The CED 1902 Mk IV Owners Handbook

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Life support

CED products are not authorized for use as critical components in life support systems without the express written approval of the chairman of the board of directors of CED.

Life support systems in this context are systems which support or sustain life, and whose failure to perform, when properly used in accordance with instructions for use provided, can be reasonably expected to result in a significant injury to the user. A critical component in this context is any component of a life support system whose failure to perform can reasonably be expected to cause the failure of the life support system, or to affect its safety or effectiveness.

Potential for Radio/Television Interference *(USA only)*

The 1902 generates and uses radio frequency energy and may cause interference to radio and television reception. Your 1902 complies with the Specification in Subpart J of Part 15 of the Federal Communications Commission rules for a Class B computing device. These specifications provide reasonable protection against such interference in a residential installation. However there is no guarantee that interference will not occur in a particular installation. If the 1902 does cause interference to radio or television reception, which can be determined by turning the 1902 off and on, you can try to eliminate the interference problem by doing one or more of the following:

- Re-orient the receiving antenna
- Re-orient the position of the 1902 with respect to the receiver
- Move the 1902 away from the receiver
- Plug the 1902 into a different outlet so that the 1902 and the receiver are on different branch circuits

If necessary, consult CED or an experienced radio/television technician for additional suggestions. You may find the booklet, prepared by the Federal Communications Commission, helpful: *How to Identify and resolve Radio/TV Interference Problems.* This is available from the US Government Printing Office, Washington DC 20402, Stock no. 004-000-00345-4.

To comply with FCC rules, Part 15 J Class B Computing device, use only shielded interface cables.

Storage and operating environment

The storage and operating environment for a 1902 must not exceed the temperature range 0° to +50° Celsius, in conditions of non-condensing humidity which should not exceed 95% saturation, in an atmospheric pressure range of 500 hPa to 1060 hPa. The 1902 complies with relevant EU and USA requirements for electromagnetic interference. The 1902 is suitable for continuous operation. The 1902 is not protected against ingress of water or dust. There are no hazardous voltages inside the 1902. The 1902 can be recycled; please contact CED for further details.

Protection

The 1902 offers Class I protection against electric shock. To maintain the safety standard, accessory equipment attached to the 1902 must also comply with relevant safety requirements such as IEC601-1 or the relevant IEC standard e.g. EN60601-1 configured to comply with EN60601-1-1:2000.

Electrode 'Common' leads

The 'Common' lead on a three-wire electrode cable provides a return path for the input amplifier bias currents. UNDER NO CIRCUMSTANCES should this lead or any other electrode lead be connected to mains earth. This will negate the 1902's isolation provisions and expose subjects to the risk of fatal shock.

Anaesthetic gases

The 1902 is not protected against flammable anaesthetic mixtures. It must NOT be used in the presence of such mixtures.

Typographic conventions

The following conventions apply to the text in this manual:

- Titles of manual sections, other manuals and other publications are in *italics*
- Labels and identifiers appearing on the equipment described in this manual are in Arial
- Menu items, buttons, and other contents of computer displays are in *Arial italics*
- Text entered by keyboard is in `Courier New`. Names of keys are enclosed in angular brackets, e.g. `<esc>`, `<enter>`

Use of symbols

Where applied, the symbols below have the following meanings:

This symbol is used on the CED-approved power supply, to denote that the electrical isolation is to IEC Type B standard.

This symbol is used on the power supply to indicate the mains input is for AC power only.

This symbol is used on the power supply to show that the outputs are DC only.

The CED 1902 is subject to the EU WEEE regulations and may be returned to CED Ltd. for recycling.

Observe precautions against electrostatic discharge.

Attention, consult accompanying documents.

Installation

Introduction

This section will guide you through the installation of your CED 1902 Mk IV isolated pre-amplifier. This involves loading the operating software and running an initial confidence check.

Checklist

The installation kit for your 1902 comprises:

- One or more 1902s, either free-standing or rack-mount
- A power block with attached DC power cable
- A power-block mains cable suitable for your country
- An RS232 cable to connect the 1902 to your computer
- A kit of accessories, including plugs to match the front-panel connectors
- An installation disk to allow you to install and check out your 1902
- CED Electrode or Head Stage Boxes (optional)
- This owners manual

The power block

The 1902 power block will run with no adjustment on any mains voltage from 100 V to 240 V, 50 Hz - 60 Hz, drawing 1.3 A maximum. It has no switch, being controlled by plugging in and switching on at the mains socket.

The 1902 itself has no DC power switch. For electrical isolation to be complete, mains power must be disconnected from the power block.

The power block

Powerbox™ PMP55 shown

Cables

Use only the cables supplied by CED. They have the metal shells and screening braid that are necessary to meet the requirements for control of electromagnetic interference. Others may not do so.

The Electrode Box

The CED1902-11 family comprises optional electrode adaptor boxes that plug into the electrode input sockets of CED 1902 isolation amplifiers. There are four variants of the smaller box:

- CED1902-11-2 2 channel (bipolar)
- CED1902-11-2B 2 channel (bipolar or common-reference)
- CED1902-11-4 4 channel (bipolar)
- CED1902-11-4B 4 channel (bipolar or common-reference)

CED also manufactures two 16-channel electrode boxes:

- CED1902-11-16 16 channel (common-reference)
- CED1902-11-16B 16 channel (bipolar or common-reference)

The electrode boxes have input connectors for up to 16 electrode pairs plus common electrodes. The connectors can be either 1.5mm or 2mm safety (touch-proof) types. The boxes are passive, i.e. they do not amplify the signals. The outputs are connected to the electrode inputs of CED 1902 isolation amplifiers via shielded cables. The boxes have two or more Common input connectors that are linked together and to the Common leads of all the output cables. The interior of the box is coated with electro-conductive paint which is electrically connected to the screens of the output cables.

The 1902 Electrode Box
2-channel model shown

Buffer option

The –B option on the 2- and 4-channel boxes adds an input and output connector for the 1902 buffer option and also a rotary switch for selecting common-reference (buffer output drives all the –ve inputs) or bipolar (buffer not used) modes of operation. Note that the buffer connectors are inoperative unless the correct output lead (usually channel 0) is connected to a CED 1902 fitted with the buffer option. For details of common-reference operation using a buffer, see page 36.

The 16-channel boxes are available with either 16 signal electrode inputs plus common reference or 16 electrode pairs plus 4 buffer connections.

The Active Head Stage

The CED1902-10 Active Head Stage is an optional electrode adaptor box similar to the CED 1902 11 mentioned above, with safety-plug connections for up to four electrodes. It contains either two or four channels of battery-powered differential amplifiers with switchable gains of ×1, ×3, and ×10. The outputs are AC coupled, with a corner frequency of 1.6 Hz. The Active Head Stage links together the Common leads of all electrodes connected to it. The 1902 clamp option (see page 41) cannot be used if this adaptor is present, because its amplifiers are upstream of the clamp circuitry. If clamping is required, the CED 2804 External Clamp Box should be considered instead.

The 1902 Active Head Stage
4-channel model shown

The External Clamp Box

This four-channel device can be used with any amplifier to prevent input saturation, as for instance when high voltages or intense magnetic fields are used as stimuli. On receipt of a TTL signal from external trigger equipment it clamps incoming electrode signals for the duration of the trigger signal. It can operate in several different clamping modes, as selected by a rear-panel switch.

The 2804 External Clamp Box

Installing the 1902 software

To install the 1902 operating software, autorun the *1902 Support* CDROM supplied with the hardware. This should be completely automatic under any version of Windows. It will install Try1902, a diagnostic and calibration program. It will also install the 1902 Control Panel, which can be opened by the user to run the 1902 in stand-alone mode.

Confidence check – Try1902

Once the software is installed, you can run Try1902 to check that the 1902 is, to the first order, working, and has not been damaged in transit. Before it is run, the 1902 must be powered up and connected to your computer.

Connecting the 1902

With mains power off, insert the DC power cable and the RS232 cable into the back of the 1902. The power cable will only plug-in one way, and the RS232 cable is reversible end-for-end. Make a note of which physical com port the RS232 goes into (most likely Com1; many computers only have one com port.) Some computers, especially laptops, have no com port at all; in this case, use a USB–RS232 adaptor (see page 13).

Running Try1902

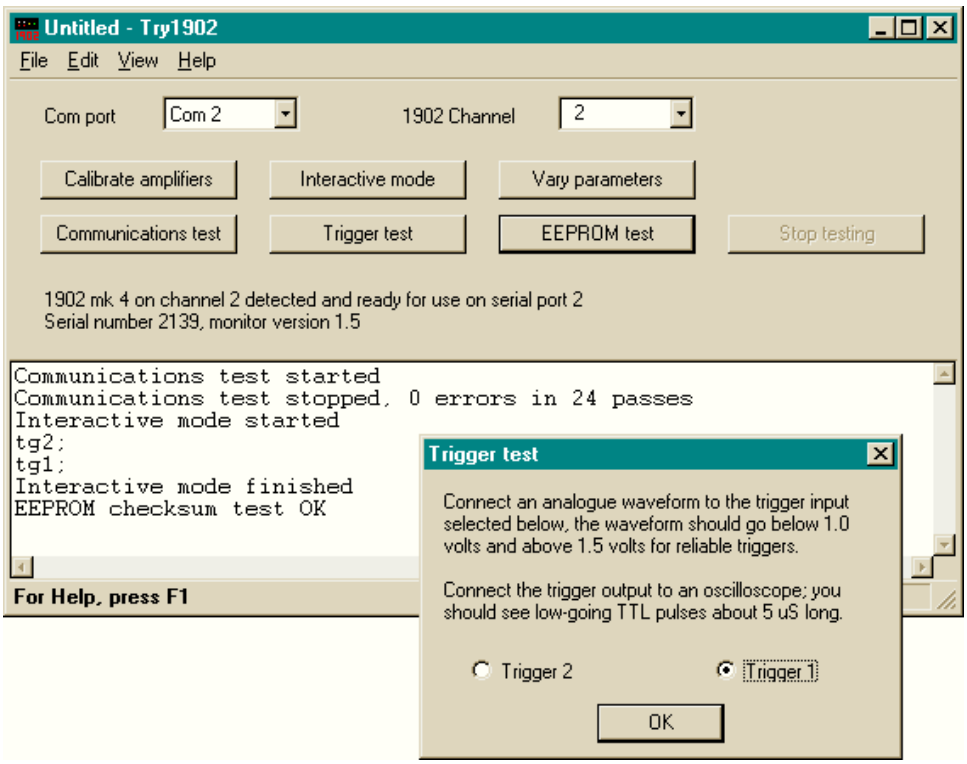
Switch 1902 power on at the mains. Observe on the front panel that the green Power LED comes on. Open Try1902 by selecting *Start, Programs, 1902 Support, Try1902*.

Com port and channel number

First of all, you must set the com port and the 1902 channel dropdown lists. These identify the com port being used, and the channel number to which the 1902 is set. As soon as they correspond to the 1902 present, it will be identified and reported. In multiple installations, where all 1902s share the same com port, the 1902 identified will change as the channel number is changed. The numbers will correspond to the 1902 unit numbers (0, 1, 2, etc.) In single installations the channel number will be 0, unless specified otherwise.

Communications test

This is the most basic test, simply checking that the 1902 will accept and return data. Press *Communications test* to start the test; *Stop testing* stops the test and reports the number of passes (repetitions) done, and errors found, if any.



Try1902 with Trigger test prompt

Trigger test Pressing *Trigger test* opens a small window that invites you to test the trigger inputs with a signal generator and oscilloscope. However, just toggling the two radio buttons will change which of the yellow Gate LEDs is lit on the front panel.

EEPROM test *EEPROM test* checks the validity of data in a part of the flash ROM that is equivalent to the EEPROM of earlier 1902s. This stores information that is specific to the 1902 in question, such as its serial number and daughterboard configuration. The test takes a few seconds, and reports either success or failure.

Other tests If you are familiar with the 1902 command set (documented in the *1902 Technical Manual*), you can send command strings to the 1902 by selecting *Interactive mode*. *Vary parameters* allows you to set the high- and low-pass filters, the notch filter, and AC coupling, as well as input mode, gain and offset. *Calibrate amplifiers* opens the calibration procedure; this is dealt with below (see page 46.)

Machine control

In equipment used in research and industry, it is highly desirable that all functions of instrumentation are readable and controllable by computer. The 1902 achieves this by one of the most universal means: the RS232 serial line, or else an RS232 virtual port implemented on a USB adaptor.

Electrical isolation

When recording electrophysiological signals from live human subjects, it is a legal and ethical necessity to protect them from electric shock. This is all the more so since, with electrodes close to vital organs, a very small current can be fatal. Consequently, the 1902 has provision for an isolation amplifier that has been approved for use with human subjects.

RFI approvals

The 1902 has been type-tested and found to meet the requirements of the European EN55022:1987 Class B and the USA FCC Part 15 J Class B radio frequency interference specifications when used with the specified power supplies and cables.

Safety approvals

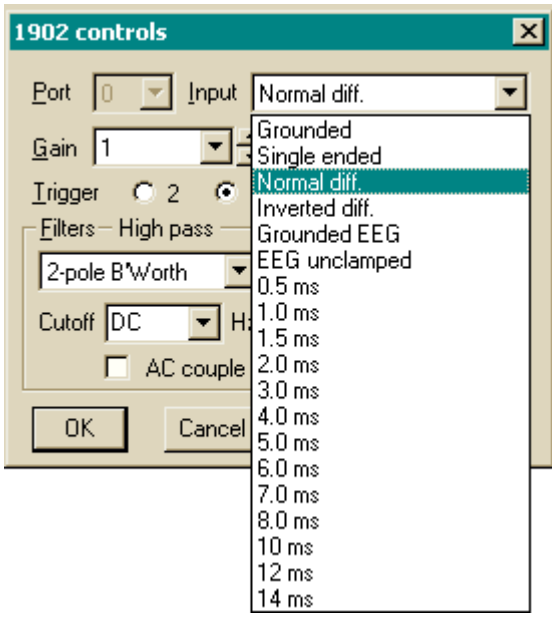
The 1902 meets the safety requirements of BS EN5724 (IEC EN60601-1) when used with a CED-approved power supply, BSI certificate no 221/000018, issued 17 September 1997.

Warning

The 1902's isolation approvals may not be relevant to industrial users. The unit will run on other power supplies (see page 32) but it is important to note that the 1902 does not meet EN 60601-1-1:2000 safety and EN 60601-1-2:2001 EMC standards unless used with the CED-approved power supplies.

Signal input to the 1902

To amplify signals with the 1902, you must first select the input source and mode of operation. The sources are the transducer and the isolated amplifier. You cannot use both at once. The transducer has four input modes; the isolated amplifier operates either normally, i.e. with differential inputs, or with a clamp of varying duration. The source and mode are selected by one drop-down list in the 1902 Control Panel. See page 20 for how to open the Control Panel, and for more about the other controls. See page 41 for a description of input clamping.



Input drop-down list; version with electrode clamping

Important! Please note that the input source DEFAULTS TO THE TRANSDUCER.

If you wish to use EEG (or ECG, EMG, etc.) input, you must first SELECT ONE OF THE ISOLATED INPUTS mentioned above.

Input mode table The input modes are tabulated below. For the pinout of the transducer and isolation amplifier sockets, see pages 27 and 28. For more on the fundamentals of differential input, see page 34. Note that, when selecting isolated input, 'EEG' is taken to include ECG, EMG, etc.

Source	Mode	Effect
Transducer	Grounded	Both amplifier inputs grounded
	Single ended	Input +ve to amplifier non-inverting input; inverting input grounded
	Normal diff.	Input +ve to non-inverting input; Input –ve to inverting input
	Inverted diff.	Input +ve to inverting input; Input –ve to non-inverting input
Isolation amplifier	Grounded EEG	Both amplifier inputs grounded
	Isolated EEG / EEG unclamped	Input +ve to non-inverting input; Input –ve to inverting input
	Clamped EEG — 0.5 ms, 1.0 ms, … 12 ms, 14 ms	Differential input as with normal EEG, but input is clamped (see page 41) for interval selected

1902 functional organization

To the user, the 1902 comprises two completely separate functional blocks: the waveform signal conditioner and the trigger generator.

The waveform conditioner

The waveform conditioner provides one channel of output, with the input selected via software from a range of input connections. There is a comprehensive set of conditioning controls: gain selection, filtering and offsetting, and overrange detection. The 1902 may readily be adapted to different specialized signal sources, requiring additional control (for instance clamping), by a choice of internal daughterboards. The computer can read back the characteristics of these daughterboards.

Digital filter

By default, digital filtering is installed in your 1902 (the alternative being analogue filter sections on a daughterboard). The digital filter processing section is based on a 16-bit ADC carrying out conversions at 30 kHz; this interrupts the microprocessor, which carries out digital processing as required before writing the modified data to the DAC, which is also clocked at 30 kHz. The digital processing imposes a time delay (latency) of approximately 0.35 ms on the data at the time of recording. During playback, *Spike2* or *Signal* can be configured to remove this delay if required.

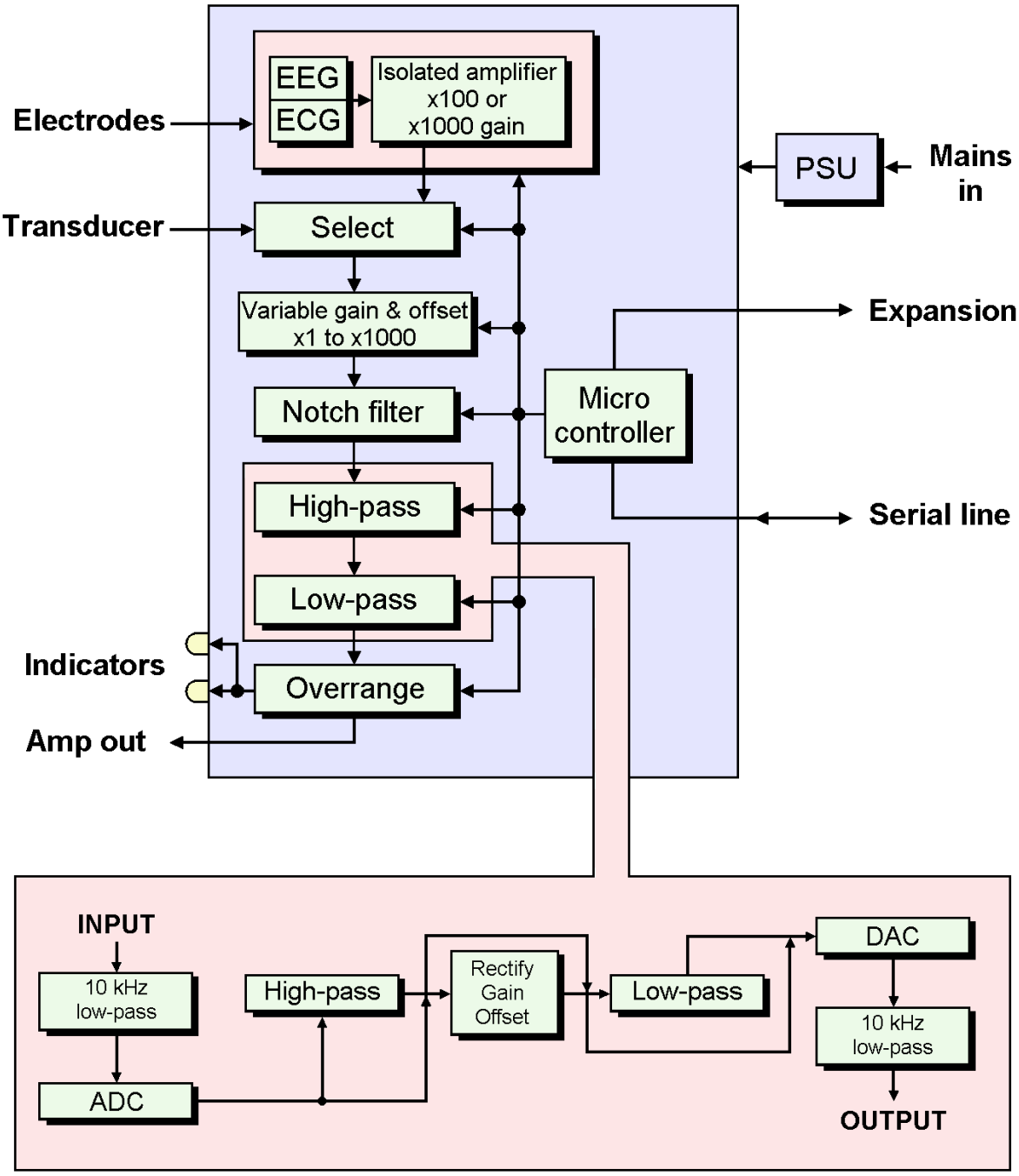
Response

2-pole or 3-pole digital filters can be applied, with either Bessel or Butterworth response. The corner frequencies are selected from dropdown lists, or users may type in their own values: high-pass from 0.01 to 1000 Hz, low-pass from 1 to 10,000 Hz. There is a rectification option, useful for EMG studies. The digital filtering system can also be used to output ADC data down the serial line at up to 100 Hz.

The trigger generator

The trigger generator provides one output channel of pulses, derived from a choice of two inputs selected by program. It uses comparator circuitry with hysteresis to generate clean TTL pulses from a variety of trigger input sources.

The Trigger2 input can be used to trigger the EEG input-clamping circuit, if this option has been fitted (see page 41).



Waveform signal flow in the 1902,
detailing digital filtering subsystem

Features seen by the user

Features of the 1902, all selected by program control, are:

- Differential or single-ended transducer waveform inputs (non-isolated, not for human subjects)
- Optional isolated EEG electrode input
- Optional input clamping with EEG input
- Optional isolated ECG 5-lead input selection
- Gains from ×100 to ×100,000 in steps of ×1, ×3, ×10…
- Optional gains from ×1,000 to ×1,000,000 in steps of ×1, ×3, ×10… (build option)
- AC/DC coupling switch
- 12-bit DC voltage offset
- Selectable mains-frequency notch filter, 50 Hz or 60 Hz
- Overload indicators, readable by computer
- Trigger input: converts from high-level pulses or switch-closures to TTL, with program-selectable choice of 2 inputs (non-isolated)
- Digital filter with a wide range of user-selectable settings
- Optional precision unity-gain buffer for use in multi-electrode configurations

Physical construction

The 1902 is built on a multilayer printed circuit motherboard, to which a daughterboard may be attached to provide one of the various isolation options. This is contained in a two-part folded-steel inner can that provides electromagnetic containment. This assembly is mounted in the outer case, also of folded steel, that provides mechanical protection.

Installations with multiple 1902s

It is often the case that 1902s are purchased as multiple units. Usually these will be dual or quad 1902s; they are accommodated with external cases bolted together as a stack, inside which the separate inner cans are mounted. Multiple units are powered from a single power supply and cable, and are driven from a single RS232 port in 'multi-drop' mode.

Typically, the bottom unit will be the 'master', to which the cables are attached. Usually this will be set to the highest channel number. For more on channel numbers, see below.

Rack-mount installations

Rack-mount installations can accommodate up to four 1902s in a traditional 19-inch rack. The folded-steel case is 2U (89mm) high; inside this the 1902s are mounted in their inner cans. The power-supply is internal to the case and there is also a cooling fan. A rack-mount case presents only one load to an RS232 port and may contain buffers to drive other racks of 1902s.

Using a USB port

Computers, especially laptops, are increasingly being supplied without an RS232 port. In this case, the 1902 can be connected to one of the USB ports via a "USB virtual com port". This is a cable that plugs into a USB port, with a 9-way RS232 plug at the other end. The RS232 port is powered from the USB socket. It connects with the RS232 cable supplied by CED (a standard RS232 cable will not work). This hardware is inexpensive and readily obtainable.

Com port number

The USB virtual com port should be installed before the 1902. During installation, it will be assigned a com number, e.g. Com5, which can be found by looking in *Control Panel, Device Manager, Ports*. This is the com port that should be set during 1902 installation (see page 5).

Channel numbers and how to set them

Wherever there are multiple 1902s, the software uses *channel numbers* to identify which 1902 is being addressed. Up to thirty-two channels can be set. In the 1902 Mk IV, channel numbers 0 - 15 are set by a sixteen-way rotary switch, accessed through a hole in the back panel. Using a 3mm flat-bladed screwdriver, turn the switch clockwise to increment the channel number. The stepping 'feel' is satisfactorily distinct. In position 0 (and 8) the screwdriver slot is vertical. The switch positions are printed on the back panel (in hex) as a guide.

Channel numbers 16 - 31

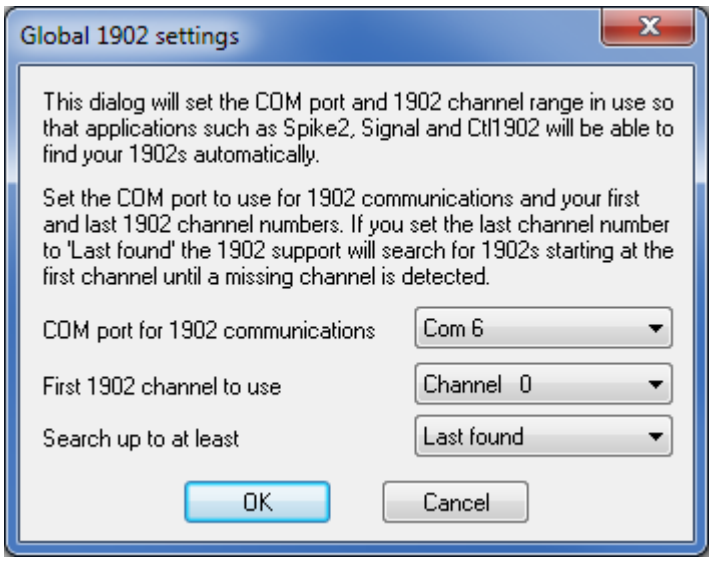
If you need to set channel numbers above 15, you must access a switch inside the 1902. See sections on opening the 1902 on page 47, and on the options switchpack on page 52. When the switch 'OPT 0' is in the *off* position, the rotary switch selects channels 16 - 31.

1902 communication configuration

The 1902 communication settings, that is to say the com port number and the channel number(s) of the 1902(s), are stored in the Windows registry, in keeping with modern programming practice. Formerly this information was stored in a system file named `CEDCOND.INI`. These settings only affect communication with the host computer; they have no bearing on the function of the 1902, such as the amplifier gain, filter response, etc. Consequently they need only be set once, unless you want to rearrange your 1902s in relation to your computer.

Setting the 1902 configuration

Once you have used Try1902 to check that your 1902s are working correctly (as described in *Confidence check* above) you should use the Try1902 *File* menu *Set port and channels* command to save your settings. The command opens a dialog box used to set the 1902 communications parameters. There are three fields, as described below:



1902 communications dialog box

COM port for 1902 communications

This sets the com port (serial line) used to communicate with your 1902s. Try1902 will set this field automatically so you should not need to change this.

First 1902 channel to use

This sets the channel number used to start the search for 1902s. Set this value to the lowest-numbered channel that you are using. 1902 channel numbers normally start at zero.

Search up to at least

The search for 1902s starts at the first 1902 channel specified, and continues until a missing 1902 is detected after the channel specified in this field. So if there is a gap in your 1902 channel numbers, you can use this field to force the search to cross the gap by setting it to your highest 1902 channel number. Normally 1902 channel numbers are contiguous and you would leave this field set to *Last found*.

Saving to the registry

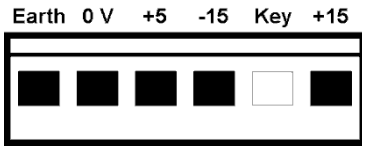
Once the settings are correct hit *OK* to save them to the Windows registry. Once this is done, all software using the 1902, either within a CED application or as stand-alone support, will be able to find and use your 1902s. If you change the com port or the 1902 channel numbers you should use this Try1902 dialog to adjust your settings to match the new arrangements.

Cable connections

The 1902 needs both power and RS232 cables to be connected; it will not function usefully without RS232 control, although, once the 1902 has been set up and is working properly, the RS232 cable can be removed. The two cables are applied to connectors on the rear panel.

Power

The connector from the power supply is a Molex-style cable socket at 0.156" pitch with a retaining ramp. There are six pin positions, one of which is blanked to provide a polarizing key. This socket engages with the connector marked Power In.



1902 power cable socket

If the CED power supply is being used, this must be connected to normal AC mains by the standard IEC cable provided. There will be a mains plug suitable for your country. This power supply can run on any mains voltage from 100 V to 240 V AC, 50 Hz - 60 Hz. There are no switches on the 1902 or the power supply; power is entirely controlled by switching at the mains socket.

RS232

The RS232 cable for the 1902 has two 9-way D-type connector sockets and is reversible end for end. Offer one end to the D-type plug marked RS 232 and the other to your computer's RS232 port. You will have to inform your application software which port you intend to use (see *1902 communication configuration*, page 14.) Make sure that the jackscrews on both connectors are screwed home to reduce the possibility of radio/television interference.

Signal cables

We expect users to furnish their own input cables for the trigger and transducer connectors, for which we supply suitable mating plugs, and also their own BNC output cables. Details of the front-panel socket pin-outs are described in the *Electrical Specification* section below. The two outputs from the 1902, trigger and amplifier, are brought out through BNC connectors, which can be connected using standard BNC cables to measuring and recording equipment, such as the CED 1401.

Electrode cables

When specified, the EEG (or ECG) electrode inputs will normally be routed through the CED1902-11 Electrode Box (see page 2), which accepts standard 1.5mm (optionally 2mm) safety plugs, and connects to the 1902s via a 6-pin DIN plugs. Alternatively, users may wire the 6-pin DIN plug supplied with the 1902 to their own requirements.

Mating connectors

A full kit of mating front-panel connectors is supplied with the 1902, as are the serial-line control cable and the power supply mains cable.

The kit

The standard connector kit comprises:

- One 8-pin DIN plug for transducers
- One 4-pin mini DIN plug for the trigger
- One 6-pin DIN plug for electrode signals

Further connectors can be obtained from a variety of suppliers but, for reference, we have obtained ours here:

Component	Part number	Supplier	UK tel. No.
Trigger, 4-pin mini DIN	152-208	Farnell	08701 200200
Transducer, 8-pin DIN	809-792	"	"
Electrode, 6-pin DIN	809-779	"	"

- To meet the requirements of EN60601-1 only the DIN parts specified (apart from trivial details of colour, etc.) can be used for the electrode connectors.
- If the DIN 6-pin connector is used, the plastic cover must be kept fully pushed onto the plug body at all times.

Firmware – the 1902 flash ROM

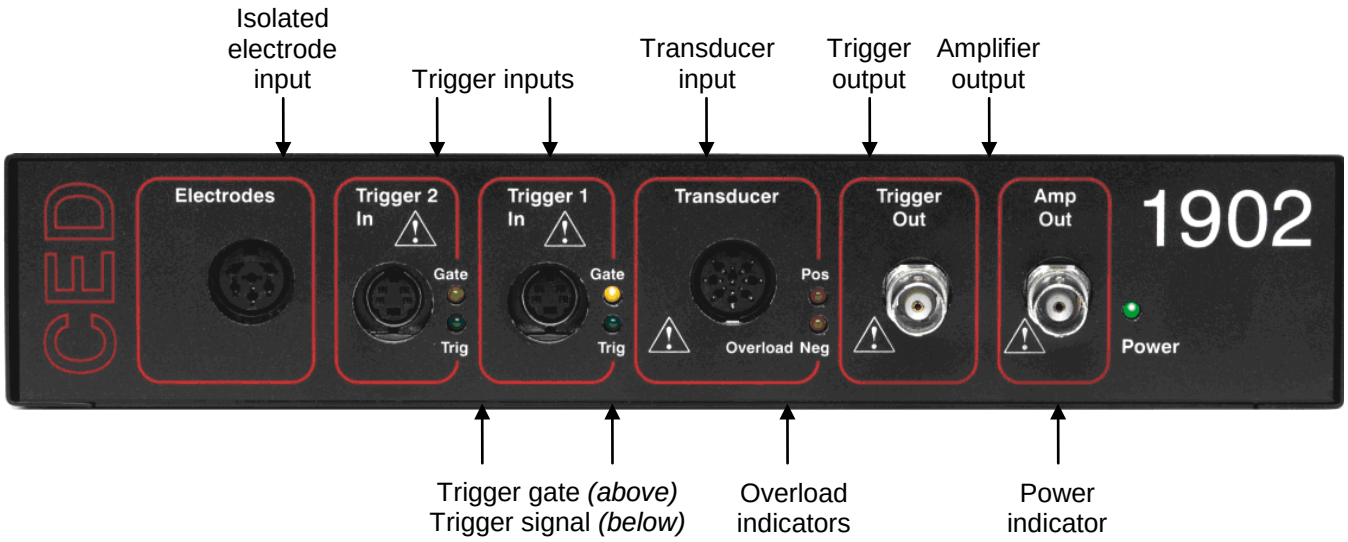
Because the 1902 has so many user-specified options (e.g. choice of front end, high-pass and low-pass filter values, notch filter frequency), an internal read-only memory is provided to hold the characteristics of the options fitted and suitable names (in English) for these options. This simplifies the task of any controlling software. In the 1902 Mk IV, this memory is an area of the flash ROM. Earlier models used a small EEPROM.

Other firmware

The operating system (the 1902 monitor) is run directly from flash ROM. The flash ROM also stores the data needed to boot up the microprocessor and configure the FPGA. As a component of the 1902 processing core, flash ROM data is part of the physical design, and subject to revision and upgrade.

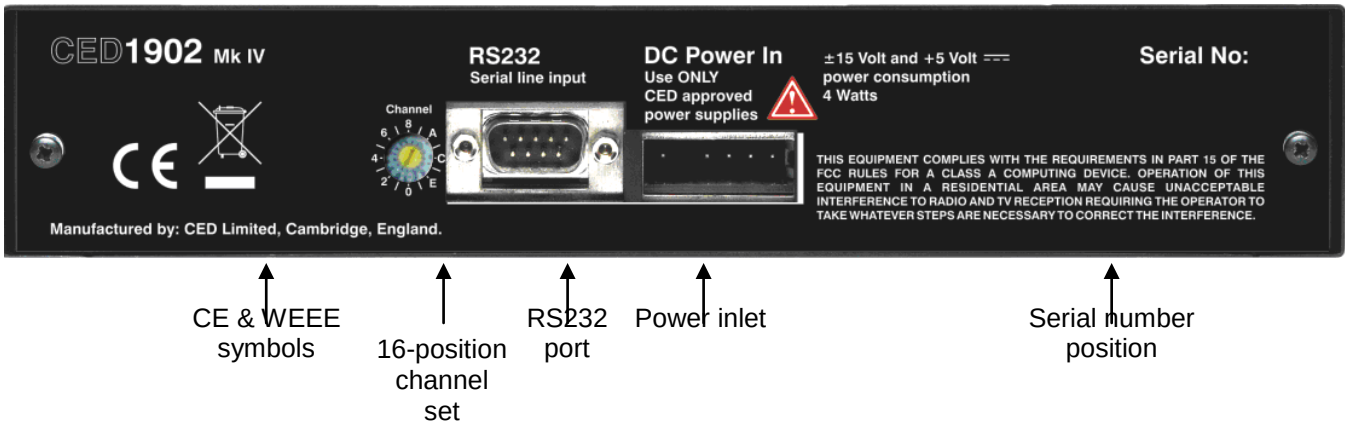
Firmware upgrades & the Internet

Updating the firmware is done through an option of Try1902 (see page 46). As and when it becomes desirable to do so, upgrade files will be offered as free downloads from CED's website, `www.ced.co.uk`. Your current firmware version is displayed, as the 'monitor version', in the Try1902 window.



Front panel features

Rear panel features



Software supplied with the 1902

The 1902 is supplied with Try1902, a test and calibration program, which is referred to throughout this manual. Also supplied is Ctl1902, a stand-alone applet for users who wish to run the 1902 as a simple electronic box. In effect, it supplies the knobs and switches of a logical front panel. A similar applet is invoked by CED's principal software packages, *Spike2* and *Signal*, to provide full operational control of the 1902.

Try1902 More details of Try1902 are given in the Help sections and in *Maintenance & Calibration*.

Note: 1902 ASCII commands Whatever the application, all communication with the 1902 is, ultimately, in the form of short ASCII strings. A full description of these is provided in the *1902 Technical Manual*.

The Stand-alone Control Panel

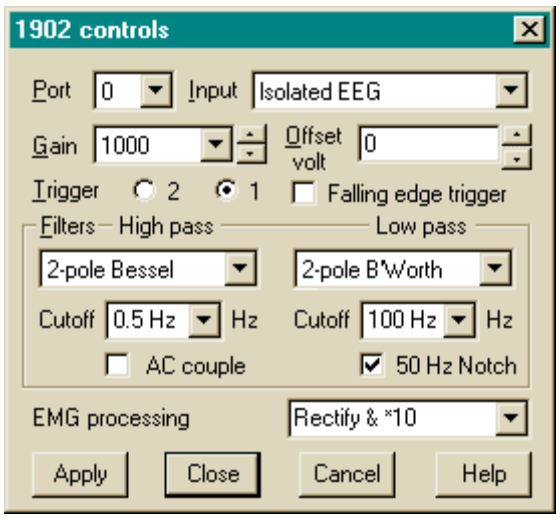
Open the Control Panel by selecting *Start, Programs, 1902 Support, Ctl1902*. A window opens holding the 1902 controls. These comprise dropdown lists and check boxes. The contents and ranges on offer depend on the 1902. Ctl1902 interrogates the 1902 to see which options to display. For example, the notch filter check box will display either '50 Hz' or '60 Hz'. Here, briefly, are the controls:

Port This is the 1902 channel number. For use with just one 1902, it is greyed out.

Input This selects waveform input from the transducer or the isolation amplifier. It sets the various operating modes, such as single-ended or differential for the transducer, or various clamp delays on the isolation amplifier.

Gain This is the voltage gain of the input selected. It may not go down to unity: some inputs have minimum gains of 100× or 1000×. Rather than use the dropdown list, the spin controls to the right may be used.

Offset This is a fixed DC voltage summed with the input, to centre the signal about zero; a positive or negative value (in millivolts) may be entered by keyboard, or the spin controls can be used for steps of 5%.



1902 Stand-alone Control Panel

Low-pass & high-pass filters For digital filters, the corner frequencies are selected from dropdown lists, or users may type in their own values. They can also select slope (2-pole or 3-pole) and filter type (Bessel or Butterworth). If this channel has analogue filters rather than digital, the two dropdown lists have just four values each. The choice of corner frequencies depends ultimately on the values of components fitted on the filter daughterboard. One choice is always 'None' or 'DC', i.e. straight through.

EMG processing The signal can be rectified (i.e. all negative excursions of the signal are inverted). This is mainly of interest during EMG studies. As well as rectifying, you can choose ×10 gain.

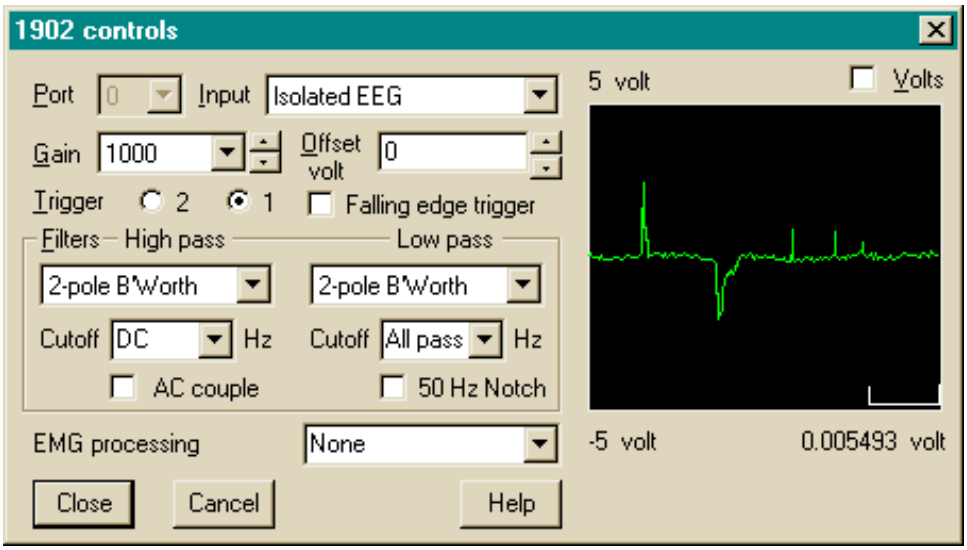
Notch filter This is a filter to attenuate mains pickup. It is set during manufacture to either 50 Hz or 60 Hz; the check box switches it in or out. Note that this is provided for diagnostic purposes only; it is not intended for use during experiments. See page 43.

AC couple AC coupling blocks the DC component of a signal. It can be very useful, for instance, if your signal happens to be a small ripple on a large DC level. It does attenuate very low frequencies: the corner frequency is approximately 0.16 Hz. Note that DC values of greater than ±150 mV applied to the isolated electrode input may cause saturation in the input amplifier, even with AC coupling selected.

Trigger This toggles between the two trigger inputs, which are functionally identical. A check box can set triggering to occur on the falling edge. (In previous versions of the 1902 only the rising edge could be used.) Unchecking Trigger 1 sets Trigger 2; one must always be selected. Note that the clamp option (see page 41) always uses Trigger 2; when the clamp option is in use, Trigger 1 may be used as an independent trigger channel.

The control panel with CED applications

Most users will run the 1902 as a hardware adjunct to a CED 1401 interface, operating under one of CED's principal software packages, *Spike2* or *Signal*. CED applications control the 1902 hardware through an applet similar to the Stand-alone Control Panel. This appears either with or without an oscilloscope-style display on the right. The version with the display appears during the setup phase; the display assists the user in adjusting gain, filtering, offset, etc. It is not a true oscilloscope, of course, but a digitized simulation using data from the 1401's ADC (analogue to digital converter) sampling the appropriate input channel.



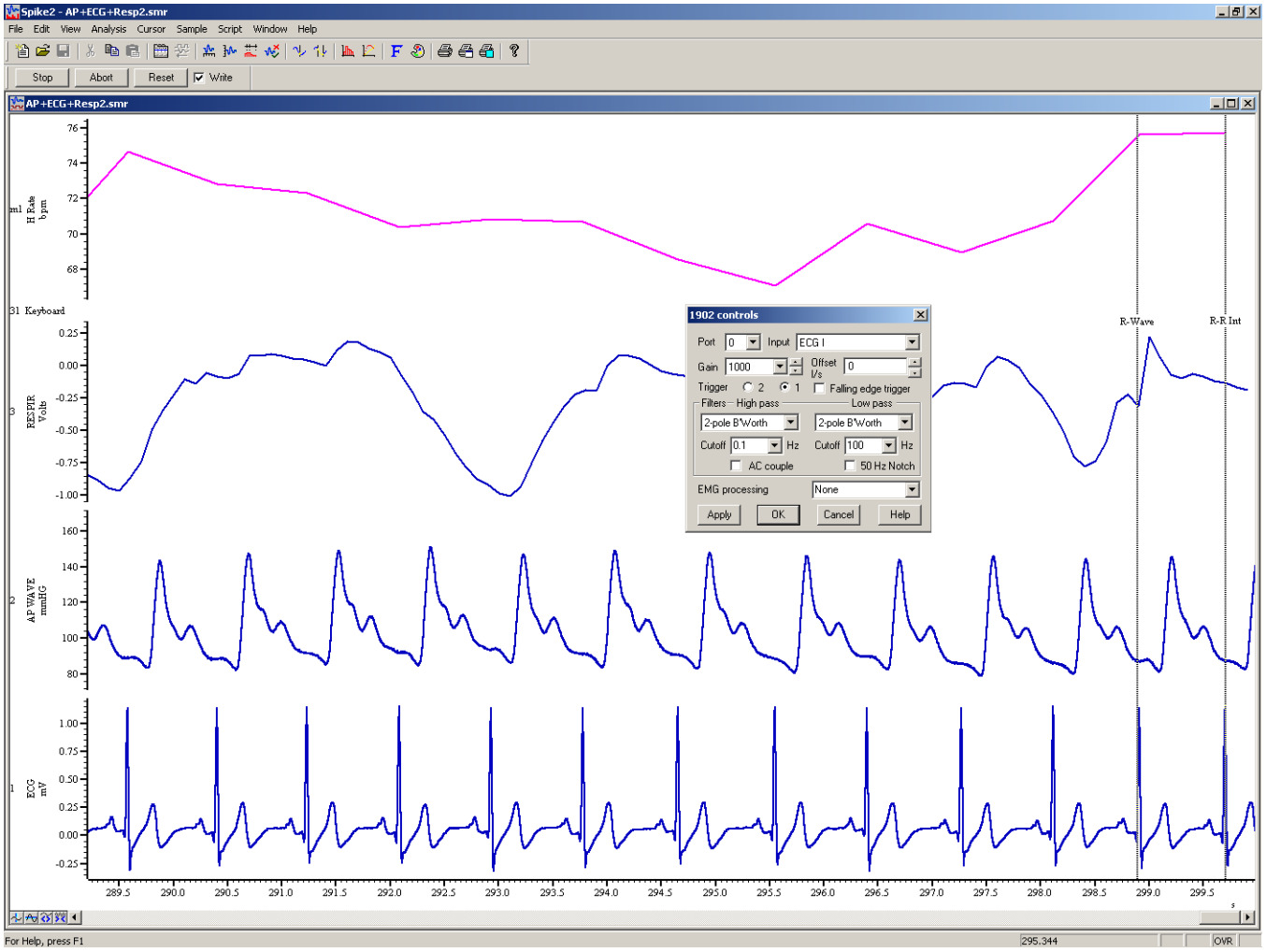
Control of 1902 setup from CED application

During sampling, the oscilloscope display is not available. Access to the ADC cannot be guaranteed; quite likely it will be too busy doing other things! Also, the display generated by the application itself (see examples below) usually renders the oscilloscope superfluous.

Running the 1902 from *Spike2*

Spike2 is optimized for the analysis and recording of continuous data, possibly on many channels. Analysis of EEGs during sleep would be a typical task involving 1902s.

All controls remain accessible during data sampling, but, if offset and gain are altered, the last settings are recorded as the offset and gain of the entire data. The alterations are logged on a marker channel, however, so earlier data can be re-scaled.

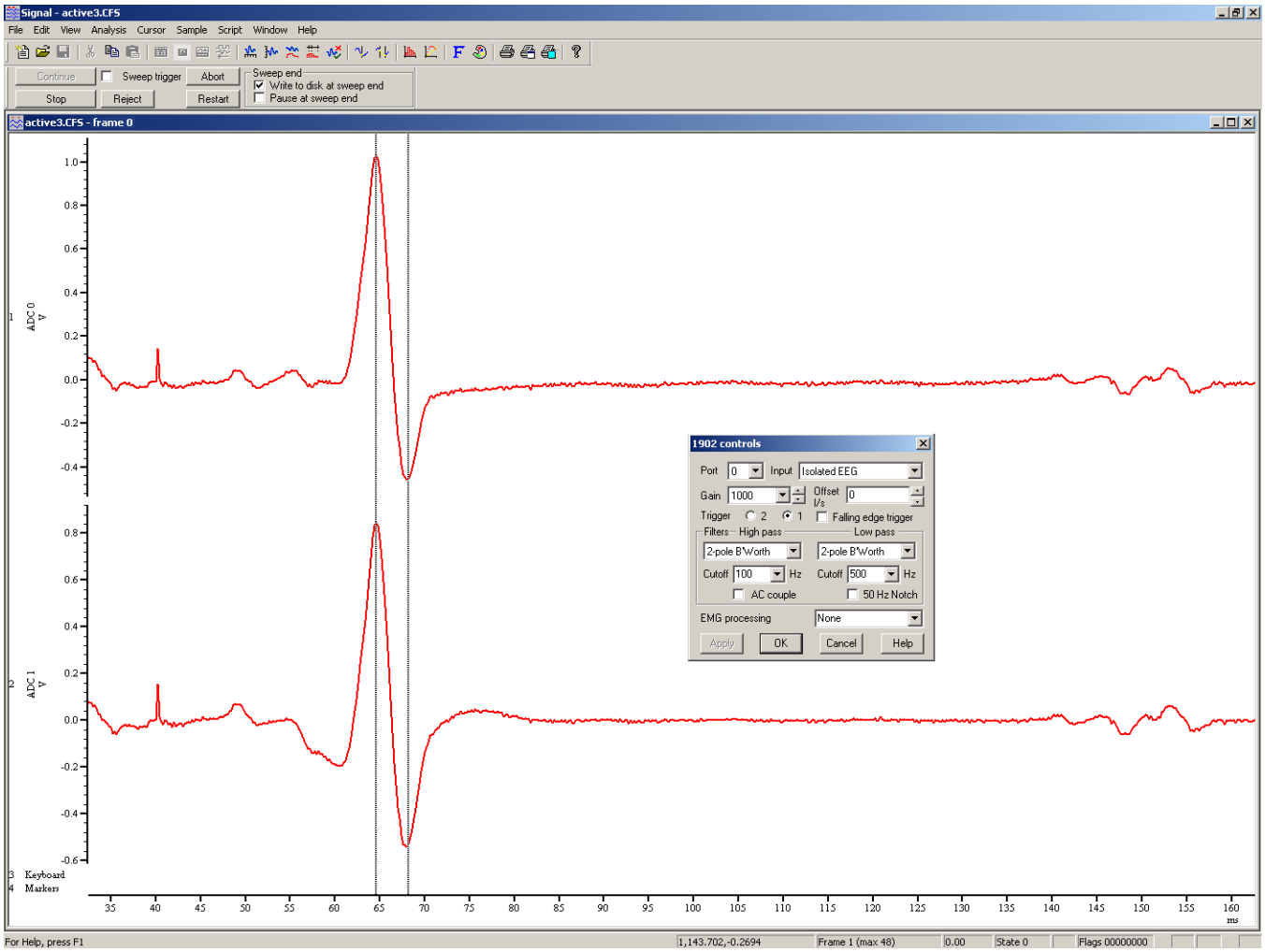


***Spike2** sampling ECG, with 1902 control panel*

Running the 1902 from *Signal*

Signal is optimized for the analysis of sweep based information, where a sequence of data is recorded repetitively, often synchronized to a repeated stimulus. The classic example of this, and one for which a 1902 is ideal, is evoked-response recording; here segments of brain activity are correlated with recurrent stimuli, in order to extract responses buried in the noise.

During data sampling under *Signal*, all the 1902's controls are accessible and can be adjusted. All settings are recorded with each sweep; each sweep can be regarded as a separate data file.



***Signal** controlling 1902s for multi-channel data acquisition*

Main amplifier

The main amplifier comprises a programmable-gain amplifier, a selectable mains notch filter, a programmable selection of low-pass and high-pass filters (analogue or digital), and programmable selection of input sources. The output of the amplifier is through a standard coaxial BNC socket.

Bandwidth (with analogue filters)	DC to 50 kHz (-3dB) in DC mode 0.16 Hz to 50 kHz in AC mode
Bandwidth for gains over ×3000	25 kHz (-3dB)
Bandwidth (with digital filters)	DC to 10 kHz (-3dB)
Gain accuracy	±2%
Digital filter response	Bessel or Butterworth
Filter slope (low- and high-pass)	2^{nd} or 3^{rd} order (12 or 18 dB/octave)
Low-pass filter corner frequency	1 Hz - 10 kHz cont. variable
High-pass filter corner frequency	0.01 Hz - 1 kHz cont. variable
Rectification	User-selectable
Filter latency	0.35 ms (approx.)
Mains notch cut (50 Hz or 60 Hz)	50 dB (typical)
Overload indicator indicate when input is overrange	2 yellow LEDs (1 for each polarity)
Transducer input:	
Input impedance	1 GOhm
Input bias current	±50 nA max
Range of gains available	×1 to ×100,000 in steps of 1, 3, 10…
Common mode range	±10 V
CMRR	>100 dB

Isolation pre-amplifier

A daughterboard option provides the 1902 with a medical-specification isolation pre-amplifier and associated isolated power supply. This amplifier can be DC blocked, with a corner frequency of 0.16 Hz. Any resistive electrode balancing network is expected to be external to this unit.

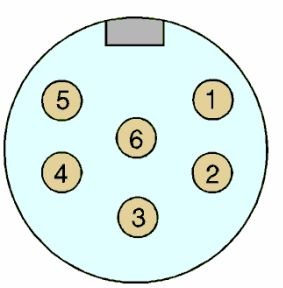
Input impedance	10 GOhm
Input bias current at 25ºC	±150 pA
Noise referred to input, 1 Hz - 10 kHz	0.3 μV rms.
Common-mode rejection at 50 Hz	100 dB
Common-mode voltage range	±1 V
Input offset voltage, initial adjusted	less than 10 μV after 1-hour warmup
Input offset voltage vs. temperature	5.5 μV/ °C
Input offset voltage vs. time	1.5 μV / 1000 hrs
Gain ranges – Low-noise EEG	×1,000 - ×1,000,000
– ECG	×100 - ×100,000
Gain step sequence	×1, ×3, ×10…
Gain accuracy	±2%
Bandwidth, all gains	DC - 10 kHz
Isolation voltage, continuous	1500 V DC
Isolation voltage, peak for 5 sec	2500 V peak
Input-output leakage at 240V, 50 Hz	less than 20 μA
Input clamp option – Low-noise EEG	0.5 ms - 14 ms
Lead configuration – ECG	I, II, III, aVR, aVL, aVF, and V
Calibrator – ECG	1 mV pulse

Note: wire colours & socket drawings

The 'Wire colour' columns in the tables below are for your convenience if you have to make up cables. All 1902 sockets are drawn as the user sees them, i.e. viewed from *outside*. This is also the view of the backs of their mating plugs as seen while wiring them up!

Isolated input

The 1902 Mk IV is fitted with a 6-pin DIN socket with a metallic shell that acts as a screen. To conform with safety requirements, mating plugs must be of the type with a plastic outer sleeve; the inner metallic body must be fully inserted into the plastic sleeve whenever the plug is in use.



Isolation input

6-pin DIN socket

DIN pin	EEG function	ECG function [1]	Wire colour
1	Input +ve	Left leg	
2	Input –ve	Left arm	
3	Buffer input / +iso power [2]	Right arm	
4	Buffer output / –iso power [2]	Vagus	
5		Common [4]	
6	Common	Common	
Shell	Cable screen [3]	Cable screen [3]	

Notes

1 The ECG lead configurations are leads:
I, II, III, aVR, aVL, aVF and V.

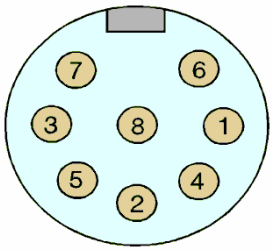
2 Buffer I/O available with the CED1902-4-B buffer option (see page 39). Iso power is a factory-fitted build option.

3 The cable screen is AC-coupled to mains earth by 1 nF (6 kV continuous rating).

4 Connected to Common except in older ECG 1902s having the right-leg drive option fitted.

Transducer input

The 1902 transducer input is an 8-pin DIN socket. Input is inherently differential; for single-ended use, the inverting input is grounded. The main amplifier offsetting DAC is brought out, and may be used as a simple programmable signal source when the waveform conditioner is not required.



Transducer input

8-pin DIN socket

Pin	1902 function	Single-ended	Differential	Wire colour
1	Ground	Ground	Ground	
2	+12 V power	+12 V power	+12 V power	
3	–12 V power	–12 V power	–12 V power	
4	+5 V power	+5 V power	+5 V power	
5	Input +ve	Input	Bridge output +ve	
6	DAC output	DAC output	DAC output	
7	Input –ve	Link to pin 1	Bridge output –ve	
8	No connection			
Shell	Mains earth	Screen	Screen	

- A human subject must NOT be connected to this socket
- The power outputs are intended for driving transducers only. Transducers should have impedances greater than 500 Ohms (5 volt) or 1200 Ohms (12 volt)
- Transducer current should not exceed 10 mA

Bridge transducers

The differential input is connected to a force or pressure transducer, or to a strain gauge. The 1902 can provide the voltage excitation needed. For half-bridge types, binding adaptors must be used to complete the bridge.

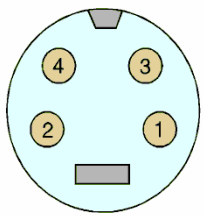
Single-ended transducers

Single-ended transducers should be connected between the +ve input (pin 5) and ground (pin 1). The –ve input (pin 7) should be linked to ground. The 1902 voltage offset facility on pin 6 can be used to back off a static voltage level at the transducer output.

Trigger circuit

The trigger circuit accepts signals from high-impedance sources that cannot drive TTL inputs, such as sensors; it can also be wired to a switch. Trigger connections are made to two mini-DIN sockets on the front panel, one of which will always be active, as shown by its yellow Gate LED. Each trigger input drives a comparator, which responds to a positive-going signal (by default), giving a flash on its yellow Trig LED. In 1902 Mk IV, the comparator may be set to trigger on a negative-going signal. The comparator has hysteresis: it fires on a rising voltage at 1.5 V, but does not relax until it has fallen back to 1.0 V. This reduces repeated triggering from noisy signals. The trigger circuit output is through a standard BNC socket. The driver is a 74HCT04 inverter element; this chip is in a socket, for easy replacement in case of damage.

Trigger input voltage range, operating	±15 V
no damage	±50 V
Input impedance	100 kOhm
Trigger threshold for +ve going input	+1.5 V approx.
Lower trigger threshold	+1.0 V approx.
Output pulse	TTL negative-going
Output pulse length	3 μs nominal
Trigger output drive capability	0.8 mA maximum



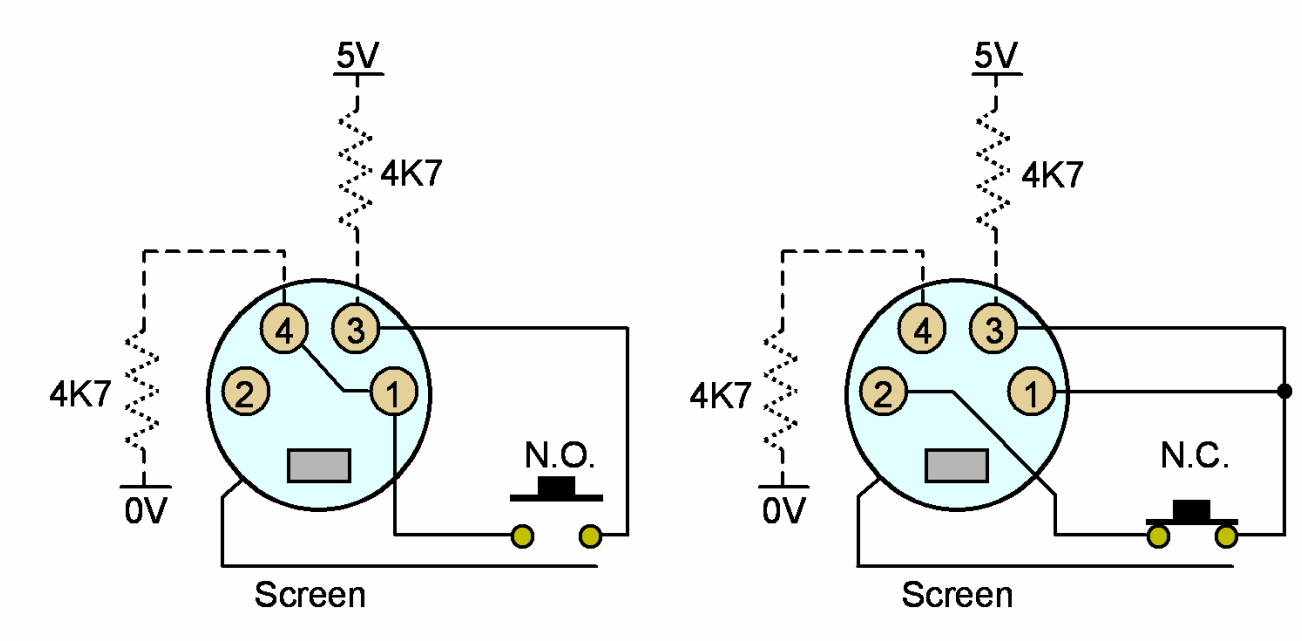
Trigger input

4-pin mini-DIN socket

Pin	Function	Wire colour
1	Comparator input	
2	Trigger ground	
3	Internal pull-up: 5V via 4K7	
4	Internal pull-down: 0V via 4K7	
Shell	Mains earth	

- A human subject must NOT be connected to this input socket

Wiring switches To use a switch that is normally open as a trigger source, connect pins 1 and 4 to one contact, and pin 3 to the other. Connect the screen to the switch body. Closing the switch raises the input from 0 V to 2.5 V. To use a switch that is normally closed, connect pin 1 to pin 3, the switch between pin 3 and pin 2, and the screen to the switch body. Opening the switch raises the input from 0 V to 5 V.

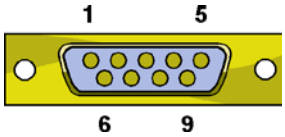


Wiring for normally-open switch

Wiring for normally-closed switch

RS232 port

The RS232 port is a standard 9-pin D plug. The functions DSR, CD, and RTS are connected together within the 1902 case so that a simple pin-to-pin cable can be used. The RS232 serial-line cable provided with the 1902 has a 9-way D-type socket at each end, suitable for AT and ATX chassis PCs. The baud rate is fixed at 9600.



RS232 port

9-pin D-plug

Pin	Function	Wire colour
5	Signal ground	
4	DTR to 1902	
3	Data to 1902	
2	Data from 1902	
1	CD	
6	DSR	
7	RTS	
8	CTS from 1902	
9	No connection	
Shell	Cable screen	

- For correct EMC performance it is essential that the serial-line cable connectors have good-quality metal shrouds, and that they are clamped with integral jackscrews to the threaded posts provided on the 1902 and on the computer
- The cable must be screened with metal braid or foil, which should be clamped to the shrouds at both ends

RS232 to USB converters

To use the 1902 with a computer such as a laptop that may not have a physical com port, consider one of the commercially-available devices that implement a virtual RS232 port on the end of a USB plug. The special RS232 cable supplied by CED must still be used. See page 13 for more on this.

Power supply

The 1902 must be powered from a CED-approved power supply if it is to meet the EN 60601-1-1:2000 safety and EN 60601-1-2:2001 EMC standards. The Powerbox™ model PMP55-32-J12 is the current (April 2008) approved supply.

Mains electricity

This power supply accepts mains voltages from 100 V AC to 240 V AC at frequencies from 50 Hz to 60 Hz, without needing adjustment by the user. The 1902 power supply draws typically 30 VA.

Mains earth

There is electrical earth continuity from the mains plug and mains cable, through the power supply and DC cable, to the 1902 can and case, and all connector bodies apart from the isolation amplifier. (The 'Cable screen' pin of the isolation connector is AC-coupled to mains earth through a 1 nF, 6 kV working capacitor.) The 1902 power supply must be plugged into a mains socket with a good earth.

Other power supplies

For applications that do not need EN 60601-1 isolation, the 1902 can be powered from another suitable source of stable power. Any such power supply must have a mains earth through-connection. The 1902 requires approximately 220 mA at +5 V, 75 mA at +15 V and 20 mA at –15 V, plus whatever current is required for external transducers (see page 28).

Basic mode of operation

The simplest method of acquiring an electrophysiological signal with a 1902 is the "Isolated EEG" mode of *Spike2*, using a bipolar electrode configuration. This involves three wires: two as a differential signal input, and a common lead to provide a return path for the very small input bias currents. NONE OF THESE LEADS must ever be connected to mains earth. Note that, for skin-surface recording, the electrodes are always connected to the isolated input. The transducer input must not be used with human subjects.

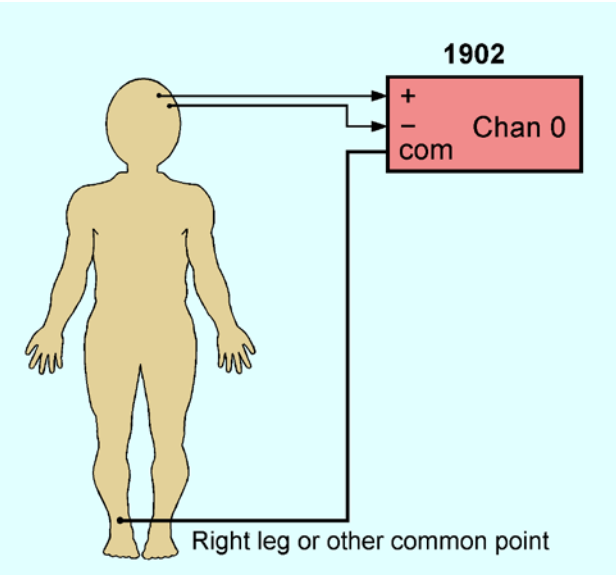
Bipolar input

The two signal leads form a *differential* input. The signal that is detected and amplified is the algebraic difference between the voltages on the two electrodes. This is achieved by inverting the –ve input and summing it with the +ve input. Consequently, any voltage that is present on *both* inputs is cancelled out and not amplified. This is known as common-mode rejection; it applies to AC as well as DC, so long as there is no phase shift. It is also limited to a comparatively small input range: about ±1 volt. As an example, if there are +0.500136 volts on the +ve input and +0.500289 volts on the –ve input:

$$0.500136 + -0.500289 = -0.000153$$

The approximately half-volt common-mode signal disappears; the difference remains and, since the larger signal is on the inverting input, the result is negative. This is what will be amplified. Note that in this configuration the electrodes are symmetrical; neither signal electrode (nor the voltage it records) is privileged over the other.

All more advanced modes of operation are elaborations of this basic configuration.



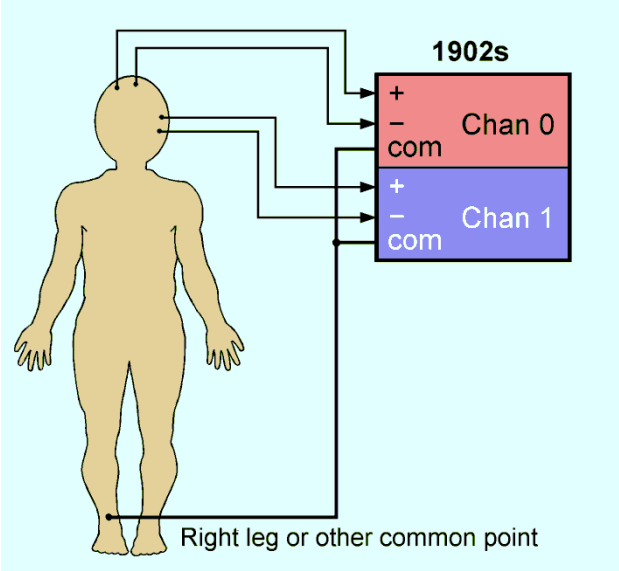
Bipolar electrode configuration

Multiple independent channels

The 1902 electrode inputs are inherently differential; they will reject a signal that is common to both electrodes. This section describes two or more independent differential inputs. Later sections will discuss multiple electrode input where there is a common, shared reference.

Dual bipolar input

Consider the simplest recording using multiple-input: two independent bipolar channels. Each channel will detect and amplify the *local* voltage difference between its +ve and –ve electrodes. Because each channel is independent, any voltage difference *between* the two electrode pairs will not be amplified. Additionally, a significant voltage gradient between widely-spaced electrode pairs will entail only insignificant voltage differences between the closely-spaced electrodes of a single channel.



Dual-channel bipolar configuration

The Common electrode

Because the isolated sides of separate 1902s are isolated from each other, the Common inputs of all 1902 channels need to be tied together. The Common input pin is connected to the zero-volts point of the floating circuitry and serves as a return path for the very small bias currents of the electrode inputs.

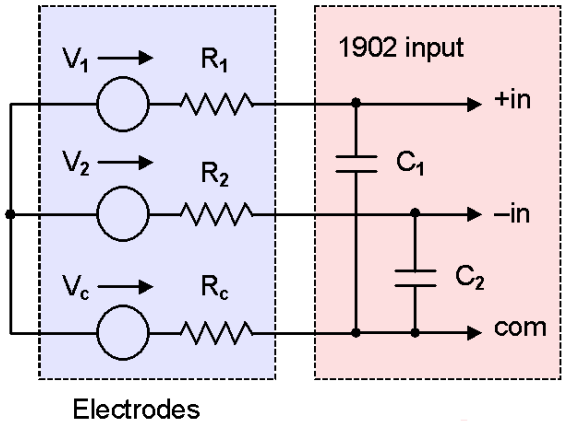
If you are using either the CED1902-10 Active Head Stage or one of the CED1902-11 Electrode Boxes, note that the Common inputs of all 1902s are connected together inside the box and brought to a single input socket.

Multi-channel configurations and the1902 input buffer

The input buffer option (CED1902-4-B) is used in multi-channel configurations where a shared reference potential is required. The option is completely housed inside one of the boxes (usually channel 0) of a multi-channel configuration. It uses spare pins on the isolation input connector to take an input signal in, buffer it and feed it back out. The user may then connect the buffer output to one terminal of several normal input channels without imposing additional load on the reference electrode. The presence of the buffer option does not affect the normal operation of the channel that houses it.

Why use a buffer?

To understand why a buffer amplifier may be necessary, we need an explanation of the effects of *input impedance*: practical considerations that receive scant attention in medical instrumentation literature. The diagram shows a single bipolar channel using two electrodes (plus common). It shows the electrode–skin junction as a pure voltage generator with series output resistance. It shows the capacitance of the cable, plus the input capacitance of the amplifier, as a single component.



Channel with unshared electrodes

It is important that the *time-constants*, the products of the series resistance and the combined capacitance at each input, should balance. Unbalanced time-constants cause differential phase shifts in the input, which lead to a reduction in the common-mode rejection ratio (CMRR). Common-mode rejection is particularly important for reducing pickup of mains-frequency and its harmonics.

Since the input capacitances tend to be similar, and in any case difficult to modify, the emphasis is on ensuring that the electrode contact resistances are balanced; the usual way to achieve this is to try to make them as close to zero as possible.

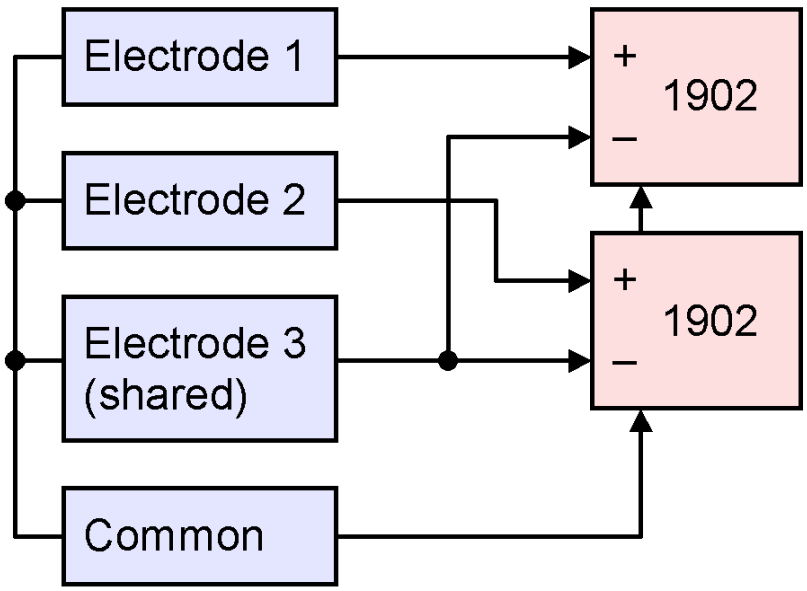
Impedance mismatch

The table shows the calculated degradation of CMRR with impedance mismatch. Note how an initial small mismatch causes the steepest fall-off in performance.

Impedance mismatch (kOhm)	CMRR @ 50Hz (dB)
0	>120
0.5	90
1	84
2	78
5	70
10	64
20	58

Shared electrodes

The diagram below shows the situation when two channels are used, with a shared reference electrode. The shared electrode now 'sees' a load equal to twice the load seen by each of the unshared electrodes. Its time-constant may be expected to be approximately double that of the other two. This is a configuration to avoid, by one of the methods that follow.



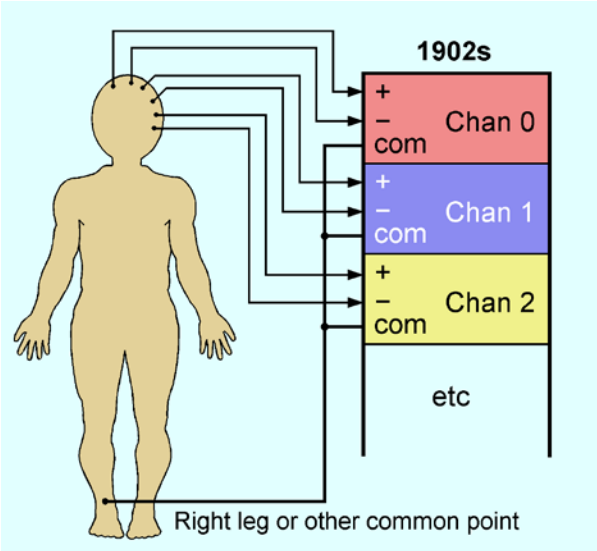
Channels with shared reference electrode

Independent electrode pairs

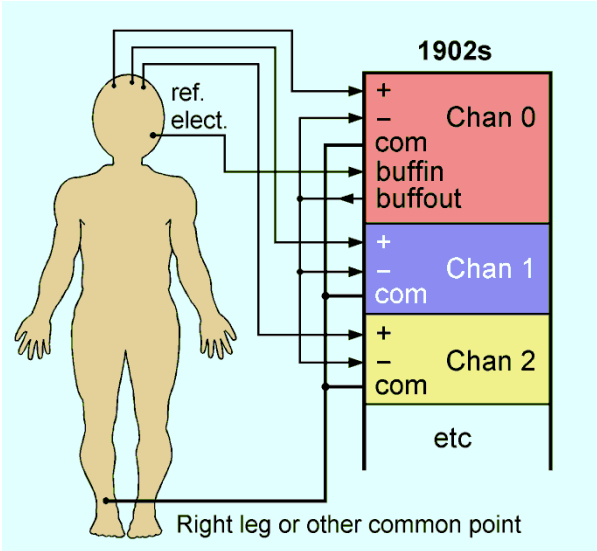
The diagram on the left shows a multi-channel 1902 setup where each channel has separate +ve and –ve electrodes. Each channel produces an independent measurement of the potential difference between the electrodes associated with that channel. There is one common electrode providing the bias current return path. This type of arrangement is appropriate for measurement of parameters such as EMG where individual muscle sites are being examined.

Electrodes with shared reference

The diagram on the right shows the configuration with a buffer circuit in operation. One electrode (the reference electrode) is taken to the buffer input, and the output of the buffer is fed in parallel to the –ve inputs of all the channels. In this arrangement, each channel produces a measurement of the potential difference between its own electrode and the shared reference electrode. Each electrode sees the same input capacitance load.



Multi-channel with independent electrode pairs



Multi-channel with shared buffered reference

The Common electrode

If you are using either the CED1902-10 Active Head Stage or one of the CED1902-11 Electrode Boxes, note that the Common inputs of all 1902s are connected together inside the box and brought to a single input socket.

Advantages of using a buffer

The table shows the calculated degradation of CMRR with input loading. It can be seen that the buffer circuit has clear advantages in multi-channel configurations.

Number of inputs	CMRR @ 50Hz (dB)	
	Without buffer	With buffer
1	>120	>120
2	91	96
3	85	96
4	79	96
6	67	96
8	55	96

Drawbacks of using a buffer

There are several possible problems associated with the use of a buffer circuit:

1. The buffer introduces additional noise. The amplifier used in the 1902 buffer option is the same type as is used in the main inputs, so the resulting noise voltage is not more than $\sqrt{2}$ times that of an unbuffered configuration.
2. The buffer has to be *exactly* unity gain if the common-mode rejection performance is to be maintained. The standard circuit using an operational amplifier as a buffer falls short of unity gain by an amount proportional to the reciprocal of the open-loop gain of the amplifier at the frequency being considered. The 1902 uses a more sophisticated circuit that is adjusted to exactly unity gain at (say) 50 Hz.
3. A buffer introduces some phase shift in the signal passing through it. This can reduce the common-mode rejection of the multiple-channel system, but the resulting performance is independent of the number of channels connected to the buffer output (see table above.)

Buffer connections

For wiring the buffer in, see the isolated input connector pinout table on page 27. CED Electrode Boxes (CED1902-11-2B and CED1902-11-4B) make the buffer input and outputs available as touch-proof terminals.

The Active Head Stage

As mentioned above, common-mode rejection is a major element in noise reduction (see page 36.) This is because many forms of noise, mains interference in particular, are picked up equally by both leads. Common-mode rejection is essentially a DC phenomenon, but will apply to AC signals provided there is no phase shift between the electrodes.

It is important to note, there must *be* two electrodes! The common electrode should not be confused with a grounded input. The differential inputs are high-impedance, so, if one terminal is left unconnected it will float at an indeterminate voltage. This configuration is highly susceptible to noise pickup. The input will not somehow default to a single-ended configuration.

Minimizing input capacitance

To maximize AC common-mode rejection, phase shift must be minimized. That is to say, the input time constant, C_nR_n, must be minimized (see diagram on page 36.) Minimizing and balancing the time constant by eliminating shared inputs has been discussed above. Input capacitance can also be minimized, using the Active Head Stage, 1902-10/2 and 1902-10/4 (see page 3.) This is particularly useful if you are using mixed electrode types: the capacitance of an Ag/AgCl surface-contact electrode will be quite different from that of a skin-penetrating needle electrode.

The Active Head Stage minimizes capacitance differences very simply by reducing electrode lead lengths, thereby reducing their capacitance. The 1902-10 is a battery-powered local amplifier with low-impedance outputs which can satisfactorily drive signals down long leads to the 1902. Being identical to each other, these leads introduce no phase shift.

Using the Active Head Stage

In order to be effective, the Active Head Stage has to be close to the subject. Be careful not the let the box touch the subject since this will increase noise pickup. The box should be positioned out of the way, e.g. on the back of a headrest. The 1902-10 is internally shielded with a coat of conductive paint. It MUST NOT BE EARTHED since this will compromise the 1902's isolation.

1902 input clamp option

The input clamp option (CED1902-4-C) is designed for use with triggered stimulation of a subject, where the stimulus would otherwise overload the isolation amplifier input. Such overloads may not be electrically damaging, but the amplifier can take several seconds to recover afterwards, making it difficult to measure fast responses to the stimulus.

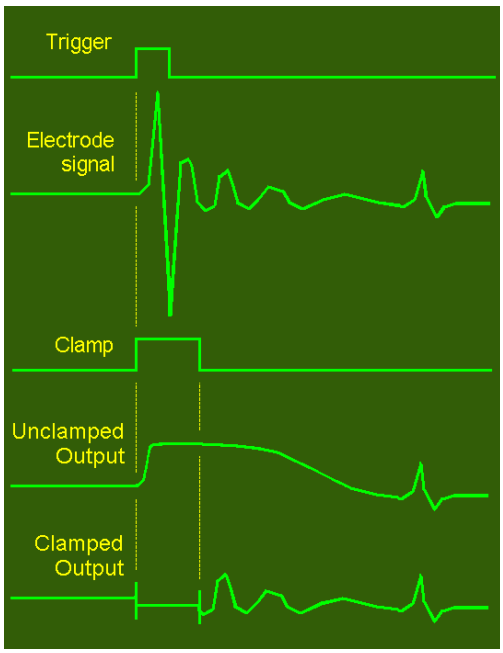
The types of stimulus where clamping can be useful include fast magnetic field changes and somatosensory stimulus pulses.

When is the clamp needed?

In experimental situations where, for example, EMG recordings are taken from the hand during magnetic stimulation to the brain, clamping is generally not necessary. However, when very fast responses (i.e. 2-10 milliseconds after stimulation) are to be measured, or recordings are taken from the facial area during stimulation to the head, then input clamping can prevent amplifier input saturation and allow these recordings to be made successfully. *The clamp will not give good results with AC coupling, or with the notch filter or high-pass filters enabled in the 1902.*

How does it work?

The clamp input has FET switches that operate at the isolated electrode input. They are opened and closed by a timing circuit that is triggered by a pulse at the Trigger 2 front panel input. Note that the trigger input is referenced to system ground (electrically isolated from the electrodes), and that the trigger LED does not need to be set to Trigger2 for a trigger pulse to be routed to the clamp circuit.



Clamping waveforms

Details of operation

The timing unit can generate pulses in the range 0.5 to 14 milliseconds, the length being determined by the input source selected by software. On receipt of the selected edge on the Trigger 2 input, the timing circuit generates a pulse of the selected length. The 1902 Mk IV has the option of selecting to trigger on positive (rising) or negative (falling) edges of the trigger signal.

The timed pulse operates switches that disconnect the electrode inputs from the input amplifier. During the length of the timing pulse, the 1902 output will be undefined, but will stay within its linear range. At the end of the timing period, the input is 'unclamped' and the amplifier output will jump to a level representing the new value of the inputs.

Selection of timing values

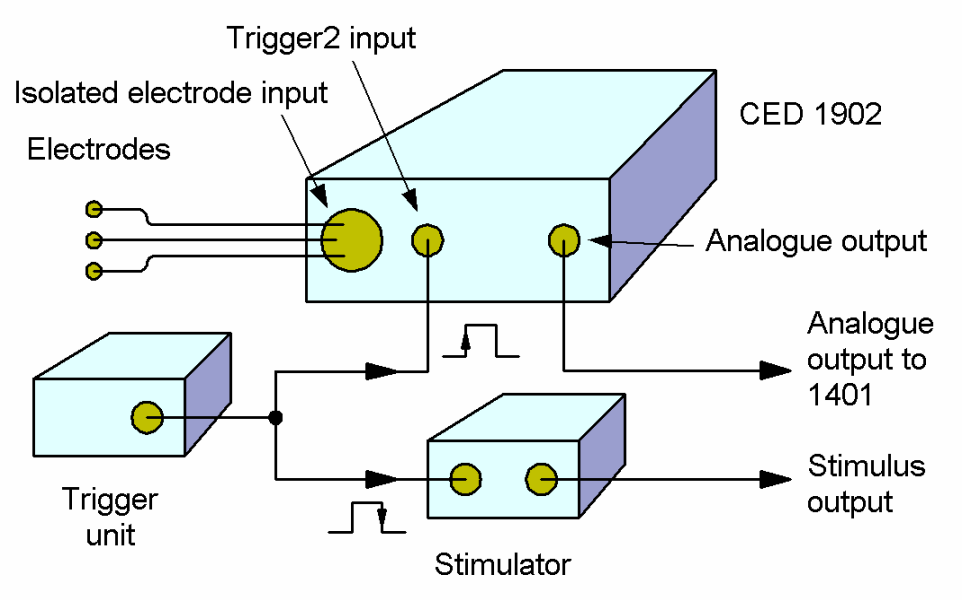
In addition to the four transducer input selections (Ground, Normal differential, Reverse differential and Single-ended) and the two isolated selections (Grounded EEG and Unclamped EEG), there are thirteen additional isolated input settings. These are given times in milliseconds:

0.5 ms, 1.0 ms, 1.5 ms, 2.0 ms, 3 ms, 4 ms,
5 ms, 6 ms, 7 ms, 8 ms, 10 ms, 12 ms, 14 ms

Other multiples of these basic times are available to special order. So far as the user is concerned, these are normal EEG inputs. However, selecting one of these timed inputs will arm the clamp circuit, which will then clamp the inputs for the selected length of time on receiving a trigger.

Connection of external equipment

The clamp circuit begins to operate within a few tens of microseconds of receiving a trigger, and the amplifier is fully clamped after about 200 microseconds. The circuit can best deal with large potentials on the electrode inputs if they do not arrive before this time. The implication is that, if possible, the clamp circuit should be triggered marginally *before* the stimulator. One way of achieving this is to use external positive trigger pulses about 0.5 to 1.0 milliseconds in duration, trigger the 1902 from the front (rising) edge and trigger the stimulator from the trailing (falling) edge. The 1902 clamp time selected should be 0.5 to 1.0 milliseconds longer to compensate.



Clamping before stimulus

Use of the notch filter

The 1902 incorporates a mains-frequency notch filter, set at time of manufacture to be either 50 Hz or 60 Hz, depending on the country of destination.

It is important to note that *a notch filter is a diagnostic tool for use during the set-up phase of laboratory work, and is not intended for use during the main recording*. If you suspect mains hum is corrupting your signals, you should compare the amplified signal with and without the notch filter in circuit, and then make adjustments to the electrode cable routing, positioning of the subject relative to overhead lighting etc. The aim would be to minimize the waveform differences with and without the notch filter in place.

Mains harmonics

Note also that interference from sources such as fluorescent lights can be rich in harmonics of the mains frequency, and a notch filter will only remove the fundamental component. This can leave components at 150 Hz, 250 Hz etc., and hence the need for reduction of interference coupling at source by making improvements to the cable routing and the positioning of the subject.

Theory of electrical isolation

To be safe for use on live human subjects, the electrodes, and the circuitry connected to them, have to be *isolated*. To understand why, first consider what actually happens when one receives an electric shock from the mains. (This illustration uses UK, earthed-neutral mains, which can be quite lethal. For our purposes, AC can be regarded as slowly-changing DC.)

Current flows in circles

You usually receive a shock by touching a live point while grounded, whereupon an electric current flows through your body to earth. You may not be interested in what happens to it after that, but it is relevant. At the local substation transformer, the neutral terminal of the secondary windings is robustly strapped to earth. *As much charge will flow out of earth as has flowed in through the victim.* This happens because, were it not to, a static voltage would rapidly build up and oppose further current flow. So, the current has to complete a circuit.

You cannot rely on insulation

If no circuit can be completed, no current can flow. If you stand on a dry plastic bucket and touch one live point, you will merely gain a static charge to mains voltage. In the case of a person attached to mains-powered equipment, relying on insulation is completely impractical: there is usually more than one wire connected to the subject, not to mention intentional or accidental contacts with other equipment and earthed conductors, including other persons. There are too many possible paths for current flow.

Floating power supplies

The solution is to shrink the entire power supply circuit until it is contained within the 1902, and not connect it to earth at all. (This is known as a *floating* supply.) In the 1902, a miniature transformer provides power for the isolated circuitry; signals to and from the rest of the 1902 pass through optoisolators. There is an isolation gap of 6 mm between copper tracks on the two sides. Insulation between the two sides is guaranteed to withstand mains voltages. This greatly reduces the scope for current-flow paths. Charge cannot flow out of the electrode circuit so long as there is *no way for it to come back*; it can only travel round the electrode wires. The isolation socket has no connection to any mains conductors, so it cannot act as a conduit for shock current from other equipment. To keep it this way, 1902 electrodes should NEVER be earthed.

Limits of isolation

It will be apparent from the foregoing that, while *one* contact between a floating circuit and the rest of the world is safe, *two* contacts are not, because the possibility then exists of their forming a current loop that includes the subject. An experimental set-up can only be as safe as its least-safe component; the best that each piece of equipment can do is not to provide a conduit for shock current flowing through *itself*.

Cleaning the 1902

The 1902 needs regular cleaning to remain in good condition. Before cleaning, remove power and all cables from the 1902.

The exteriors of the 1902 case and the power supply should be cleaned annually to remove deposits of foreign matter, with a soft cloth moistened with water. Avoid spilling drops of water or any other liquid on the 1902.

Check the sockets for pieces of paper or fluff. If any are seen, remove them with a pin.

Check the cables visually for fraying or other mechanical damage.

Updating firmware

The 1902 Mk IV has user-updatable firmware. Updating the firmware is only necessary if the version available for free download from CED's website is later than your own. To find which version you have, open Try1902. Once your 1902 is recognized, look for the monitor version number, displayed along with the port settings and the serial number.

Having downloaded a firmware update file (with a `.fli` extension), select *File*, *Update firmware…* from inside Try1902. The process is then almost completely automatic! Repeat for each channel of 1902.

Calibration

Calibration should be performed every six months to retain the specified offset accuracy, but if small discrepancies can be tolerated, the interval may be extended to three years. Bear in mind that calibration is a complex and time-consuming procedure, and should only be undertaken by an experienced technician. To make the task as easy as possible, the calibration option of Try1902 provides step-by-step instructions, with graphic prompts for each. The test sequence adapts itself to the particular configuration of the 1902 it finds. Even so, there are thirty-six stages to be gone through in a unit with an isolation amplifier.

Calibration at CED

In view of the complexity of the task, we strongly recommend that users return their 1902s to CED for calibration.

Calibration: tools required

You will need:

- A digital voltmeter capable of resolving to 1 microvolt, with a cable to mate with the internal test connector, a Radiall SMB snap-on socket (see page 51)
- A dual-channel oscilloscope with bandwidth of at least 10 MHz and sensitivity of 5 mV per division, to attach to the same test connector
- A 1-pt cross-head screwdriver for undoing the outer case
- A small, flat-blade, insulated trimming tool for adjusting potentiometers
- A sinewave generator capable of generating 50 or 60 Hz at some ±5 V, for adjusting the mains notch filter
- BNC cables and (for the 1902 MK IV fitted with digital filters) a BNC to 1902 transducer input cable

Opening the 1902

The 1902 circuit board is mounted in an inner can, enclosed by an outer case. You have to remove the inner can and take off its lid to do the calibration.

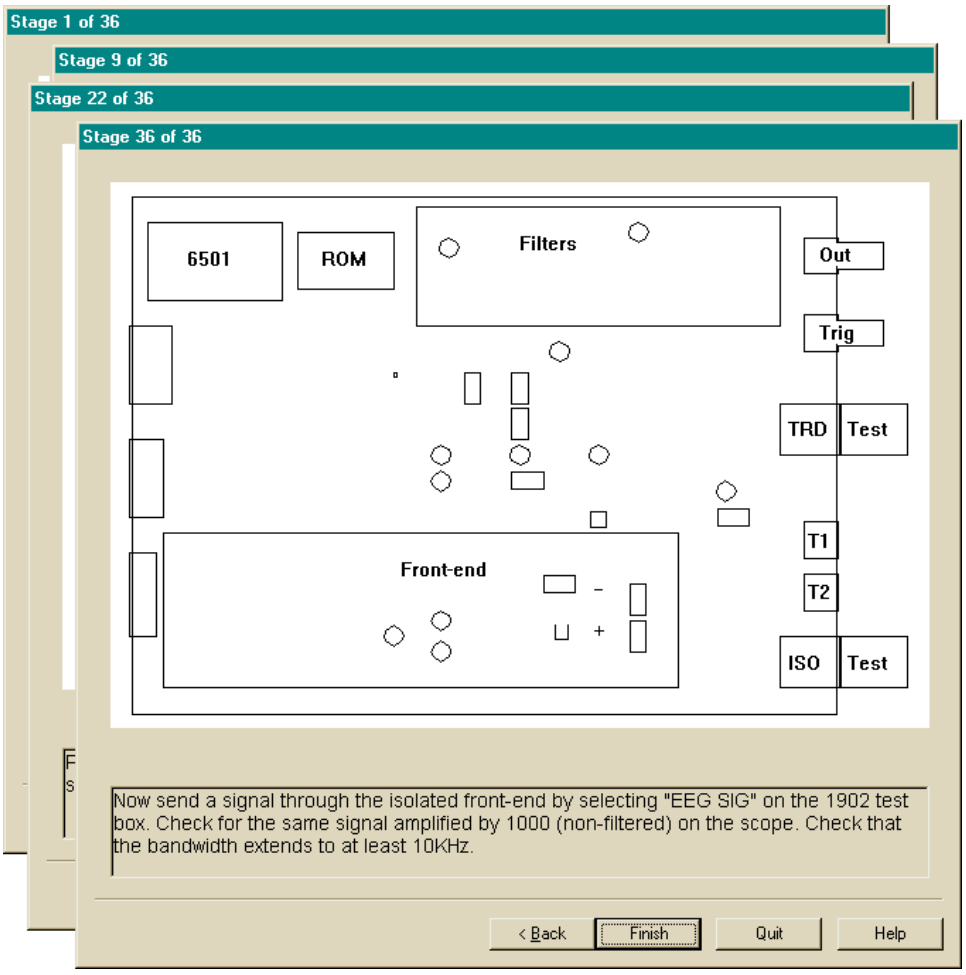
1. Take due precautions against electrostatic discharge. Earth yourself to the 1902 with a wrist strap and earth the 1902 to mains earth.
2. First, remove power and all cables from the 1902.
3. At each side of the back panel of the outer case is a small black screw. Undo these with a 1-pt cross-headed screwdriver.
4. Push the BNC connectors on the front of the case so that the inner can slides out by a couple of centimetres, dislodging the back panel. You can now see that the inner can is also restrained by an earthing strap of green & yellow wire, attached by a small screw.
5. Undo the screw and lock-washer from the inner can. Make a note of the order of these fixings, since it is important to replace them the same way (see also *Reassembly*, page 53). Slide the bright-metal inner can out of the black outer case.
6. Remove the lid. There are four small screws near the corners of the inner can that hold the lid to the base, clamping the

circuit board. These screws have built-in shakeproof washers ('combo' screws). Undo the screws and lift off the lid.

7. Replace the RS232 and the power cables and apply power. You are now ready to run the calibration software.

Try1902: the calibration utility

Run the program Try1902 (see page 5). Click the button marked *Calibrate amplifiers*. Full instructions appear on the screen. Items to be adjusted or connected-to will flash. (With up to twenty pots to adjust, this is a great help.) You may step back as well as forward.



Calibrating the 1902

Contacting CED

CED operates both hardware and software help desks. These are staffed by the same engineers and programmers who design CED's equipment and write the software.

Info to have ready

If you need to phone either help desk, but particularly hardware help, it will be of great assistance to us if you could have the following information to hand:

- The model and serial number of your 1902(s); the serial number is printed on the rear panel
- The 1902 Monitor revision number (from Try1902)
- Details of the isolation daughterboard, if present (also from Try1902)
- The version numbers of any CED application programs you are running (from *Help*, *About…*)

Servicing the 1902

Servicing other than calibration, replacing daughterboards, and firmware updates should not be attempted by users. The 1902 can only be serviced by CED, at:

Cambridge Electronic Design Limited
Technical Centre
139 Cambridge Road
Milton
Cambridge
CB24 6AZ
UK

Telephone (general inquiries) (+44) 1223 420186
Telephone (hardware help) (+44) 1223 433477

Email hardhelp@ced.co.uk

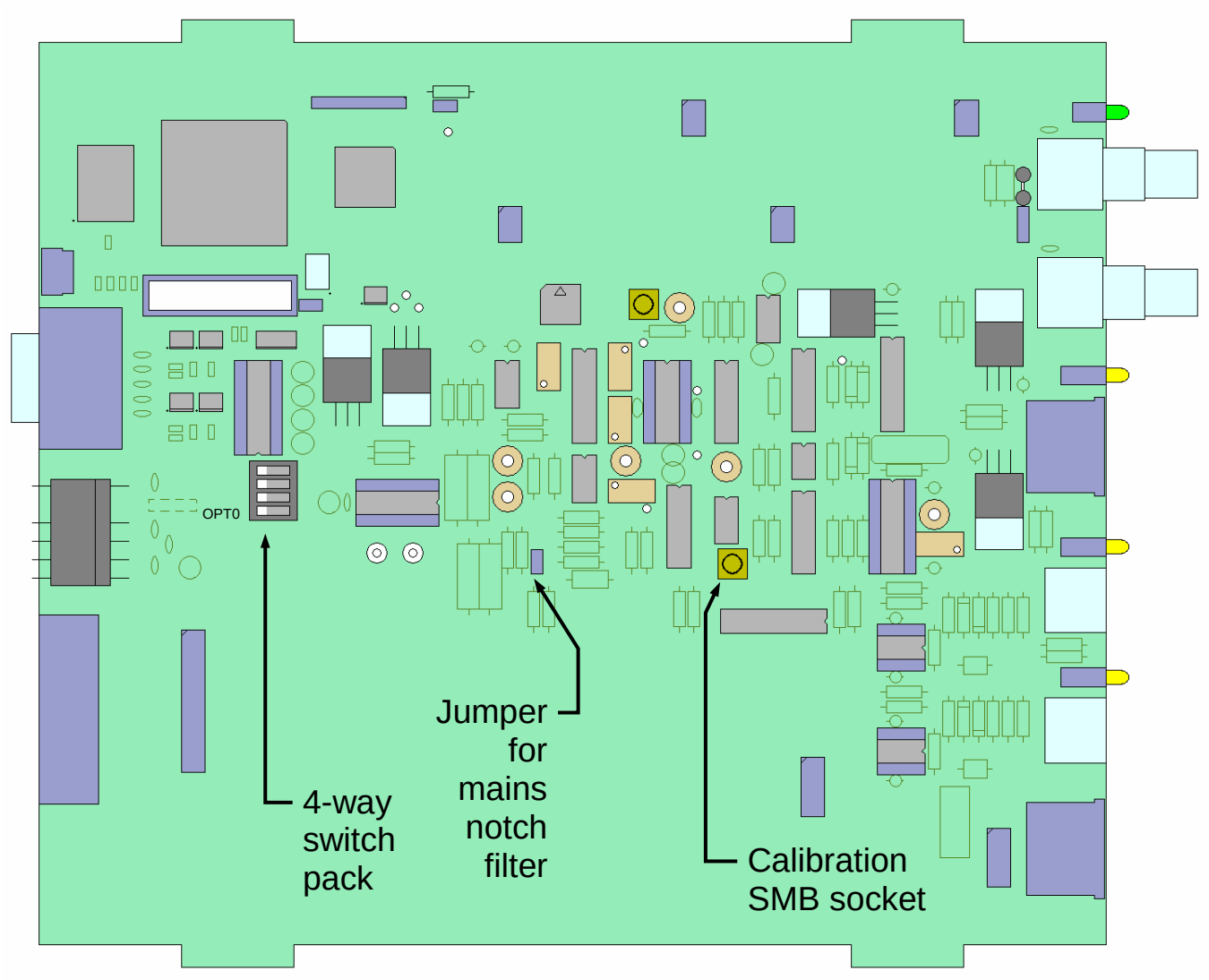
Sending it back

Ideally, the 1902 should be returned to CED in its original packaging, which is robust and will protect it against damage. Before sending it back:

- You must first get a returns number from CED.
- We advise you to dispatch the machine to us CIF. CED is not responsible for the safety of the equipment until it is inside our premises.
- If you are dispatching from outside the EU, it is essential to call us for advice on the documentation necessary to get your machine through Customs. If you do not provide the correct documentation, it may be subject to additional taxes or duties, be turned back, or even impounded.
- Include a written description of the problem with the equipment.
- Make sure the packaging is adequate to avoid damage in transit.

The 1902 motherboard

The main circuit board in the CED 1902 Mk IV is designated the CED 1902-20. It has a different computational core from the previous version, and uses a Cirrus EP7312 with associated FPGA and flash ROM. These are SMT (surface-mount technology) devices. There are passive SMT components mounted on both sides of the board. The CPU can drive an ADC / DAC pair in order to implement a digital filter. So far as the analogue circuitry is concerned, it is the same as the 1902 Mk III.



CED 1902-20 D – the 1902 motherboard

Features of the motherboard

The various adjustable pots and the Radiall SMB calibration connector are described in the calibration procedure (see page 46 onwards). Apart from that, there are only two features on 1902 circuit boards that may be relevant to users:

The options switchpack

The switch labelled 'OPT0' on the 4-way switchpack is the most significant bit of the 1902 channel number. When this is *off*, the most significant bit is set to 1, and the channel number selectable by the rear-panel rotary switch will be in the range 16-31. The switchpack is indicated on the diagram on page 51.

The other three switches are reserved for future expansion. They should be left as they are.

The notch filter link

If you need to change the notch filter frequency, a link has either to be closed (for 60 Hz) or open (for 50 Hz). This link is indicated on the diagram on page 51.

Circuit diagrams

A full set of circuit diagrams can be supplied to authorized personnel on request. There will be an administration charge for this service, and purchasers must sign a non-disclosure agreement.

Exchanging 1902 daughterboards

Open the case, as detailed on page 47. Remember to observe precautions against electrostatic discharge; earth yourself to the 1902 by a wrist strap, and earth the 1902 to mains earth. Preferably you should work at a bench topped with conductive plastic.

Taking out the old daughterboard

The filter module is located just behind the output connector. 1902s fitted with digital filters do not have this module installed. The front-end module is a little way behind the isolated input connector. Using a strong plastic pry tool, gently lever the circuit board upwards. It may help to use a pair of pliers to pinch the split tops of the nylon stand-offs to spring the board off the stand-offs. Ease the board *vertically* off its connector pins. It is important that these pins are not bent.

Installing the new daughterboard

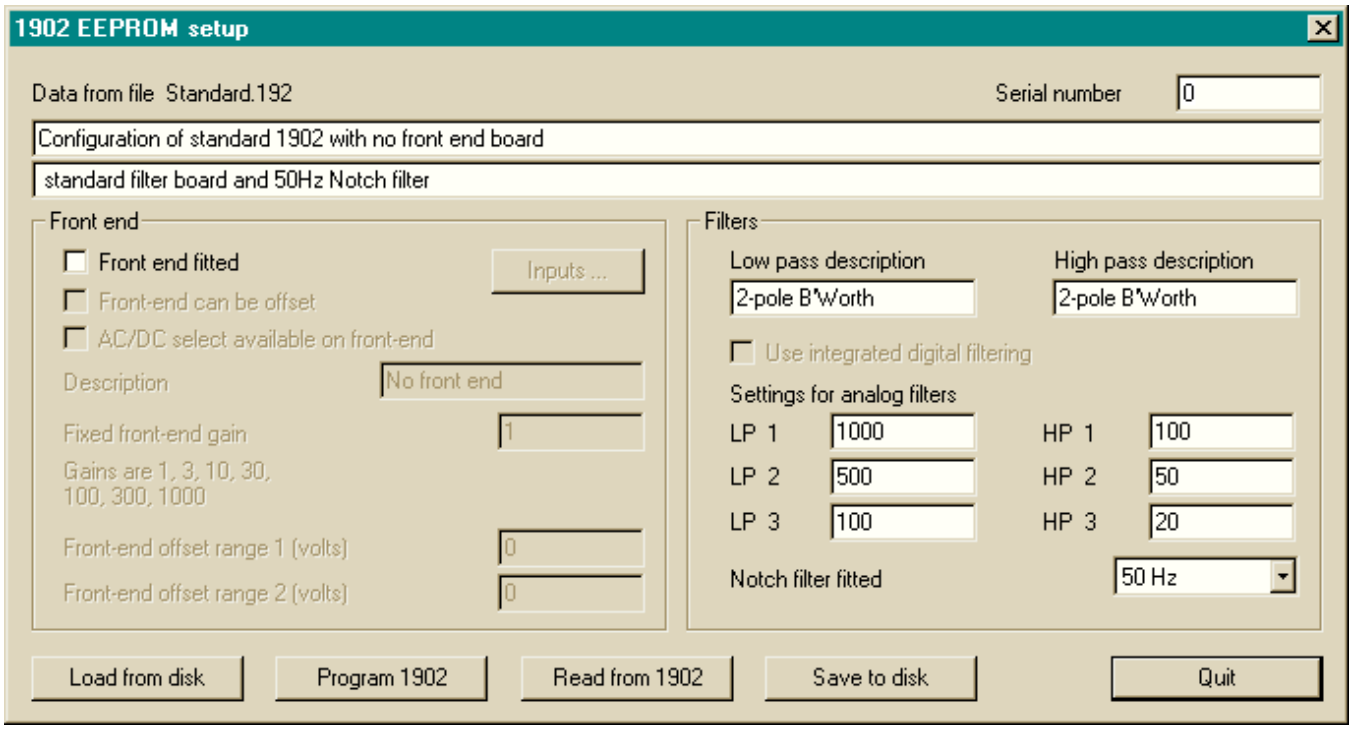
Install the replacement board in place of the original. Take care to align the bottom-entry connector sockets correctly with the connector pins on the motherboard. Be patient! Push the board down until it locates firmly on the shoulders of the nylon stand-offs. If any of the stand-offs have come away with the old board, push them out and re-fit them in the motherboard. The larger-diameter end fits into the motherboard.

Reassembly

Reassembly is the reverse of disassembly. Take care to replace the star washers correctly; they form part of the IEC601-1-1 approval. The screws holding the inner case lid have star washers between the screw heads and the lid (these are specials that cannot be separated); the earth bonding strap has a star washer between the ring tag and the case (not under the screw head); the rear panel has star washers under the screw heads.

Updating the EEPROM

If any change has been made to the daughterboards (apart from swapping a faulty unit for one that is identical), the EEPROM will have to be updated. You will have been sent a file with a `.192` extension with the correct information. To reprogram the EEPROM, start the Try1902 program, select *File*, *EEPROM Setup…*and press the *Load from disk* button. Browse to wherever you have saved the `.192` file, select it, and press the *Program 1902* button. If you expect that you may revert to your previous configuration, you can save the pre-existing EEPROM data with the *Read from 1902* and *Save to disk* buttons.



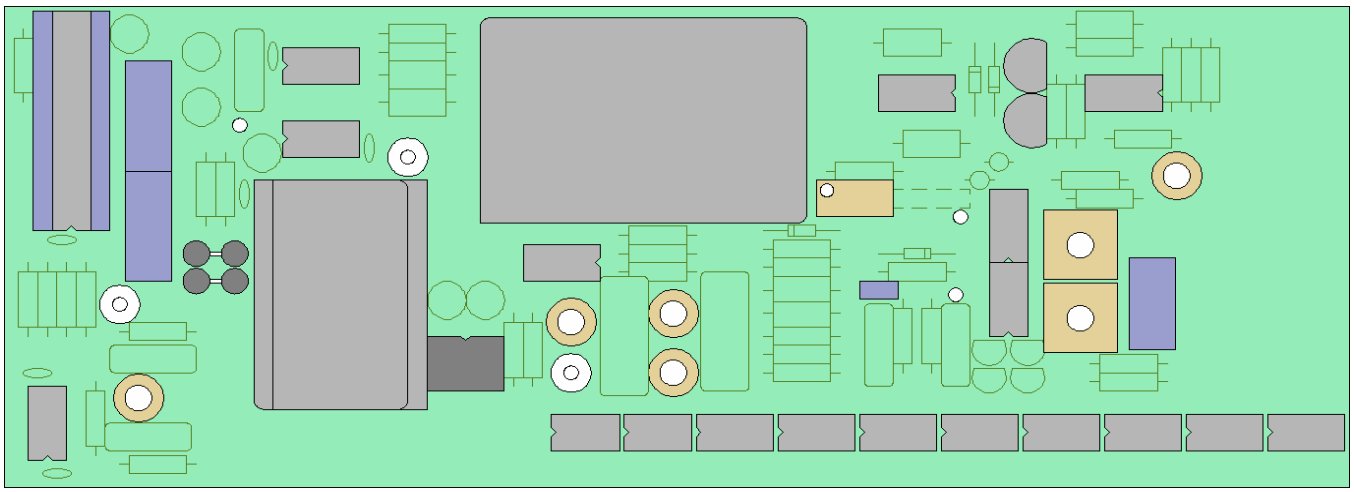
EEPROM update dialog

The EEG daughterboard

The EEG daughterboard, designated the CED1902-04, provides medical isolation designed to meet EN60601-1 isolation standards. There are several design options for this card that are implemented at board assembly. Some options are mutually exclusive, so the board is never fully populated.

Build options include the buffer (see page 35), isolated transducer power and the input clamp (see page 41).

This board is optimized for low noise and a high common-mode rejection ratio (CMRR), which makes it ideal for EEG recording. Using the standard model of daughterboard, overall 1902 voltage gain is software-selectable between ×1,000 and ×1,000,000, or between ×100 and ×100,000, these build options being at the user's choice.

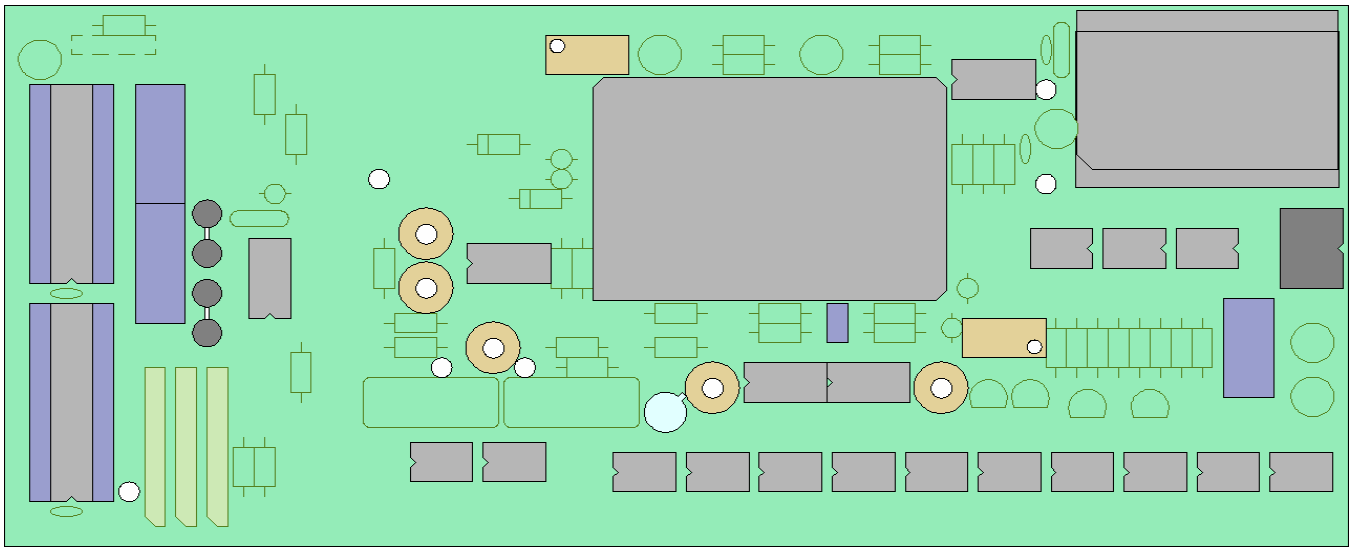


CED1902-04 C – the EEG daughterboard

The ECG daughterboard

The ECG daughterboard, designated the CED1902-02, provides medical isolation designed to meet EN60601-1 isolation standards. It has input lead switching, so the one connector can measure differential (or resistively summed) voltages between four electrodes, nominally Left arm, Right arm, Left leg, and Vagus.

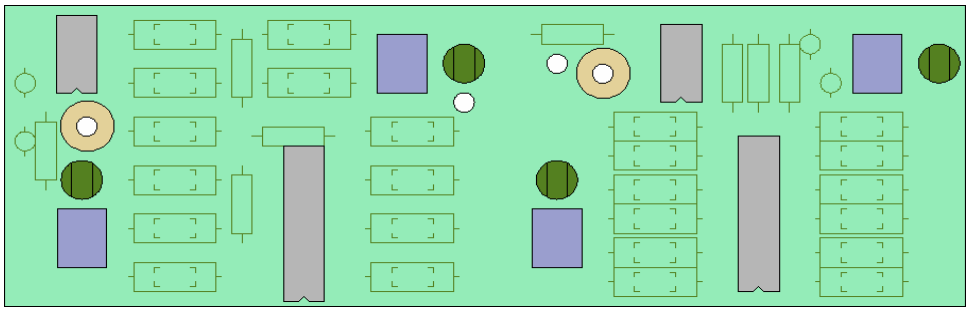
Overall 1902 voltage gain is selectable between ×100 and ×100,000.



CED1902-02 – the ECG daughterboard

The filter daughterboard

The analogue filter daughterboard is built to implement 2nd-order filters with 12 dB per octave roll-off. The standard configuration is Butterworth, optimised for flatness of response before the corner frequency; Bessel or Chebyshev polynomials can also be supplied to special order. The corner frequencies and the response are determined by the precise value of the resistors and capacitors fitted. High-frequency and low-frequency sections each have four selectable positions, including straight-through. The high-pass filter comes before the low-pass filter.



CED1902-03 – the filter daughterboard

If the digital filter has been implemented, this daughterboard is omitted, and the digital filter components are fitted in its place. For details of the digital filter see page 10.

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Important note

Important note: From 22 July 2014 we are no longer able to offer the CED 1902 for sale in the European Union and a number of other countries owing to new RoHS waste disposal legislation.

Accordingly, from that date the CE mark shown on the rear panel of the CED 1902 is technically no longer valid.

Note that the change in RoHS legislation applies solely to the disposal of the CED 1902 after its operational life, and in no way compromises the safety specifications of the product during normal use.

EC Declaration of Conformity

This is to certify that the:

CED 1902

Manufactured by:

Cambridge Electronic Design Limited
Science Park, Milton Road, Cambridge CB4 0FE, UK
Tel (+44) 01223 420186

Conforms with the protection requirements of Council Directive 2004/108/EC,
relating to Electromagnetic Compatibility,
by the application of the following EMC standards:

Conducted and radiated emissions:

EN55022 (1987) Class B	-	COMPLIES
Vfg1046/1984	-	COMPLIES
FCC CFR47 Part 15 Subpart J Class A	-	COMPLIES

EN50082-1:1991 Immunity standards:

EN50082-1 (Generic immunity)	-	PASS
EIC801-2 (Electrostatic discharge)	-	PASS (8kV) Criterion A
EIC801-3 (RF field immunity)	-	PASS (3V/m) Criterion B
EIC801-4 (Electrical fast transients)	-	PASS (2kV - Heavy industrial) Criterion A

Signature 

Peter Rice
Technical Director

Date 20 July 2009