/02** regulates via **perfusion cannula PH01** the temperature. The fluid flow is controlled by the peristaltic perfusion pump **PPS2**-System.

Raw data from the MEA electrodes are amplified by MEA1060 filter amplifiers with custom bandwidth and gain, which are built very small and compact using SMD (Surface Mounted Devices) technology. The small-sized MEA1060 amplifier combines the interface to the MEA probe with the signal filtering and the amplification of the signal. The compact design reduces line pick up and keeps the noise level down. All MEA1060 amplifiers are available either for Inverted microscopes or for upright microscopes, MEA1060-Inv and MEA1060-Up, respectively.

The analog input signals are acquired and digitized either by the internal data **acquisition device** in MEA2100-Systems and USB-MEA256-Systems or by an external USB based data acquisition device in USB-ME-Systems.

68-pin MCS high grade cables in different length are used for connecting the MEA1060 amplifier, the USB based data acquisition, and any additional devices. The supply power is distributed to the amplifiers via the MCS high grade cable as well. Please note that you need an **external power supply PS40W** if you use an USB-ME device for operating multiple amplifiers.

Recorded data is graphed, analyzed, and reviewed with the powerful and easy-to-use **MC_Rack** program. You can export the data in standard formats to other programs with **MC_DataTool**. The data acquisition programs **Cardio2D** and **LTP-Director** are specially developed for cardiac and for neuronal applications.

2.2 System Configurations and optional Components

Multi Channel Systems MCS GmbH provides several complete standard configurations and custom systems. This chapter will give an overview on different system configurations. Please see also both handouts "MEA - System Suggestions" and "USB-MEA-Systems - System Suggestions", which show diagrams of several typical setups.

Please note that you have various options for setting up your personal (USB-) MEA-System configuration. For more information about the scope of delivery of your system, please see the separate shipping documents.

Please see the separate documentation for information on installing and operating the individual components of your (USB-) MEA-System. All warnings and safety related information of the separate documents apply and must be regarded.

Do not hesitate to contact MCS or your local retailer if you are interested in a particular setup or if you have other questions.

2.2.1 Single Components for MEA-Systems

The following components are part of (USB-) MEA standard systems. Please make sure that you have carefully studied the documentation on the single components before setting up your system. All manuals can be found on the installation volume shipped with the system. Updated versions can also be downloaded from the Multi Channel Systems MCS GmbH web site.

Web link to the manuals download page on the MCS web site:
http://www.multichannelsystems.com/downloads

Product	*Manual / Reference*
MEA2100-System in different configurations	MEA2100-System Manual
USB-MEA256-System for MEAs with 256 electrodes	USB-MEA256-System Manual
USB-ME64-, 128-, 256-Systems data acquisition for one, two or four MEA1060 amplifiers	USB-ME64- 128- 256-System Manual
MEA1060 amplifier(s) with or without blanking circuit for upright or Inverse microscopes with custom bandwidth and gain settings	MEA Amplifier (with Blanking Circuit) for Upright / Inverse Microscopes Manual, MEA_Select Help
MEA probes	MEA Manual
Temperature controller TC01 or **TC02**	TC01/2 Manual
Perfusion cannula PH01 with programmable fluid temperature (systems with enhanced perfusion **E** only)	PH01 Manual
Perfusion Peristaltic System PPS2 for perfusion control (systems with enhanced perfusion **E** only)	PPS2 Manual
Magnetic Perfusion Holder MPH to fix the PH01	MPH Datasheet
MEA Signal generator **MEA-SG** for systems with 60, 120 or 256 electrodes	60-, 120-, 256MEA-SG Datasheet
Test-MEA for systems with 60, 120 or 256 electrodes	60-, 120-, 256-TestMEA Datasheet
Data acquisition and analysis software **MC_Rack** and **MC_DataTool**	MC_Rack Manual / Help, MC_Rack Tutorial
Data acquisition and analysis software **LTP-Director**	LTP-Director Manual / Help
Data acquisition and analysis software **Cardio2D**	Cardio2D Manual / Help

2.2.2 MEA2100-System

The **MEA2100-System** is the latest development in the MEA product family of Multi Channel System MCS GmbH. The **MEA2100-System** is a compact and portable stand-alone system with integrated amplification, data acquisition, online signal processing, integrated stimulus generator as well as temperature control.

The **MEA2100-System** consists of two main devices: The interface board with integrated signal processor and the headstage equipped with amplifier, A / D converter and stimulus generator. It is possible to connect one headstage only or two headstages to one interface board. If you are dealing with two headstages, each headstage can be operated independently by opening the data acquisition software MC_Rack, for example for each headstage separately.

It is a highly flexible system, using a headstage that will fit on Inverted and upright microscopes. The **MEA2100-System** acquires data from up to 240 electrode channels, 120 channels per headstage and a sampling frequency of 50 kHz per channel. Eight additional analog IN channels are available, and a 16 bit digital IN / OUT channels. The digitized electrode data is transmitted to the connected interface board via eSATAp cable. The connection between interface board and computer uses a high speed USB connection. Thus, it is possible to use any computer as a data acquisition computer, also a laptop.

Data is recorded, stimulated, analyzed, graphed and reviewed with the powerful and easy-to-use MC_Rack program from Multi Channel Systems MCS GmbH. The control functions of the internal stimulator are also integrated into MC_Rack. The MC_Rack data format can be converted in other standard formats with the software MC_DataTool.

2.2.3 USB-MEA256-System

The **USB-MEA256-System** is a complete system for *in vitro* recording from a special microelectrode array with 256 electrodes (256MEA). The **USB-MEA256-System** is a compact and portable stand-alone solution for MEA recordings with integrated amplification, data acquisition, and analog / digital conversion. The system acquires data from up to 252 electrode channels, four additional analog channels, and 16 digital in / out channels. The digitally converted electrode signals are transmitted to **any** data acquisition computer via USB 2.0 (High Speed).

2.2.4 USB-MEA-Systems

The **USB-MEA60-System** is a complete system for *in vitro* recording from microelectrode arrays (MEAs). The external data acquisition device USB-ME64 acquires data from up to 60 MEA electrodes and four additional analog channels. An audio channel and 16 digital in / out channels are available. The device has an integrated analog-digital converter board. The digitally converted electrode signals are transmitted to **any** data acquisition computer via USB 2.0 (High Speed).

The **USB-MEA120-System** is a complete system for *in vitro* recording from microelectrode arrays (MEAs). The external data acquisition device USB-ME128 acquires data from up to 120 MEA electrodes and four additional analog channels. An audio channel and 16 digital in / out channels are available. The device has an integrated analog-digital converter board. The digitally converted electrode signals are transmitted to **any** data acquisition computer via USB 2.0 (High Speed).

The **USB-MEA240-System** is a complete system for *in vitro* recording from microelectrode arrays (MEAs). The external data acquisition device USB-ME256 acquires data from up to 240 MEA electrodes and four additional analog channels. An audio channel and 16 digital in / out channels are available. The device has an integrated analog-digital converter board. The digitally converted electrode signals are transmitted to **any** data acquisition computer via USB 2.0 (High Speed).

2.2.5 MEA1060-BC Amplifier with Blanking Circuit

All USB-ME-Systems are available with MEA1060 amplifiers for upright or inverted microscopes. Amplifiers with MEA1060-BC amplifiers with blanking circuit featuring stimulus artifact suppression. Electrodes can be grounded or selected for recording or stimulation with the **MEA_Select** program.

2.2.6 Enhanced Perfusion System (- E)

A perfusion system is required especially for recordings from acute slices. All systems can be upgraded with an enhanced perfusion system (indicated by the code E), featuring a perfusion cannula PH01 with programmable fluid temperature and a two-channel temperature controller TC02 for controlling both the MEA culture chamber temperature and the fluid temperature in parallel. The PPS2 Perfusion Peristaltic Pump provides the fluid flow.

2.3 Accessories

MCS provides a wide range of accessories that will make your (USB-) MEA-System even more efficient and convenient to use. All accessories are perfect for use with MCS products, but are easily adaptable to custom systems as well. Some accessories are included in complete systems, other have to be ordered separately.

- **1- or 2-channel Temperature controller** for MEAs and for **perfusion cannula PH01**.
- **Peristaltic perfusion system PPS2** for the perfusion of biological samples.
- **Perfusion cannula PH01** for temperature controlled perfusion of the slice.
- **Magnetic perfusion holder MPH** to fix the perfusion cannula PH01.
- **Magnetic metal plates MP** and plates with M3 threads for positioning and tightly fixing tools next to the MEA.
- **Digital in / out extension** for connecting other devices to single digital input and output channels of the data acquisition devices (up to 16 inputs and 16 outputs), for example, for synchronizing stimulation and recording, or for applying feedback.
- **External power supply PS40W** for use with the USB-MEA-Systems or for custom setups.

2.4 Add-ons for Stimulation

In MEA2100-Systems the stimulation unit is already integrated. For all other systems MCS provides general purpose stimulators like the advanced **4000 series** with **2**, **4** or **8** channels.

The flexible **MC_Stimulus II software** enables complex stimulus waveforms in **current** and **voltage** mode. Waveforms designed in the program or imported from an external file are converted by the STG into pulses, which are sent to the amplifier to stimulate electrodes. The operating of the STG 4000 series is possible in download and streaming mode that means continuous down streaming of pulses from connected computer.

Stimulus isolation units are integrated in the STG for each channel. Thus, no additional stimulus isolations units are required.

Trigger in- and outputs are available for an exact timing of stimulation and for controlling other instruments by TTL pulses. For example, stimulation and recording can be synchronized with a digital trigger signal (TTL) sent from the Sync Out output of the stimulus generator to the USB devices via digital inputs.

With the advanced MEA preamplifier with **blanking circuit (BC)**, you will be able to ground electrodes or select electrodes for recording and stimulation by software control MEA_Select from the data acquisition computer. Stimulus artifacts and amplifier saturation are effectively prevented with a blanking circuit.

2.5 Setting up the (USB-) MEA-System

Warning: Please read the separate manuals of all individual instruments before installation, especially the warnings and safety information. Make sure all devices are switched off before you connect them to the power supply. Damage to the devices and even fatal injuries may result from improper installation or use.

See also the documentation "Microelectrode Array Systems, System Suggestions" and "Microelectrode Array USB-Systems, System Suggestions" with detailed diagrams and various setup suggestions. Provide a power supply in the immediate vicinity of the installation site.

1. Place all devices on a stable and dry surface, where the air can circulate freely and the devices are not exposed to direct sunlight.
2. Set up the computer with installed MC_Rack program.
3. Set up the MEA amplifier as described in the amplifier`s manual.
4. Set up all other system components as described in the separate manuals.

With MEA2100-System:

5. Connect the headstage of the MEA2100-System via eSATAp cable to the interface board.
6. Connect the interface board via power supply unit to a power outlet.
7. Connect the interface board with an USB 2.8 A-mini B cable to the computer.
8. Ground the system.

With USB-ME64 / 128 / 256 device:

5. Connect the MEA amplifier(s) to the front panel of the USB-ME64 / 128 / 256 device with 3 m 68-pin MCS standard cable (C68x3M).
6. Connect the USB output connector of the USB-ME64 / 128 / 256 device to a free USB 2.0 port of the data acquisition computer. It is not recommended to use a hub.
7. Connect the USB-ME64 / 128 / 256 device via power supply unit to a power outlet of the same electrical system as the other components of the setup, for example, the computer or shielding.
8. Ground the system.

With USB-MEA256 device:

5. Connect the USB output connector of the USB-MEA256 device to a free USB 2.0 port of the data acquisition computer. It is not recommended to use a hub.
6. Connect the USB-MEA256 device via power supply unit to a power outlet of the same electrical system as the other components of the setup, for example, the computer or shielding.
7. Ground the system.
8. Optional: Connect the internal heating element to the temperature controller's output channel (D-Sub9 connector) with the integrated cable. Do not connect the heating element cable to the computer!

3 Extracellular Recording from MEAs

3.1 Introduction

Over the last 30 years, non-Invasive extracellular recording from multiple electrodes has developed into a widely used standard method. Systems and methods have been greatly improved, leading to more features, higher throughput, and lower costs. Almost all excitable or electrogenic cells and tissues can be used for extracellular recording *in vitro*, for example, central or peripheral neurons, heart cells, retina, or muscle cells.

3.2 Background

The semi permeable lipid bilayer cell membrane separates different ion concentrations (charges) on the inner and outer side of the membrane. Therefore, the cell membrane has the electrical properties of a plate capacitor. The electrochemical gradient results in a membrane potential that can be measured directly with an intracellular electrode. When ion channels are opened due to chemical or electrical stimulation, the corresponding ions are moving along their electrochemical gradient. In other words, the resistance of the membrane is lowered, resulting in an inward or outward flow of ions, measured as a transmembrane current.

The extracellular space is conductive as well, and though the resistance is very low, it is not zero. According to Ohm's law (U=R*I), the extracellular current results in a small voltage that can be measured with extracellular electrodes. Extracellular signals are smaller than transmembrane potentials, depending on the distance of the signal source to the electrode. Extracellular signal amplitudes decrease with increasing distance of the signal source to the electrode. Therefore, a close interface between electrode and cell membrane is very important for a high signal-to-noise ratio.

The transmembrane current and the extracellular potential follow the same time course and are roughly equal to the first derivative of the transmembrane potential.

A microelectrode array (MEA) is an arrangement of several (typically 60) electrodes allowing targeting several sites for stimulation or recording at once.

The following components are important for an extracellular recording system:

- Signal source (cells / tissue);
- Cell / sensor interface;
- Biosensor (MEA);
- Filter amplifier (MEA2100, USB-MEA256, MEA1060);
- Recording hardware (MEA2100, USB-ME or USB-MEA devices) and software (MC_Rack, LTP-Director, Cardio2D).

3.3 Signal Types

3.3.1 Single Unit Activities

Usually several cells are plated onto a MEA. The waveform of a single unit spike depends on the signal source, the geometry of the extracellular space, and the distance of the signal source to the electrode. The property of a waveform derived from a single neuron is reproducible over time and therefore specific for that neuron. That is, the differences of waveforms from separate signal sources can be used to distinguish the activities and to sort spikes into single unit spikes. Thus, you can acquire single unit data from multiple cells in parallel by recording from a single electrode.

You have to discriminate between independent activities and network responses. Responses of cells on a MEA triggered by a chemical, electrical, or light stimulus can be either statistically independent or show a specific pattern. The latter is quite interesting for studying the role of cells and different tissues in a pathway. MEA recording allows such studies under controlled experimental settings and is much easier and less labor intensive than an *in vivo* experiment.

3.3.2 Local Field Potentials

If the dendrite soma axes of the active cells are aligned, the waveforms from multiple units on a MEA overlay and from a compound potential, or local field potential (LFP). The higher the activity, that is, the spike rate, the higher is the amplitude of the LFP. A modulation of the stimulus results in a higher frequency of action potentials that will result in a graded multiunit response. LFPs often show a high signal-to-noise ratio, which is very beneficial for the analysis.

If dendrites are arranged in a nonparallel or radial fashion forming a closed field, the waveforms may cancel each other out, when the neurons fire in synchrony.

3.4 Recording and Stimulation

The MEA sensor is placed directly into the small sized MEA amplifier or MEA2100 headstage. When the amplifier is closed, the contact pins in the lid of the amplifier are pressed onto the MEA contact pads. The very close location of the amplifier to the MEA sensor is very favorable concerning a high signal-to-noise ratio.

If you use the MEA amplifier with blanking circuit, MEA_Select software control allows to select any electrode on a MEA for stimulation and recording. In MEA2100 headstages the blanking circuit feature is always provided. A user defined, typically 500 µs long, blanking signal switches off stimulating electrodes during stimulation and thus removes stimulus artifacts.

With the MEA_Select software, it is easy to change the electrode selection during the experiment, for example, to use stimulation electrodes for recording and vice versa. It is also possible to use the same electrode for recording shortly after stimulation provided that you use a dedicated biphasic pulse protocol that compensates for the slight DC offset that a stimulation electrode always shows after stimulation. When using MEA2100-Systems the MEA_Select software is already included in the data acquisition program MC_Rack, Cardio2D or LTP-Director, you do not have to change the software program for blanking. Please read the MEA2100-System manual.

3.4.1 Microelectrode Arrays (MEAs)

The recording field of a standard MEA with 60 electrodes is a square grid of 8 x 8 electrodes with a total length between 120 µm to 5 mm in the middle of a circular, which is about 2 cm wide. 256MEAs for USB-MEA256-Systems have 256 electrodes in a 16 x 16 electrode grid, 120MEAs for MEA2100-120-Systems have 120 electrodes in a 12 x 12 grid, perforated MEA32S12-Lx for MEA2100-32-System have 32 recording and 12 stimulation electrodes. It is possible to glue a culture chamber onto the MEA, made of plastic (Macrolon) or of glass.

The layout of the MEA electrodes follows the scheme of a standard grid: The first digit is the column number, and the second digit is the row number. For example, electrode 23 is positioned in the third row of the second column. The numbering follows the standard order from left to right, and from top to bottom. This numbering is used in the documentation of the MEAs, the MEA amplifiers, MEA2100 headstages, and in the data acquisition programs MC_Rack, LTP-Director, and Cardio2D. That means, if you want to record data from electrode 23, you choose channel 23 for setting up the channel layout map. Please make sure that the appropriate 2-dimensional data source setup "2 dim. (MEA)" or "Configuration" selected in the data source settings of MC_Rack. For more details, please refer to the MC_Rack help or manual.

Microelectrode arrays are available in various configurations:

- Different electrode layout grids (8x8, 6x10, High Dense 2x(5x6), 4 Quadrants, Hexa, 6wellMEAs);
- Different electrode diameters and spatial resolutions;
- Different electrode materials (Titanium nitride, gold or PEDOT);
- Opaque (titanium) or transparent (indium tin oxide) tracks and contact pads.

For more information on MEA types, electrode layouts, MEA handling, coating and cleaning, please refer to the MEA manual.

3.4.2 Signal Amplification and Filters

The standard MEA amplifier combines the probe interface with a band pass filter and the signal amplification in one instrument.

The MEA1060-BC amplifier with blanking circuit is a 60-channel preamplifier with a broad bandwidth. Filter specifications and gain are defined by the following filter amplifier.

Different filter settings are used to enhance the signal-to-noise ratio. The pass band of the filter amplifier depends on the signal type. It is generally useful to filter the data with a cutoff at the highest signal frequency.

For slow signals like field potentials, a bandwidth of 1 to 300 Hz is appropriate. If you like to record fast signals like spikes, a pass band of 300 Hz to 3 kHz is suitable. Cardiac signals have fast and slow components; therefore, you usually need a wider bandwidth of 1 Hz to 3 kHz.

Multi Channel Systems MCS GmbH provides custom amplifiers with a bandwidth of your choice, from 0.1 Hz to 10 kHz. Please note that it is often wise to acquire the data with a broadband amplifier and use the digital filter of the MC_Rack program to change the pass band and filter the raw data. This way, you are much more flexible in designing your experiments. As a further advantage, you can see the original (not filtered) data as well. This is especially important because all filters are known to distort signals. On the other hand, you may need a higher sampling rate to avoid aliasing, and the signal-to-noise ratio is lower. See also the chapter "Data Acquisition" for more information.

The MEA2100 amplifier with blanking circuit is a 60- or 120-channel headstage with a hardware defined bandwidth. Default settings for the hardware filter will be 1 Hz to 3 kHz. However, a different bandwidth can be achieved by an additional software program, called “MEA2100 Configuration”, no hardware modification is necessary. The hardware defined bandwidth marks the upper and lower limit of the frequency range, fine tuning within this range can be done with software filters in MC_Rack.

Note: To change the hardware filter settings without changing the firmware, you can use the add on software “MEA2100 Configuration”.

Please see the manual for the “MEA2100 Configuration” software in the Appendix. The MEA2100-System has a fixed hardware gain of 10. However, due to the large resolution of 24 bit, it is possible to adjust the actual signal input range used for recording in a wide range from +/- 812 µV to a maximum of +/- 227 mV. The 24 bits are distributed among this complete voltage range.

The standard gain of a MEA1060 amplifier is 1200, which is fine for most applications, but MCS also provides amplifiers with a gain of your choice (from 100 to 5000) as well. In MEA2100 the bandwidth of the filter settings on the headstage are adjustable via the software program “MEA2100 Configuration”. For large signals (for example, from heart preparations), you need a lower gain to prevent a saturation of the amplifier. Please note that the gain is a fixed hardware property; and that you cannot change the gain of the amplifier by software controls.

Please note that the ratio of the output signal to the input signal, that is, the gain, is not a fixed parameter for the complete bandwidth. The gain that was specified for the amplifier, for example, 1200, is not fully reached at the borders of the amplifier's pass band. The general rule is, that at the lower and upper limit of the frequency band, the gain is $\sqrt{2}/2$, that is approximately 70 %, of the full gain. Therefore, you should use a bandwidth that is at a safe distance of the signals of interest. Outside the pass band, the gain decreases with the frequency and finally approaches zero.

For information on the gain and filters of the (USB-) MEA amplifiers, please see the appropriate amplifier manual. For more information on gain and filters in general, please refer to standard literature or contact your local retailer.

3.4.3 Data Acquisition

Recording from up to 240 channels is easy with the respective **hardware** and the **MC_Rack software** or with **LTP-Director, Cardio2D**. The MEA2100-System and USB-MEA data acquisition devices provide the possibility to record from up to 240 electrodes with the designated software.

You configure the input voltage range from +/- 400 mV to +/- 4 V and the sampling rate with software control in the MC_Rack program. Please refer to the MC_Rack help or manual for more information.

The input voltage range affects your dynamic range, that is, the lower the input voltage range, the higher is the voltage resolution.

DC Offset correction

An offset correction is generally not necessary, because the intrinsic DC offsets of the MCS amplifier outputs and the data acquisition are very low in comparison to the signals of interest.

You can use the MC_Rack offset correction feature to remove even this low offset and reset all channels to zero. Please refer to the MC_Rack help or manual for more information.

Note: If you observe a large offset on any channel(s), you should contact your local retailer for troubleshooting. The offset correction is not intended for removing large offsets, because the offset correction will decrease the input voltage range.

Sampling rate

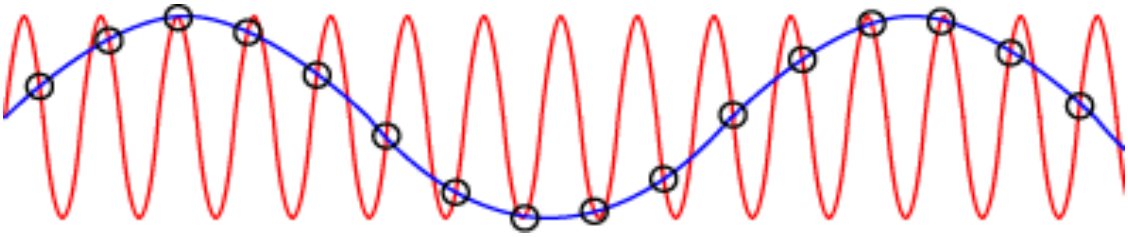
It is recommended to adjust the sampling rate according to your signals, because the higher the sampling rate, the bigger the file size will be.

As a rule of thumb, the sampling rate should equal five times the highest signal frequency for a good digitized representation of the continuous analog signals. If the sampling rate is too low, you will miss signals and / or see artifacts. Considering the preceding statements about filtering data, you would for example use a 5 kHz sampling rate when using a MEA amplifier with a cutoff frequency of 1 kHz.

Please note that if you use a broadband amplifier and a digital filter, you may have to use an even higher sampling rate.

This is the case because the whole amplifier bandwidth is recorded and then high frequency noise is removed with a digital low pass filter after recording. Frequencies (noise) that are above half the sampling rate (for example above 2.5 kHz at a 5 kHz sampling rate) will be transformed into lower frequencies. This is called aliasing. This low frequency noise passes the digital “Low Pass” filter and increases your noise level.

According to the Nyquist-Shannon sampling theorem, the sampling rate should equal twice the bandwidth of the analog (hardware) low pass filter. The 1/2 bandwidth frequency is also called Nyquist frequency. You may ignore this if saving hard disk space is more important for your application than the noise level.



Aliasing

Note: The sampling frequency should be at least five times the highest signal frequency and at least twice the bandwidth of the MEA amplifier.

Example:

You have a broadband MEA1060 amplifier with a bandwidth of 0.1 Hz to 10 kHz. The expected signals have a maximum frequency of 1 kHz. Therefore, you want to filter the data with a digital Low Pass filter and a cutoff frequency of 1 kHz. A sampling rate of 5 kHz (five times the highest signal frequency) would be required for faithfully reproducing the signals, but you should use a sampling rate of at least 20 kHz because the sampling rate should equal twice the bandwidth of the analog filter, regardless of the digital filter properties.

If you have a MEA1060 amplifier with a cutoff frequency of 1 kHz instead, no digital filter would be required, and a sampling rate of 5 kHz would be enough.

Software packages

With the high-performance data acquisition and analysis program **MC_Rack**, you can flexibly manage all data streams. For example, you can display the raw data of all channels while recording only the raw data of the channels of interest and the extracted parameters of all channels. This saves computer performance and hard disk space.

MC_Rack is not limited to special applications, but can be flexibly adapted to a wide range of applications.

Unlimited software licenses and support come free with the (USB-) MEA-System, and free software updates lower the costs as well.

The MC_Rack "*.mcd" data format is supported by several third party programs for further analysis. You can also easily convert recorded data to universal formats such as ASCII with the **MC_DataTool** program.

The **LTP-Director** is an easy to use data acquisition and analysis program to do standardized LTP (long term potentiation) and LTD (long term depression) recordings in hippocampal acute slices. The program controls MEA amplifiers and stimulus generators from Multi Channel Systems MCS GmbH from within one software.

The **Cardio2D** data acquisition and analysis program maps cardiac action potential spreading in cell and tissue preparations. The software allows the mapping of cardiac excitation on microelectrode arrays via local activation times, and spatial distribution of local activation times. The spatial distribution of local field potentials and conduction velocity are measured, and false colour maps and movies are generated. The Cardio2D software can be used in conjunction with cardiomyocyte cultures, cardiac slices or with flexible MEAs for cardiac surface mapping. Perfect for drug testing in primary cardiomyocytes, cardiac slices, whole heart surfaces and stem cell derived cardiomyocytes.

3.5 Using the additional Analog Inputs

The additional analog inputs A1 to A4 of the data acquisition devices are intended for recording additional information from external devices, for example, for recording patch clamp in parallel to the MEA recording, for monitoring the temperature, or for recording voice. You could also use the analog inputs for triggering the MEA2100 headstage or the USB devices, but please note that the digital inputs are intended for accepting TTL pulses.

As the gain is generally completely different on the electrode inputs and on the additional analog inputs, signals on the analog channels are recorded "as is", with no respect to the gain specified in MC_Rack.

Recording Voice on Analog Inputs

Microphones do not generate enough voltage to directly connect them to the analog inputs. You need to use some kind of amplifier that adapts the output voltage of the microphone to the input voltage range of the data acquisition device.

You can then use one of the MC_Rack **sound** tools for replaying the recorded voice.
Please see the MC_Rack manual for more information.

3.6 Digital Input / Output, System Synchronization

TTL stands for Transistor-Transistor Logic. A TTL pulse is defined as a digital signal for communication between two devices. A voltage between 0 V and 0.8 V is considered as a logical state of 0 (LOW), and a voltage between 2 V and 5 V means 1 (HIGH).

Warning: A voltage that is higher than +5 Volts or lower than 0 Volts, that is, a negative voltage, applied to the digital input would destroy the hardware. Make sure that you apply only TTL pulses (0 to 5 V) to the digital inputs.

3.6.1 Triggering the Data Acquisition and MC_Rack

The digital input accepts TTL pulses. This feature can be used for triggering the USB device and MC_Rack, for example, for synchronizing stimulation and data acquisition.

For example, you can connect the Sync Out of a STG (stimulus generator) to one of the digital input bits. If you use only one instrument for triggering, connect it to bit 0. In MC_Rack, add a Trigger Detector to your virtual rack, and select the Digital Data D1 input stream as the Trigger. Select the appropriate logical state (generally HIGH) for triggering. Mask all unused bits. The standard settings of the Trigger Detector are for using bit 0.

Please see the documentation on the Recorder and on the Trigger Detector instrument and on triggered data in the MC_Rack help or manual for more details.

Important: It is recommended to apply TTL pulses with a duration of at least 200 µs. Shorter pulses may be ignored by the USB device. Please mask unused (not connected) digital input channels in the MC_Rack program to ignore undefined states of the open inputs that can cause unwanted trigger events. Please see the MC_Rack manual for more details.

3.6.2 Triggering other Instruments by MEA2100-System or USB-Device

The digital output of the USB device generates and sends 20 ms TTL pulses (0 V = LOW and 5 V = HIGH). This feature can be used to apply a feedback triggered by a signal or a parameter stream.

For example, you can connect the “Trigger In” of a stimulus generator (STG) to the digital output via the “Digital IN / OUT” connector. You can also use the digital output for a synchronization of the (USB-) MEA-System with other systems, for example, for Calcium imaging or video tracking, provided that the other system of choice is able to receive TTL pulses.

Please see the documentation on the digital output instrument in the MC_Rack help or manual for more details.

4 Troubleshooting

4.1 About Troubleshooting

The following hints are provided to solve special problems that have been reported by users. Most problems occur seldom and only under specific circumstances. Please check the mentioned possible causes carefully when you have any trouble with the product. In most cases, it is only a minor problem that can be easily avoided or solved.

If the problem persists, please contact your local retailer. The highly qualified staff will be glad to help you. Please inform your local retailer as well, if other problems that are not mentioned in this documentation occur, even if you have solved the problem on your own. This helps other users, and it helps MCS to optimize the instrument and the documentation.

Please pay attention to the safety and service information in the separate manuals of the related products and in the software help. Multi Channel Systems has put all effort into making the product fully stable and reliable, but like all high-performance products, it has to be handled with care.

4.2 Triggering / Digital Input does not Work

You have connected a TTL source (for example, the Sync Out of a stimulus generator) to the digital input of the USB device or the interface board of the MEA2100-System, and configured the virtual rack in MC_Rack for triggering displays or data acquisition by the TTL source, but you do not see any sweeps.

Possible causes:

? You have mismatched the digital input with the analog input. To test this, please add a **Digital Display** to your virtual rack. You should see the trigger event as a logical state of HIGH (=1). If you cannot see any signals, please add a Data Display to your rack and select the analog raw data as the input stream. Make sure the channel layout map of the display shows all three / four analog input channels (A1 to A4). If you have mismatched the inputs, you will now see the (clipped) trigger events.

→ Connect the TTL source to the "Digital In" of the USB device or to the interface board of the MEA2100-System. If you have only one instrument for triggering recording (for example, the Sync Out of a stimulus generator), connect it to bit 0 or to D0 IN.

→ If you use a **digital in / out extension (Di/o)** accessory, you can connect up to 16 digital input sources and up to 16 devices that you want to be triggered by the **Digital Output** instrument of MC_Rack.

? The TTL source does not generate true TTL signals (5 V), or the TTL pulse is shorter than 200 µs.

→ The USB device can only accept TTL signals (CMOS 5 V TTL level) as a digital input stream. A minimum TTL pulse of 200 µs is recommended. Otherwise, a detection of the trigger by the USB device is not guaranteed.

? The software settings for the **Trigger Detector** do not match with the hardware configuration.

→ In MC_Rack, add a Trigger Detector to your virtual rack, and select the Digital Data D1 input stream as the Trigger. Check the digital inputs and make sure that the same bit input that is connected is selected in the software. (The standard settings of the Trigger Detector are for using bit 0.) Mask all unused bits. Select the appropriate logical state (generally HIGH) for triggering. Please see the MC_Rack help or manual for more details.

4.3 Artifacts caused by Perfusion

You observe artifacts or an increased noise level after you started the perfusion.

Possible causes:

? The artifacts correlate with an oscillation of the liquid level. The oscillation will cause the artifacts, and also mechanically stress the biological sample.

→ Use a bevelled tip for the perfusion in- and outlet. If the tip of the perfusion outlet has a blunt end, there will be no continuous liquid flow, but instead, the following can be observed: The liquid level will rise until it reaches the blunt tip; a discrete volume of liquid will be aspirated in a short moment; the liquid level will rise again, and so on, leading to an oscillation. The tip should be cut in an angle of about 45 °. You can also use commercially available metal needles with a bevelled tip.

? The perfusion is not appropriately grounded.

→ Connect the perfusion line to the ground of the amplifier / setup. You should consider using a metal cannula that can directly be connected to ground for the perfusion inlet and outlet. You could also insert a metal wire that is connected to ground into the tubing.

? The aspiration pump is oscillating.

→ MCS recommends the use of the peristaltic perfusion system PPS2 for an open perfusion system. The more rollers the pump head has, the lower are the oscillations of the fluid flow. For a continuous perfusion in a closed system, you can also use an infusion-withdrawal syringe pump.

5 Appendix

5.1 Contact Information

Local retailer

Please see the list of official MCS distributors on the MCS web site.

User forum

The **Multi Channel Systems User Forum** provides an excellent opportunity for you to exchange your experience or thoughts with other users worldwide.

Web link to the User Forum

Mailing List

If you have subscribed to the mailing list, you will be automatically informed about new software releases, upcoming events, and other news on the product line. You can subscribe to the list on the contact form of the MCS web site.

http://www.multichannelsystems.com/

5.2 Ordering Information

Please contact your local retailer for pricing and ordering information.

5.2.1 MEA2100-Systems

Product	Product	Description
MEA2100 recording-System with 60 electrode channels	MEA2100-60-System	Complete with MEA2100-60-headstage, MEA2100-interface board, 5 MEAs, data acquisition computer with preinstalled software, 1-channel temperature controller, power supply, and accessories. USB High Speed data transfer with a sampling rate of up to 50 kHz/channel.
MEA2100 recording-System with 60 electrode channels	MEA2100-60-System-E	Complete with MEA2100-60-headstage, MEA2100-interface board, 5 MEAs, data acquisition computer with preinstalled software, 2-channel temperature controller, heatable perfusion cannula with temperature sensor, peristaltic perfusion system, power supply, and accessories. USB High Speed data transfer with a sampling rate of up to 50 Hz/channel.
MEA2100 recording-System with 120 electrode channels	MEA2100-2x60-System	Complete with MEA2100-2x60-headstage, MEA2100-interface board, 5 MEAs, data acquisition computer with preinstalled software, 2-channel temperature controller, power supply, and accessories. USB High Speed data transfer with a sampling rate of up to 50 kHz/channel.
MEA2100 recording-System with 120 electrode channels	MEA2100-2x60-System-E	Complete with MEA2100-2x60-headstage, MEA2100-interface board, 5 MEAs, data acquisition computer with preinstalled software, two 2-channel temperature controllers, two heatable perfusion cannulas with temperature sensor, peristaltic perfusion system, power supply, and accessories. USB High Speed data transfer with a sampling rate of up to 50 kHz/channel.
MEA2100 recording-System with 120 electrode channels	MEA2100-120-System	Complete with MEA2100-120-headstage, MEA2100-interface board, 5 MEAs, data acquisition computer with preinstalled software, 1-channel temperature controller, power supply, and accessories. USB High Speed data transfer with a sampling rate of up to 50 kHz/channel.
MEA2100 recording-System with 120 electrode channels	MEA2100-120-System-E	Complete with MEA2100-120-headstage, MEA2100-interface board, 5 MEAs, data acquisition computer with preinstalled software, 2-channel temperature controller, heatable perfusion cannula with temperature sensor, peristaltic perfusion system, power supply, and accessories. USB High Speed data transfer with a sampling rate of up to 50 kHz/channel.

MEA2100 recording-System with 120 electrode channels	MEA2100-60-2-System	Complete with two MEA2100-60-headstages, MEA2100-interface board, 5 MEAs, data acquisition computer with preinstalled software, 2-channel temperature controller, power supply, and accessories. USB High Speed data transfer with a sampling rate of up to 50 kHz/channel.
MEA2100 recording-System with 120 electrode channels	MEA2100-60-2-System-E	Complete with two MEA2100-60-headstages, MEA2100-interface board, 5 MEAs, data acquisition computer with preinstalled software, two 2-channel temperature controllers, two heatable perfusion cannulas with temperature sensor, peristaltic perfusion system, power supply, and accessories. USB High Speed data transfer with a sampling rate of up to 50 kHz/channel.
MEA2100 recording-System with 240 electrode channels	MEA2100-2x60-2-System	Complete with two MEA2100-2x60-headstages, MEA2100-interface board, 5 MEAs, data acquisition computer with preinstalled software, two 2-channel temperature controllers, power supply, and accessories. USB High Speed data transfer with a sampling rate of up to 50 kHz/channel.
MEA2100 recording-System with 240 electrode channels	MEA2100-2x60-2-System-E	Complete with two MEA2100-2x60-headstages, MEA2100-interface board, 5 MEAs, data acquisition computer with preinstalled software, four 2-channel temperature controllers, four heatable perfusion cannulas with temperature sensor, peristaltic perfusion system, power supply, and accessories. USB High Speed data transfer with a sampling rate of up to 50 kHz/channel.
MEA2100 recording-System with 240 electrode channels	MEA2100-120-2-System	Complete with two MEA2100-120-headstages, MEA2100-interface board, 5 MEAs, data acquisition computer with preinstalled software, 2-channel temperature controller, power supply, and accessories. USB High Speed data transfer with a sampling rate of up to 50 kHz/channel.
MEA2100 recording-System with 240 electrode channels	MEA2100-120-2-System-E	Complete with two MEA2100-120-headstages, MEA2100-interface board, 5 MEAs, data acquisition computer with preinstalled software, two 2-channel temperature controllers, two heatable perfusion cannulas with temperature sensor, peristaltic perfusion system, power supply, and accessories. USB High Speed data transfer with a sampling rate of up to 50 kHz/channel.
MEA2100 recording-System with 32 electrode channels	MEA2100-32-System	Complete with MEA2100-32-headstage with integrated perfusion element, MEA2100-interface board, 5 MEAs, data acquisition computer with preinstalled software, 1-channel temperature controller, heatable perfusion cannula with temperature sensor, power supply, and accessories. USB High Speed data transfer with a sampling rate of up to 50 kHz/channel.

MEA2100 recording-System with 64 electrode channels	MEA2100-2x32-System	Complete with MEA2100-2x32-headstage with integrated perfusion elements, MEA2100-interface board, 5 MEAs, data acquisition computer with preinstalled software, 2-channel temperature controller, 2 heatable perfusion cannulas with temperature sensor, power supply, and accessories. USB High Speed data transfer with a sampling rate of up to 50 kHz/channel.
MEA2100 recording-System with 64 electrode channels	MEA2100-32-2-System	Complete with two MEA2100-32-headstages with integrated perfusion elements, MEA2100-interface board, 5 MEAs, data acquisition computer with preinstalled software, 2-channel temperature controller, 2 heatable perfusion cannulas with temperature sensor, power supply, and accessories. USB High Speed data transfer with a sampling rate of up to 50 kHz/channel.
MEA2100 recording-System with 64 electrode channels	MEA2100-2x32-2-System	Complete with two MEA2100-2x32-headstages with integrated perfusion elements, MEA2100-interface board, 5 MEAs, data acquisition computer with preinstalled software, two 2-channel temperature controllers, 4 heatable perfusion cannulas with temperature sensor, power supply, and accessories. USB High Speed data transfer with a sampling rate of up to 50 kHz/channel.

5.2.2 USB-MEA-Systems

Product	**Product Number**	**Description**
MEA recording system with integrated data acquisition, filter amplification, and data transfer via USB 2.0 High Speed to any computer, 252 electrode channels	USB-MEA256-System	Complete with 5 x 256MEAs, data acquisition computer, software package, and accessories
MEA recording system with integrated data acquisition, filter amplification, and data transfer via USB 2.0 High Speed to any computer, 252 electrode channels	USB-MEA256-System-E	Complete with 5 x 256MEAs, TC02 and PH01, data acquisition computer, software package, and accessories
MEA recording system with integrated data acquisition, and data transfer via USB 2.0 High Speed to any computer, 240 electrode channels	USB-MEA**240**-Inv-4-System	Complete with 5 MEAs, 4 x MEA1060-Inv amplifier, 2 x TC02, and accessories
MEA recording system with integrated data acquisition, and data transfer via USB 2.0 High Speed to any computer, 240 electrode channels	USB-MEA**240**-Up-4-System	Complete with 5 MEAs, 4 x MEA1060-Up amplifier, 2 x TC02, and accessories

MEA recording system with integrated data acquisition, and data transfer via USB 2.0 High Speed to any computer, 240 electrode channels	USB-MEA**240**-Inv-4-System-E	Complete with 5 MEAs, 4 x MEA1060-Inv amplifier, 4 x TC02, 4 x PH01, 4 x PPS2, and accessories
MEA recording system with integrated data acquisition, and data transfer via USB 2.0 High Speed to any computer, 240 electrode channels	USB-MEA**240**-Up-4-System-E	Complete with 5 MEAs, 4 x MEA1060-UP amplifier, 4 x TC02, 4 x PH01, 4 x PPS2, and accessories
MEA recording system with integrated data acquisition, and data transfer via USB 2.0 High Speed to any computer, 240 electrode channels	USB-MEA**240**-Inv-4-BC-System	Complete with 5 MEAs, 4 x MEA1060-INV-BC amplifier, 2 x TC02, and accessories
MEA recording system with integrated data acquisition, and data transfer via USB 2.0 High Speed to any computer, 240 electrode channels	USB-MEA**240**-Up-4-BC-System	Complete with 5 MEAs, 4 x MEA1060-UP-BC amplifier, 2 x TC02, and accessories
MEA recording system with integrated data acquisition, and data transfer via USB 2.0 High Speed to any computer, 240 electrode channels	USB-MEA**240**-Inv-4-BC-System-E	Complete with 5 MEAs, 4 x MEA1060-INV-BC amplifier, 4 x TC02, 4 x PH01, 4 x PPS2, and accessories
MEA recording system with integrated data acquisition, and data transfer via USB 2.0 High Speed to any computer, 240 electrode channels	USB-MEA**240**-Up-4-BC-System-E	Complete with 5 MEAs, 4 x MEA1060-UP-BC amplifier, 4 x TC02, 4 x PH01, 4 x PPS2, and accessories
MEA recording system with integrated data acquisition, and data transfer via USB 2.0 High Speed to any computer, 120 electrode channels	USB-MEA**120**-Inv-2-System	Complete with 5 MEAs, 2 x MEA1060-INV amplifier, 1 x TC02, and accessories
MEA recording system with integrated data acquisition, and data transfer via USB 2.0 High Speed to any computer, 120 electrode channels	USB-MEA**120**-Up-2-System	Complete with 5 MEAs, 2 x MEA1060-UP amplifier, 1 x TC02, and accessories
MEA recording system with integrated data acquisition, and data transfer via USB 2.0 High Speed to any computer, 120 electrode channels	USB-MEA**120**-Inv-2-System-E	Complete with 5 MEAs, 2 x MEA1060-INV amplifier, 2 x PH01, 2 x TC02, 2 x PPS2, and accessories
MEA recording system with integrated data acquisition, and data transfer via USB 2.0 High Speed to any computer, 120 electrode channels	USB-MEA**120**-Up-2-System-E	Complete with 5 MEAs, 2 x MEA1060-UP amplifier, 2 x PH01, 2 x TC02, 2 x PPS 2, and accessories
MEA recording system with integrated data acquisition, and data transfer via USB 2.0 High Speed to any computer, 120 electrode channels	USB-MEA**120**-Inv-2-BC-System	Complete with 5 MEAs, 2 x MEA1060-INV-BC amplifier, 1 x TC02, and accessories

MEA recording system with integrated data acquisition, and data transfer via USB 2.0 High Speed to any computer, 120 electrode channels	USB-MEA**120**-Up-2-BC-System	Complete with 5 MEAs, 2 x MEA1060-UP-BC amplifier, 1 x TC02, and accessories
MEA recording system with integrated data acquisition, and data transfer via USB 2.0 High Speed to any computer, 120 electrode channels	USB-MEA**120**-Inv-2-BC-System-E	Complete with 5 MEAs, 2 x MEA1060-INV-BC amplifier, 2 x PH01, 2 x TC02, 2 x PPS2, and accessories
MEA recording system with integrated data acquisition, and data transfer via USB 2.0 High Speed to any computer, 120 electrode channels	USB-MEA**120**-Up-2-BC-System-E	Complete with 5 MEAs, 2 x MEA1060-UP-BC amplifier, 2 x PH01, 2 x TC02, 2 x PPS2, and accessories
MEA recording system with integrated data acquisition, and data transfer via USB 2.0 High Speed to any computer, 60 electrode channels	USB-MEA**60**-Inv-System	Complete with 5 MEAs, 1 x MEA1060-INV amplifier, 1 x TC02, and accessories
MEA recording system with integrated data acquisition, and data transfer via USB 2.0 High Speed to any computer, 60 electrode channels	USB-MEA**60**-Up-System	Complete with 5 MEAs, 1 x MEA1060-UP amplifier, 1 x TC02, and accessories
MEA recording system with integrated data acquisition, and data transfer via USB 2.0 High Speed to any computer, 60 electrode channels	USB-MEA**60**-Inv-System-E	Complete with 5 MEAs, 1 x MEA1060-INV amplifier, 1 x PH01 1 x TC02, 1 x PPS2, and accessories
MEA recording system with integrated data acquisition, and data transfer via USB 2.0 High Speed to any computer, 60 electrode channels	USB-MEA**60**-Up-System-E	Complete with 5 MEAs, 1 x MEA1060-INV amplifier, 1 x PH01 1 x TC02, 1 x PPS2, and accessories
MEA recording system with integrated data acquisition, and data transfer via USB 2.0 High Speed to any computer, 60 electrode channels	USB-MEA**60**-Inv-BC-System	Complete with 5 MEAs, 1 x MEA1060-INV-BC amplifier, 1 x TC01, and accessories
MEA recording system with integrated data acquisition, and data transfer via USB 2.0 High Speed to any computer, 60 electrode channels	USB-MEA**60**-Up-BC-System	Complete with 5 MEAs, 1 x MEA1060-UP-BC amplifier, 1 x TC01, and accessories
MEA recording system with integrated data acquisition, and data transfer via USB 2.0 High Speed to any computer, 60 electrode channels	USB-MEA**60**-Inv-BC-System-E	Complete with 5 MEAs, 1 x MEA1060-INV-BC amplifier, 1 x PH01 1 x TC02, 1 x PPS2, and accessories
MEA recording system with integrated data acquisition, and data transfer via USB 2.0 High Speed to any computer, 60 electrode channels	USB-MEA**60**-Up-BC-System-E	Complete with 5 MEAs, 1 x MEA1060-UP-BC amplifier, 1 x PH01 1 x TC02, 1 x PPS2, and accessories

5.2.3 Stimulus Generators

Product	Product Number	Description
2-Channel stimulus generator	STG4002	4000 series: General-purpose stimulus generator for current and voltage-driven electrical stimulation, with integrated stimulus isolation unit for each output channel. Operating in download and streaming mode (continuous down streaming of pulses from connected computer). MC_Stimulus II program with advanced features.
4-Channel stimulus generator	STG4004	
8-Channel stimulus generator	STG4008	

5.2.4 MEA Amplifiers

Product	Product Number	Description
MEA amplifier for Inverted microscopes	MEA1060-Inv	Probe interface and 60 channel pre- and filter amplifier with custom gain and bandwidth.
MEA amplifier for upright microscopes	MEA1060-Up	
MEA amplifier with blanking circuit for Inverted microscopes	MEA1060-Inv-BC	Probe interface and 60 channel pre- and filter amplifier with custom gain and bandwidth. The blanking circuit prevents the amplifier from getting saturated and thus prevents stimulus artifacts.
MEA amplifier with blanking circuit for upright microscopes	MEA1060-Up-BC	

5.2.5 Accessories

Product	Product Number	Description
Peristaltic Perfusion System	PPS2	The peristaltic pump PPS2 with software control is developed for the perfusion of biological samples.
Magnetic Perfusion Holder	MPH	The magnetic perfusion holder is for fixing the perfusion cannula PH01.
Holder with M3 threads	MPM3	For fixing tools with M3 threads next to the MEA.
1-Channel temperature controller	TC01	PID based technology, set-point temperature reached fast within 30 s to 5 minutes, control temperature range from ambient temperature to +50 °C.
2-Channel temperature controller	TC02	
Perfusion cannula	PH01	Temperature can be programmed with the temperature controller TC01 or TC02.
Digital in / out extension	Di/o	For connecting other devices to single digital input and output channels via BNC connectors (up to 16 inputs and 16 outputs), for example for synchronizing stimulation and recording, or for applying feedback.
External power supply PS40W with 40 W power and ±7 V output voltage	PS40W	External power supply for supplying power to MEA1060 amplifiers and / or other peripheral devices.