Manual 1.0

PG 310/PG 390
PG 340

Potentiostat / Galvanostat

HEKA

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1. Introduction

1.1 Introducing the PG 310, PG 390, and PG 340

The PG 300 series potentiostat/galvanostat feature state-of-the-art amplifier technology. They include amplification ranges for large currents, new hardware filters and an external preamplifier design (optional) to reduce noise levels for small currents. The most significant advance is the complete software controlled adjustment of the amplifier. This provides the tools necessary to perform virtually every electrochemical experiment. This also allows for the simplification and automation of experimental procedures and gives enormous flexibility for future extensions. The instant automatic versatile and easy-to-use macro features yield measurements of the highest quality, all while retaining the possibility of full manual control of the amplifier. Therefore, this instrument fulfills the needs of testing industrial electrodes and scientific research. The versatility of the amplifier and its superb technical specifications make the PG 300 the instrument of choice for all electrochemical experiments.

The integration of the PG 300 amplifier with the LIH 8+8 AD/DA interface and the connected computer constitutes a further step in the minimization of total recording noise. Complemented by the intrinsic low noise level of the PG 300 itself with the low current preamplifier, this integrated system effectively eliminates all interferences because it is fully decoupled by optical isolation that in conventional systems often arise from ground loops. Furthermore, the full digital control by a computer running our dedicated software achieves a well-compensated measuring arrangement necessary for a minimum of noise.

Automatic calibration and testing procedures implemented in the software control of the PG 300 guarantees exact functioning of the amplifier at all times. The user can easily run a calibration process whenever it might be

Figure 1.1: PG 340 USB Potentiostat / Galvanostat

necessary. The highly advanced integration of hardware and software of the `PG 300` system eliminates compatibility problems, time consuming set-up operations, and training time. Furthermore, it saves the expenses for additional instruments. The `PG 300` controlled by the software Potmaster and combined with a computer is equivalent to a fully equipped set-up which includes a potentiostat/galvanostat, digital storage oscilloscope, variable analog filter, sophisticated pulse generator, and a full featured data acquisition and analysis system.

1.2 Naming Conventions

PG 310 USB, PG 390 USB, and PG 340 USB

Throughout the present manual we will address all three amplifier types as "`PG 300`". We will explicitly mention the particular amplifiers, where it is required.

1.3 Product Intended Usage

The HEKA PG 300 is intended for research use only in a laboratory by persons trained in its use. Users are expected to be able to properly operate the PG 300 and associated instruments.

The HEKA PG 300 is not intended for medical use. The HEKA PG 300 is not intended for use in life support situations, or in situations were improper operation or failure of the PG 300 can result in personal injury.

HEKA makes no representation that the design, implementation, testing, or manufacture of the PG 300 meet reasonable standards for use as a medical product. As stated in the HEKA Limited Warranty Statement, supplied with each product, "HEKA expressly disclaims all warranties to buyer except the limited warranty set forth above, including without limitation to any and all implied warranties of merchantability and fitness for a particular purpose."

1.4 Supplied Components

The following items should have been packed with your PG 300:

- 1 PG 300 potentiostat/galvanoststst
- 1 USB 2.0 shielded cable (3 meters)
- 1 HEKA CD-ROM
- 1 Printed user's manual
- 1 power cord (110 or 220 Volt depending on application)

If any of these items are missing please contact HEKA or your dealer immediately.

1.5 Unpacking

After unpacking the PG 300 and accessories from the shipping carton, please inspect each piece for any signs of shipping damage. Please contact the delivering carrier and HEKA immediately if there is any damage. Do not dispose of the shipping carton. The carrier will want to examine the shipping carton to process a damage claim. HEKA insures all shipments to cover shipping damage. It is also advisable to keep the shipping carton in the event that the instrument must be returned for service.

1.6 Computer Requirements

1.6.1 Windows

- Pentium 4 or faster processor
- Windows 2000, XP or Vista
- Available USB 2.0 Hi-Speed port (480 Mbits/second)
- CD-ROM or internet access

1.6.2 Macintosh

- Macintosh G5 or faster processor
- Mac OS X (10.4 or higher)
- Available USB 2.0 Hi-Speed port (480 Mbits/second)
- CD-ROM or internet access

Please note that many newer computer systems are supplied with multiple USB 2.0 ports, but only some of these ports are capable of Hi-Speed operation. The PG 300 will work on the slower speed ports, but the maximum transfer rates will be greatly reduced. For optimal performance, the PG 300 should only be connected to a USB 2.0 Hi-Speed port.

If your computer system does not have a Hi-Speed USB 2.0 port, then a USB 2.0 adapter may be used. These adapters are available in many configurations (PCI, PC Slot, etc).

1.7 Support Hotline

If you have any question, suggestion, or improvement, please contact HEKA's support team. The best way is to send us an e-mail or fax specifying:

- Your postal and E-mail address (or fax number)
- The program name: Potmaster
- The program version number: v2.30, v2.32
- Your operating system and its version: MacOS 10.4, Windows XP Prof., etc.
- Your type of computer: Mac G5, Pentium 4, 1.8 GHz, etc.
- Your acquisition hardware, if applicable: PG 310 USB, LIH 8+8
- The series number and version of your potentiostat.
- The questions, problems, or suggestions you have
- Under which conditions and how often the problem occurs

We will address the problem as soon as possible.

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2. Description of the Hardware

2.1 Characteristics

2.1.1 Power Requirements

AC-power	110 V or 220 V, 50 to 60 Hz, 170 W maximum (PG 310) 260 W maximum (PG 390)

2.1.2 Dimensions

Housing	43 cm W x 18 cm H x 35 cm D (16.9" W x 7.1" H x 13.8" D)
Front panel	48,3 cm x 18 cm (19" x 7.1") with two handles

The PG 300model potentiostat/galvanostat can be mounted in a standard 19" rack assembly.

Weight	12.2 kg (27 lb)

2.1.3 True Plug-and-Play

Simply connect the `PG 300` to an available Hi-Speed USB 2.0 port on the host computer system using the supplied USB cable. The computer will automatically identify the `LIH 8+8` and install the appropriate driver software, if needed, to operate it. This connection scheme greatly reduces start-up time. It is no longer necessary to open the computer to add a board. Simply make all of the connections to the recording setup and execute the data acquisition software. Within minutes, data can be acquired.

2.1.4 Hot-Swappable

Another advantage of the USB based PG 300 data acquisition interface is that it can be installed or removed while the computer is running. Just plug the device in, use it, and unplug it when done. There is no need to power down the computer. The PG 300 is self-enumerating and self-identifying. The device driver is dynamically loaded when connected and dynamically unloaded when unplugged.

2.1.5 Expandability

If an application requires more channels than are available on a single PG 300, then multiple units can be connected and fully synchronized. Each PG 300 unit requires a dedicated Hi-Speed USB 2.0 port and an external cable connection between the units. This external connection is used to synchronize the acquisition clocks of the units and is made with a standard CAT5 patch cable. A single external trigger will start the multiple units simultaneously. Please note that PG 300 interfaces installed on separate computers can also be synchronized in the same manner. The number of units that can be installed is only limited by the number of available Hi-Speed USB 2.0 ports.

2.1.6 DC Characteristics

PG 310	**PG 390**
Counter Electrode: Compliance Voltage ±20 V Output current ±2 A	 Compliance Voltage ±20 V Output current ±1 A
Continuous Power: 20 W	 90 W
Resolution current monitor: 0.02 % of full range *Resolution voltage monitor:* 1 mV	
Input specifications (reference electrode): impedance: 100 $G\Omega$ in parallel with 1.5 pF	

2.1.7 Potentiostatic Mode

PG 310	**PG 390**
Counter electrode: Potential range: $\pm 20\ V$	 $\pm 90\ V$

2.1.8 Galvanostatic Mode

Current range	$\pm 1 \mu A$ to $\pm 2 A$ (PG 590: ±1 A) in 8 (7) steps
Minimum resolution	0.02 %

2.1.9 Dynamic Data

Small signal rise time	0.1 μs up to 200 μs maximum in 4 steps controlled by a 3-pole Bessel filter
Slew rate	10 $V/\mu s$
Bandwidth	$>$ 1 MHz in 1 mA-range at -3dB
Phase shift	$<$ 10˚ at 200 kHz

2.1.9.1 Low Current Preamplifier

The input circuitry is contained in a hybrid integrated circuit (available only for PG 310).

Current measuring resistors:
500 MΩ (1 nA; 100 pA)
5 MΩ (100 nA; 10 nA)

Noise measured with open input:
8-pole Bessel filter; 1 nA - 100 pA, 500 MΩ? feedback resistor:
DC to 10 kHz: ¡ 400 fA (RMS)

Maximum bandwidth: 100 kHz

2.1.9.2 Filters

The PG 310/PG 390 contains three built-in filters.

Voltage filter The voltage monitor can be filtered by a 3-pole Bessel filter in three steps of 10, 100, or 1000 Hz.

Current filter The current monitor can be filtered by a 4-pole filter with selectable Bessel or Butterworth characteristics from 0.5 to 16 kHz (Bessel) or to 25 kHz (Butterworth).

Bandwidth control The power amplifier bandwidth can be controlled in 8 steps from 0.1 to 300 kHz.

2.1.10 Initial Potential

Total range of ±10 V can be set manually or through software control.

2.1.11 Polarity Convention

The `PG 300` model potentiostats/galvanostats conforms to the polarity convention that defines a cathodic current to be negative. That is a current is negative if reduction is taking place. Positive current is anodic that is a current is defined as positive if oxidation is taking place. The current monitor and the monitor display are consistent with this convention.
In potentiostatic operation, applying a more positive potential will results in a more anodic current. In contrast, a more negative potential applied will results in a more cathodic current. This is also true for `EXTERNAL INPUT` Stimulus voltages.
In the galvanostatic mode, applying a more positive current will tend to cause a more anodic current. Conversely, a more negative applied current will cause a more cathodic current. This sensing applies for any current change regardless of its source. This includes the `PG 300` `EXTERNAL INPUT`.

> ***Note:*** *The EXTERNAL INPUT has 5 KΩ input impedance in both the potentiostatic and galvanostatic modes.*

2.2 Main Unit

The PG 300 main unit contains the analog main board with the analog scan generator, the display board including two digital display modules and the power-supply.

2.2.1 Rear Panel

Voltage Switch: A switch on the rear panel of the main unit selects between the 110 and 220 volt operation. Make sure that the switch is in the proper position, and that the correct fuse is installed.

Rear-panel connectors: Three 40-pin connectors and an analog trigger input and output allow connection of the PG 300 to other devices:

USB: This is the connection to the host computer, that allows the computer to communicate with the PG 300.

Digital I/O: TTL-level, digital input and output lines are available here for the control and monitoring of digital signals.

Trigger In: Input for an external trigger to start data acquisition when the LIH 8+8 is waiting for an external trigger. This mode is set in *POTMASTER* when either *Trigger Series* or *Trigger Sweeps* is selected in the *Pulse Generator*.

$\sum$ **Gate Out:** Output for trigger signals. In common application this output is not used.

2.2.2 Front Panel

Power Switch: In order to be initialized properly, the PG 300 should be switched on before starting the *POTMASTER* program. However, this program allows you to re-initialize the amplifier in case you forgot to turn it on first.

> ***Note:*** *Since the calibration settings of the potentiostat have been determined for a warmed-up potentiostat, switch on the*

potentiostat ∼15 min before starting an experiment. This will ensure that the potentiostat has warmed up to the regular working temperature and that the calibration parameters are most accurate.

GND-CHAS: The chassis (CHAS) is connected to the ground line of the power cord, as is typical of most instruments. The *Signal ground* (GND) is kept separate from the chassis to avoid ground loops, but can be connected to it through an external connector. To run the potentiostat with floating ground, remove the external connector. Both with floating and with chassis ground, the signal ground can be connected to other parts of the experimental setup if necessary. In the first case, the banana jack of *Signal ground* provides a high-quality connection to the other parts. In the latter case the banana jack in the external connector must be used.

DA and AD connectors: The BNC connectors to the built-in laboratory interface (LIH 8+8) are grouped into *Digital to Analog* (DA) converter outputs and *Analog to Digital* (AD) converter inputs.

DA Outputs: Four DA channels are provided (0-3). They carry the following signals:

DA-0 Free (Trigger output)

DA-1 Free (Trigger output)

DA-2 TEST (Trigger output)

DA-3 SCAN = Internal stimulus output (used to monitor the stimulus)

Note: *These are output connectors. Make sure that you never feed stimuli into these outputs!*

DA-0 to DA-2 are typically used to trigger an oscilloscope or an isolation unit. Up to three triggers can be assigned by *POTMASTER* (see *POTMASTER* Manual *Chapter 10 - Pulse Generator*). Using the same DA channel for more than one trigger can create simple pulse patterns. The convention for these patterns is that the DA template for the first trigger is loaded first. The non-zero values for the following triggers are then added, i.e. in case of overlapping the DA values will become additive. DA-2 is also intended to be used for tests which have not yet been implemented. DA-3 is internally wired as the internal stimulus generator.

AD Inputs: The LIH 8+8 interface provides eight AD channels (0-7). AD channels 5 and 6 are internally connected to the PG 300potentiostat circuit and are used by the software supplied. Channel 5 is labeled "U-Cell" and carries the *U-Cell Monitor* output. Channel 6 is labeled "I-Cell" and carries the *I-Cell Monitor* output. Channel 7 carries the output of the PG 300's internal multiplexer. You normally should not connect anything to channels 5 and 6, unless you wish to inspect the signals for diagnostic reasons. However, channels 0-4 are freely available for application programs. For example, the *POTMASTER* program can use these channels to monitor temperature, pH-value, or outputs from other sensors.

Standby: The user can disconnect the electrochemical cell from the potentiostat by pressing a hardware standby button. The *Standby* mode of the potentiostat is indicated by flashing of the button. The cell cannot be connected to the potentiostat by remote control, if the hardware standby button is pressed. Hence, be sure that the hardware standby button does not flash while an experiment is being performed. This button can be used to disconnect the cell independently of the *POTMASTER* software.

Electrodes: As usual for common potentiostats/galvanostats, the current flow through the electrochemical cell is measured or controlled between the counter and working electrodes. In the potentiostatic mode the PG 300can be driven in both the three- and four-electrode mode. In any case, the voltage is controlled between the both reference electrodes, *Reference I* and *Reference II*. In the three-electrode mode, however, the *Reference II* connection is short-circuited to the working electrode. Hence, in this mode the usual setup is realized for controlling the voltage between reference and working electrodes.

Counter Electrode: Connect your counter or auxiliary electrode here.

Reference I: In the three electrode mode, connect your reference electrode here. In the four-electrode mode, connect your first reference electrode here.

Reference II: In the four-electrode mode, connect your second reference electrode here. In the three-electrode mode, *Reference II* is not used.

Working Electrode: Connect your working electrode here.

> ***Important note:*** *The electrode connectors are supplied with a voltage up to 90 V. Take care not to touch these connectors to avoid an electric shock hazard.*

U-Cell Monitor: This output signal provides a monitor for the electrochemical cell voltage, i.e. the potential difference between the working and reference electrodes (three-electrode mode) or both reference electrodes (four-electrode mode). The output impedance is 50 Ω. This signal may be viewed on the software oscilloscope.

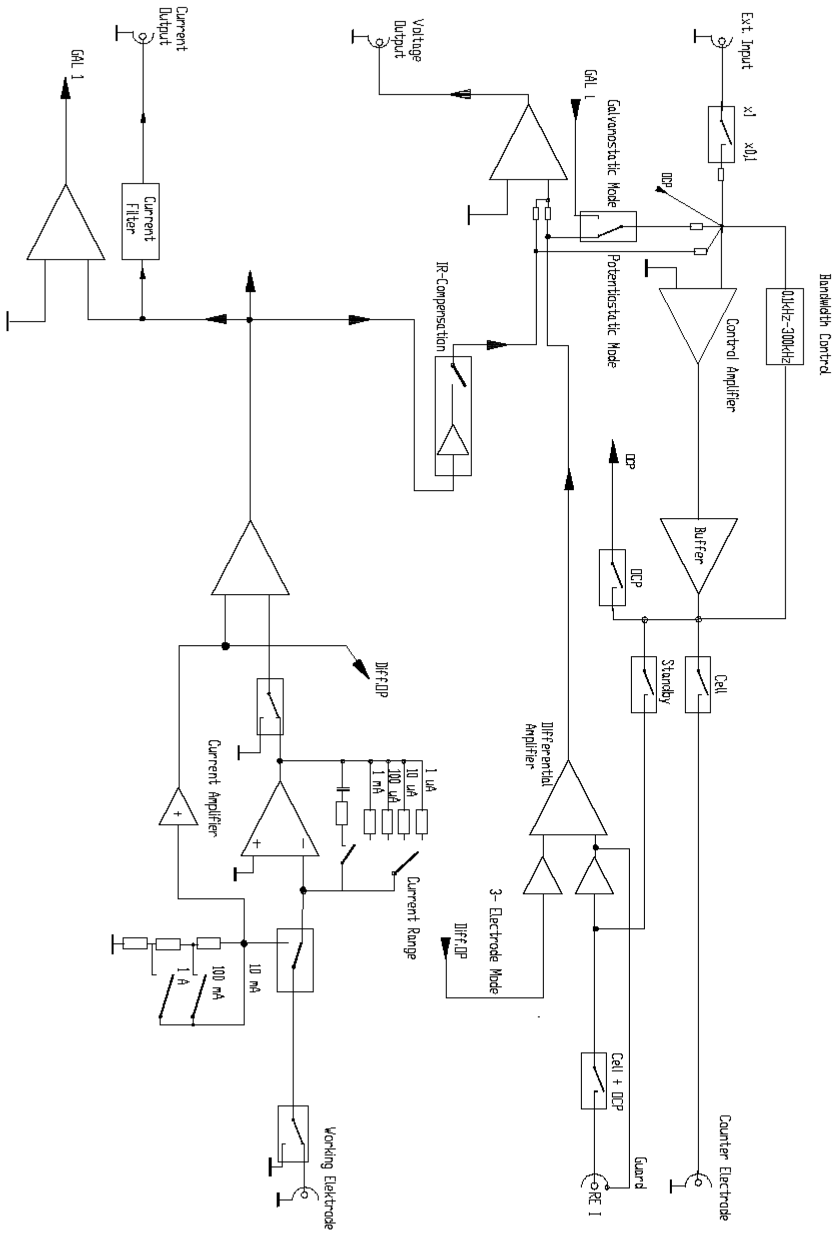
I-Cell Monitor: This output signal provides a monitor for the current density flowing through the electrochemical cell. A voltage between the limits of 10 V is supplied by this output, where 10 V means a current density of 100 % of the selected current range. The output signals are filtered in accordance with the settings in the software. Positive voltages correspond to positive current flows. Typically, the I-Cell output is fed to an oscilloscope for monitoring the progress of the experiment. This signal may also be viewed on the software oscilloscope.

External Input: Signals from an external stimulus source are applied here; they can be summed with the internal stimulus if desired. The combined stimulus signal is passed through a 2-pole filter to round off stepwise changes in voltage. This avoids non-linearities (from slew-limiting amplifiers) in the command processing circuitry. and also reduces the amplitude of the current transients from rapid charging of the electrode. Four degrees of filtering, specified as the rise times (time from 10% to 90% of the amplitude of a step change) are available in the software: 2 μs, which is the minimum required to avoid non-linearities in the internal circuitry, and 20 μs, which is preferable for all but the fastest measurements, to reduce the capacitive transients. For slow experiments 200 μs and 2000 μs filters can also be used.

OVERLOAD: This LED lights whenever an amplifier saturates in the current monitor pathway. This indicator is important in order to avoid destroying the electrochemical cell. It is particularly useful as it will indicate clipping by internal amplifiers even if the output voltage is not saturated, because of filtering. Moreover, this LED lights whenever digital information is sent from the computer to the PG 300potentiostat.

2.3 Simplified Block Diagram

Although the PG 300potentiostat/galvanostat is a complex instrument, the organization of its analog part is straightforward and depicted in the following figure. The succeeding paragraphs discuss the PG 300potentiostat/galvanostat, in combination with the different operating modes, in some detail.


Current Output
GAL 1
Current Filter
Voltage Output
Ext. Input
x1
x0,1
Galvanostatic Mode
Potentiostatic Mode
DCP
Bandwidth Control
0.1kHz-300kHz
Control Amplifier
IR-Compensation
Buffer
DCP
Diff.DP
Standby
Cell
Differential Amplifier
Current Amplifier
1 uA
10 uA
100 uA
1 mA
Current Range
10 mA
100 mA
1 A
3- Electrode Mode
Diff.DP
Cell + DCP
Guard
RE I
Counter Electrode
Working Elektrode

3. Installation

3.1 Connecting the PG 300

1. The PG 300 can be installed into a standard nineteen-inch instrument rack or used as a desktop unit. If installing on a rack, please do not use the PG 300 as a shelf to support any other instrument. The PG 300 case was not designed to do this and damage to the front panel will result. To minimize noise, it is advisable to mount the LIH 8+8 away from devices that emit high-frequency signals (i.e monitors, power supplies, etc).

2. Connect the power cord to the PG 300. The internal power supply used in the PG 300 is an auto switching multi-voltage supply that will operate from 90 Volts to 250 Volts. Make sure that the PG 300 power cord is plugged into a properly grounded AC receptacle. Improper grounding of the PG 300 could result in an electrical shock hazard. It is advisable to plug all equipment into a common outlet strip. This will minimize power line induced noise in the system.

3. Install the USB cable from the USB connector on the rear panel of the PG 300, labeled USB, to an available USB 2.0 Hi-Speed port on the computer. This connection should be made directly to the computers USB 2.0 port and not to a USB HUB.

4. As soon as the PG 300 is detected by the host operating system the appropriate system files will be initialized and the PG 300 will be ready for use.

> ***Important note:*** *The host operating system treats the* PG 300 *as it would any Flash memory device. Therefore, only standard operating system files are required. This provides ease of installation and flexibility for moving the* PG 300 *from one computer system to another.*

5. If multiple PG 300 interfaces are to be connected, repeat the steps as outlined above for each unit. In addition, for the acquisition clocks to be properly synchronized, a connection between the Master clock output of one unit to the Slave clock input of the other (connectors located on the rear panel) must be made using standard CAT5 patch cables.

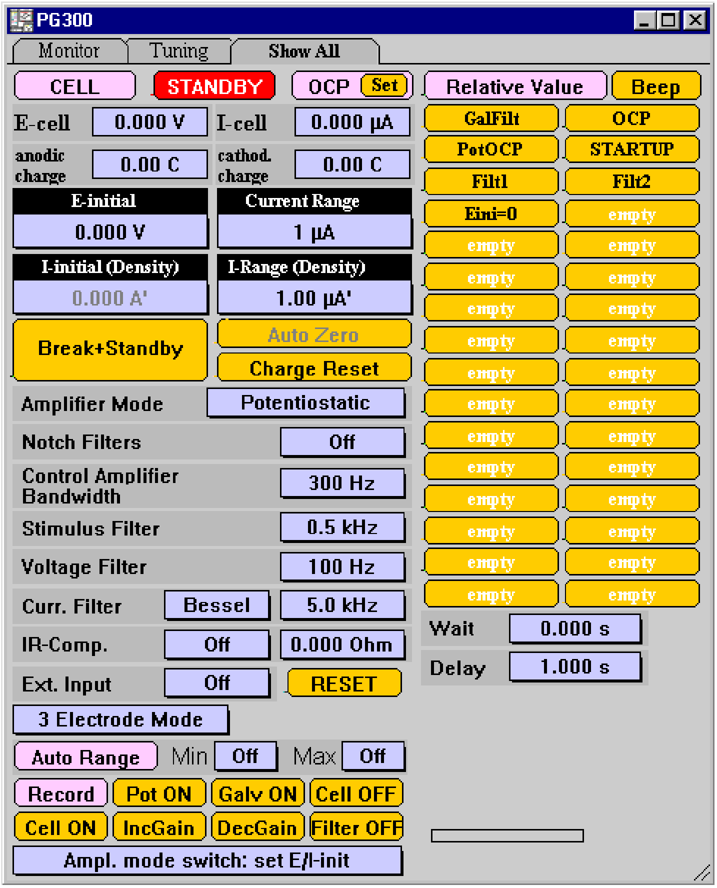
   Important note: *Please note that the sync clock is a high-frequency signal. The shortest possible length patch cable should be used.*

6. Before powering up, please recheck all connections. If all connections are proper then the power LED will illuminate once the PG 300 is powered ON.

   Important note: *Please note that the Status LED will not be illuminated until the acquisition software has initialized the interface.*

The PG 300 is now connected and ready to go.

4. The Control Software

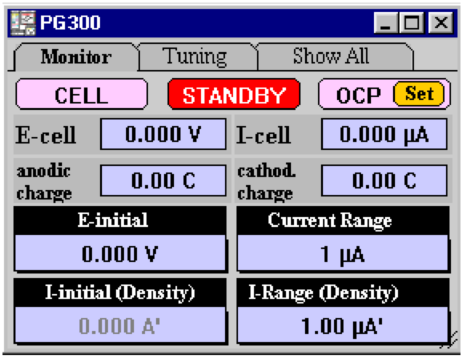


The `Potentiostat` window is used for controlling, adjusting and displaying the amplifier settings. The window might differ depending on the type of amplifier you are controlling with POTMASTER. We will describe the window of the PG 300 in most detail and focus to special details only when describing the windows of other amplifiers.

4.1 Controlling the PG 310/390 - Main Functions

The `PG 300Potentiostat` window is used for controlling, adjusting and displaying the PG 310/390 POTENTIOSTAT/GALVANOSTAT operating modes.

The `Potentiostat` window has three different `Panes` (`Monitor`, `Tuning`, and `Show All`) to allow switching between the display of different sets of controls.



Monitor: Shows only the most important parameters and functions of the window like `Cell Potential`, `Cell Current`, `Current Density` and `Charges`.

Tuning: Shows additionally the settings of `Filters`, `IR-compensation` and `Current Auto Range`.

Show All: Shows all controls.

4.1.1 Cell Connection

Cell/Standby/OCP: Via these buttons the connection of the PG 310/390 POTENTIOSTAT/GALVANOSTAT to the cell can be controlled.

Cell: Connects all the electrodes to the respective inputs of the Pg 310/390 Potentiostat/Galvanostat. In the potentiostatic mode the cell potential is controlled by the Pg 310/390 Potentiostat, and the current flowing through the cell is displayed as I-Cell. In the galvanostatic mode the current flow through the cell is controlled by the Pg 310/390 Galvanostat, and the respective cell potential is shown in the E-Cell display.

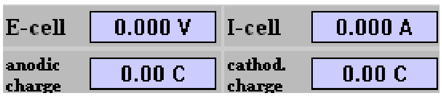
In the `Standby` mode all the connections are switched off, and the potential can neither be read nor set.

In the `OCP` mode the counter-electrode is disconnected. The cell is in the zero current state, and the open cell potential is exhibited in the E-Cell display. The small `Set` insert button is used to set the Initial Potential value to the actual Open Cell Potential.

> ***Note:*** *It is also possible to switch to the Standby mode by pressing the '0' key of the numeric keypad.*

4.1.2 Potential / Current settings

E-cell: Cell potential monitor. The cell potential is displayed in relation to the chosen Zero Potential (E-zero) .



I-cell: Direct current monitor. The current flowing through the cell is displayed.

Charge: The charge which is passing through the cell is subdivided into anodic charge and cathodic charge. With respect to electrochemical notation, the anodic charge is due to the positive portion of the current flow through the cell, and the cathodic charge, which is displayed as absolute value, is due to the negative current flow.

Initial Potential: Sets the desired initial value of the cell potential in the potentiostatic mode. The range is ±10 V and can be set by dragging the mouse or entering via the keyboard.

- Dragging with the mouse will change the potential in 1 mV steps.

- Pressing ← and → changes E-initial in steps of 10 mV.
- Pressing `Option´ ← / → (MacOS) or CTRL ← / → (Windows) will change Einitial in 1 mV steps.

In the galvanostatic mode, the item will display the Iinitial(Initial current). The current is calculated by multiplying the current density and the electrode area, which can be specified either in the Configuration or Parameter window. It is also possible to set I-initial (Density) instead of I-initial. In the potentiostatic mode, the I-initial (Density) field is *not* activated.

Current Range: Sets the scaling of the current monitor output (I-cell). The ranges are 1μA to 10A incremented by decades.

To set the current range, click with the mouse on the Current Range button and selecting the desired range in the pop-up window by tagging.

If the high gain pre-amplifier is connected to the PG 310 POTENTIOSTAT/GALVANOSTAT, the current ranges from 100pA to 100nA are selectable. The Auto Range mode is also available (see below).

If the HIGH CURRENT BOOSTER HCB 20 is connected, the 20 A range is selectable.

The current range is calculated by multiplying the current density range and the electrode area, which can be specified either in the `Configuration` window or the Parameter window . Alternatively, the user can choose the range of current density instead of the current range. The unit of the current density is labeled with a prime, e.g., A.

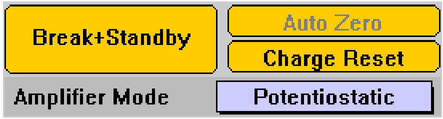
If there is a saturation of amplifiers in the current monitor circuitry, a blinking box labelled Over on the Current Range button is displayed. This is a warning that excess artifacts or noise may occur as a result of the saturation of amplifiers.

Break + Standby: Corresponds to the buttons Break and Standby, thus stopping all data acquisition immediately and turning the cell to Standby mode.

Auto Zero: In `Standby` mode a connected external preamplifier is set to zero current. Please use this option in case of eliminating current offsets of your external preamplifier.

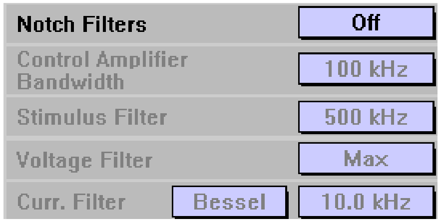
Charge Reset: Resets both the anodic and the cathodic charge.

Amplifier Mode: Allows a selection between potentiostatic and galvanostatic mode.



4.1.3 Filter Settings

Notch Filter: The PG 310/390 Potentiostat/Galvanostat provides a notch filter for both the voltage and the current pathway. The notch frequency (50 Hz or 60 Hz) is pre-set at the factory as desired by the customer, and cannot be set by the user. If the notch filter is On, incoming signals at the power supply frequency will be effectively filtered out.



Control Amplifier Bandwidth, Stimulus Filter, Voltage Filter, Current Filter: This filters can be set either manually or automatically. (The Notch Filter has to be switched manually by the user in any case.

For automatic filter mode, please activate the Auto Filter option in the `Configuration` window. The automatic settings dependance is that way:

- The automatic settings of the Control Amplifier Bandwidth, the Voltage Filter, and the Current Filter depend on the user defined Sample Interval and Filter Factor in the `Pulse Generator` (Free waveform) window.

- The automatic setting of the Stimulus Filter depends on the Sample Interval.

If the Auto Filter mode is selected, the filter settings are unable for manual settings and displayed with grayish numbers.

> ***Note:*** *If you are using an electrochemical cell with a high capacity and low Ohmic drop, a problem may arise with the automatic setting of the Stimulus Filter. In combination with a high frequency Stimulus Filter a pulse-like stimulus may cause oscillations at the potential steps with the use of such cells. In this case, try to select the manual filter mode and reduce the frequency of the Stimulus Filter. The other three filter settings proposed in the Auto Filter mode can be left unchanged.*

Control Amplifier Bandwidth: The potential control amplifier can be filtered to avoid oscillations of the control circuit. Eight of the nine possible settings of the bandwidth (plus Max) are available:

• 10 Hz • 100 Hz • 300 Hz • 1 kHz • 3 kHz • 10 kHz • 30 kHz • 100 kHz • Max

The possible settings depend on the PG 310/390 POTENTIOSTAT version:

- If you are using a PG 310/390 POTENTIOSTAT/GALVANOSTAT with a "A" or "B" labeled serial number, the low frequency bandwidth of 10 Hz will not be available.
- If you are using a PG 310/390 POTENTIOSTAT/GALVANOSTAT with a "C" or "D" labeled serial number, the high frequency bandwidth of 300 kHz will not be available.

> ***Note:*** *A transient problem may arise if the potential change is very fast in combination with a low bandwidth setting. There will be a rise time lag in the cell potential with respect to the given potential pulse. The time constant as the inverse of the bandwidth defines the shortest time domain over which the cell will accept a significant perturbation.*

Stimulus Filter: The stimulus can be filtered (2-pole Bessel) to reduce the amplitude of fast capacitance transients when the speed of potential changes is not critical. Four settings are available:

• 500 kHz • 50 kHz • 5 kHz • 0.5 kHz

> ***Note:*** *In a ramp segment the stimulus change is step-like rather than line-like. The number of steps needed for representing the ramp is defined by the quotient of the segment length and the "sample interval" (see also Chapter* Pulse Generator*, page* **??***). To improve the smoothness of the stimulus change, these steps are filtered to yield exponential, which reach about 63 percent of the step height during a term of one time constant. Hence, a filtered stimulus will become a chain of exponential, which exhibits a phase shift relative to the unfiltered stimulus. For instance, if you* choose a filter time constant equal to the sample interval, *the filtered stimulus will be a nearly smooth line with a phase shift of about 90 percent of the step length (i.e. of the sample interval).*

Voltage Filter: The voltage output (U-cell monitor) can be filtered by a 3-pole Bessel filter to reduce high frequency noise. The bandwidth can be set in four steps:

• 10 Hz • 100 Hz • 1000 Hz • Max

With the selection of Max no filtering is active and all frequencies are allowed to pass the AD channel.

Current Filter: Controls a switchable analog Bessel/Butterworth filter (4-pole) in the current monitor pathway. The menu provides the following settings:

- Bessel
- Butterworth
- Bypass (e.g., no filter active)

Dragging the mouse or entry on the keyboard allows bandwidth fine adjustment from 0.1-16 kHz in 0.1 kHz steps (Bessel) or 0.1-25.5 kHz (Butterworth). They differ in the following way:

- The Bessel setting is the best characteristic for general use. As such it is always used in automatic mode.

- The Butterworth response rolls off more rapidly with frequency and is useful mainly for power spectral analysis.

Under most conditions a 10 kHz bandwidth is more than ample, and the filtering reduces the high-frequency noise substantially.

> ***Note:*** *In automatic mode always the Bessel filter is used.*

4.1.4 Additional Settings

IR-Comp.: The series resistance compensation corrects for the voltage drop between the reference and working electrodes under conditions of high access resistance or high current flow between counter- and working electrode. In the 4-Electrode Mode the serial resistance between both reference electrodes is corrected. The compensation is based on the value of R-series, which can be changed by dragging the mouse or entering on the keyboard (range: 0 to 1 M) and will be effective only when IR-Comp is On (see also *PG310/390 Manual – IR Compensation*).

Ext. Input: The `External Input` (front panel of the PG 310/390) is scaled by a selectable factor (range: 0.1x and 1x), to allow for different external stimulators. It is strongly recommended to set Ext. Input to Off (i.e., equal to zero), if no external stimulator is connected to Ext. Input. This will prevent pick-up of external noise.

> ***Note:*** *The E-Initial (the Initial Potential) is not affected by changing the external scale factor. The scaling will only affect the initial potential, if the user sets the* ***`Initial Potential`*** *externally (e.g., with a stimulator or another computer).*

Reset: Selecting this button will reset the PG 310/390 to its initial default configuration. Reset is very useful for defining the initial state of the PG 310/390, when recording a macro. It will reset the DA channels to zero. E-Initial (the Initial Potential) will be unchanged by resetting the PG 310/390.

4.1.5 Cell mode

Cell Mode: Two separate cell setups are supported by the PG 310/390 POTENTIOSTAT:

- 3 Electrode Mode
- 4 Electrode Mode

The 3 Electrode Mode consists of a working, a counter and a reference electrode. In this mode the second reference electrode input (Reference II) on the front panel of the PG 310/390 is short-circuited to the working electrode, so that the potentiostat controls the voltage between the working and reference electrodes. This commonly used mode is the default setting.

The 4 Electrode Mode provides two distinct reference electrodes (Reference I and Reference II on the front panel of PG 310/390), between which the potentiostat controls the voltage.

4.1.6 Auto Range

During a sweep POTMASTER can adjust the current range to higher or lower ranges if the current was out of bounds. This function is available during slow data acquisition when in the Pulse Generator window Auto Current Range is selected.

Min: Specifies the lower threshold of current within the given current range in percentages of full range. If the current reaches the Min percentage of the actual current range, the next lower current range is selected and the current resolution increases. The minimum value for Min is 1%, the maximum value for Max is 100%.

Max: Specifies the upper threshold of current within the given current range in percentages of full range. If the current reaches the Max percentage of the actual current range, the amplifier switches to the next higher current range. The current resolution decreases. The values for `Max` range between 1% and 100%.

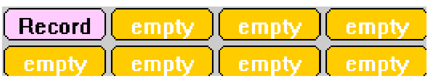
> ***Note:*** *`Auto Range` is also possible with the extended current ranges of the `External Preamplifier` and the `High Current Booster`.*

The desired thresholds of current within a given current range are defined in the `Min` / `Max` boxes in percentages of full range. For instance, a `Max` setting with 90% will force POTMASTER to switch to the next higher current range if the current exceeds 90% of the actual range.

4.1.7 Macro Recording

The following buttons give you some of the features from the PGF-Editor menue Macros option (see Chapter `Macros`).

- Record corresponds to Start Recording.
- The macro buttons corresponds to Execute [1..7].
- Clicking on an empty macro after recording and choosing Assign and name recorded macro corresponds to Stop Recording. Here the index of the macro is directly the index number of the empty macro button.
- Clicking on Record at the end of recording aborts recording directly.



You can save 20 macros at once, whereas the macro items of macro 8..20 and higher are in that part of the window which gets exposed when you zoom out the `PG 300` window (see below in Chapter *Hidden Controls*, page 30).

You have the option of actually executing all actions as they are entered, or of disabling execution and only logging the actions to the macro. This option you have to set in the PGF-Editor menu Macro options before you record.

Record: To start macro recording, click on the Record button. Then, perform all desired actions. (The Notebook window will print a protocol of the macro actions.) You may record up to 50 actions in the `PG 300`, `Oscilloscope` and `Online Analysis` windows. To specify a parameter value, enter it as usual by dragging or keyboard entry. When clicking on a macro button you will see a dialog with the following options:

- **Delete Macro:** This will erase the selected macro.
- **Cancel:** This will disregard the macro call. You can continue recording.
- **Record call to macro itself:** This will execute the macro as part of the macro being recorded (embedded macro call).
- **Copy contents of macro**: This will copy each of the macro instructions of the selected macro into the macro being recorded. This avoids the problems of recursive macros (i.e., macros calling each other and causing an infinite loop).
- **Assign and name recorded macro**: This will prompt you to give a name to the macro. This name will become the button text. This is the function you need for saving a newly recorded macro!

To abort recording a macro, click again on `Record` and the sequence just recorded will be lost.

Normally, macros are only available until you leave the program. You have to save the macros explicitly in a file on disk (see PGF-Editor menu Macro options options), if you want to use it further.

Macro 1..39: To start a recorded macro you can either click on the desired macro button or hit the key with the same number on the numeric block of your keyboard (macros 1..9).

In a macro file (`*.mac`) up to 40 macros (1.. 39) can be stored. One macro can exist of max. 255 instruction lines.

4.2 Hidden Controls

Some rarely used controls are on the right and bottom of the `Potentiostat` window. They can be accessed by clicking on the zoom box of the window or by pulling the window with the mouse on the right and lower sight.

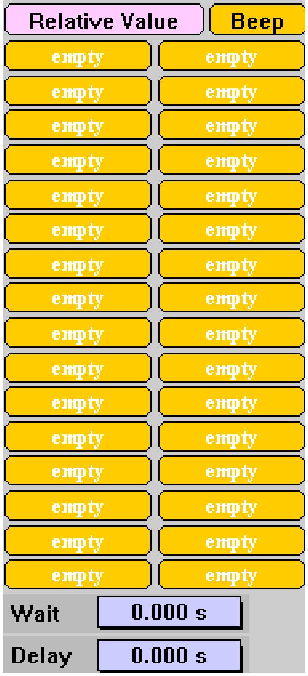
The following features can be found at the bottom of the `Potentiostat` window.

Ampl. Mode switch: set E/I-init: This feature ensures that by switching the Amplifier Mode between potentiostatic and galvanostatic, no current or voltage leap will occur. Thus, in the potentiostatic mode the actual current is measured and applied to the cell after the amplifier mode is switched to galvanostatic. This is the default setting.

If the function `Ampl. Mode switch: keep E/I-init` is chosen, current or voltage leaps may occur and affect the electrochemical processes at the working electrode.

4.2.1 Features for Macros

These features can be found at the right side of the `Potentiostat` window.



Relative Value: This control button allows the performance of relative changes of control settings during macro recording.

> ***Note:*** *For instance, if you want to compare different data monitors because of different filter settings, you can start a sweep while recording a macro, change the current filter setting relative to the first one by 1 kHz (click on Relative Value and then set filter to 1 kHz), start the sweep again, etc., and save the macro.*

Beep: Plays the system sound. In recording a macro it is useful to acoustically indicate the end of an experiment or other events.

Macros 8..39: Buttons for all macros with index numbers higher than 7.

Wait: This button is used to pause a macro execution. Pausing is indicated by a flashing Initial Potential field, which displays "Continue?" and the Wait button, as well as by a "Beep" sound. Macro execution is resumed by a click on the mouse. The Wait button can be used to inspect a particular sweep when playing a collection of sweeps. The time in seconds for the Wait function is set in the field above.

Delay: This determines how many seconds the program has to wait before the next action is started by the PG 310/390 POTENTIOstat/Galvanostat. When the Record button is activated, the label changes to Wait.

4.3 Controlling the PG 340 - Special Functions

With the Potmaster software you can also control the Pg 340 Bipotentiostat/Galvanostat.

The main feature of the Pg 340 Ring/Disc Potentiostat/Galvanostat is its design as a double potentiostat which allows to control two independent working-electrodes. This not only provides the tools to control rotating ring-disc electrodes, which are almost essential for the thorough study of mechanisms and kinetics of electrochemical reactions. It also allows the control of microelectrodes and ultra-microelectrodes connecting two external preamplifiers and makes innovative microelectrochemical technologies possible as generator- and collector-electrode mode for a Scanning Electrochemical Microscope (SECM).

The Pg 340 allows to set a sample substrate to a well defined potential versus a reference electrode while recording currents in the lower pA-range at an ultramicroelectrode in the same solution. Using two current channels strongly different currents can be simultaneously recorded. The bipotentiostat Pg 340 is therefore the heart of the HEKA ElProScan, the new developed Electrochemical Probe Scanner which is much more then a SECM.

The `Potentiostat` window of Pg 340 is amended with some buttons and functions for the two working electrodes, in comparison to the normal `Potentiostat` window, (see Chapter 4.1 *PG 310/390 Potentiostat/Galvanostat*).

4.3.1 Electrode Conditions

Via the buttons `Disk` and `Ring` the active electrode can be set and controlled.

- **Disk** – all settings in the `Potentiostat` window apply to the `DISK` electrode
- **Ring** – all settings in the `Potentiostat` window apply to the `RING` electrode

4.3.2 Cell Connection

Cell/Standby/OCP: Via these buttons the connection of the Pg310/390 Potentiostat/Galvanostat to the cell can be controlled.

Cell: Connects all the electrodes to the respective inputs of the Pg 340 Bipotentiostat/Galvanostat. In the potentiostatic mode the cell potential is controlled by the Pg 340, and the current flowing through the cell is displayed as I-Cell. In the galvanostatic mode the current flow through the cell is controlled by the Pg 340, and the respective cell potential is shown in the ECell display.

> ***Note:*** *The galvanostatic mode can only be set with the DISK electrode.*

In the `Standby` mode all the connections are switched off, and the potential can neither be read nor set.

In the `OCP` mode the counter-electrode is disconnected. The cell is in the zero current state, and the open cell potential of the selected electroded – either DISK or RING - is exhibited in the E-Cell display. The small Set insert button is used to set the Initial Potential value to the actual Open Cell Potential.

> ***Note:*** *It is also possible to switch to the Standby mode by pressing the '0' key of the numeric keypad.*

4.3.3 Potential/Current Settings

Almost all functions are the same as for the standard PG 310/390 POSTENTIOSTAT/GALVANOSTAT, see Chapter 4.1 *PG 310/390 Potentiostat/Galvanostat*. However, there are some small differences to be taken into account.

All settings apply to the selected electrode, e.g., DISK or RING.

Exceptions are:

- `Standby`, `Cell` and `OCP`, which act on the DISC and the RING electrode.
- `Control Amplifier Bandwidth` Filtering, which acts on the DISC and the RING electrode.
- `Stimulus Filter`, which is active only with the DISK electrode.

4.3.4 Additional Settings

The IR-compensation in the 3-Electrode Mode as well as in the 4-Electrode Mode applies only to the DISC electrode.

4.3.5 Cell Mode

Cell Mode: Two separate cell setups are supported by the PG 340 POTENTIOSTAT:

- `3 Electrode Mode`
- `4 Electrode Mode`

The `3 Electrode Mode` consists of a working (DISK and RING), a counter and a reference electrode. In this mode the second reference electrode input (Reference II) on the front panel of the PG 340 is short-circuited to the working electrode (DISK), so that the potentiostat controls the voltage between the working (DISK and RING) and reference electrodes. This commonly used mode is the default setting.

The `4 Electrode Mode` provides two distinct reference electrodes (Reference I and Reference II on the front panel of PG 340), between which the potentiostat controls the voltage.

5. Operating Modes

The PG 500 is fundamentally an instrument for controlling cell potential or current and measuring electric currents and potentials. In low current ranges it uses a current-to-voltage (I-U) converter circuit to convert the currents to an analog voltage, which is then made available at the current monitor output for display or recording. In higher current ranges, a resistor cascade replaces the I-U converter. In the potentiostatic mode, cell currents are recorded at the same time while the potential is controlled. In the galvanostatic mode, the current flowing through the cell is specified, and the potential at the working electrode is recorded. The connection of the electrochemical cell to the PG 500 potentiostat/ galvanostat is possible in three different cell modes and can be controlled manually or by the POTPULSE software.

- In the `Standby` mode, the cell is not connected to the `REFERENCE` and `COUNTER` electrodes; however the working electrode is always connected to the cell.

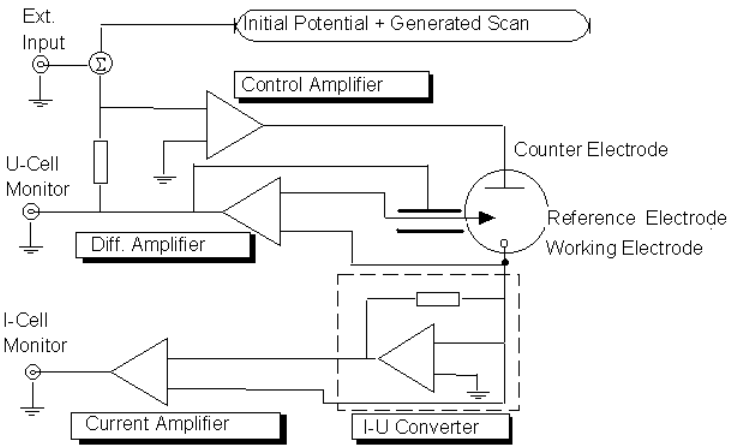
- In the `OCP` (open cell potential) mode, the REFERENCE and WORKING electrodes are connected to a measuring circuit with high input impedance (see section Differential Amplifier below) for allowing observation of the equilibrium potential (zero current potential).

- In the `Cell` mode, each of the three electrodes is connected to the terminals of the potentiostat/galvanostat circuit.

Note: *for any cell mode selection, the working electrode is connected to the current amplifier.*

5.1 Potentiostatic Mode

This is the basic amplifier mode and is implemented by the circuitry shown schematically in the figure below.



5.1.1 Differential Amplifier

The cell potential (`reference` vs. `working` electrodes) is derived from a generated scan (pulse) with a variable offset added from the `Initial Potential` control. An external voltage (`External Input`) can be superimposed on this software-generated signal. The sum of these two sources is displayed and monitored as the `VOLTAGE` Monitor signal. Furthermore, the high-resistance reference electrode input (input impedance of 100 GΩ) is very sensitive to any capacitive load or change in those electrode leads. Please bear in mind that even movement of the electrode leads may cause changes in capacitance. To maximize the bandwidth of the electrode inputs and to minimize the potential errors due to lead capacitance, a shield that remains fixed at the potential of the signal lead guards the reference electrode connector. This is realized by an electrometer amplifier that feeds the signal potential to the lead shield, that is, the outer part of the BNC connectors (see sketch above). Thus, it is not permissible to ground (set to earth potential) the shield of the coaxial cable used for the reference electrode lead.

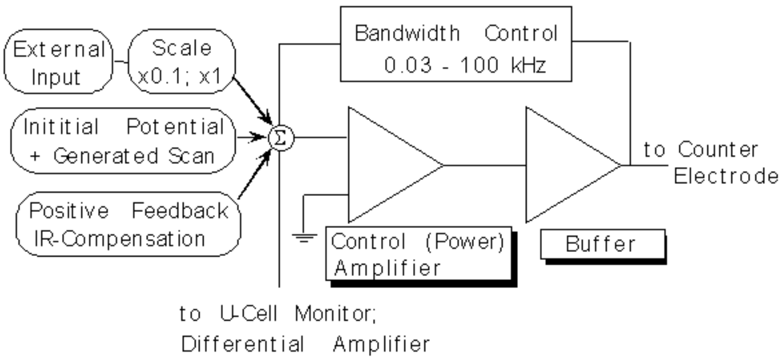
5.1.2 Current Amplifier

In a low current range situation, that is, 1 μA to 1 mA, the current flowing through the cell is converted to a voltage by the I-U converter (see sketch above). If the current range is changed, the appropriate feedback resistor will selected for that range. In higher current ranges, a resistor cascade replaces the I-U converter, and the potential drop across this resistor corresponds to the cell current. In both cases, the current amplifier amplifies the resulting voltage. Bear in mind that the PG 500 series potentiostat does not incorporate a truly grounded-potential working electrode. However at low currents the working electrode is virtually grounded by the I-U converter input and at higher currents the voltage difference between the working electrode and ground can be as high as the potential drop across the current-sensing resistor.

5.1.3 Control Amplifier

The control amplifier circuit is basically a ±20 V, ±2 A (PG 510) or ±90 V, ±1 A (PG 590) power operational amplifier. The various input signals supported are summed together at the input of the control amplifier (Internal Scan Generator, `External Input` and `IR-Comp`. Please note that the External Input is scalable by 1 or 0.1 only in `REMOTE` mode in local mode it defaults to 1. A sum of these voltages in excess of ±10 V is not permitted. The control amplifier unit is actually more complex than is shown in the upper schematic diagram and consist of the power amplifier itself, a buffer to boost the power amplifier output, and the bandwidth control.

The output of the buffer is driven to the voltage that is required to cause the feedback signal to be equal in its absolute value and opposite in sign to the summed input voltage. The bandwidth of the control amplifier is selected within the limits of 30 Hz to 100 kHz by changing a capacitor in the feedback loop. The maximal bandwidth (MAX) with non-capacitive feedback is defined by the internal circuit of the operational amplifiers and

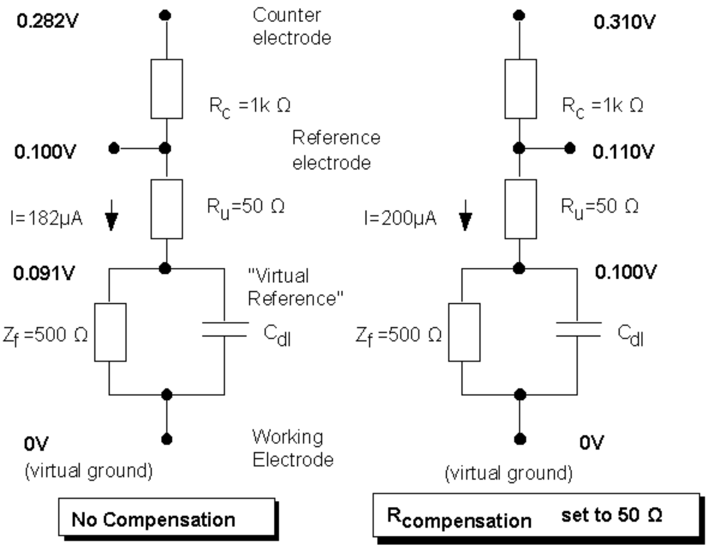


exceeds 1 MHz in the 1 mA range at -3 dB representing a signal amplitude reduction of a factor of approximately 0.7. The control amplifier is faster without any bandwidth settings however the circuit may oscillate under IR Compensation.

Whenever currents are passing through the electrochemical cell, there is always a potential control error I_{Ru}, due to the uncompensated resistance Ru. Usually, this error is small, or can be reduce to an insignificant level by selecting a proper choice of cell parameters. As long as this error is proportional to the cell current, using a signal of equal magnitude and opposite polarity can compensate it. The magnitude of the compensation signal is determined by the setting of the Ru compensation control on the current amplifier (positive feedback compensation). In the PG 500 series potentiostat, a voltage compensation based on this positive feedback compensation scheme is implemented. When IR Compensation is enabled, a fraction of the voltage (opposite in sign) developed by the I-U converter or resistance cascade in the current measuring circuit is fed back through a digital-to-analog converter (DAC) as an additional input to the control amplifier. This internal signal is applied to the working electrode terminal.

The following equivalent circuit illustrates the principle of compensation illustrated in a comprehensive manner.

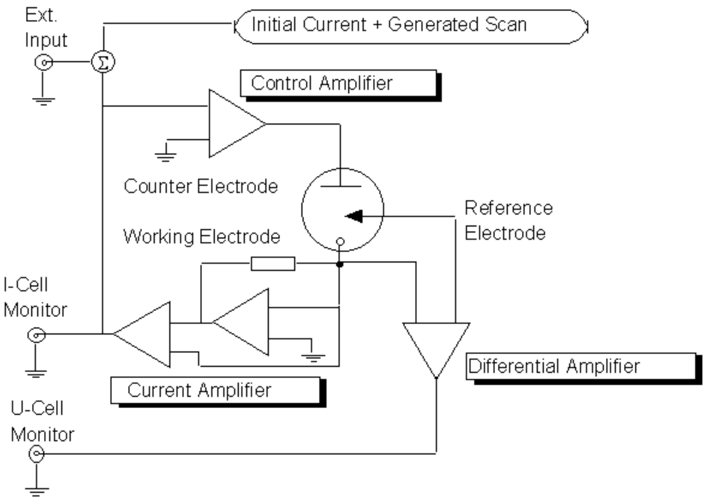
In this model the desired potential difference between the working and reference electrodes is maintained at 0.100 V. As a result of IR compensation, however, this potential difference no longer includes a voltage drop error due



to uncompensated resistance. That is, the reference electrode is virtually shifted. Thus, the `Voltage Monitor` output signal, 0.100 V in this example, is the signal coming from the differential amplifier, that is, 0.110 V, corrected for the amount of IR compensation; thus, 200 $\mu A \cdot 50\ \Omega = 0.010\ V$. Please note that the uncompensated resistance can be defined only as a fraction of the resistance across which the current is determined as a voltage. As a consequence, the highest compensation resistance as well as the resolution of the compensation resistance depends on the current range, too, therefore the IR compensation procedure must be performed for each current range used. The highest compensation resistance (Rcomp max.) and the resolution of the compensation resistance are a function of the current range.

5.2 Galvanostatic Mode

In the galvanostatic mode, the cell current is controlled by involving only two cell elements, the counter and working electrodes, in the control circuit (see figure below). The potential of the working electrode with respect to the reference electrode is followed and monitored by the differential amplifier, which acts as an summing measuring circuit. However the amplifier makes no contribution to the control circuit.



For performing galvanostatic measurements, the connections between the cell and the potentiostat/galvanostat system are the same as those for potentiostatic operation.

The functions of the three amplifiers (control, current, and differential amplifiers) are the same as described in the section for the potentiostatic mode. The more detailed description above, including shielding of the reference electrodes, the different I-U converter provided for high and low current ranges, the bandwidth control of the control amplifier and the summing of the various input signals, also applies to galvanostatic operation. The input signals, consisting of an Initial Current, a generated Scan and an

External Input, are provided as a voltage, whereby a voltage magnitude of 10 V means a cell current of 100 percent of the selected current range.

> ***Note:*** *in the galvanostatic mode the output of the differential amplifier also includes a contribution from uncompensated resistance. Compensation of this potential error is performed by IR compensation with positive feedback as described in the section above.*

5.2.1 IR Compensation

Whenever currents are passing through the electrochemical cell, there is always a potential control error IR_u because of the uncompensated resistance $\mathrm{R_u}$. If a cathodic current flows, the true working electrode potential will be less negative than the nominal value. The opposite holds for an anodic current. Usually, this error is small, or can be made insignificant by a proper choice of the cell parameters. As long as this error is proportional to the cell current, it can be compensated by using a signal of equal magnitude but of opposite polarity. The magnitude of the compensation signal is determined by the setting of the $\mathrm{R_u}$ compensation control on the current amplifier (positive feedback compensation). In the PG 300 series potentiostat/galvanostat, a voltage compensation based on this positive feedback compensation scheme is implemented. When *IR Compensation* is enabled in the *POTPULSE* program, a fraction of the voltage (opposite in sign) developed by the I-U converter or resistance cascade in the current measuring circuit is fed back through a digital-to-analog converter (DAC) as an additional input to the control amplifier. This internal signal is effective at the working electrode terminal.

The working electrode potential (vs. reference electrode) differs from the desired value defined by the sum of the software and external settings by the control error $\mathrm{I(R_u\text{-}R_{compensation})}$.

In *galvanostatic* operation the differential amplifier is not part of the control circuit, and the voltage drop error due to uncompensated resistance should only be corrected, if the cell potential is monitored. IR compensation will act as an additional voltage to the *U-Cell Monitor*; it is determined by the $\mathrm{R_{compensation}}$ setting and the output signal from the current amplifier.

The following equivalent circuit illustrates the principle of compensation in an easily comprehensible manner.

In this model circuit the desired potential difference between the working and reference electrodes is maintained at 0.100 V. As a result of IR compensation, however, this potential difference no longer includes a voltage drop error due to uncompensated resistance. That is, the reference electrode is virtually shifted. Thus, the *U-Cell monitor* output signal, 0.100 V in this example, is the signal coming from the differential amplifier (*Reference Electrode I* vs. *Reference Electrode II*), that is, 0.110 V, corrected for the amount of IR compensation; thus, 200 μA $_*$50 $\Omega = 0.010$ V.

Please note that the uncompensated resistance can be defined only as a fraction of the resistance across which the current is determined as a voltage. As a consequence, the highest compensation resistance as well as the resolution of the compensation resistance depends on the current range, too, and thus the IR compensation procedure has to be performed for each current range used. The highest compensation resistance (R_{comp} max.) and the resolution of the compensation resistance are a function of the current range, as follows.

6. Appendix I: Technical Data

6.1 PG 300 Series

6.1.1 Digital I/O Connector

The digital IN and OUT lines of this connector carry TTL-compatible signals. The connector is intended to connect other HEKA devices, such as the TIB 14 to the PG 300. For other purposes the Digital In connector and the Digital Out connector should be used.

PIN 1 of the 40-pin connector is labelled with a small arrow:

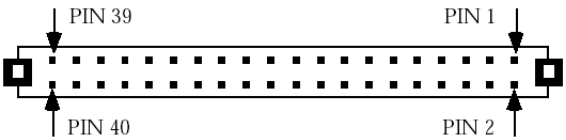


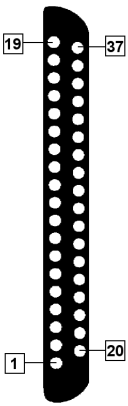
Figure 6.1: Digital I/O connector of the PG 300

Pin number	EPC 10	Pin number	EPC 10
1	IN-0	2	OUT-14
3	Not connected	4	OUT-15
5	IN-2	6	IN-10
7	IN-3	8	IN-11
9	IN-4	10	IN-12
11	IN-5	12	IN-13
13	IN-6	14	IN-14
15	IN-7	16	IN-9
17	IN-1	18	Not connected
19	GND	20	GND
21	GND	22	GND
23	Not connected	24	STROBE
25	OUT-0	26	OUT-8
27	OUT-1	28	OUT-9
29	OUT-2	30	OUT-10
31	OUT-3	32	OUT-11
33	OUT-4	34	OUT-12
35	OUT-5	36	OUT-13
37	OUT-6	38	IN-8
39	OUT-7	40	Not connected

Figure 6.2: Digital I/O connector of the PG 300

6.1.2 Digital In Connector

The Digital In connector at the rear panel can be used to read TTL trigger signals from external devices.

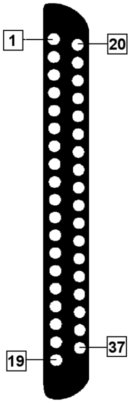


PIN	Signal	Pin	Signal
1	GND	20	GND
2	GND	21	In 0
3	GND	22	In 1
4	GND	23	In 2
5	GND	24	In 3
6	GND	25	In 4
7	GND	26	In 5
8	GND	27	In 6
9	GND	28	In 7
10	GND	29	In 8
11	GND	30	In 9
12	GND	31	In 10
13	GND	32	In 11
14	GND	33	In 12
15	GND	34	In 13
16	GND	35	In 14
17	GND	36	In 15
18	GND	37	GND
19	GND		

Figure 6.3: Digital In connector of the PG 300

6.1.3 Digital Out Connector

The Digital Out connector at the rear panel of the PG 300 amplifiers can be used to trigger external devices, which require TTL inputs. The signals of pin 21 (OUT-0) to 23 (OUT-2) can also be accessed from the BNC trigger outputs at the front panel of the amplifier.



PIN	Signal	Pin	Signal
1	GND	20	GND
2	GND	21	Out 0
3	GND	22	Out 1
4	GND	23	Out 2
5	GND	24	Out 3
6	GND	25	Out 4
7	GND	26	Out 5
8	GND	27	Out 6
9	GND	28	Out 7
10	GND	29	Out 8
11	GND	30	Out 9
12	GND	31	Out 10
13	GND	32	Out 11
14	GND	33	Out 12
15	GND	34	Out 13
16	GND	35	Out 14
17	GND	36	Out 15
18	GND	37	GND
19	GND		

Figure 6.4: Digital Out connector of the PG 300

6.2 PG 300 USB Series

6.2.1 Digital I/O Connector

The digital IN and OUT lines of this connector carry TTL-compatible signals. The connector is intended to connect other HEKA devices, such as the TIB 14 to the PG 300amplifier. For other purposes the Digital In connector and the Digital Out connector should be used.

PIN 1 of the 40-pin connector is labelled with a small arrow:

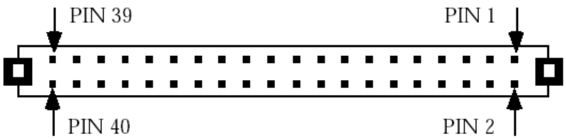


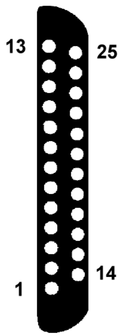
Figure 6.5: Digital I/O connector of the PG 300USB

Pin number	EPC 10	Pin number	EPC 10
1	IN-0	2	OUT-14
3	Not connected	4	OUT-15
5	IN-2	6	IN-10
7	IN-3	8	IN-11
9	IN-4	10	IN-12
11	IN-5	12	IN-13
13	IN-6	14	IN-14
15	IN-7	16	IN-9
17	IN-1	18	Not connected
19	GND	20	GND
21	GND	22	GND
23	Not connected	24	STROBE
25	OUT-0	26	OUT-8
27	OUT-1	28	OUT-9
29	OUT-2	30	OUT-10
31	OUT-3	32	OUT-11
33	OUT-4	34	OUT-12
35	OUT-5	36	OUT-13
37	OUT-6	38	IN-8
39	OUT-7	40	Not connected

Figure 6.6: Digital I/O connector of the PG 300USB

6.2.2 Digital In Connector

The Digital In connector at the rear panel can be used to read TTL trigger signals from external devices.

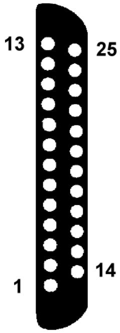


PIN	Signal	PIN	Signal
1	In 3	14	In 4
2	In 2	15	In 5
3	GND	16	In 6
4	GND	17	In 7
5	GND	18	In 8
6	GND	19	In 9
7	GND	20	In 10
8	GND	21	In 11
9	GND	22	In 12
10	GND	23	In 13
11	GND	24	In 14
12	In 1	25	In 15
13	In 0		

Figure 6.7: Digital In connector of the PG 300USB

6.2.3 Digital Out Connector

The Digital Out connector at the rear panel of the PG 300 amplifiers can be used to trigger external devices, which require TTL inputs. The signals of pin 21 (OUT-0) to 23 (OUT-2) can also be accessed from the BNC trigger outputs at the front panel of the amplifier.



PIN	Signal	PIN	Signal
1	In 3	14	In 4
2	In 2	15	In 5
3	GND	16	In 6
4	GND	17	In 7
5	GND	18	In 8
6	GND	19	In 9
7	GND	20	In 10
8	GND	21	In 11
9	GND	22	In 12
10	GND	23	In 13
11	GND	24	In 14
12	In 1	25	In 15
13	In 0		

Figure 6.8: Digital Out connector of the PG 300USB

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