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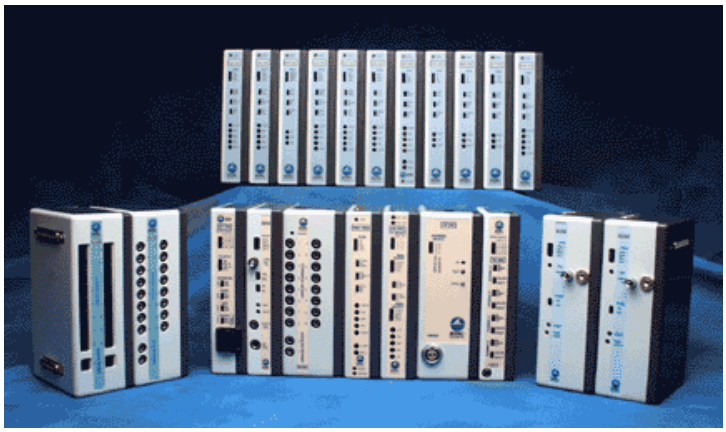
MRI SMART MODULES



The MRI smart amplifiers incorporate advanced signal processing circuitry which removes spurious MRI artifact from the source physiological data. Signal processors can distinguish between physiological signal and MRI artifact as manifested by gradient switching during MRI sequences, such as Shim or EPI.

Because MRI-related transient artifact is removed at the source, the MRI version amplifier can be sampled at the same rate as during normal (non-MRI) physiological recording. There is no longer any requirement to over-sample the amplifier output to capture every nuance of MRI artifact to train secondary computer-based processing steps to remove such artifact.

In every aspect, data recording is easier, and the final results are cleaner when using the MRI version amplifiers to record physiological data in the fMRI or MRI.

FEATURES

- Less sensitivity to electrode and transducer lead placement
- Improved gain selectability
- No missing spectra in physiological signal frequency band
- No requirement for acquisition oversampling
- No need for computer-based real-time or post-processing signal processing
- Clean data available as real-time analog output

Safety Guidelines for Recording Biopotential Measurements in the MRI Environment

1. Place **EL 508** or **EL509** MR Conditional and Radio Translucent electrodes on the subject as follows:
    a. Prepare the subject's skin surface with ELPAD to create low contact source impedance at the electrode attachment site. Be careful to wipe away any excess electrode gel from the surface of the subject's skin.
    b. Attach the electrodes as close to each other as possible (on the subject's skin) for the measurement.
    c. Place electrodes in as straight of a line as possible which is perpendicular to the magnet's axis.
    d. Place electrodes between 3-5 cm apart, if possible; the larger the area between the electrodes, the stronger the MRI gradient artifact.
2. Connect the electrode lead set to the electrodes according to these guidelines:
    a. Make sure that the electrode leads do not loop in a “circle”, “S” or “U” shape. Also, do not twist or braid the electrode leads. **Looped, braided or twisted leads pick up RF energy, resulting in current induction and increased localized heating.**
    b. Run the leads out of the chamber bore in the simplest (straightest) manner possible.
    c. Do not allow the electrode leads to touch the subject's bare skin. Electrode leads may heat up in the MRI.
        - Use a thermal insulator (such as a blanket or towel) between the electrode lead and the subject's skin.
        - It's also possible to use thermally-insulating foam jacket, similar to those used for insulating copper tubing, for placing the electrode leads to keep them away from the subject's skin.

See also Safety Awareness Notes for Cables and Electrodes During MRI

ECG100C-MRI

Gain:	500, 1000, 2000, 5000
Output selection:	Normal, R wave indicator
Frequency Response	Maximum Bandwidth (.05 Hz - 150 Hz) can be customized at BIOPAC
Low Pass Filter:	35 Hz, 150 Hz
High Pass Filter:	0.05 Hz, 1.0 Hz
Notch Interference Filter:	50 dB rejection @ 50 or 60 Hz
Noise Voltage (0.05-35 Hz):	0.1 µV (rms)
Zin:	2M ohm (Differential), 1000M ohm (Common mode)
CMRR:	110 dB min (50/60 Hz)
Common Mode Input Voltage Range:	±10 V (referenced to amplifier ground) ±1500 VDC (referenced to mains ground)
Output Range:	±10 V (analog)
Input Voltage Range:	Gain Vin (mV) 500 ±20 1000 ±10 2000 ±5 5000 ±2

Maximum Over-Voltage for Differential Input: ±25 V

Input Connectors:	Five 1.5 mm male Touchproof sockets (VIN+, Gnd, VIN-, 2 of shield)
Subject Interface:	EL508 MR Conditional and Radio Translucent electrodes and LEAD108 Series MR Conditional and Radio Translucent leads
Hardware Interface:	MECMRI-BIOP to MP160/150 System

EDA100C-MRI

Gain:	20, 10, 5, 2 µsiemens/volt (i.e. µmhos/volt)
Low Pass Filter:	1 Hz, 10 Hz
High Pass Filter:	DC, 0.05 Hz, 0.5 Hz
Sensitivity:	0.7 nano-siemens (with MP System)
Constant Voltage Excitation:	Vex = 0.5 VDC
Output Range:	±10 V full range (analog); 0-10 V nominal range
Input Signal Range:	Gain Range (µmho) 20 0-200 10 0-100 5 0-50 2 0-20
Input Connectors:	Three 1.5 male Touchproof sockets (VIN+, Gnd, VIN-)
Subject Interface:	EL509 MR Conditional and Radio Translucent electrodes and LEAD108 Series MR Conditional and Radio Translucent leads
Hardware Interface:	MECMRI-TRANS to MP160/150 System

Note: Normal human range is 1-50 µmho.

Unit Note—BIOPAC software calculates SCL/SCR in µmho, the traditional unit of conductance. Micromho (µmho) is interchangeable with the alternative microsiemen (µS). To use Ohm, the traditional measure of *resistance*, convert as 1 µmho corresponds to 1,000,000 ohm.

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EEG100C-MRI

Gain:	5000, 10000, 20000, 50000
Output selection:	Normal, Alpha wave indicator
Low Pass Filter:	35 Hz, 100 Hz
High Pass Filter:	0.1 Hz, 1.0 Hz
Notch Interference Filter:	50 dB rejection @ 50/60 Hz
Noise Voltage (0.1-35 Hz):	0.1 µV (rms)
Zin:	2 Mohm (Differential) 1000 Mohm (Common mode)
CMRR:	110 dB min (50/60 Hz)
Common Mode Input Voltage Range:	±10 V (referenced to amplifier ground) ±1500 VDC (referenced to mains ground)
Output Range:	±10 V (analog)

Input Voltage Range:

Gain	Vin
5000	±2 mV
10000	±1 mV
20000	±0.5 mV
50000	±0.2 mV

Maximum Over-Voltage for Differential Input: ±25 V

Input Connectors:	Five 1.5 mm male Touchproof sockets (VIN+, Gnd, VIN-, 2 of shield)
Subject Interface:	EL508 MR Conditional and Radio Translucent electrodes and LEAD108 Series MR Conditional and Radio Translucent leads
Hardware Interface:	MECMRI-BIOP to MP160/150 System

EMG100C-MRI

Gain:	500, 1000, 2000, 5000
Low Pass Filter:	500 Hz, 5000 Hz
High Pass Filter:	1.0 Hz, 10 Hz, 100 Hz
Notch Interference Filter:	50 dB rejection @ 50/60 Hz
Noise Voltage (10-500 Hz):	0.2 µV (rms)
Zin:	2 Mohm (Differential), 1000 Mohm (Common mode)
CMRR:	110 dB min (50/60 Hz)
Common Mode Input Voltage Range:	±10 V (referenced to amplifier ground) ±1500 VDC (referenced to mains ground)
Output Range	±10 V (analog)

Input Voltage Range

Gain	Vin (mV)
500	±20
1000	±10
2000	±5
5000	±2

Maximum Over-Voltage for Differential Input: ±25 V

Input Connectors:	Five 1.5 mm male Touchproof sockets (VIN+, Gnd, VIN-, 2 of shield)
Subject Interface:	EL508 MR Conditional and Radio Translucent electrodes and LEAD108 Series MR Conditional and Radio Translucent leads
Hardware Interface:	MECMRI-BIOP to MP160/150 System

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PPG100C-MRI

Gain:	10, 20, 50, 100
Low Pass Filter:	3 Hz, 10Hz
High Pass Filter:	DC, 0.05 Hz, 0.5 Hz
Noise Voltage:	0.5 µV (RMS); amplifier contribution
Output Range:	±10 V (analog)
Excitation:	6 V
Input Connectors:	Three 1.5 mm male Touchproof sockets (Vsup, Gnd, Input)
Subject Interface:	TSD200-MRI MR Conditional PPG Transducer, (red connector to VIN+/Vsup, black to Gnd, white or blue to VIN-/Input)*
Hardware Interface:	MECMRI-TRANS to MP160/150 System

*When used in the MRI scanner room, the TSD200-MRI connects to the MECMRI-1 cable. Connect red lead connector to Vin+/Vsup, black connector to Gnd, and white or blue connector to Vin-/INPUT.

NICO100C-MRI

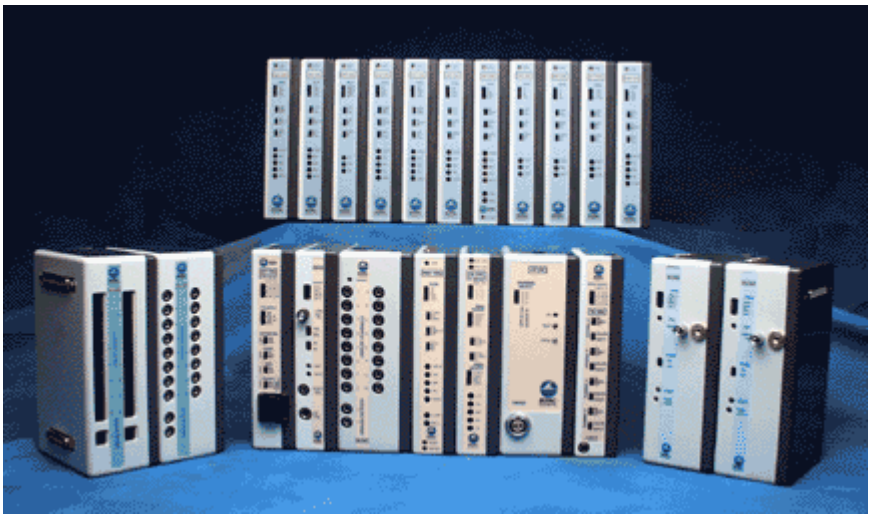
Number of Channels:	2 – Magnitude (Zo) and dZ(t)/dt
Operational Frequencies:	50 kHz
Current Output:	4 mA (rms)—constant sinusoidal current
Outputs:	MAG of Impedance: 0-100 Ω dZ(t)/dt of Impedance: 2 (Ω/sec)/V
Output Range:	±10 V (analog)
Maximum Over-Voltage for Differential Input:	±25 V
CMIV, referenced to:	Amplifier ground: ±10 V Mains ground: ±1500 VDC
Gain Range:	MAG: 10, 5, 2, 1 Ω/V dZ(t)/dt: 2 (Ω/sec)/v constant (independent of MAG Gain)
LP Filter:	MAG: 10 Hz, 100 Hz dZ(t)/dt: 100 Hz
HP Filter:	MAG: DC, 0.05 Hz dZ(t)/dt: DC coupled
Sensitivity:	MAG: 0.0015 Ω rms @ 10 Hz bandwidth dZ(t)/dt: 0.002 (Ω/s)/V rms @ 10 Hz bandwidth
Subject Interface:	EL508 MR Conditional and Radio Translucent electrodes (8,) LEAD 108B and/or LEAD108C MR Conditional and Radio Translucent electrode leads (8,) CBL204-MRI “Y” electrode lead adapters (4)
Hardware Interface:	MECMRI-NICO to MP160/150 System

Usage Statement

Bioimpedance methods to perform stroke volume and cardiac output measurements via application of electrodes on the neck and torso are considered by BIOPAC to be research and educational tools. Historically, there have been numerous research efforts to measure stroke volumes and cardiac outputs using bioimpedance techniques. The performance of these systems is subject to evolving algorithms. New bioimpedance methods, such as TransRadial Electrical bioimpedance Velocimetry (TREV) are examples that show new promise in this area. Additionally, machine learning strategies are beginning to accommodate the variabilities of

bioimpedance methods due to electrode type, placement, body position, movement artifacts, and electrical signal filtering. Research is ongoing as bioimpedance techniques offer profound non-invasive advantages compared to thermodilution and similar "gold-standard" historical methods for measuring stroke volume and cardiac output. BIOPAC is committed to continue to offer educational and research solutions for the application of bioimpedance methods to measure cardiovascular parameters despite the present "state of the art" showing these measures to be generally more useful for determining relative changes versus absolute values.

AMPLIFIER MODULES



100C series modules

The 100C series biopotential/transducer amplifier modules are single channel, differential input, linear amplifiers with adjustable offset and gain. These modules are used to amplify smaller voltage signals coming from raw electrodes and transducers (typically less than ±0.01 volt). In addition to amplifying signals, most of the 100C series modules include selectable signal conditioning ability so that data may be filtered or transformed as it is being collected.

- **Biopotential modules**: ECG100C, EEG100C, EGG100C, EMG100C, EOG100C, ERS100C
- **Transducer modules**: EDA100C; PPG100C; RSP100C; SKT100C
- **MRI Smart modules**—advanced signal processing circuitry removes spurious MRI artifact from the source physiological data: ECG100C-MRI; EDA100C-MRI; EEG100C-MRI; EMG100C-MRI; PPG100C-MRI; NICO100C-MRI.

Modules can be cascaded by snapping the modules together. Up to sixteen 100C series modules can be connected to the MP System at any one time.

IMPORTANT

When cascading modules, it is important to remember that **no two amplifiers may be set to the same channel**. If two connected amplifier modules are left on the same channel, then contention will result and both amplifier outputs will give erroneous readings.

Amplifier offset Set by the zero adjust control trim potentiometer near the top of the module. The offset control can be used to adjust the zero point or "baseline" of a signal.

Gain Switch The four-position slide Gain switch controls sensitivity. Lower gain settings will amplify the signal to a lesser extent than higher gain settings. If the signal plotted on the screen appears to be very small for a given channel, increase the Gain for that particular channel. Conversely, if the signal seems to be "cropped" at +10 Volts or –10 Volts, decrease the Gain.

Connections Transducers and electrodes connect to the amplifiers using 1.5 mm female Touchproof connectors.

Electrodes

The biopotential amplifier modules use a three-electrode arrangement (VIN+, GND, VIN–). Although certain applications may require different arrangements of electrodes and/or transducers, some generalizations about electrode and transducer connections can be made. Electrodes measure the electrical activity at the surface of the skin, and since electricity flows from – to +, measuring the flow of a signal requires that there be (at least) one "-" electrode and (at least) one "+" electrode. An additional electrode, a "ground" (or earth) electrode is used to control for the general level of electrical activity in the body.

Leads

Typically, electrode leads are used to connect individual electrodes to the *xxx*100C amplifier. Most electrode leads are shielded, which means they introduce less noise than an unshielded lead. A shielded electrode lead has an extra jack on one end that plugs into the SHIELD input on the amplifier modules. A standard electrode lead configuration consists of two LEAD110S electrode leads (one connected to the VIN + input and one to the VIN – input on the amplifier) and a single LEAD110 (connected to the GND input on a biopotential amplifier).

Transducers

Transducers, on the other hand, are not designed to measure electrical activity directly and usually involve simpler connections. The transducers discussed in this manual translate physical changes (in temperature, for instance) into electrical signals. Connections for individual transducers are discussed in each section.

Channel

The active channel is selected using the channel select switch on the top of the module. The channel select switch can direct the amplifier output to one of sixteen possible MP System input channels. *Remember to make sure that each amplifier module is set to a unique channel.*

Zero Adjust

On input signals, a limited range in baseline level (DC offset) can be "zeroed out" using the zero adjust potentiometer. Typically, the zero adjust will not have to be used (as it is preset at the factory). However, some of the 100C series modules can measure DC signals and, in certain circumstances, signal "zeroing" may be required.

Setup

All 100C Series biopotential or transducer amplifiers incorporate specific gain, coupling and filtering options that are appropriate for the biopotential type or transducer signal that requires measurement. Generally, when an electrode or transducer is inserted into the corresponding 100C series module, the amplifier will immediately produce a useful output, with no user adjustments necessary.

Certain functionality is added to each module to optimize its performance with its intended signal measurement. For example, all 100C series biopotential amplifiers incorporate a selectable interference filter. When the interference filter is on, 50/60 Hz interfering signals are suppressed.

Filters

All 100C series amplifiers are constructed with filters that have a high degree of phase linearity. This means the 100C series modules will filter signals with as little distortion as possible. These modules also incorporate protection circuitry to limit input current in the event of input signal overload. Notch and bandstop filters have the potential to cause distortion, especially in the form of "ringing" in the data stream; biopotential hardware notch filters are implemented in conjunction with LP or HP functions to minimize distortion.

Line Freq

Line Frequency is set using the recessed switch boxes on the left panel of the amplifier module (50 Hz = all switches down, 60 Hz = all switches up). It is important to select the correct line frequency for your geographical region. Typically, U.S. line frequency is 60 Hz; Europe and China 50 Hz. Contact BIOPAC for additional line frequency information. All MP biopotential amplifier modules which contain a 50/60 Hz notch filter only engage the filter when the pass filter is also ON:

- ECG100C, EEG100C, EOG100C amplifiers: the 50/60 Hz notch is only engaged when the 35 Hz LPN low pass notch filter switch is set to ON.
- EMG100C, ERS100C amplifiers: the 50/60 HZ notch is only engaged when the 100 Hz HPN high pass notch filter switch is set to ON.

See individual module sections for details.