Operating Instructions

for the

PLUGSYS® - module

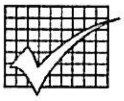
BPA <u>B</u>io <u>P</u>otential <u>A</u>mplifier Type 675

(Version June 1992 from Ser.No.: 9101 Hel.)

Contents

Introduction

These Operating Instructions describe the functions and the use of the PLUGSYS module BPA Type 675 developed and manufactured by Hugo Sachs Elektronik. Before working with your new PLUGSYS module please check first that the module has been correctly installed in your PLUGSYS housing. Further information on the installation of modules will be found in the Operating Instructions for the PLUGSYS housing.



Descriptions of a multi-talented unit like the HSE BPA signal amplifier can never really be complete or cover fully all applications. Any queries should be directed to the distributor from whom you have obtained the unit, or directly to Hugo Sachs Elektronik.

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Important. Essential Note:

The Operating Instructions for the BPA Bio-Potential Amplifier have to be read in conjunction with the remaining system documentation for the PLUGSYS housing used.

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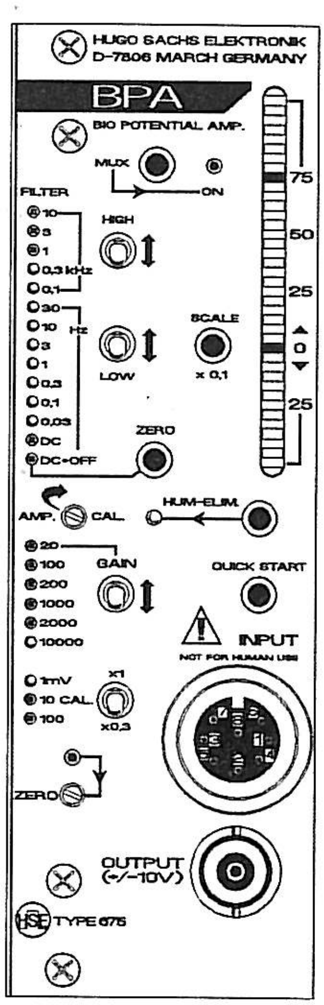
March-Hugstetten, June 1992

1 General Description



The HSE Bio-Potential Amplifier BPA Type 675 is a universal signal amplifier for the direct recording of bio-signal voltages such as ECG, EEG, EMG, ENG, and also for measurements using resistive transducers. The input circuit of the BPA is arranged without isolation amplifier (no voltage isolation between the recording electrodes and the circuit null of the PLUGSYS measuring system). It is specially designed for physiological and pharmacological research using animal experiments and for recording signals from isolated organs and tissues. A isolation amplifier IPH Type 675/1 (headstage) is available for direct measurement on human subjects or for isolation in difficult animal experiments. The modular circuit design of the BPA module offers a general facility for adapting the input circuit to the requirements of special applications through headstages, e.g. the microelectrode preamplifier Type 675/2 for direct recording of intracellular action potentials.

1.1 Your BPA module presents itself

Signal input	Direct for biological signals (ECG, EMG, EEG, ENG) and resistive transducers.
Input circuit	Push-pull differential amplifier with protection circuit against static discharges and 15 kHz input filter for HF suppression.
Signal input	8-pin Binder (Amphenol) socket with screw lock. The pin arrangement of the differential input corresponds to the standard ECG input cable with 3-pin Binder (Amphenol) plug.
Signal output	(a) Internally through the system bus of the PLUGSYS measuring system. The assignment of the signal output to the bus lines AV-1 to AV-16 is provided by a jumper. (b) On the front panel through a BNC socket 10 V with an output impedance of 100 Ohm.
Frequency range	D.C. to 10 kHz (-3 dB).
Low pass filter	12 positions ranging from 0.03 Hz to 10 kHz (-3 dB).
High pass filter	10 positions ranging from d.c. to 100 Hz (-3 dB).
Filter indication	The settings of the high and low pass filters are indicated as a frequency pass band through an LED bargraph on the front panel.
Blocking filter	A 50 (60) Hz blocking filter can be switched in by a key to suppress interference from the A.C. supply.

Quick start	Rapid discharge of the coupling capacitors in a.c. operation (e.g. in ECG recording) on pressing a key.
Amplification	20x, 100x, 200x, 1000x, 2000x and 10 000x selected in steps by a switch, and variable by multi-turn trimmer within the range 10% to 100% (based on gain settings range 20x to 10 000x).
Calibration	Key-operated calibration signal for evaluating the input signal. The calibration signal 1-10-100 mV is changed automatically to suit the gain setting.
Bridge supply	5 Volt supply for resistive transducers. When operating the BPA amplifier with a headstage the supply voltage is automatically changed by the plug coding to the 5 Volt supply of the power supply.
Zeroing	(a) Auto Zero: automatic zero adjustment by pressing a key or by a control command from a laboratory PC. (b) Manual zero: to correct large offset voltages if the automatic adjustment range of the auto zero facility is exceeded.
Analogue indication	Through LED bargraph +12/-6 LEDs for visual monitoring of the applied input signal. The sensitivity can be changed by a key from +10/-5 V to +1/-0.5 V.
MUX-ON	On pressing the MUX-ON key the output signal of the BPA is switched for monitoring to an output (AM) common to all modules of the PLUGSYS system. Monitoring by the DVM (Digital Volt Meter) module or by an external oscilloscope or high-speed recorder.

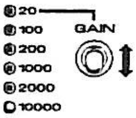
2 Construction

The BPA Bio-Potential Amplifier Type 675 takes the form of a plug-in module for the PLUGSYS measuring system from Hugo Sachs. It occupies two slots in the housing, corresponding to twice 4E (40.6 mm).

2.1 Controls

The BPA amplifier is controlled centrally by a small internal micro processor. Setting the instrument is user-friendly through the use of a conventional toggle switch and pushbuttons. The arrangement of the controls and the front panel layout correspond to that of a conventional signal amplifier. In addition to specially convenient operation, such as automatic zeroing by a key, incorrect operation is prevented by the intrinsic intelligence. For example, it is not possible to set any overlap between the high and low pass filters. All instrument settings are stored in a non-volatile data memory and are loaded automatically when the instrument is switched on (no inconvenient programming required after switching on).

2.1.1 Gain [20x ... 10 000x]



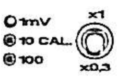
The "GAIN" switch is used to set the overall amplification within the range 20x to 10000x. Pushing the switch lever up or down automatically reduces or increases the gain. The current setting is shown on an LED to the left of the gain factor.

NOTE! The overall amplification depends on the variable amplitude setting of the "AMP.-CAL" control. In addition, the calibration voltage step 1-10.100 mV is automatically set by the gain factor.

2.1.2 Amplitude adjustment [variable 10 to 100%]

The multiturn trimmer "AMP.-CAL" reduces the amplification of the BPA within the range 100 to 10%. The overall amplification is therefore given by the gain setting and the position of the "AMP.-CAL" amplitude attenuator. When the control is turned fully clockwise the amplification is calibrated in accordance with the gain setting. The variable amplitude attenuation can be used to adjust the BPA to various signal input voltages or to calibrate recorders connected to the instrument.

2.1.3 Output of the calibration reference [CAL]



For evaluating the amplitude of an applied signal voltage the BPA amplifier has a facility for keying in a positive calibrated reference voltage. The magnitude of the reference voltage is automatically set according to the selected gain. The current setting is shown by an LED on the left of the switch. The size of the voltage step is determined by the user with the switch "CAL x1" and "CAL x0.3". The voltage is fed into the first amplifier stage; this also permits evaluation of the filter time constants.

Calibration voltages based on the BPA input for different gain settings

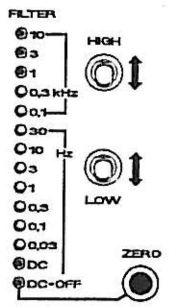
[GAIN]	[CAL x 1]	[CAL x 0,3]	Output x 1	Output x 0,3
20	100 mV	30 mV	2 V	0,6 V
100	100 mV	30 mV	10 V	3 V
200	10 mV	3 mV	2 V	0,6 V
1 000	10 mV	3 mV	10 V	3 V
2 000	1 mV	0,3 mV	2 V	0,6 V
10 000	1 mV	0,3 mV	10 V	3 V

The output voltage is based on the 100% setting of "AMP.- CAL" (calibrated).

2.1.4 Quick-start

Rapid discharge of the coupling capacitors in a.c. operation (e.g. during ECG recording) by pressing a key. Immediate return to amplifier zero.

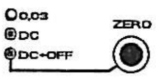
2.1.5 Output filter band pass (high and low pass filters)



The operation of the filter is provided jointly for the high and low pass filters, using two switches and an LED bargraph. The combination of the two filters produces a band pass filter with an upper and lower frequency limit (-3 dB). The actual setting of the filter is indicated by the LED bargraph as a frequency pass band. The pass band is set with the "HIGH" switch for the upper frequency limit and the "LOW" switch for the lower frequency limit. Overlap between the high and low pass filters it prevented by the built-in intelligence of the module; the opposite frequency limit is shifted automatically. In addition to the various permitted combinations of the high and low pass filters there are two special cases, "DC" and "DC+OFF", which are important for understanding the filter function. When the lower frequency limit is set to DC the high pass filter is switched off; the input amplifier is directly coupled. With DC + OFF the high pass filter is again switched off and in addition a correction voltage is injected into the input amplifier to shift the zero, e.g. for zero adjustment of a pressure or force transducer.

NOTE! The Quick Start key for rapid discharge of the coupling capacitor has no function at the settings DC and DC + OFF !

2.1.6 ZERO (zero adjustment)



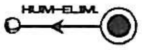
The BPA incorporates an automatic zero adjustment to compensate input offset voltages, e.g. due to resistive transducers in a bridge circuit. NOTE! Zero adjustment operates only when the filter is set to "DC+OFF". For this reason a line is shown in the front panel linking the "ZERO" function to the status LED "DC + OFF" in the filter field. Should zero adjustment be started with the "ZERO" key in any filter position other than "DC+OFF", all the filter status LEDs flash rhythmically for a brief period in order to warn the user that the operation is incorrect. Under normal conditions, pressing the "ZERO" key is followed by automatic compensation of the input offset voltage to zero. This can be checked visually by means of the analogue bargraph indication on the BPA or on a recording device (high-speed recorder or oscilloscope) connected to the module. If, for example in case of extremely non-symmetrical transducers or large input offset voltages, the range of the auto zero function is exceeded, the zeroing operation is stopped and the automatic system returns to its normal position in the centre of the adjustment range.

The user is attention is drawn to this problem by the flashing LED above the "ZERO" multi-turn trimmer. Coarse adjustment of the zero is then required, using the "ZERO" trimmer, followed by again pressing the "ZERO" key in order to achieve accurate zeroing through the automatic system. The adjustment range of the auto-zero is normally adequate for balancing transducers, and the "ZERO" trimmer should therefore remain in its centre position. Manual zero pre-adjustment is required only with extremely unbalanced transducers or large input offset voltages.

Zeroing takes place digitally through a digital/analogue converter, using the computer built into the BPA. This completely excludes any zero drift with time, as found in analogue systems with storage capacitor. The numerical offset vector of the zero adjustment is stored in the non-volatile data store and is loaded again when the instrument is switched on.

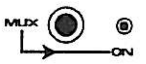
2.1.7 HUM-ELIM (50/60 Hz blocking filter)

Hum elimination refers to a 50/60 Hz blocking filter to suppress hum interference from the a.c. supply.



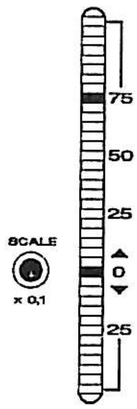
The blocking filter is switched on and off using the "HUM-ELIM." key. The LED on the left of the operating key indicates the current status. The blocking frequency of 50 or 60 Hz is set at the factory through a link on the BPA circuit board in accordance with the requirement of the despatch country. The blocking frequency can readily be changed later by the user. For further information on slope and mode of action refer to the detailed description of the blocking filter.

2.1.8 MUX (key)



On pressing the "MUX" key the output signal of the BPA is switched to the AM signal line (Analog Multiplex) common to all modules. The key function is self-maintained. The activation of this function is indicated by the LED to the right of the key lighting up. At the same time the line RDVM (Reset Digital Voltmeter Multiplex) is activated and ensures that the module previously selected is disconnected from the AM signal line. This facility allows the output signals of the individual amplifier modules to be switched to a central analogue or digital display unit (e.g. the DVM Digital Voltmeter Module of the PLUGSYS system or an external oscilloscope or voltmeter). When the PLUGSYS housing is switched on, a Power Up Reset signal is generated which de-activates all analogue multiplex outputs.

2.1.9 Analogue indication (bargraph)



A series of LEDs along the right edge of the module permits visual monitoring of the input signal. The resolution is 12 LEDs in the positive direction and 6 LEDs in the negative direction.

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- - - - - - 0 + + + + + + + + + + + +

- 6 LEDs  zero                 + 12 LEDs
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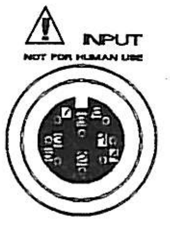
For accurate zeroing, e.g. with pressure transducers, the sensitivity of the display can be changed with the "SCALE" key to 0.1x sensitivity. With Scale x1 each LED corresponds to a signal voltage of 0.83 Volt; the working range is therefore -5 Volt to +10 Volt. In position SCALE x0.1 the value for each LED is 0.083 Volt, giving an indication range from -0.5 to +1 Volt.

NOTE
Changing the sensitivity with the "SCALE" key to x0.1 has no influence on the signal outputs. It only alters the amplification of the bargraph.

3 INPUT (signal input)

The input socket "INPUT" (8-pin Amphenol, Tuchel or Binder socket with screw lock) has the following pin connections:



Pin	1	(-) signal input
	2	circuit zero (signal GND)
	3	(+) signal input
	4	input INFO_HS (coded if headstage is connected)
	5	input TA_QUICK (external quick start key)
	6	(+) supply
	7	(-) supply
	8	output OFFSET

Suitable connectors, e.g. from Binder:

1.) 8-pin, No. 09-0067-00-08

or

2.) 3-pin, No. 09-0005-00-03

NOTE! The input circuit of the BPA is arranged without isolation (no potential separation between the recording electrodes and the circuit ground of the PLUGSYS measuring system). For direct measurement on human subjects a plug-in isolation amplifier IPH Type 675/1 (headstage) can be supplied as an accessory.

It is your own responsibility to conform to the safety requirements applicable to you at the time of the measurement.

3.1 Circuit description of the signal inputs

1.) **Signal inputs (+) and (-)**

Positive and negative signal input of the differential amplifier. The maximum differential input voltage must not exceed 0.5 Volt, otherwise the first amplifier stage of the BPA is overloaded. The amplitude of the signal peaks is then cut off.

2.) **Circuit ground**

Reference potential for the signal inputs (+) and (-). NOTE! This signal line must not be used as current return for the supply voltage.

3.) **Input INFO_HS**

Control input to code whether or not a headstage is connected to the BPA. When operating without headstage the input INFO_HS is not in use. In order to switch the BPA to the external headstage mode a change is made by fitting a wire link inside the input plug from INFO_HS (pin 4) to circuit ground (pin 2).

4.) **Input TA_QUICK**

Control input for the rapid discharge of the coupling capacitors during a.c. operation (e.g. in ECG recording) by external key on the headstage. The external quick start key is connected between circuit ground (pin 2) and TA_QUICK (pin 5). In the operating mode without headstage the input TA_QUICK is not in use.

5.) **(+) and (-) supply**

a.) **Operation without headstage**

(+/-) is a d.c. source for supplying resistance transducers in bridge circuit. The supply voltage is isolated from the remainder of the power supply and connected directly to the circuit ground of the input amplifier through two symmetrical 10 kOhm resistors. The supply voltage is protected against short-circuit and set at 5 Volt. The output current is 50 mA, corresponding to a maximum permitted bridge impedance of 100 Ohm.

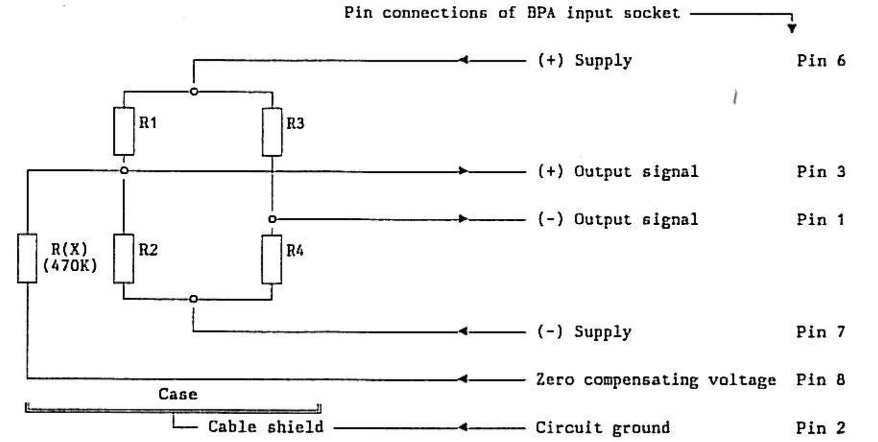
b.) **Operation with headstage**

During operation with a headstage the (+/-) supply lines carry the +5 Volt supply out of the PLUGSYS housing to supply DC/DC converters for the power supply of the headstage. The line (+) supply (pin 6) then corresponds to +5 Volt and the line (-) supply (pin 7) to D-GND. Die +5 Volt supply is not proof against short-circuit and is protected by an 800 mA miniature fuse on the circuit board of the BPA.

6.) **OFFSET output**

Signal output with +/- 10 Volt corresponding to the sum of the correction voltages of manual and automatic zero adjustment for external compensation in the input amplifier of the headstage. When operating without headstage the signal output is used for adjusting the sensitivity of the zero adjustment on resistive transducers. The zero compensation voltage is fed into the positive limb of the bridge through a resistance. The correction resistance depends on the transducer sensitivity and the bridge impedance.

3.2 Connection diagram for transducers in bridge circuit



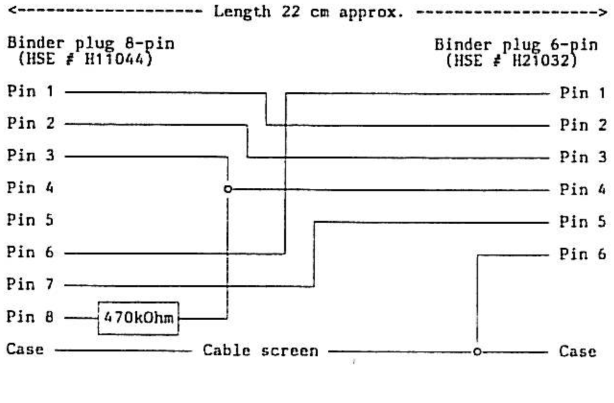
R1 and R2 - positive half-bridge
R3 and R4 - negative half-bridge
R(X) - compensation resistance for manual and automatic zeroing. The resistance value of R(X) (470 kOhm) depends on the transducer sensitivity and on the bridge impedance.

NOTE

Inside the plug to the BPA the circuit zero (pin 2) must not be connected to the plug case. The plug case is connected through the front panel of the BPA amplifier to the ground potential of the mains supply to the PLUGSYS housing. If circuit ground and supply ground are connected together through the input plug there is a danger of a ground loop, resulting in hum interference. Theoretically there is also a possibility of screening the transducer housing and the connecting cable through the plug case (supply ground). It is then essential to ensure that the screw lock of the plug is screwed firmly to the socket; otherwise there is no assurance of a reliable connection to the supply ground.

3.3 Adapter for a resistance transducer with 6-pin Binder plug

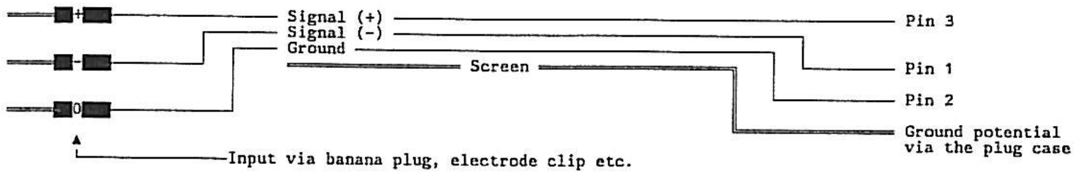
The signal input on the BPA amplifier is mechanically and electrically incompatible with the 6-pin input socket widely used in laboratory measurement, and an adapter cable is required to operate the transducer. There is of course the possibility of changing the plug on the transducer to suit the BPA. This makes sense only if the transducer is to be used exclusively with the BPA amplifier. The diagram below shows the wiring of the adapter cable which is available from Hugo Sachs Elektronik as a standard accessory. The compensating voltage for zeroing the resistance bridge of the transducer is fed in through the 470 kOhm resistance. The value of the coupling resistance has to be varied to suit the transducer sensitivity and input impedance.



NOTE

Please note also the points in Section 3.2 (connection diagram, Note) concerning linking the BPA circuit ground to the mains supply ground potential.

3.4 Recording cable for ECG, EMG and EEG.



NOTE

Please note also the points in Section 3.2 (connection diagram, Note) concerning linking the BPA circuit ground to the mains supply ground potential.

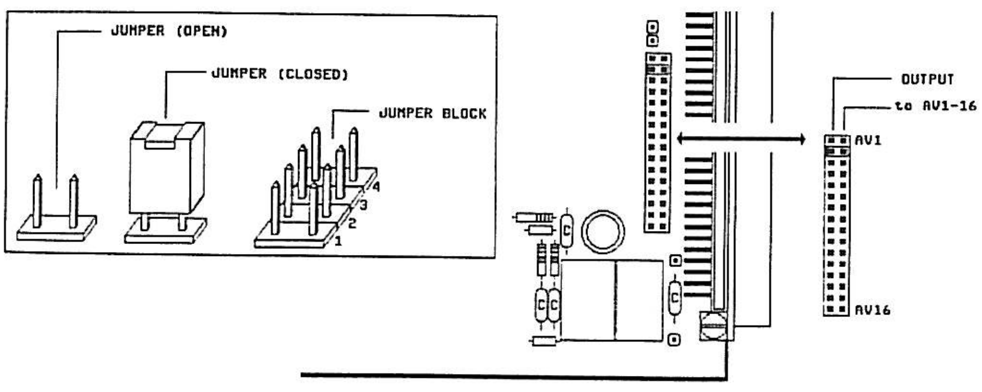
4 Signal outputs

4.1 Signal output (OUTPUT) on the front panel

The output signal of the BPA is available at the BNC socket on the front panel for monitoring or recording. The signal voltage is +/- 10 Volt with an output impedance of 100 Ohm and a bandwidth of up to 10 kHz depending on the filter setting.

4.2 Signal output to the PLUGSYS system bus

The assignment of the BPA output signal takes place through a jumper on the BPA circuit board to one of the analogue connecting lines AV-1 to AV-16. The output voltage is +/- 10 Volt at an output impedance of 100 Ohm.



Position of the jumper block for selecting the internal output on the circuit board of the BPA module.

The signal bandwidth of the PLUGSYS output module ROM Type 670 is d.c. to 3 kHz. For this reason the output signal of the BPA cannot be taken out via the ROM module at its full bandwidth of d.c. to 10 kHz. The remedy is to use the BNC output on the front panel, or to modify the appropriate output filter on the ROM module. Conversion of an existing ROM cannot be carried out by the user; the module has to be returned to Hugo Sachs Elektronik for modifying the filter.

5 Use of the output filter of the BPA when recording e.g. human ECG
5.1 Preliminary note

Before capturing, recording and evaluating biological signals it is essential to consider the technical specification of the measuring system in order to achieve signal reproduction without distortion. An aid for on-line signal processing is to filter the signals with low and high pass filters and with blocking filters. The use of filter circuits makes it possible to remove interference such as e.g. amplifier noise, 50/60 Hz hum or a polarisation d.c. level from the wanted signal. However, interference can only be filtered out if its frequency spectrum is outside that of the wanted signal. Otherwise the shape of the wanted signal is distorted. As an example, the effect of the low pass filter on the signal shape of human ECG will be discussed below.

<u>Description of the measuring system</u>

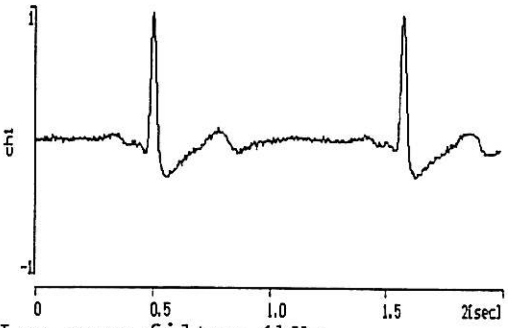
* HSE Bio-Potential Amplifier
  high pass filter 1 Hz / blocking filter OFF
  low pass filter set to 1 kHz - 300 Hz - 100 Hz - 30 Hz - 10 Hz - 3 Hz

* isolated preamplifier headstage 5000 (IPH) Type 675/1

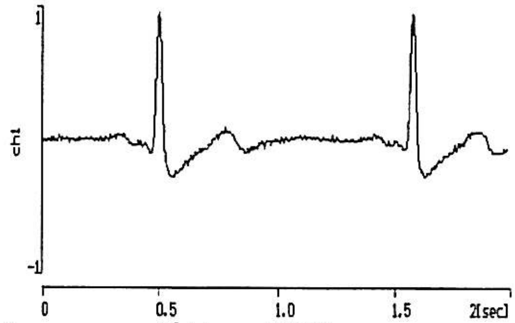
* plate electrodes for direct recording of the ECG at the extremities

* digital data handling system with 1 kHz sampling rate

* PC for signal presentation



Low pass filter 1kHz

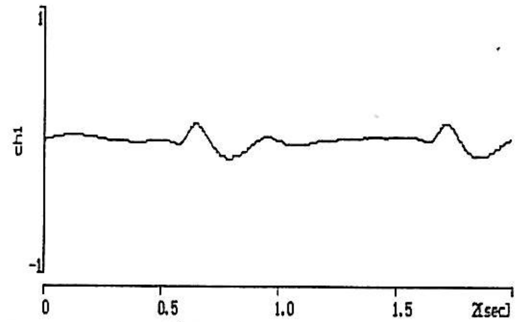


Low pass filter 300Hz

Low pass filter 100Hz

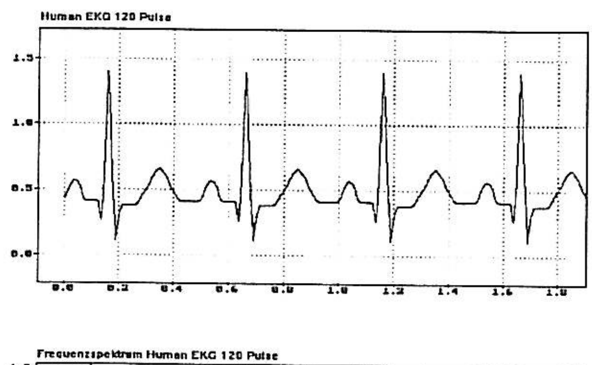
Low pass filter 30Hz

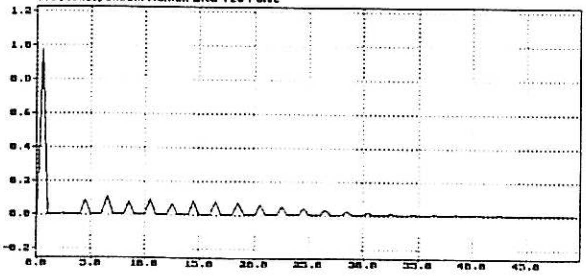
Low pass filter 10Hz



Low pass filter 3Hz

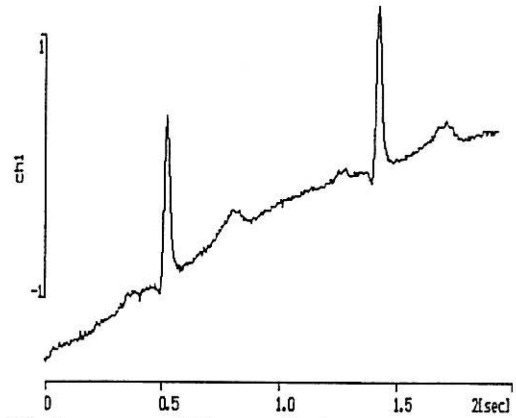
As shown by the illustrations, the signal is clearly distorted from a limiting frequency of 30 Hz. This can readily be explained from an analysis of the frequency content of human ECG, as shown below.



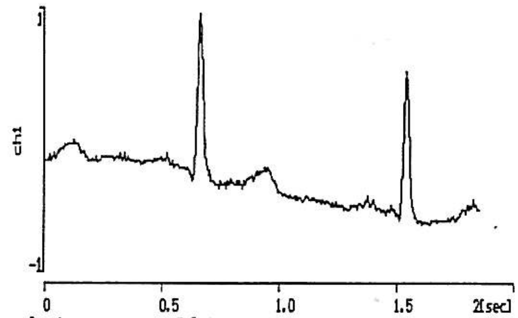


As you can see in the frequency spectrum (lower curve), the frequency components in human ECG above 30 Hz are no longer significant so that there is serious distortion of the signal only with a low pass setting below 30 Hz. This limit depends greatly on the species used. For small animals such as rats and guinea-pigs the limit is about 120 to 150 Hz, for rabbits it is about 80 Hz.

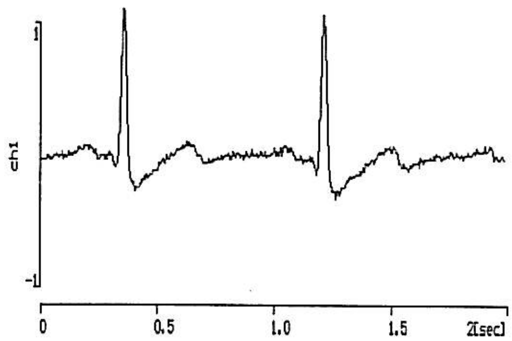
As in considering the low pass filter, the filter setting for the high pass also has a lower frequency limit, beyond which the signal is clearly restricted. For human ECG a limit below 1 Hz can readily be seen from the spectrum. The following traces illustrate this condition.



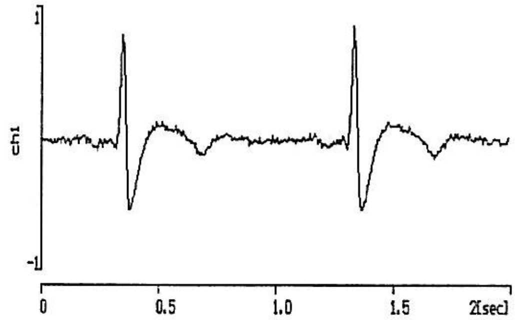
High pass filter 0,1 Hz



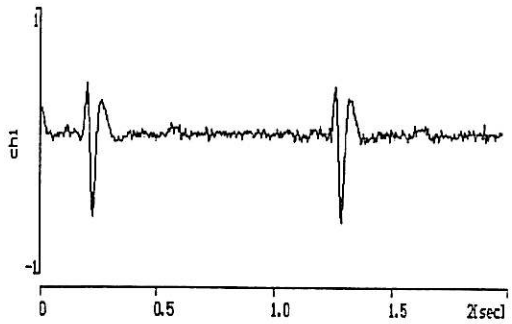
High pass filter 0,3 Hz



High pass Filter 1 Hz



High pass filter 3 Hz

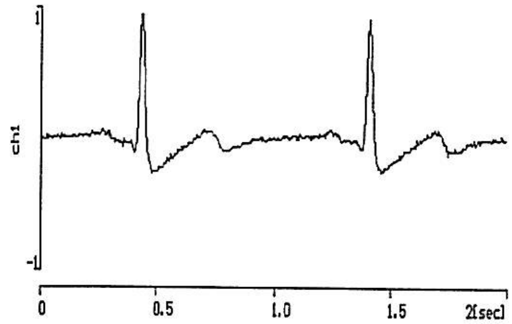


Low pass filter 10 Hz

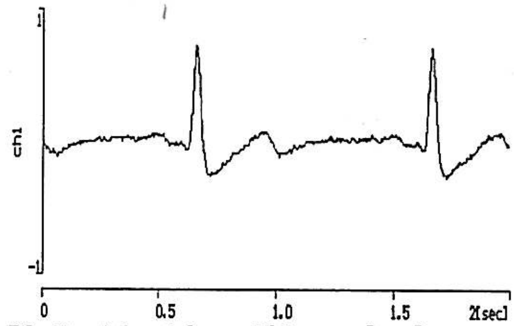
High pass filter 30 Hz

The traces for the 0.1 and 0.3 Hz filter settings of the high pass filter indicate severe fluctuations in the baseline due to the slow a.c. coupling. These drifts are completely suppressed at the 1 Hz filter setting, but the trace at this setting already shows a slight differentiation of the signal course in the QRS complex. Unlike the low pass filter settings, the setting of the high pass is barely dependent on the animal species. It should normally not exceed 1 Hz for ECG recording.

More serious are the effects of the 50/60 Hz blocking filter on the signal course of an ECG recording. Due to the finite steepness and filtering efficiency of the blocking filter the frequency spectrum is affected over the range from 10 to 200 Hz. In human ECG with its low frequency spectrum the changes on the signal course are not serious (see the following illustration).

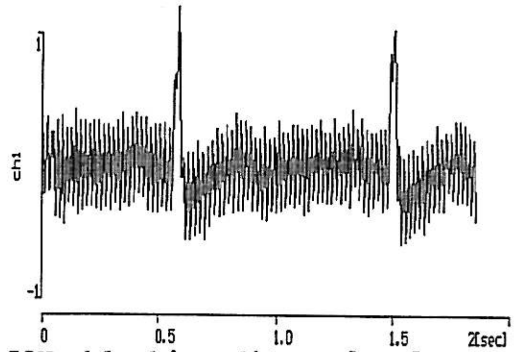


50Hz blocking filter [off]

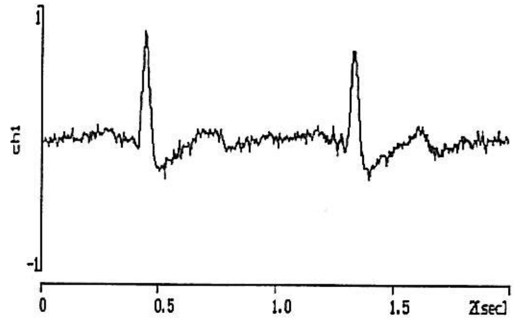


50 Hz blocking filter [on]

The following diagram illustrates the action of the blocking filter on the hum interference.

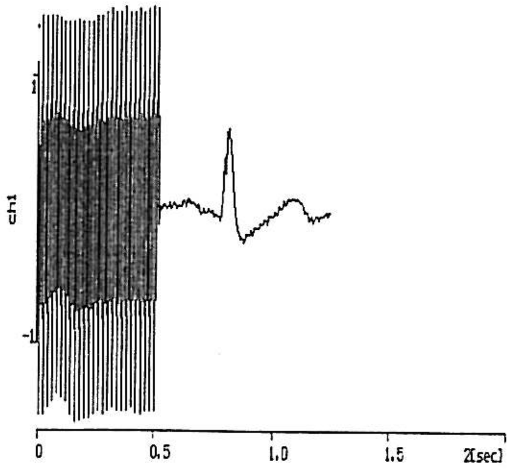


50Hz blocking filter [off]



50 Hz blocking filter [on]

The wanted ECG signal is clearly filtered out even with maximum hum interference.



Note:

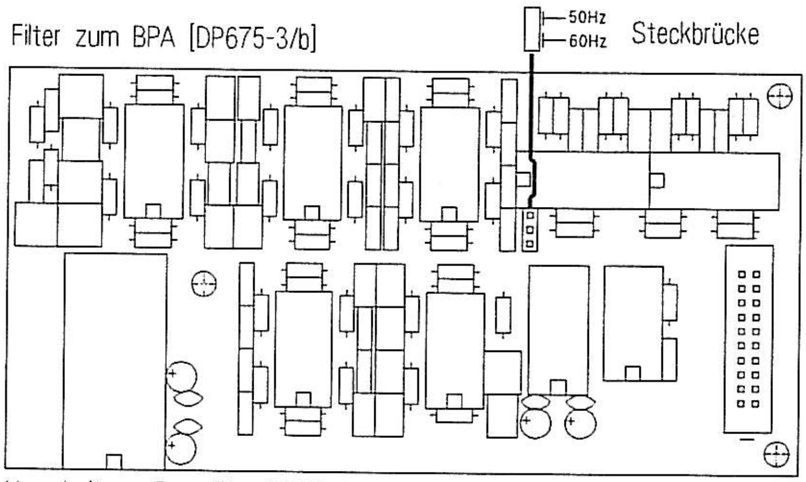
With small animals , such as rats or guinea-pigs, the use of a 50/60 blocking filter is in our view not advisable since the frequency spectrum of the QRS complex overlaps the blocking range of the filter. ECG signal analysis is therefore not possible since the recorded ECG signal is greatly distorted.

5.2 Procedure for filter setting

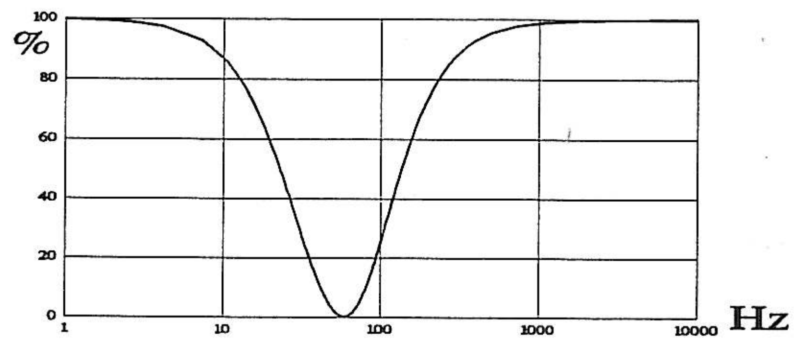
It is generally advisable to perform as little filtering of the signals as possible in order to prevent distortion of the signals through a high or low pass filter or blocking filter. But following the principle that a chain is only as strong as its weakest link, it makes more sense in practice to make a decision based on the subsequent recording or evaluation device. If, for example, a signal is to be recorded on an analogue high-speed recorder, it is evidently appropriate to limit the bandwidth of the BPA to a range from d.c. to 300 Hz. In this example the high-speed recorder is the limiting (weakest) link in the measurement chain, since mechanical writing systems normally permit recording only up to 150 Hz. The same applies to the input signal from mechanical transducers, such as force or pressure transducers. Here the maximum bandwidth is again in the range from d.c. to 300 Hz. Starting from this maximum bandwidth as required for transmission in a measuring system, the frequency range can then be further restricted to damp out any possible interference. Such interference can often be excluded by optimising the measurement equipment, e.g. through electrical screening, central star-shaped grounding, or mechanical de-coupling of transducers through vibration dampers.

5.3 The 50/60 Hz blocking filter (HUM-ELIM.)

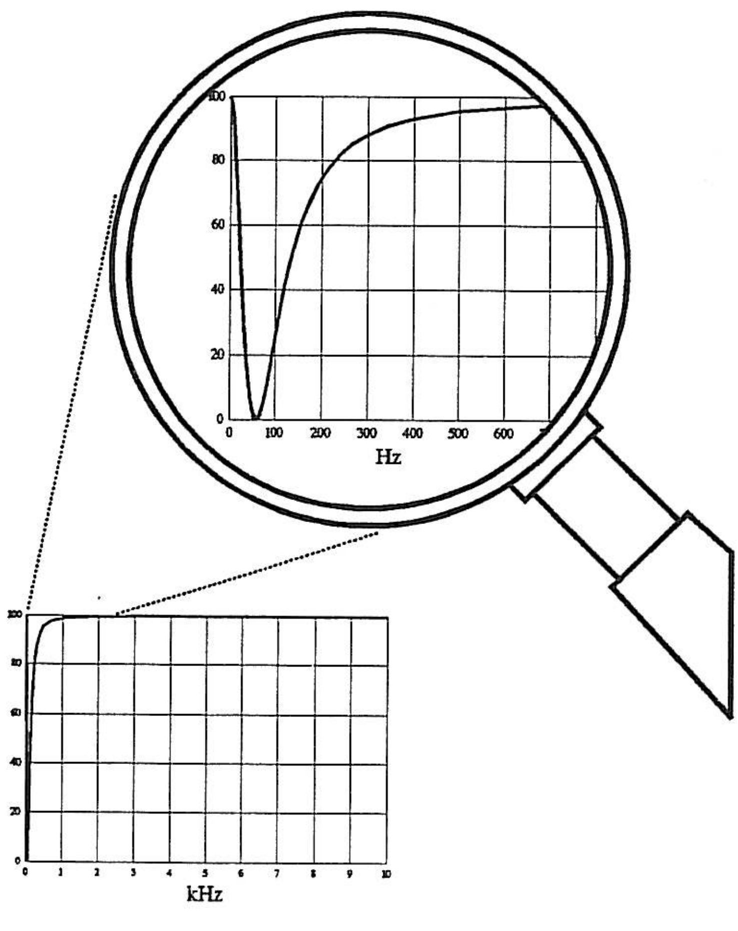
The blocking filter offers the facility of filtering out possible hum interference from the measurement signal. The blocking frequency of 50 or 60 Hz is set at the factory using a jumper on the BPA circuit board to suit the requirement of the shipment country. The blocking frequency can readily be changed subsequently by the user (see diagram showing the position of the jumper).



The following two diagrams illustrate the frequency pass characteristic of the blocking filter. The first diagram employs the logarithmic scale commonly used in engineering. The damping at the blocking frequency is about 58 dB, corresponding to a voltage ratio (useful signal to interference) of about 1 to 800. The second diagram indicates the pass region from d.c. to 10 kHz corresponding to the bandwidth of the BPA.



Logarithmic presentation of the frequency pass characteristic of the BPA blocking filter



Linear presentation of the frequency pass characteristic of the BPA blocking filter

6 Use of the BPA output filter in measurements with resistance transducers

Low pass filter (upper frequency limit)
Before making any measurement with force or pressure transducers the upper frequency limit of the BPA should be set at 300 Hz. Mechanical signal transducer with a bandwidth greater than 300 Hz are rarely found in practice.

50/60 Hz blocking filter (hum suppression)
The 50/60 Hz blocking filter should be switched off since any hum pick-up can be avoided by screening the connecting cable and the transducer housing.

High pass filter (lower frequency limit)
For the measurement of static signals, such as force or pressure, the high pass filter must be switched off, corresponding to the filter setting DC+OFF. It is only at this setting that the transducer can be zeroed and calibrated.

For measuring dynamic signals the BPA, unlike conventional bridge amplifiers, offers the facility of a.c. coupling (a.c. voltage coupling using the high pass filter), e.g. for recording the phasic changes of a blood pressure signal. In this way it is possible to achieve enlarged measurement of periodic pressure fluctuations (systolic <-> diastolic pressure) without recording the mean value of the signal (static base pressure). Useful coupling time constants are 0.03 to 1 Hz. To ensure rapid settling down of the amplifier it is advisable to press the quick start key after switching over from d.c. to a.c. coupling.

7 Calibrating resistive transducers on the BPA amplifier

The amplification of the BPA has to be adjusted to the transducer output signal according to the desired measuring range. The maximum measuring range (e.g. +/- 100 mN) has to correspond to the maximum signal amplitude +/- 10 Volt of the amplifier.

7.1 Adjustment procedure

The adjustment, for example to have 100 mN correspond to 5 cm writing width on the recorder, is made on the BPA as follows:

Adjustment step by step

Step 1 For calibration the transducer should be fixed in a laboratory stand or some other clamp in its eventual operating position.

Step 2 Connect the transducer to the input socket of the BPA amplifier.

Step 3 Switch on the PLUGSYS housing and wait about 5 to 10 minutes for it to warm up in order to achieve stable temperature conditions and therefore minimum zero drift.

Step 4 Set the upper frequency limit "HIGH" to 300 Hz, for example.

Step 5 The lower frequency limit must be set to DC + OFFSET, since zero adjustment of the transducer is only possible at this setting.

Step 6 Switch off the 50/60 blocking filter "HUM-ELIM.".

Step 7 Set the amplitude adjustment "AMP.-CAL" to maximum (fully clockwise).

Step 8 Set the gain to 10 000x.

Step 9 The zero is adjusted with no load on the transducer. If adjustment with the automatic adjustment facility should prove impossible, a coarse adjustment has to be made with the "ZERO" trimmer. Zeroing with "AUTO-ZERO" should then be possible.

Step 10 Load the transducer with a known calibration reference and select the gain so that the required range is covered.

Step 11 Using the variable amplitude adjustment "AMP.-CAL" adjust the output voltage so that 100 mN corresponds to 5 cm on the recorder, as assumed in this example.

8 Note on the use of the CAL key when working with resistance transducers

The CAL key [x1 <-> x0.3] on the BPA produces a fixed voltage step based on the signal input. It is used mainly for evaluating amplitudes in the case of voltage recordings such as ECG or EMG. There is no provision for variable adjustment to suit the transducer. It is therefore usually not possible to key in appropriate calibration steps in the signal recording. There is, however, the possibility of determining the overall amplification of the BPA with variable amplitude setting (division of the output amplitude by the keyed-in calibration value = amplification factor). This may be useful, for example, to check the gain setting and therefore the calibration range when working with implanted pressure transducers. The voltage step at the BPA output for Cal x1 and Cal x0.3 should be noted down after calibration and before implantation. During any subsequent measurement a comparison between the current calibration steps and the deflections during transducer calibration can be used to ensure that the device calibration agrees with the original calibration value.

The following tables shows again the relationship between amplification factor and calibration voltage.

[GAIN]	[CAL x 1]	[CAL x 0,3]	Output x 1	Output x 0,3
20	100 mV	30 mV	2 V	0,6 V
100	100 mV	30 mV	10 V	3 V
200	10 mV	3 mV	2 V	0,6 V
1 000	10 mV	3 mV	10 V	3 V
2 000	1 mV	0,3 mV	2 V	0,6 V
10 000	1 mV	0,3 mV	10 V	3 V

The output voltage is based on the 100% setting of "AMP.- CAL" (calibrated).

9 Internal user adjustment on the BPA circuit board during installation

The user has to make 3 specific settings on the BPA module during installation. The selected values should be entered in the table below.

BPA Module Type 675 Serial No.: __________

Fitted into housing type __________ Serial No.: __________ Slot No.: __________

Date: ____ ____ ________ Name: ______________________________

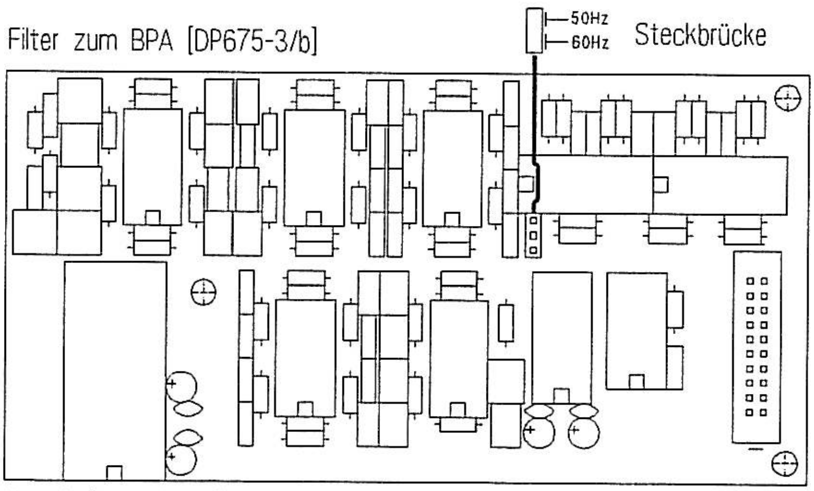
1. The assignment of the internal signal output to a free analogue bus line AV1 to AV16. When choosing the bus line the connections of the other modules fitted in the PLUGSYS housing must be taken into account.

   NOTE
   If two output amplifiers are connected to the same AV bus line, they are short-circuited to each other.

AV-01	AV-02	AV-03	AV-04	AV-05	AV-06	AV-07	AV-08

AV-09	AV-10	AV-11	AV-12	AV-13	AV-14	AV-15	AV-16

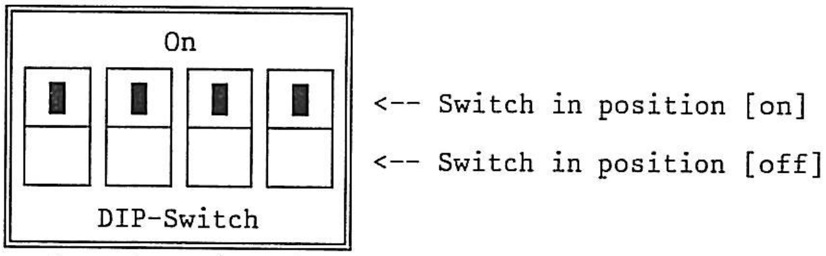
2. Choice of frequency of the 50/60 Hz blocking filter. The setting is made in accordance with the frequency of the supply, using a jumper on the BPA circuit board. The diagram below shows the position of the jumper on the circuit board.



Umschaltung Sperrfilter 50/60Hz

Blocking filter set to 50 Hz_____ 60 Hz_____

3. In an automatic evaluation system the BPA offers the facility of remotely operating the automatic zeroing through a laboratory PC. In order to be able the address the BPA module from the computer through the additional hardware (ICI and BI) it is necessary to set on the BPA a free module address for communication, using the DIP switch provided for this purpose. The correct address for data transfer is normally determined by the control software. The correct switch settings can be taken from the Tables below. If the facility for remote zeroing is not used in your application, set the BPA to address 16.



Please tick here (✓) Set to -->	PLUGSYS I/O address	switch bit - 3	switch bit - 2	switch bit - 1	switch bit - 0
	01	on	on	on	on
	02	on	on	on	off
	03	on	on	off	on
	04	on	on	off	off
	05	on	off	on	on
	06	on	off	on	off
	07	on	off	off	on
	08	on	off	off	off
	09	off	on	on	on
	10	off	on	on	off
	11	off	on	off	on
	12	off	on	off	off
	13	off	off	on	on
	14	off	off	on	off
	15	off	off	off	on
Address 16 when not being used -->	16	off	off	off	off

10 Electrical data of the BPA Type 675

Amplifier type	push-pull differential amplifier.
Input voltage	500 mV (maximum with 20x gain).
Bridge supply	5 Volt 80 mA to supply resistance transducers.
Amplification	2x to 10 000x through selector switch for 20x, 100x, 200x, 1000x, 2000x and 10 000x, and attenuation 100% to 10% using multi-turn trimmer.
Frequency range	d.c. to 10 kHz.
Low pass filter	12 settings ranging 0.03 Hz to 10 kHz.
High pass filter	10 settings ranging d.c. to 100 Hz.
Quick start	Key for rapidly discharging a.c. coupling capacitor of high pass filter to permit rapid settling down of amplifier.
Blocking filter	50/60 Hz blocking filter for suppressing hum from the a.c. supply.
Signal input	8-pin socket with screw lock on the front panel (Binder, Amphenol, Tuchel).
Signal output	a. On the front panel through BNC socket, 10 Volt (Ri = 100 Ohm). b. Through the bus connector to the PLUGSYS measuring system, 10 Volt (Ri = 100 Ohm). c. MUX On pressing the "MUX" key the output signal is switched to the MUX-OUT output common to all modules, for example for zeroing or calibration using a digital voltmeter DVM Type 666.
Analogue indication	through LED bargraph with a resolution of (+)12 and (-)6 LEDs (approx. 1 Volt per diode). The sensitivity can be briefly switched by a key to 0.1 Volt per LED for checking the zero.
Zeroing	1. Automatic zeroing through the built-in computer of the BPA, digital with 12 bit resolution. 2. Manual zeroing for compensating large input offset voltages as coarse adjustment if the auto zero range is exceeded. 3. Automatic zeroing as under 1. but triggered externally from a laboratory PC through PLUGSYS interface hardware.
CMOS-RAM	the current instrument settings are stored in a non-volatile data store and loaded again when the equipment is switched on.
Calibration	built-in calibration source for amplitude evaluation of the applied input signal voltage. The calibration pulse is added to the measurement signal with a switch

	[x1] or [x0.3]. The calibration value is set automatically within the range 1 - 10 - 100 mV on selecting the amplification.
Supply	5 Volt 1.4 A through bus connector from the PLUGSYS bus system.
Headstage	The BPA offers the facility to be adapted to special measurement requirements by means of a headstage. For example, isolation in human use in the clinical area (Isolated Preamplifier Headstage 5000 IPH Type 675/1 available, or Microelectrode Preamplifier for measuring intracellular potentials Type 675/2, under development).
Supply for headstage	5 V d.c., 800 mA max.

10.1 Mechanical data

Dimensions	width: 8E (40.5 mm) height: 3U (127.5 mm) depth: Eurostandard 220 mm
Bus connector	DIN 41612, 96-pin VG
Weight	500 g
Standard accessories	8-pin input connector, Operating Instructions
Special accessories	3-wire electrode cable ECG or EMG
	transducer adapter cable, 6-pin Binder socket to 8-pin BPA input
	Isolation Preamplifier Headstage 5000 Type 675/1
	Microelectrode Preamplifier Headstage Type 675/2 (to special order)

11 Appendix A: Connections to PLUGSYS system bus

VG 96-pin connector, rows a,b and c used

Row (a)	Pin No.	Row (b)	Pin No.	Row (c)
D-GND	1	D-GND	1	D-GND
A-GND	2	A-GND	2	A-GND
+ ANALOG	3	+ ANALOG	3	+ ANALOG
- ANALOG	4	- ANALOG	4	- ANALOG
DB-0	5	DAV	5	TRIGGER 1
DB-1	6	NRFD	6	TRIGGER 2
DB-2	7	NDAC	7	TRIGGER 3
DB-3	8	R/W	8	TRIGGER 4
DB-4	9	DS-1	9	RDVM
DB-5	10	B-INT	10	AM
DB-6	11	DV-1	11	AV-1
DB-7	12	DV-2	12	AV-2
CS-0	13	DV-3	13	AV-3
CS-1	14	DV-4	14	AV-4
CS-2	15	DV-5	15	AV-5
CS-3	16	DV-6	16	AV-6
GS-0	17	DV-7	17	AV-7
GS-1	18	DV-8	18	AV-8
GS-2	19	DV-9	19	AV-9
DS-2	20	DV-10	20	AV-10
/RESET	21	DV-11	21	AV-11
TAKT	22	DV-12	22	AV-12
X-1	23	X-6	23	AV-13
X-2	24	X-7	24	AV-14
X-3	25	X-8	25	AV-15
X-4	26	X-9	26	AV-16
X-5	27	X-10	27	CAL
POWER-0	28	POWER-0	28	POWER-0
POWER-1	29	POWER-1	29	POWER-1
POWER-2	30	POWER-2	30	POWER-3
SHIELD	31	SHIELD	31	SHIELD
+ 5 VOLT	32	+ 5 VOLT	32	+ 5 VOLT

11.1 Appendix B: Notes on instrument care

- ✓ Never use scouring powder or plastic-dissolving cleaning agents for cleaning the front panel, controls or connecting cables.
- ✓ Remove any dust with a fluff-free cloth or a fine dust brush.
- ✓ Dirt can be removed with soapy water or a mild domestic detergent, using a soft cloth. Then wipe off with clean water. Ensure that no liquid finds its way inside the module or the toggle switches.
- ✓ Marks on the aluminium front panel can readily be removed by a plastic pencil rubber.
- ✓ The inside of the BPA amplifier requires no servicing or cleaning.

11.2 Appendix C. Remote operation of automatic zeroing from a laboratory PC

This description is intended mainly for the small circle of undaunted users and "PC gurus" who wish to utilise the extended facilities of the PLUGSYS measuring system. As a "normal" user of the BPA amplifier you should not worry yourself with the bit, byte and other mousy talk in the sections below.

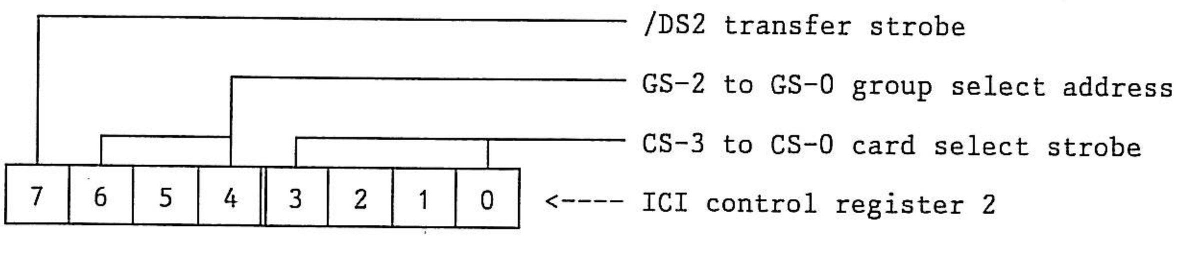
11.2.1 General note on the PLUGSYS interface architecture

The control of the BPA module operates through the plug-in interface card ICI (IBM Control Interface Type 659) and the PLUGSYS interface BI (Bus Interface Type 663). Data transfer takes place through the non-intelligent interface of the PLUGSYS. Automatic zeroing of the BPA is started through a write or read operation using the card address (1 - 16) set on the BPA main board and the group address 0. A transfer of a complete control command via the data bus is not necessary. The selection of the BPA module in the system takes place only via the address lines CS0 - CS3 and the group select lines GS0 - GS2 as well as the transfer strobe DS2. Since the data bus is not used to trigger the zeroing, it is possible in multi-channel systems to operate all BPA modules on a common control address (card address). An operating sequence from the computer then acts simultaneously on all the installed BPA modules.

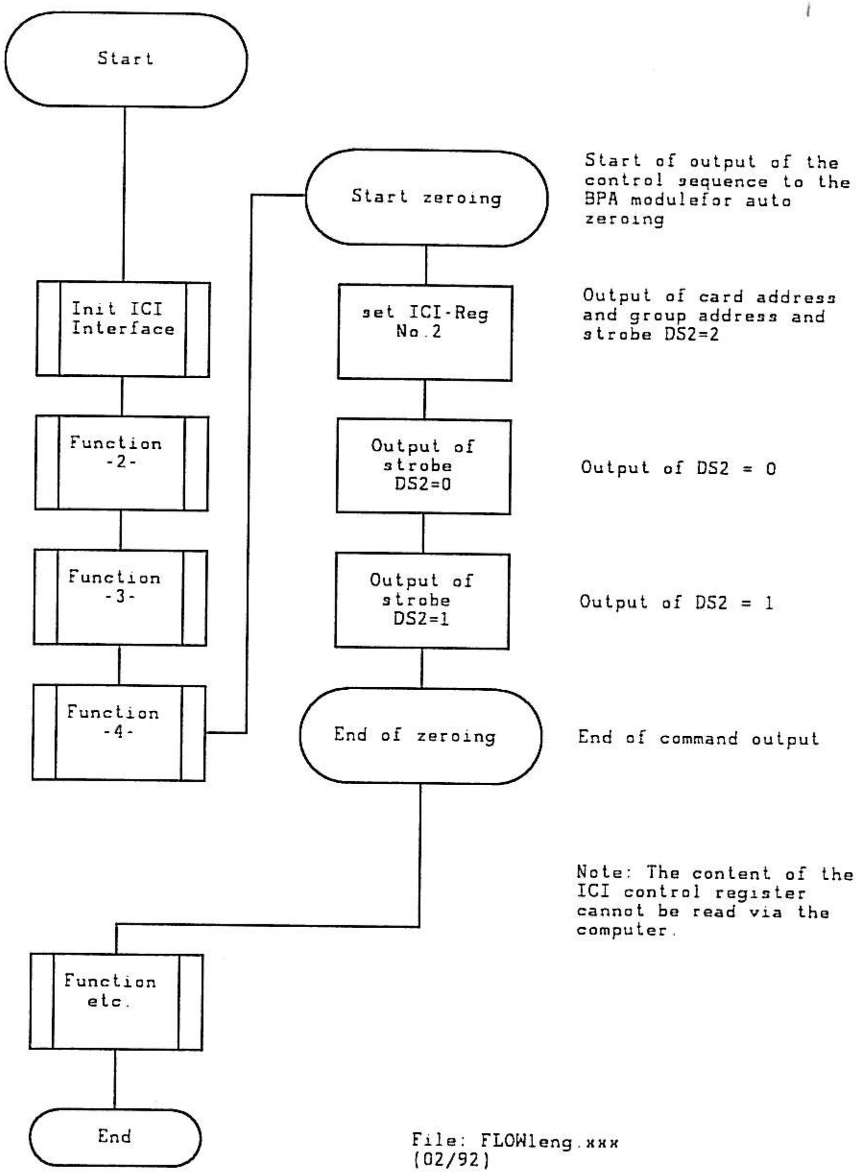
11.2.2 Control lines used

CS0-3	CS-0 to CS-3 --> addressing the module according to the card address set on the DIP switch of the BPA.
GS-2	GS-0 to GS-2 --> addressing the auto zero function with address 0 on the BPA module
/DS2	transfer strobe --> trigger to start auto zero
Data bus	DB-0 to DB-7 --> not used
R/W	read/write control signal --> no effect on the data transfer
/RESET	VG-BUS Reset --> as above

After assigning the control lines used to the control register structure of the ICI interface we can see that the entire output of the auto zero control sequence takes place via control register 2.



11.2.3 Structure of the control program



The entire output can be reduced to 3 write commands in the control register of the ICI interface. The timing of the transfer is not critical since a hardware flip-flop is set with the DS2 strobe. There is therefore no need to introduce a delay between the write commands. It is however a general rule that all data transfers between a computer and the PLUGSYS should not exceed a manipulation sequence frequency of 200 kHz on the control bus. It follows that the time interval between the write operations should be at least 5 µsec. After recognition of the zeroing request by the CPU of the BPA module the transfer flip/flop is reset.

11.2.4 Example of command sequence in "C"

A command sequence for operating the BPA, e.g. as "C" program for Borland Turbo C, could be as follows:

```
/* ============================================================
   Global definitions
============================================================ */

#define IciAdr            0x300    /* base address of the ICI*/
#define OffsetIciReg2     0x13     /* addressoffset on the ICI base address */
#define IciReg2           IciAdr+OffsetIciReg2  /* computing the address */
#define BpaBaseAdr        10       /* BPA module address */
#define BpaAutoNull       0        /* group select address on the BPA */

/* ============================================================
   Program sequence
============================================================ */

... /* user program code */
...
...

outport(IciReg2, (BpaBaseAdr + BpaAutoNull+0x80));

          /* Computing the card address of the BPA with the group select
             address of the auto zero and the strobe DS2 == 1
             corresponding to 0x80 */

outport(IciReg2, (BpaBaseAdr + BpaAutoNull+0x00));

          /* Transfer with the sane card address and group address
             and strobe DS2 == 0 */

outport(IciReg2, (BpaBaseAdr + BpaAutoNull+0x80));

          /* Transfer with the same card address and group address
             and strobe DS2 == 1 */
...
...
...
```

11.3 Appendix D: Fault finding

Function faults which may arise during the operation of the BPA can be divided roughly into three groups:

1. Faults during the installation of the module
2. Incorrect operation
3. Component faults on the BPA module or the PLUGSYS housing

The following list describes possible faults with symptoms, causes and remedies.

Symptom: rapid flashing of all LEDs in the filter indication for approx. 10 seconds when switching on the BPA.

Cause: The checksum of the CMOS-RAM data store is incorrect and therefore also the stored base settings. The computer loads the base settings (default values). The flashing LEDs draw the user's attention to this fault. The cause is a spent lithium battery (after approx. 8 years' operation). The same fault appears once when the equipment is switched off fortuitously while the instrument settings are being stored in the CMOS-RAM.

Remedy: In case of a spent lithium battery the CMOS-RAM has to be replaced. A suitable service kit is obtainable directly from Hugo Sachs Elektronik or from your distributor.

Symptom: All LEDs in the filter indication of the BPA are flashing eight times.

Cause: Automatic zeroing is possible only if the filter is set to DC+OFFSET. The flashing LEDs indicate incorrect operation.

Remedy: Set the high pass filter to DC+OFFSET and restart the zeroing operation.

Symptom: Continuous flashing of all LEDs at the same frequency as for auto zero other than on DC+OFFSET.

Cause: This fault appears after starting the evaluation software, e.g. ACAD, on the computer. There is an address conflict with other PLUGSYS modules or alternatively in the setup file of the evaluation program.

Remedy: Alter the communication address (DIP switch on the BPA) or the address assignment in the setup file of the evaluation program.

Symptom: The power LED on the headstage does not light up, despite correct cable connection.

Cause: The fuse on the BPA circuit board for the power supply to the headstage has blown.

Remedy: Remove the BPA module from the housing and check the fuse with an Ohm-meter. The fuse is located at the bottom edge of the main circuit board, about 7 cm from the VG bus connector. A spare fuse can be obtained from Hugo Sachs Elektronik or from your distributor. If the fuse fails repeatedly, return the headstage used together with its connecting cable and the BPA for repair.

Symptom: The output signal of the BPA is distorted internally via the system bus or is coupled with adjacent channels.

Cause: The assignment of an AV output line is incorrect.

Remedy: Check the output lines of all PLUGSYS modules in case any lines have been used twice.

Symptom: Hum interference when operating a resistive transducer on the BPA.

Cause: Ground loops or incorrect screening of transducer housing or connecting cable.

Remedy: Check the wiring from the transducer to the BPA.

Symptom: The action of the blocking filter is insufficient, but the function is otherwise correct.

Cause: The jumper for selecting the 50 or 60 Hz blocking frequency is not set correctly.

Remedy: Check the jumper position.

Symptom: The transducer used cannot be zeroed.

Cause:

1.: The pin connections on the connecting plug do not correspond to the input circuit of the BPA.

2.: The transducer is faulty.

Remedy: Check the wiring and change it if necessary. If the transducer is being used on several amplifier types it is advisable to make up an adapter cable. The transducer can then readily be used on different amplifiers.

Symptom: Pronounced hum during voltage recording, e.g. ECG or EEG.

Cause: Ground loops, no screening or highly asymmetrical interference from adjacent electrical lines or loads.

Remedy:

1. Check the wiring of the electrode cable for a fault or mistakes.
2. Ground all larger metallic objects in the neighbourhood.
3. With ground loops, check the neutral connection and provide star-shaped grounding of all electrical equipment through a central ground where required.

4. With asymmetrical hum interference at the electrode cable, running the individual lines of the cables far as possible in parallel with each other usually provides a remedy.

5. Check on the PLUGSYS terminator module that the jumpers circuit null to digital zero and circuit zero to ground (screen) have been installed correctly.

Symptom: The steps of the digital/analog converter are too large or too small during automatic zeroing of resistive transducers. Accurate zeroing is not possible.

Cause: A compensating current is fed in during transducer zeroing through the resistance R(X), using pin 8 of the input socket (see wiring diagram in Section 3.2). The effect of the zero change per digital step of DAC depends on the transducer impedance.

Remedy: Change R(X) to a larger resistance in case the steps are too large. If the effect is too small the resistance R(X) has to be reduced.

Glossary

a.c.	alternating current, applied to both voltage and current.
bandpass	a combination of a high pass and a low pass filter. The amplifier bandwidth is limited at both higher and lower frequencies.
bit	the smallest digital calculating unit, with the values "zero" or "one".
blocking filter	a special, very steep filter for removing interference to the measurement signal caused by the system; in the case of the BPA the hum interference from the 230 V (115 V) a.c supply system.
byte	digital word, with a length of 8 bit.
CMOS-RAM	a data store, designed in CMOS technology in order to achieve extremely low current requirement. In the case of the BPA amplifier the CMOS-RAM is used to store the instrument settings. The data store is backed up by a small lithium battery when the equipment has been switched off.
DAC	electronic circuit (digital/analogue converter) to change a digital value into a corresponding analogue output voltage. For example in the automatic zeroing DAC of the BPA with 12 bit resolution (4096 different values) corresponding to a step size of approx. 50 mV.
d.c.	direct current, applied to both voltage and current.
decibel	(also abbreviated as -3 dB, for example) is an indication of a voltage ratio as a logarithmic value, generally used in engineering. The value -3 dB for the limiting frequency of filters represents an amplitude reduction of approx. 71% of the original amplitude.
differential amplifier	a signal amplifier with two independent input branches, corresponding to a positive and a negative signal input. The input signal voltage, the difference between the positive and the negative input, is amplified.
DIP switch	a digital selector switch (sometime called "mouse piano") for setting data specific to a user, e.g. an interface address.
ground potential	potential of ground (earth), connected up through the ground conductor of the 230 V a.c. supply system. Often used in instrument technology for screening signal lines or transducer housings. Note, however, the difference between screening for hum suppression and grounding to the supply socket as protection against electrical hazard through insulation failure. Cable screening must never be used as protection against insulation failure since the conductor cross-section is rarely sufficient to meet the requirements.
hardware interface	used in the BPA for the hardware extensions ICI (IBM Control Interface) and BI (PLUGSYS Bus Interface). Both items refer to a system extension (interface) for data transfer between a laboratory PC and the PLUGSYS housing.

headstage	a preamplifier or matching amplifier designed for a special application. The headstage is designed solely for operation with the BPA signal amplifier.
high pass filter	filter for cutting the lower frequency range. The d.c. component is filtered out, together with the lower frequency components depending on the filter setting.
HUM-ELIM.	the expression "hum elimination" refers to a measure for suppressing the hum pick-up from the 230 V a.c. supply.
impedance	complex resistance consisting of e.g. resistive, inductive and capacitive components. The expression "impedance" is often used in technical data on the input resistance of amplifiers or the output resistance of transducers.
interface	used in the BPA in connection with the automatic zeroing through the PLUGSYS computer interface. It is a digital parallel link with data, control and address lines for the transmission of control commands from the laboratory computer (IBM AT compatible PC) to the function module of the PLUGSYS measuring system.
jumper	a small plug-in link for making user-specific settings on the circuit board of electronic units.
LED bargraph	a line of LEDs to indicate e.g. analogue voltage variations or the filter pass band.
low pass filter	the amplifier bandwidth is restricted for higher frequencies in accordance with the filter setting.
offset voltage	zero error of the input signal.
resistive transducers	transducers with a measuring system which changes its resistance in accordance with the measured parameter. Such transducers are based e.g. on straingauges or on field plates in a magnetic field, both forms arranged in a bridge circuit and with a d.c. source as bridge supply.

12 Response ....

Please take a few minutes of your time in order to tell us of any difficulties you are having in understanding the Operating Instructions or in operating the BPA. With this "feedback" you will be helping us to render our products and the system documentation more user-friendly.

Please tell us,

☹ where you have found mistakes

☹ what you have found unclear or unintelligible

☹ and where you would like to see improvements.

Many thanks for your kind assistance.
Yours Hugo Sachs Elektronik

Your name ______________________________

Your organisation ______________________________

Full address ______________________________

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Phone / Fax ______________________________

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Please send this sheet or a copy to:

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