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SMART AMPLIFIER 100D SERIES

Biopotential Smart Amplifiers: ECG100D, EEG100D, EGG100D, EMG100D, fEMG100D (facial EMG), EOG100D, ERS100D

Transducer Smart Amplifiers: EDA100D, PPG100D, RSP100D, SKT100D

**Impedance Smart Amplifiers**: NICO100D, EBI100D

Smart Amplifier 100D Series are compact amplifier modules designed for recording high-quality biopotential and transducer signals. Smart Amplifiers are small, light, and offer unparalleled ease-of-use. Quick, automated setup and calibration is performed in Acq*Knowledge* software with the MP160 System. All amplifiers feature a 3-meter RJ12 cable that connects to the new AMI100D Amplifier Input Module. Plug in the amp, attach electrodes and/or transducers to the participant, and follow the automated setup wizard in Acq*Knowledge* software to begin recording high quality physiological data in minutes.

FEATURES:

- High quality, low noise signals equivalent to, or exceeding, the data quality of 100C-Series amplifiers

- Small, light form factor, comfortable, easily clips to participants' clothing

- Connects directly to the AMI100D interface module

- Mix and match with other connected 100D and 100C-Series modules using an MP160 System

- Quick, automated setup in Acq*Knowledge* software

- Acq*Knowledge* provides signal type information for connected Smart Amplifiers and software options for signal-appropriate derived signals (e.g. heart rate)

- Acq*Knowledge* software detects when 100D-Series amplifiers are connected and automatically configures the recording settings

- Smart Amplifiers utilize BN-Series electrode leads and transducers, so wired and wireless amplifiers can be easily mixed and matched

- Compatible with Acq*Knowledge* software version 5.0.4 or higher

Smart Amplifiers connect to an MP160 Research System* via an Amplifier Interface Module (AMI100D). To output collected, amplified, analog data (simultaneously with MP160 signal acquisition) to other systems, add the CBL237 with OUTISOA (isolated link) or CBL122 / CBL123 (unisolated link). Acq*Knowledge* Smart Amplifier setup includes the guides and prompts to prevent errors. Plus, channels are automatically set to be plotted and include an input values display, with the initial visual range set to the min/max input range for the Smart Amplifier signal type, in appropriate units. Acq*Knowledge* 5.0.4 and above, with an MP160 System, support Smart Amplifier functionality.

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The Smart Amplifiers are designed for the maximum expected signal bandwidth for the signal measured. This maximum bandwidth is established via analog signal filters placed inside the Smart Amplifier. Additional narrower signal filtering is implemented in Acq*Knowledge* (software) in real-time. When a Smart Amplifier is attached to an MP160 System while running Acq*Knowledge*, the software will automatically configure the data collection bandwidths to default values that are generally optimal for the input signal type. These default settings, however, are easily configurable for more optimal range as required. If no additional software filtering is needed, the "Wideband" option can be selected in the acquisition setup window as shown below. The "Wideband" option allows the MP160 to acquire the maximum input signal bandwidth, as established by the analog signal filtering present in each Smart Amplifier.
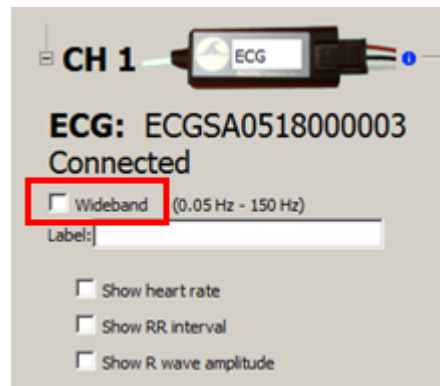
IMPORTANT: If wider signal bandwidth are needed (in excess of the "Wideband" setting), please contact BIOPAC Systems for assistance, as it's generally possible to customize (extend) the signal bandwidths for any Smart Amplifier.

*Smart Amplifiers are not compatible with MP150, MP100, HLT100C, or MP36R devices, and are not suitable for MRI use. If MRI use is required, or if any signal processing (typically narrower filtering) needs to occur independently of the MP160 System, the 100C Series amplifiers are the recommended alternative. An example here would be for MRI applications that require precise timing for scan triggering. In this situation, the biopotential data (typically ECG or Respiration/Ventilation) is output as an analog signal to control a triggering module, such as BIOPAC's DTU100/200/300.

IMPORTANT: For AMI100D and Smart Amplifier recognition, Digital Channel 15 must be left floating or held high until the system begins acquiring data.

Acq*Knowledge* software auto-detects signal types and offers configurable, optionally-enabled, software-derived signals. Default frequencies and settings can be adjusted in the Channel Setup.

Green: Configured & detected

Red: Configured but not found

White: Unused/available

Dashed: In use/not available

For quick access to Smart Amp options, click the CH# box.

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Smart Amplifier Carrying Case (included)

16 x 10 x 3.5 cm

Smart Amplifier Straps (order separately)

Dimensions: Length 20 cm, 33 cm, 76, cm, 137 cm (all widths 2.5 cm)

Material: Stretch Velcro® - hook/loop type

Use with: Smart Amplifiers
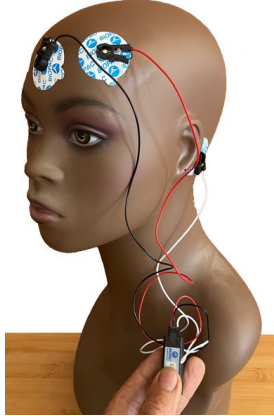
Length: BN-STRAP-20-D; 20 cm (wrist)

BN-STRAP-33-D; 33 cm (larger wrist/ankles)

BN-STRAP-76-D; 76 cm (neck/leg)

BN-STRAP-137-D; 137 cm (chest)

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SMART AMPLIFIER SPECIFICATIONS (BIOPOTENTIAL)

Amp	Gain (fixed)	Noise Voltage	Software Filter (IIR) Bandwidth*	Maximum Bandwidth (Wideband)**	Optional Derived Signal(s) default frequencies & settings (default settings are configurable in software)	Interface (not included)
ECG100D	x2000	0.1 μv rms (0.05 -35 Hz)	HP: 1 Hz LP: 35 Hz	0.05 Hz – 150 Hz	**Show heart rate** in beats per minute in a separate channel using rate detector calculation. **Show RR interval** (inter beat interval) in a separate channel using rate detector calculation, unit = sec. **Show R wave amplitude** in a separate channel using peak maximum output calculation, unit = mV **Defaults:** Positive detection, 25 ms baseline removal, 5% auto threshold detection, detection window 40-180 BPM	**Electrode lead + Electrodes** It's only needed to connect a single ground lead when using multiple biopotential amplifiers! **BN-EL*-LEAD3** if ground electrode is required or **BN-EL*-LEAD2** if participant is connected to another Smart Amplifier with ground lead *select 15, 30, or 45 cm
EEG100D	x20000	0.1 μv rms (0.5 – 35 Hz)	HP: 0.5 Hz LP: 35 Hz	0.5 Hz –150 Hz	**EEG Bands** Delta: 0.5 Hz – 4 Hz Theta: 4 Hz – 8 Hz Alpha: 8 Hz – 13 Hz Beta: 13 Hz – 30 Hz Gamma: 30 Hz – 90 Hz **Defaults:** All bands - IIR bandpass (low+high) pass filters, Butterworth-type **Example of EEG setup**	
EGG100D	x2000	0.1 μv rms (0.005 – 1 Hz)	HP: 0.005 Hz LP: 1 Hz	0.005 Hz – 1 Hz	— N/A	
EMG100D	X500	0.2 μv rms (10 – 500 Hz)	HP:10 Hz LP: 500 Hz	5 Hz – 500 Hz	**Show Integrated EMG** using an integrate calculation channel. **Default:** Average over samples mode with 1000 sample window, rectification enabled	
fEMG100D	x2000	0.2 μv rms (10 – 500 Hz)	HP: 10 Hz LP: 500 Hz	5 Hz – 500 Hz	**Show root mean square (RMS)** using an integrate calculation channel. **Default:** Average over samples mode with 1000 sample window, RMS with baseline removal **Use line frequency filter (narrowband only)** The narrowband (default) filter for the EMG and fEMG smart amplifiers includes a line frequency comb band stop filter. Although this filter helps remove common mode noise, this filter affects frequencies that lie within the physiological frequency range of EMG signals. When examining the recorded narrowband data using an FFT, this filter will cause a series of "notches" to	

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Amp	Gain (fixed)	Noise Voltage	Software Filter (IIR) Bandwidth*	Maximum Bandwidth (Wideband)**	Optional Derived Signal(s) default frequencies & settings (default settings are configurable in software)	Interface (not included)
					be visible in the spectrum, at the mains interfering frequencies and associated harmonics. Use this option to toggle on/off the line frequency comb band stop filter for EMG and fEMG amps.	
EOG100D	x2000	0.1 µv rms—(0.05 -35 Hz)	HP: 0.05 Hz LP: 35 Hz	0.05 Hz – 150 Hz	**Show derivative** of the EOG using an IIR bandpass filter (Fc=30 Hz, Q = 0.8).	
ERS100D	x20000	0.5 µv rms—(20 -3000 Hz)	HP: 20 Hz LP: 3000 Hz	1 Hz – 10,000 Hz	— N/A	

*All default bandwidth and notch filters are software-based. Default filters are generally configured as Butterworth and/or Bessel IIR filters. For the line frequency (mains noise rejection) setting, there is a software-based comb bandstop IIR filter. The default filter settings can be adjusted, as required, for any measurement.

**All Wideband filters are fixed inside the Smart Amplifier; however these can be extended for custom requirements.

COMMON SPECIFICATIONS (BIOPOTENTIAL)

Dimensions:	1.8 cm x 4.6 cm x 1.1 cm
Weight:	48 g (amp only ~ 9 g)
Cable:	3 m RJ12 (6-pin)
Weight:	48 g (amp only ~ 9 g)
Accessories:	Included: 1 x clip for attaching Smart Amplifier to subject 10 x silicone cable ID tags for easy identification (attaches to both ends of cable) 1 x zippered carrying case (16 x 10 x 3.5 cm) 1 x silicone cable wrap for optionally shortening overall cable length 1 x cable management for routing cable around the subject Electrode leads, electrodes Optional Straps: 20, 33, 76, 137 cm—order BN-STRAP-#-D (see page 2)
Notch Filter:	Set in Acq*Knowledge* software
Signal Source:	Electrodes (three electrode leads required) Only one GND required for one or more biopotential signal measurement, per participant
Output Range:	±10 V range
Z (input):	Differential: 10 GΩ Common mode: 100 GΩ
CMRR:	120 dB min (50/60 Hz)
CMIV – referenced to:	Amplifier ground: ±10 V Mains ground: 1500 VDC
Input Voltage Range:	Gain: 500 Vin (mV): ±20 / Gain: 2,000 Vin (mV): ±5 / Gain: 20,000 Vin (mV): ±0.5
Maximum Over-Voltage for Differential Input:	±25 V
Input Connectors:	3 pin header type, compatible with BioNomadix

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SMART AMPLIFIER SPECIFICATIONS (TRANSDUCER)

Amp	Software Filter (IIR) Bandwidth*	Maximum Bandwidth (Wideband)**	Optional Derived Signal(s) default frequencies & settings (default settings are configurable in software)	Interface (not included)
EDA100D[†]	HP: None/DC LP: 3 Hz	DC – 10 Hz	**Show phasic EDA** of short-term phasic EDA using IIR filter calculation channel. **Defaults:** IIR high pass, 0.5 Hz cutoff, Q=0.707 **Scaling:** 1 V = 5 µs 10 V = 50 µs	**BN-EDA-LEAD2**, 15 cm or **BN-EDA-LEAD25**, 25 cm Use EL507 and/or GEL101A
PPG100D	HP: 0.5 Hz LP: 3 Hz	DC – 25 Hz	**Show pulse rate**: heart rate derived from PPG in a separate calculation channel using rate detector calculation. **Defaults:** Positive detection, 25 ms baseline removal, 5% auto threshold detection, detection window 40-180 BPM	**BN-PULSE-XDCR** or **BN-PULSEEAR-XDCR** (finger or ear clip)
RSP100D	HP: 0.05 Hz LP: 1 Hz	DC – 10 Hz	**Show respiration rate (normal breathing)** **Show respiration rate, elevated (>20)** **Defaults:** Positive detection, 25 ms baseline removal, 5% auto threshold detection, detection window 6-20 BPM (normal), 6-50 BPM (elevated)	**BN-RESP-XDCR** respiration transducer with elastic chest band
SKT100D	HP: None/DC LP: 1 Hz	DC – 10 Hz	**Scaling:** 0 = 32º C 10 = 52º C	**BN-TEMP-A-XDCR** skin temp trans or **BN-TEMP-B-XDCR** fast response trans

[†] EDA100D Excitation: 0.5VDC (constant voltage), Isolated Input. Multiple EDA100D amplifiers may be used on the same participant, because of isolated input structure.

COMMON SPECIFICATIONS (TRANSDUCER)

Dimensions:	1.8 cm x 4.6 cm x 1.1 cm
Weight:	48 g (amp only ~ 9 g)
Cable:	3 m RJ12
Weight:	48 g (amp only ~ 9 g)
Accessories:	Included: 1 x clip for attaching Smart Amplifier to subject 10 x silicone cable ID tags for easy identification (attaches to both ends of cable) 1 x zippered carrying case (16 x 10 x 3.5 cm) 1 x silicone cable wrap for optionally shortening overall cable length 1 x cable management for routing cable around the subject Electrode leads, electrodes Optional Straps: 20, 33, 76, 137 cm—order BN-STRAP-#-D (see page 2)
Notch Filter:	Set in Acq*Knowledge* software
Output Range:	±10 V range
Input Connectors:	3 pin header type, compatible with BioNomadix

* All default bandwidth and notch filters are software-based. Default filters are generally configured as Butterworth and/or Bessel IIR filters. For the line frequency (mains noise rejection) setting, there is a software-based comb bandstop IIR filter. The default filter settings can be adjusted, as required, for any measurement.

**All Wideband filters are fixed inside the Smart Amplifier; however these can be extended for custom requirements.

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SMART AMPLIFIER SPECIFICATIONS (IMPEDANCE)

Amplifier:	NICO100D		EBI100D	
Channels (2):	Z dZ(t)/dt		Magnitude Phase	
Software Filter Bandwidth*:	**Z:** HP: None/DC LP: 1 Hz	**dZ(t)/dt:** HP: None/DC LP: 50 Hz	**Magnitude:** HP: None/DC LP: 1 Hz	**Phase:** HP: None/DC LP: 50 Hz
Scaling:	**Z:** 5 V = 100 Ω 1 V = 20 Ω	**dZ(t)/dt:** 5 V = 5 Ω/sec 1 V = 1 Ω/sec	**Magnitude**: 5 V = 100 Ω 1 V = 20 Ω	**Phase:** 2.5 V = 0º 1.786 V = 45º
Output:	**Z:** 1-200 Ω	**dZ(t)/dt:** 0-10 Ω/sec	**Magnitude:** 1-200 Ω	**Phase:** 0 - 90º
Max Bandwidth**:	DC – 100 Hz			
Operational Frequency:	100 kHz			
Current Output:	4 mA rms – constant sinusoidal current			
Output Range:	±10 V range			
CMIV – referenced to:	Amplifier ground: ±10 V Mains ground: 1500 VDC			
Maximum Over-voltage for Differential Input:	±25 V			
Signal Source:	Electrode (requires 4-lead electrode)			
Input Connectors:	4-pin header type			
Interface (not included):	**EL526 with CBL246, LEAD131** for 4-spot electrode configuration, or **LEAD132** for 8-spot electrode configuration. **NOTE:** Do not used two NICO100D or EBI100D amplifiers on the same participant. When using a NICO100D or EBI100D on a participant, then a GND lead is not used with any biopotential amplifier also attached to that same participant. GND connections are made through the NICO100D or EBI100D amplifier module. If NICO100D or EBI100D is used with EDA100D, all electrode leads for both amplifiers are used.			

NICO100D Setup Table:

Setup Type	Amplifier	MEC	Lead	Adapter	Electrode
Simulated Equipotential *Absolute measures*	NICO100D *optimal*	MEC104D	LEAD132	N/A	4 x EL500 or 8 x EL503
Fully Equipotential *Absolute measures* Uses ICG strip conductor, circumferential, cardiographic electrode tape (ICG Tape)	NICO100D (TREV)	1 x MEC104D	N/A	CBL246	EL526

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	Non-Equipotential *Relative measures* Suitable for establishing timing relationships between waves	NICO100D	MEC104D	LEAD131	N/A	4 x EL503 or 2 x EL500

EBI100D Setup Table:

Setup Type	Amplifier	MEC	Lead	Adapter	Electrode
Simulated Equipotential *Absolute measures*	EBI100D *optimal*	MEC104D	LEAD132	N/A	4 x EL500 or 8 x EL503
Fully Equipotential *Absolute measures* Uses ICG strip conductor, circumferential, cardiographic electrode tape (ICG Tape)	EBI100D	1 x MEC104D	N/A	CBL246	EL526
Non-Equipotential *Relative measures* Suitable for establishing timing relationships between waves	EBI100D	MEC104D	LEAD131	N/A	4 x EL503 or 2 x EL500

Dimensions:	53 mm x 20 mm x 11 mm
Cable Junction Dimensions:	40 mm x 22.5 mm x 10.6 mm
Cable:	3 m RJ12
Weight:	70 g
Accessories:	Included: 1 x clip for attaching Smart Amplifier to subject 10 x silicone cable ID tags for easy identification (attaches to both ends of cable) 1 x zippered carrying case (16 x 10 x 3.5 cm) 1 x silicone cable wrap for optionally shortening overall cable length 1 x cable management for routing cable around the subject Electrode leads, electrodes Optional Straps: 20, 33, 76, 137 cm—order BN-STRAP-#-D (see page 2)
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.

* All default bandwidth and notch filters are software-based. Default filters are generally configured as Butterworth and/or Bessel IIR filters. For the line frequency (mains noise rejection) setting, there is a software-based comb bandstop IIR filter. The default filter settings can be adjusted, as required, for any measurement.

**All Wideband filters are fixed internal to the Smart Amplifier; however, these filters can be extended for custom requirements.