Amplifier Selection Guide

Amplifier	AC/DC	Differential	Headstage	EMG EKG	Stimulation	Isolated	Multi-channel	Battery Powered	Connectors	Page
Intracellular Bioamplifiers										
FD223A	DC	♦	♦						2 mm pin	70
Electro 705	DC		♦					♦	2 mm pin	71
Duo773	DC	♦	♦		♦		♦		2 mm pin	72
Extracellular Bioamplifiers										
WPI's Low-Noise Amplifiers Outperform Cheap Imitations										74
DAM50	AC/DC	♦		♦				♦	RJ-11	76
DAM80	AC	♦	♦	♦	♦			♦	Mini Banana	77
ISO80	AC	♦	♦	♦	♦	♦		♦	Mini Banana	78
Transducer Amplifiers										
TBM4M	DC	♦					♦		8-pin DIN WPI transducers	80
SI-BAM21-LC **SI-BAM21-LCB**									KG Transducers only	11
Epithelial Voltage/Current Clamp Bio Amplifier										
EVC4000	DC				♦		♦		Ussing 2 mm	87
Specialty Measurement										
121 Window Discriminator										79
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ABM Audible Baseline Monitor										79
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Force Transducers										15, 81
Metal Microelectrodes										108-109

Dual Channel Differential Electrometer

● *High input impedance (10^{15} Ω)* ● *Differential (A-B) output* ● *Low noise and wide bandwidth* ● *Electrode resistance test circuitry* ● *Probe test circuitry* ● *Driven guard shield*

The **FD223a** is a dual differential, high impedance amplifier/electrometer designed specifically for electrochemical measurements using ion specific (K^+, Na^+, $C1^-$, *etc.*) or pH glass microelectrodes.

The instrument is very stable, drift free, and features a built in provision for measuring and adjusting input leakage current. DC levels may be independently adjusted for each probe channel.

The ability to locate the sensing probes directly at the measurement site overcomes the noise introduced by the long cables usually needed to bring the measured potential to the instrument. Signal-driven guards at the probe input maintains the specified high resistance and reduces the stray capacitance of the probes.

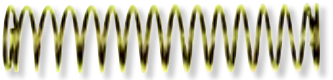
Careful design, coupled with quality component selection, particularly in the headstage, results in an excellent amplifier with low noise and wide bandwidth. The FD223a will faithfully reproduce the measured signal.

To reduce the noise and stray capacity even farther the probe housing includes a signal driven guard. A portion of this inner driven shell is exposed at the probe tip allowing a spring shield to be extended over the electrode holder and microelectrode.

The amplifier features a probe test port that permits testing of the electrode test feature and setting of the probe leakage current, (IG). A standby mode is included and should be used when attaching glass microelectrodes or electrode holders to the probe input. While in the standby mode the voltage at the probe input is clamped near zero volts thus protecting the input.

FD223A SPECIFICATIONS

INPUT IMPEDANCE	> 10^{15} Ω, shunted by 0.5 pF
INPUT CAPACITANCE	1 pF, nominal
LEAKAGE CURRENT	75 fA max
GAIN	1.000 ± 0.1%
OUTPUT RESISTANCE	50 Ω
INPUT SWING VOLTAGE	±10 V
RISE TIME (10 TO 90%)	5 µs, small signal
NOISE (0.1 HZ TO 10 KHZ)	<100 µV p-p, input shorted
BASELINE STABILITY	±0.1 mV/day
POSITION CONTROLS RANGE	±600 mV
PHYSICAL DIMENSIONS	Case: 8.8 x 21.0 x 17.5 cm (H x W x D) Probe: 12.7 x 65 mm (D x L), 1.8 m cable
POWER	90-265 VAC, 50/60 Hz, 10 VA
PROBE HANDLE	6.5 x 65 mm (D x L)
SHIPPING WEIGHT	2.5 kg
OPERATING CONDITIONS	Equipment is intended to be operated in a controlled laboratory environment. Temperature: 0-40 °C; altitude: sea level to 2000 m; relative humidity: 0-95%.



#2547 Driven Guard Shield

FD223A	FD223a Dual Channel Differential Electrometer

2 probes, driven guard shields and micropipette holder MEH1SF included for all glass microelectrodes O.D. 1.0 mm, 1.2 mm, 1.5 mm, or 2.0 mm.

OPTIONAL ACCESSORIES

M3301L	Micromanipulator *(specify left- or right-handed)*
M-3	80° Tilting base
RC1T	Reference cell (Ag/AgCl)
2547	Driven guard shield for FD223AP Probe
MEH1SF	Microelectrode holder
FD223AP	Replacement probe (includes calibration)

See cables and connectors, page 104
See microelectrode holders, page 112
See capillary glass, page 116

WPI's Quietest Intracellular Amplifier!

Electro 705

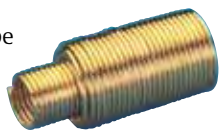
BATTERY POWERED

PORTABLE

A low noise high quality intracellular amplifier well-suited for the student lab

Photo shows two units arranged for differential recording. Manipulators not included.

- **Remote Headstage** — Easily mounted in any manipulator, this small probe, containing the first stage of amplification, includes a microelectrode holder, which plugs directly into the probe input.
- **Battery Power** — Four 9V alkaline batteries (included) power the Electro 705 for approximately 500 hours giving a super clean low noise source of power making the Electro 705 the quietest amplifier available. Batteries can be easily tested by the press of a button.
- **Capacitance Compensation** — Corrects for loss of rise time caused by the presence of electrode capacity. Up to 50 pF of electrode shunt capacity may be neutralized.
- **Driven Guard Shield** — Stray capacitance can be further reduced by placing the driven guard shield (included) over the microelectrode holder at the input end of the probe.



- **Tickler Circuit** — A momentary oscillation that helps achieve cell penetration.
- **Electrode Resistance Test** — The 705 provides a 1 nA electrode test current. Electrode resistance is monitored at the 1X output as a voltage (1 mV/M).
- **Probe Test Port** — Allows the convenience of testing the amplifier's intrinsic noise and gain without cumbersome external test hookups. Gate leakage current can also be adjusted with minimum effort.
- **Baseline Position Control** — Adds or subtracts up to 300 mV to the headstage output, allowing artifact voltages such as liquid junction potentials to be nulled prior to recording.
- **Differential Output** — Two Electro 705s can be connected in tandem to create an optional differential amplifier probe system.

ELECTRO 705 SPECIFICATIONS

INPUT IMPEDANCE	10^{12} Ohms, shunted by 1 pF
OUTPUT IMPEDANCE	100 Ohms, both outputs
GAIN	X1: ±0.1%
INPUT VOLTAGE RANGE	±5 V
RISETIME	15 µs, 10-90%
NOISE LEVEL	500 µV peak-to-peak*
INPUT CAPACITANCE COMPENSATION	0-50 pF
GATE LEAKAGE CURRENT	±10 pA, adjustable to zero
ELECTRODE RESISTANCE TEST	1 mV/ M Ohms
DC POSITIONING	± 300 mV
COMMON MODE REJECTION	>10^4 (in differential mode)
POWER	Four 9V alkaline batteries, supplied
DIMENSIONS	8.5 x 3.5 x 2.2 in. (22 x 9 x 6 cm)
SHIPPING WEIGHT	5 lb (2.3 kg)

** Full band width, with 20 M Ohms source*

SYS-705	Electro 705 Electrometer

Probe, driven guard shield and micropipette holder MEH1SF included for glass microelectrodes O.D. 1.0 mm, 1.2 mm, 1.5 mm, or 2.0 mm.

OPTIONAL ACCESSORIES

3468	Dual Rack Mount Kit
3469	Single Rack Mount Kit
M3301L	Micromanipulator *(specify left- or right-handed)*
M-3	80° Tilting base
RC1T	Reference cell (Ag/AgCl)
2541	Driven guard shield for 705PF Probe
MEH1SF	Microelectrode holder
705PF	Replacement probe (includes calibration)*

**Instrument must be returned to WPI for free calibration with new probe.*

See cables and connectors, page 104
See microelectrode holders, page 112
See capillary glass, page 116

Reference

Koch, U. (2000) "Interdependence of spatial and temporal coding in the auditory midbrain." *Journal of Neurophysiology* 83, 4, 2300-2314

Duo 773 Dual Microprobe System

2-channel intracellular amplifier

For intracellular dual or differential studies, the Duo773 has separate negative capacity controls and built-in active filtering that allows the precise balancing of time constants for artifact-free differential measurement. Comes complete with two probe headstages, 10^{15} Ohms & 10^{11} Ohms probes to monitor signals from ion-specific micro-electrodes as well as KCl-filled electrodes.

** Although injected currents are "constant," the maximum current in a given situation will always be limited by the system compliance of 10 V.*

***The 712P headstage may be used on either A or B channels, however Current Injection specifications do not apply when used on channel A. The 715P headstage may not be used on the B channel.*

DUO 773 SPECIFICATIONS

HEADSTAGE (PROBE)	**712P (red, port "B")**	**715P (blue, port "A")**
ACTIVE PROBE INPUT IMPEDANCE	$>10^{11}\Omega$	$10^{15}\Omega$
GAIN	x1, x10	x1
OUTPUT RESISTANCE	100 Ω	100 Ω
OUTPUT VOLTAGE RANGE	±10 V	± 10V
MAXIMUM INPUT VOLTAGE	±15 V	±15 V
PROBE LEAKAGE CURRENT	5×10^{-12} A	10^{-14} A
DC POSITION ADJUST RANGE	± 300 mV	± 300 mV
ELECTRODE RESISTANCE TEST CURRENT	1 nA	1 pA, 1 nA selectable
INPUT CAPACITY COMPENSATION	+10 to -50 pF	0 to -10 pF
NOISE		
Input shorted	<50 µV p-p 10kHz bandwidth	<50µV p-p 10kHz bandwidth
20 MΩ carbon resistor	<200 µV p-p 10kHz bandwidth	<200µV p-p 10kHz bandwidth
RISE TIME		
10-90% direct input small signal	1 µs, typical	
10-90% through 20 MΩ (-C "on")	25 µs, typical	
CURRENT INJECTION	(712P only)**	
Internal DC Current	± 50 nA low range, ± 500 nA high range	
Externally commanded Current	± 500nA low range, ± 5 µA high range	
External current command factor	20 mV/nA low range, 2 mV/nA high range	
Current monitor	100 mV/nA low range, 10 mV/nA high range	
Compliance	3V low range, 10V high range	
Bridge balance	0-100 MΩ, 0-1000 MΩ	
Bridge amplifier gain	x 10, x 50	
LOW PASS FILTER	40 dB/decade, continuously variable 1-30 kHz	
METER SECTION		
Display	3.5-digit LED	
Ranges	200 mV, 2000 mV, 20 V, 200 nA, 2000 nA	
Accuracy and resolution	1 digit	
DIMENSIONS		
Instrument	17 x 5.25 x 10 in. (43 x 13 x 25 cm)	
Probe	Diameter: 12 mm Length: 34 mm	
POWER	95-135 V or 220-240 V, 50/60 Hz	
SHIPPING WEIGHT	15 lb (7 kg)	
CERTIFICATION	CE, CSA	

References

L. Pluja (2000) "Electrical and mechanical effects of vasoactive intestinal peptide and pituitary adenylate cyclase-activating peptide in the rat colon involve different mechanisms." *European Journal of Pharmacology* 389, 217-224.

G. X. Wang, X. B. Zhou, *et al.* (2000) "Effects of mitoxantrone on excitation-contraction coupling in guinea pig ventricular myocytes." *Journal of Pharmacology and Experimental Therapeutics* 293, 2, 501-508.

S. Tsuruoka (2000) "Acute effect of cadmium-metallothionein on glucose and amino acid transport across the apical membrane of the rabbit proximal tubule perfused *in vitro*." *Journal of Pharmacology and Experimental Therapeutics* 292, 2, 769-777.

Headstage — Two gold-plated, epoxy sealed miniature active probes can be positioned directly to the measurement site. Microelectrode holders containing an Ag/AgCl electrochemical half-cells plug directly into the probes. Stray capacitance can be reduced by placing the included driven guard shield over the microelectrode holder at the end of the probe.

Capacity Compensation — Channel A can compensate up to 10 pF of electrode shunt capacity and Channel B can compensate up to 50 pF.

Tickler Circuit — Assists in cell penetration. The frequency and amplitude of the oscillations may be varied for differences in membrane thickness or cell size. The duration of tickle can be controlled either by using the momentary switch, a foot switch, or by applying a signal to the remote tickler input.

Active Filters — Low pass settings on a -40 dB/decade active filter vary the cutoff from 1 to 30 kHz. Either probe or bridge outputs may be selected for filtering.

Current Injection — Channel B can eject current through the microelectrode by applying a command signal to the stimulus input connector; the resulting output from the probe will then be a constant current replica of the input signal. Two ranges of current delivery are provided: 50 nA and 500 nA or by an external source. This source can be useful for delivering hyperpolarizing currents to stabilize the cell membrane potential and as a holding current for microiontophoresis.

Compliance Alarm — When the electrode voltage exceeds the probe input maximum allowed voltage, an audible over-compliance alarm will sound.

Bridge Balance — Subtracts the excess electrode voltage associated with delivering current through the recording micropipette. Electrode resistances up to 1000 MΩ can be balanced in two ranges. The balanced signal is available from x10 or x50 front panel output connectors.

Independent Outputs — The Duo773 has an output for each probe independent of gain filtering or balancing. In addition the Duo773 has a 10x and a 50x output for easy integration to most data aquisition programs.

Digital Meter — The Duo773 comes complete with a 3½-digit display for monitoring injection current or the voltages for either probe (single ended or differential).

SYS-773	Duo 773 Electrometer

Specify line voltage

Includes two probes (712P and 715P or two 712P) with driven guard shields and eight MEH1SF microelectrode holders for 1.0 mm, 1.2 mm, 1.5 mm, or 2.0 mm glass electrodes.

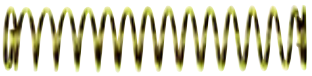
OPTIONAL ACCESSORIES

712P	Replacement probe (includes calibration)*
715P	Replacement probe (includes calibration)*

**Instrument should be returned to WPI for free calibration with new probe.*

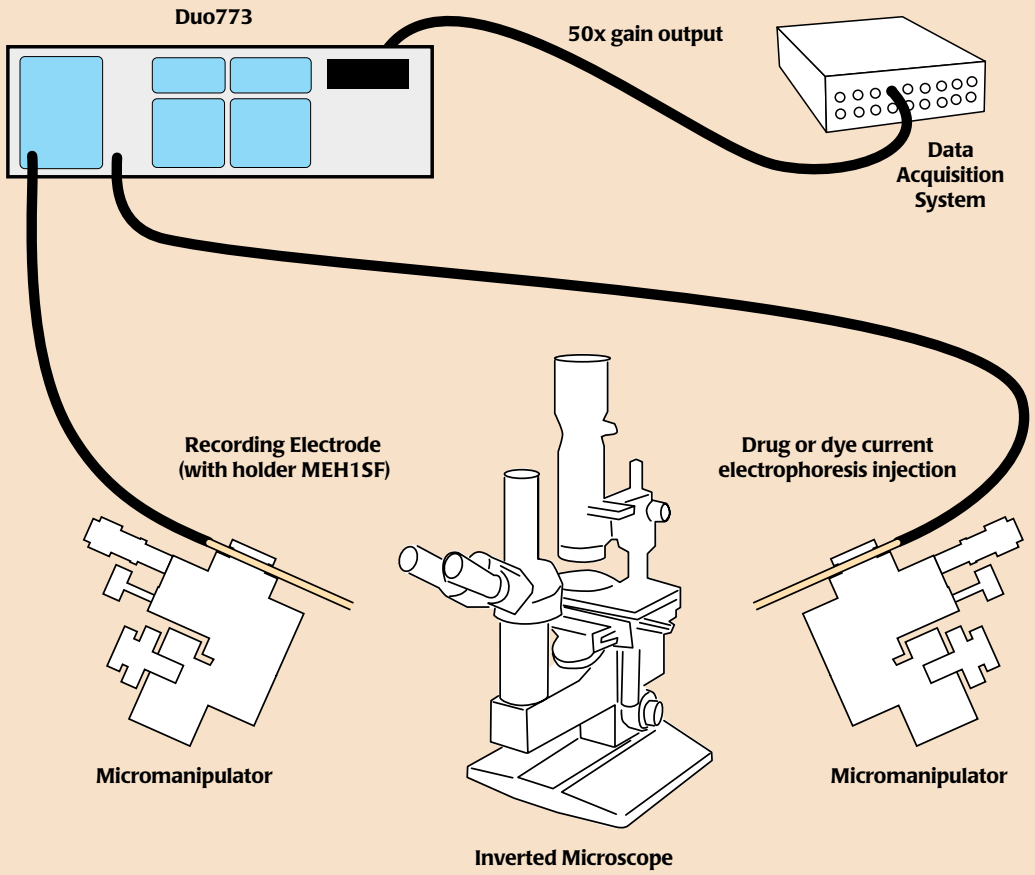
2933	Rack Mount Kit, 5¼-in. high
2547	Driven Guard Shield for 712P & 715P Probes
15790	Replacement Probe Handle
TW100F-4	Glass capillary with filament
TW150F-4	Glass capillary with filament

See Dri-Ref, page 68.
See cables and connectors, page 108.

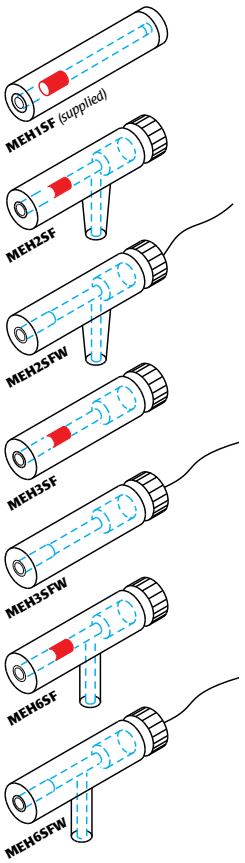


#2547 Driven Guard Shield

Typical setup:



Optional Holders for Intracellular Amplifiers



See Microelectrode Holders, page 112

WPI's Low-Noise Amplifiers *Outperform Cheap Imitations*

An amplifier, in simplest terms, is an electronic device that magnifies an input signal. However, the way an amplifier is designed to handle noise and bandwidth limitations greatly affects the quality and sustainability of the final output signal.

Defining terms

To knowledgeably discuss amplifiers, let's define a few terms.

• **Gain** – The gain is the multiplier defining how much the amplitude of an input signal is increased. A signal with an ×1 gain is not amplified. An ×10 gain produces an output signal ten times greater than the input signal.

• **Noise** – Any unwanted signal fluctuations are called noise. While noise can also result from external sources, for the purpose of this discussion, we are primarily concerned with the noise resulting from the inner workings of the electronic device, our amplifier. This intrinsic noise is called shot (or schott) noise.

• **Signal to Noise Ratio (SNR)** – The ratio of the output signal to the noise of the amplifier is called the signal to noise ratio. The smaller the shot noise signal in an amplifier in comparison with the output signal, the easier the desired signal is to discriminate. When engineering an amplifier, the SNR may be improved by boosting the first stage gain to yield a larger output signal or by using quality components to minimize the shot noise level of the amplifier.

• **Output Range** – The output range determines the maximum output signal that can be generated with the amplifier. It is determined by the maximum voltage of the power supply. If the amplitude of the output signal is too large for the output range, part of the signal is cut off (clipped).

• **Rail** – The upper or lower limit of the amplifier range is called a rail. Signals that exceed the rail cannot be faithfully reproduced.

• **DC Offset** – DC offsets can appear in biological preparations. This offset is the amount the output signal is displaced away from a zero reference point, and it is usually a result the potential difference at the electrode's tip.

How does an amplifier work?

Power Supply Rails Limits the Range

In a perfect world an input signal can be infinitely multiplied by the gain factor to determine the output signal. For example:

Input Signal	Gain	Output Signal
2mV	×1	2mV
2mV	×2	4mV
2mV	×10	20mV
2mV	×100	200mV
2mV	×10,000	20V

In the real world, however, the power supply rails limit the possible output range of the amplifier. For example, a bio-amplifier could have a range of ±5.0V. In order for the output signal to be faithfully reproduced, the input signal times the gain factor must fall within the voltage window set by the power rails. Otherwise, the output signal will go off scale, and the input signal will not be faithfully reproduced. This is called "hitting the rail."

In our example, a 1.0μV input signal at an $\times 10^6$ gain would generate a 1.0V output signal. Since the power supply is rated up to +5.0V, this output signal is clearly visible. If the input signal in this example is greater than 5.0μV, the output signal would be greater than +5.0V. Since 5.0V is the top of the range that the power supply is capable of producing, the output signal hits the upper rail and gets cut off. This amplifier will give a +5.0V DC output signal for all input signals greater than or equal to 5.0μV. In this instance, a smaller gain factor should be used to bring the output signal back into the dynamic output range of the amplifier.

Noise Limits Amplifier Useability

All electronic devices produce their own internal electronic noise, an unavoidable signal that can mask the output signal. For example, if the input signal is 2mV and the noise is 1mV, the signal to noise ratio is two to one (2:1), and the output signal would be undetectable. In this case, it is nearly impossible to discern which part of the output is generated by noise and which part is the desired signal. (Fig. 1)

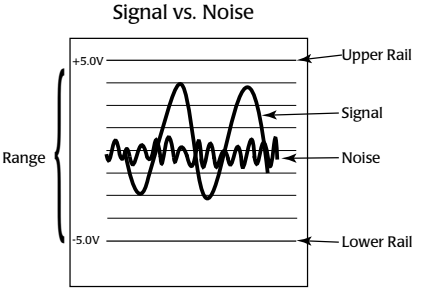


***Fig. 1**–The higher the signal to noise ratio, the more discernable the desired signal.*

Ideally, the signal to noise ratio should be at least 50 to 1 to produce a quality output signal. A good signal to noise ratio can be achieved in one of two ways:

- Boost the output signal by increasing the gain.
- Reduce the noise.

While increasing the gain is the simplest solution, too much gain can impose a limitation on the dynamic range of the amplifier. Reducing noise is a more complicated solution, but it offers a greater range and more stability in the end.

Two-Stage Amplifiers

Bio-amplifiers usually involve multiple stages of amplification.

Stage One – The unadulterated signal coming into the amplifier is unaffected by the intrinsic noise of the amplifier. Then, it runs through the critical first stage of amplification where the signal is boosted by the primary gain factor to produce an output signal with the desired signal to noise ratio. The intrinsic noise is not amplified in the first stage. Higher gain factors used in the first stage of amplification can seriously limit the dynamic range available at output stage. Large stage one gains also limit the gain factor available in the second stage of amplification.

Stage 2 – The stage one output signal enters the second stage of amplification where both the signal and the noise from the first stage are amplified together by the second stage gain factor so that the signal is large enough to be seen on a chart recorder or data acquisition system. The second stage amplification is the gain the user controls. It does not change the signal to noise ratio.

Result of Amplifier Using Gain to Control Signal to Noise Ratio

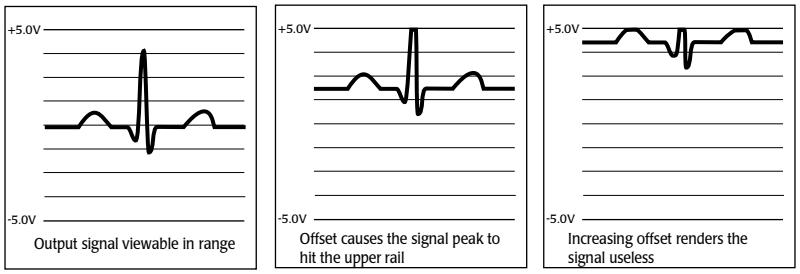


***Fig. 2**–As the offset naturally increases over time, a poorly constructed amplifier will not be able to faithfully reproduce the signal. This offset can also be a result of gain drift which can occur as the temperature rises.*

Instead of using high gains in the first stage of amplification, a well constructed bio-amplifier that uses high quality components, like WPI's DAM series amplifiers, minimizes the noise in the first stage of amplification so that the dynamic range is retained throughout the amplification process. A poorly designed amplifier will simply increase the gain of the first stage amplification until the desired signal to noise ratio is reached.

Why not boost the power rails?

Theoretically, increasing the voltage rails powering the amplifier will increase the available dynamic output range. It would seem natural to increase the power supply rails coming into the amplifier in order to provide the capability for greater first stage gains. However, most data acquisition systems are limited to a maximum input signal ranging between ±10.0V. Therefore, it is not practical to increase the power rails of bio-amplifier beyond ±10.0V. Since the industry standard limits us to ±10.0V power supply rails, the only way to improve the signal to noise ratio is to minimize the shot noise in the first stage of amplification. This is why high quality amplifier components are imperative.

Why does my signal flatline?

Regardless of the amplifier used, biological potentials are often accompanied by a DC offset, because the electrodes polarize over time. The DC offset naturally increases over time. Since the poorly constructed amplifier that utilizes greater first stage gain has restricted its dynamic range, it has limited ability to handle this offset. As the offset continues to increase, the output signal may eventually be forced by the offset into the rail causing the flat line (clipping the signal). (See Fig. 2.)

The amplifier that minimizes the noise in the first stage amplification offers a larger dynamic output range and handles a much greater offset value.

WPI's amplifiers

The purchase of a low-noise amplifier pays dividends in the end. WPI's amplifiers were engineered for the bio-medical researcher. While 20-30µV of noise is common in bio-amplifiers, WPI's DAM series amplifiers generate 0.4µV RMS (root mean squared) at 0.1-100Hz. (That's equal to 2µV peak-to-peak.) The chart at left compares WPI's bio-amplifiers.

Amplifier	AC/DC	Differential	Head-stage	EMG EKG	Stimu-lation	Isolated	Multi-channel	Battery Powered	Connectors
Intracellular Bioamplifiers									
FD223A	DC	♦	♦				2		2 mm pin
Electro 705	DC		♦					♦	2 mm pin
Duo773	DC	♦	♦		♦		2		2 mm pin
Extracellular Bioamplifiers									
ISODAM8A	DC	♦	opt	♦		♦	4 - 8		Mini Banana or 8-pin DIN
ISO80	AC	♦	♦	♦	♦	♦		♦	Mini Banana
DAM50	AC/DC	♦		♦				♦	RJ-11
DAM80	AC	♦	♦	♦	♦			♦	Mini Banana
Transducer Amplifiers									
BRIDGE8	DC	♦					4 - 8		8-pin DIN WPI transducers
TBM4M	DC	♦					4		8-pin DIN WPI transducers
Epithelial Voltage/Current Clamp Bio Amplifier									
EVC4000	DC				♦		1 - 4		Ussing 2 mm

DAM Series Bioamplifiers

A family of very low noise battery-operated amplifiers

Now with ESD Protection!

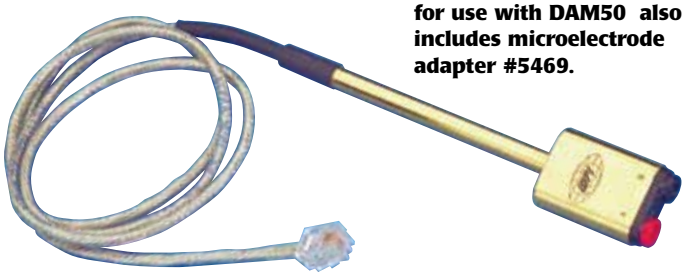
Dam50—Basic Amplifier *(optional #5447 electrode adapter not included)*

- Gated or manual current generation for histological marking, iontophoresis, or cell stimulation.
- A very low noise remote active headstage (DAM80 only) is useful for very high impedance amplification utilizing glass or metal electrodes.

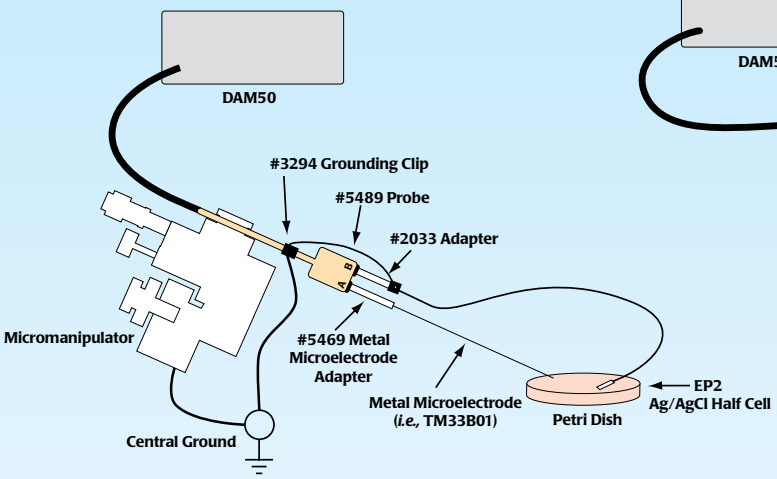
DAM series amplifiers can be used as standalone units on any tabletop, or use optional clamp-mounting hardware to locate them conveniently within the work area. Alternatively, a pair of amplifiers can be mounted into a standard equipment rack with a rack mount kit (**#3484**). A variety of hook up accessories are available to configure your application.

WPI's DAM series amplifier's are well known as a standard of the industry for extracellular potential amplification. These battery powered bio-amplifiers are designed with a compact chassis profile that enables the user to locate the unit closer to the preparation and thereby minimize long lead lengths which contribute to noise. Each amplifier is equipped with selectable high and low filters, and a position control to offset galvanic potentials which may develop during recording. A choice of models offer additional features that are useful for certain applications:

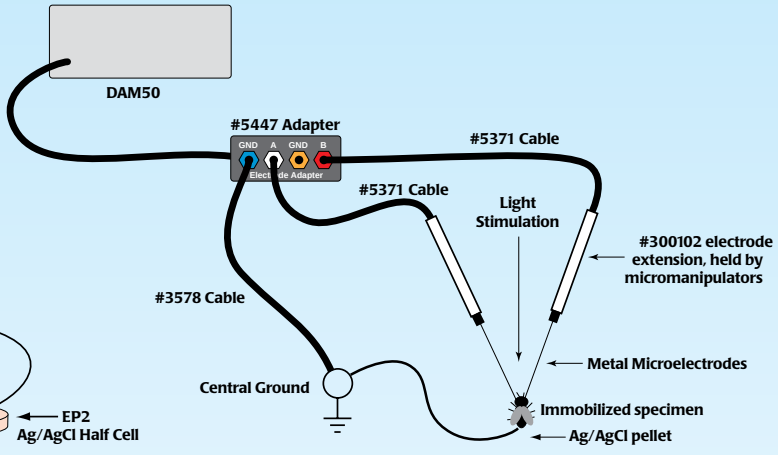
Optional probe #5489 for use with DAM50 also includes microelectrode adapter #5469.



Application Examples



Extracellular recording using metal microelectrode



ERG recording of fly eyes

Dam80— With low-noise headstage DAM80P

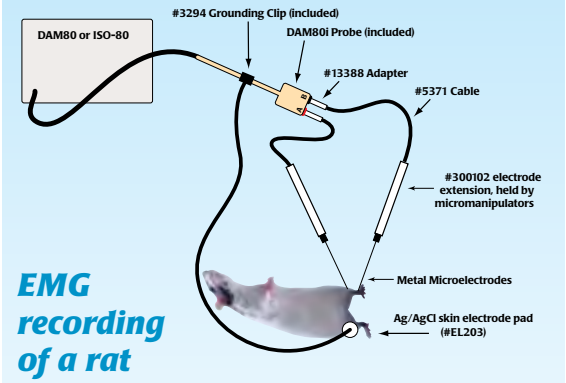
DAM80, an AC amplifier only, features a very low noise headstage probe which can be mounted in micromanipulators for up-close cortical recording, for extracellular recording from high impedance glass or metal microelectrodes. Also provides a gated current for tissue marking. Micro-electrode holder MEH3SB is recommended.

Included with the DAM-80 is a Startup Kit containing the following accessories needed for basic metal electrode electrophysiology research:

- **CBL102** Cable, BNC-to-3.5mm plug, 6 ft (2m) (two)
- **5469** Adapter, mini-banana to 0.031 skt. (two)
- **13388** Adapter, mini-banana to 2mm skt. (two)
- **3294** Cable, ground clip to wire, 3 ft
- **2033** Mini-banana plug, black
- **2034** Mini-banana plug, red
- **2035** Mini-banana plug solderable turrent (two)
- **EP1** Ag/AgCl pellet (70 mm wire) 1mm diam x 2.5 mm long
- **M3301EH** Electrode Holder, 14cm (two)
- **5470** 0.031-inch jack on 12-inch wire (package of 4)

DAM SERIES SPECIFICATIONS

INPUT IMPEDANCE	10^{12} Ω, common mode and differential
INPUT LEAKAGE CURRENT	50 pA (typical)
MAX. DC DIFFERENTIAL SIGNAL	± 2.5 V (DAM 50)
GAIN	AC: 100x, 1000x, 10000x DC: 10x, 100x, 1000x (DAM50)
COMMON MODE REJECTION RATIO	100 dB @ 50/60 Hz
INPUT CAPACITANCE	20 pF
AC MODE NOISE	0.4 µV RMS (2 µV p-p) 0.1-100 Hz
AC MODE NOISE	2.6 µV RMS (10 µV p-p) 1 Hz-10 kH
DC MODE NOISE (DAM50)	7.5 µV RMS (30 µV p-p) 3-10 kHz
BANDWIDTH FILTER SETTINGS	
AC Mode	Low frequency, 0.1, 1, 10, 300 Hz
AC Mode (DAM80)	High frequency, 0.1, 1, 3, 10 kHz
DC Mode (DAM50)	High frequency, 0.1, 1, 3, 10 kHz
OUTPUT CONNECTORS	BNC on DAM50; 3.5 mm MiniPhone connector on DAM80
OUTPUT VOLTAGE SWING	±8 V
OUTPUT IMPEDANCE	470 Ω
BATTERY TEST	Audible tone
CALIBRATOR SIGNAL	10 Hz square wave
POSITION	Approximately 250 mV
CURRENT SOURCE	
DAM80: DC Generator	0 to ±50 µA, variable
EXTERNAL COMMAND	Input Voltage ±10 V commands
AC OR DC CURRENT WAVEFORM	±50 µA max. amplitude @ 200 KΩ
BATTERIES	2 x 9V alkaline (included)
DIMENSIONS	
DAM50	8 x 4 x 1.75 in. (20.3 x 10.2 x 4.4 cm)
DAM80	7 x 4 x 1.75 in. (17.8 x 10.2 x 4.4 cm)
SHIPPING WEIGHT	3.5 lb (1.6 kg)



EMG recording of a rat

FEATURE	DAM50	DAM80
Input Mode	AC/DC	AC
Input configuration	differential/single ended	differential
Gain Range	100-10K (AC), 10-1K (DC)	100-10K (AC)
High / Low Filters	yes	yes
Offset position control	yes	yes
Current Generator	No	Yes
Remote Active headstage	No	Yes
Output connection	BNC	3.5 mm mini phone
Standard input connection*	unterminated wire	mini banana
Power supply	(2) nine volt alkaline batteries	(2) nine volt alkaline batteries

*see optional accessories for additional alternatives

SYS-DAM50	Bio-amplifier
SYS-DAM80	Bio-amplifier with active probe (DAM80P)

OPTIONAL ACCESSORIES

DAM80P	Replacement Probe
3072	6 Replacement Modular Cables (DAM50)
3517	2 Optional Shielded Modular Cables (DAM50)
CBL102	3.5 mm Phone plug-to-BNC Cable
2851	BNC-to-BNC Cable
2033	Black Insulated Mini-Banana Plug
2034	Red Insulated Mini-Banana Plug
2035	Uninsulated Mini-Banana Plug
2101	9V Alkaline Battery, each (2 required)
3484	Rack Mount Kit (for 1 or 2 DAM preamps)
3485	Ringstand Mounting Kit
5447	Electrode Adapter (DAM50)
5469	Metal Microelectrode Adapter for DAM80 *(mini-banana plug to 0.031 in. (0.79 mm) socket)*
5489	Adapter for Metal Microelectrode (DAM50)
13388	Adapter, mini-banana plug to 2mm socket
5371	Cable, Low Noise (2 mm pin to 2 mm pin)
3578	Adapter Cable for Ag/AgCl pellets (2 mm pin)
300102	Electrode Extension, 4-inch
3414	9V NiMH Battery

Also see cables and connectors, metal microelectrodes, carbon-filled micropipettes.

Isolated Differential Amplifier

The improved **ISO-80** provides low noise AC coupled amplification and offers excellent recording performance for monitoring extracellular nerve action potentials *in vitro* and in living animals. The ISO-80 is provided with a remote headstage (1 m cable) which incorporates an electrode impedance test function and a constant current stimulator. The constant current stimulator can be used for cell marking, stimulation or electrode cleaning. Typical applications include measuring EMG, EEG, extracellular and action potentials *in vitro* or *in vivo*. The ISO-80 system is DC isolated from the subject ground and employs state of the art electro-magnetic shielding for improved noise rejection. The amplifier employs both high pass and low pass filtering with gain from 100 to 10,000. The lowest low-pass setting is 5Hz and the upper passband is 10 kHz.

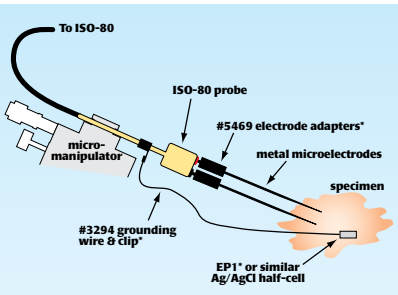
ISO-80 SPECIFICATIONS

INPUT RESISTANCE	$>10^{11}$ Ohms, Common Mode and differential
INPUT LEAKAGE CURRENT	50 picoamperes, max.
AMPLIFICATION	$\times10^2$, $\times10^3$, $\times10^4$
COMMON MODE REJECTION RATIO	100 dB typ. @ 50/60 Hz
EQUIVALENT NOISE SIGNAL INPUT	0.4 microvolts rms (0.1-100 Hz) 2.0 microvolts rms (1 Hz - 10 kHz)
FILTER SETTINGS	
Low frequency	5, 10, 100, 300 Hz
High frequency	100 Hz, 1, 3, 10 kHz
MAX. OUTPUT VOLTAGE SWING	±8 volts
ELECTRODE IMPEDANCE RANGE	100 kOhm - 10 MOhm @ 300 Hz
STIMULATION CURRENT	0 to ±20 micro amperes (constant current)
MAXIMUM STIMULATION VOLTAGE	±15 volts
MAXIMUM ELECTRODE VOLTAGE	±40 volts
DISPLAY	3 1/2-digit LCD
BATTERY TEST	Low battery display
POWER	Two 9-volt NiCad batteries & charger, supplied
SHIPPING WEIGHT	4 lb (1.8 kg)

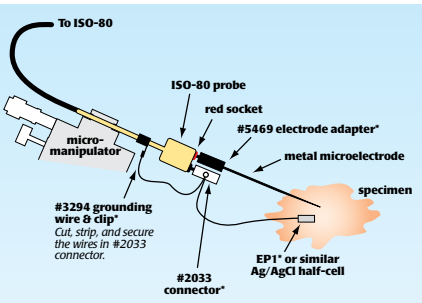
Included with the ISO-80 is a Startup Kit containing the following accessories needed for basic metal electrode electrophysiology research:

- CBL102 Cable, BNC-to-3.5mm plug, 6 ft (2m) (two)
- 5469 Adapter, mini-banana to 0.031 skt. (two)
- 13388 Adapter, mini-banana to 2mm skt. (two)
- 3294 Cable, ground clip to wire, 3 ft
- 2033 Mini-banana plug, black
- 2034 Mini-banana plug, red
- 2035 Mini-banana plug solderable turrent (two)
- EP1 Ag/AgCl pellet (70 mm wire) 1mm diam x 2.5 mm long
- M3301EH Electrode Holder, 14cm (two)
- 5470 0.031-inch jack on 12-inch wire (package of 4)

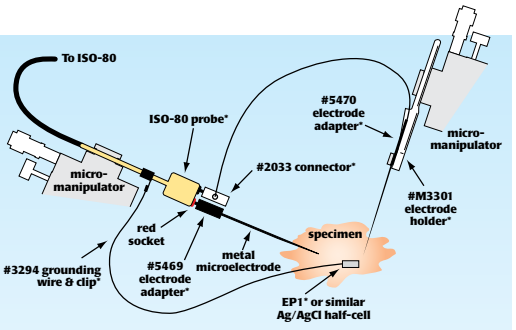
ISO-80	Isolated Bioamplifier w/ active probe (ISO80P)
	Specify line voltage
OPTIONAL ACCESSORIES	
ISO-80P	Replacement ISO-80 Probe
CBL102	3.5 mm phone plug-to-BNC cable



Differential Application



Single-Ended Application



Optional Differential Application

Dual Microiontophoresis Current Generator

The Dual Microiontophoresis Current Generator (Model 260) is an electrically isolated, battery-operated instrument designed for the electro-iontophoresis of dyes, drugs and charged substances from micropipettes. Two identical battery operated current generators are available. In ordinary use, the two current generators are operated in parallel providing two distinct currents; one for preventing substances in the micropipette from outward diffusion (the retain or hold current) and the second for actively ejecting charged material. For pipettes with submicron tips, a hold current may not be necessary if there is little outward diffusion of pipette material. Model 260 is powered by two 9-volt alkaline batteries per side (four, in total); unique circuitry converts the ±9 V to ±100 V without a transformer, yielding an exceedingly quiet output.

SYS-260	Dual Microiontophoresis Current Generator
OPTIONAL ACCESSORIES	
2933	Rack Mount Kit, 5¼-in. high

Window Discriminator

- ***Monitor signals and discriminator levels simultaneously at the multiplex output***
- ***Window height independent of lower discriminator level setting***
- ***Logic level output pulses, TTL compatible***
- ***Output pulses indicated by LED display***

SYS-121	Window Discriminator
2932	Rack Mount Kit, 3.5-in. High
2851	BNC-to-BNC cable, 5′2″
500184	BNC-to-BNC cable, 10 ft
500257	BNC-to-BNC cable, 6 inch 15 cm
500258	BNC-to-BNC cable, 12 inch 30 cm
500259	BNC-to-BNC cable, 18 inch 46 cm

Audible Baseline Monitor

The ABM, a battery-operated voltage-controlled oscillator, lets you monitor potential audibly. ABM is particularly useful because it allows the user to estimate voltage levels when using a microscope or engaged in other tasks which do not allow viewing an oscilloscope or recorder. An audible tone is generated with increasing pitch as the input voltage becomes increasingly positive.

SYS-ABM	Audible Baseline Monitor

Low-Pass Filter

Upper frequency band limit can be smoothly varied between 100 Hz and 30-kHz using a single knob. WPI's new low-pass filter is small, consumes little power, and can be located almost anywhere in your workspace. Features switch-selectable gain of ×1 or ×10 and low noise. An ideal tool for filtering an analog signal before digital conversion by data acquisition systems.

SYS-LPF30	Lo-Pass Filter

Ωmega-Tip-Z™

Millivolt and megohm meter measures impedance of metal or glass capillary microelectrodes

Omega-Tip-Z was created especially for measuring impedance in etched tungsten, platinum-iridium* and steel microelectrodes, as well as electrolyte-filled micropipettes. The meter's AC impedance-measuring circuit is unaffected by electrode offset or tip junction potentials. The gold-plated miniature probe lets you conveniently monitor micro-electrode impedance in electrolytes, and an electrode tip cleaning feature lets you remove buildup quickly. Omega-Tip-Z can also measure DC electrode tip potentials up to 2000 millivolts. The instrument operates for hundreds of hours without battery failure.

NOTE: Metal microelectrodes which have been precalibrated at 1 kHz should be baselined for use with Omega-Tip-Z.

See Metal Microelectrodes, page 108.

SYS-OMEGAZ	Omega-Tip-Z with Probe & Holder
711P	Replacement Probe
5468	Adapter to connect metal microelectrodes to probe, 2 mm socket to .031 in. receptacle
OPTIONAL ACCESSORIES	
Z-LITE	Fiber Optic Illuminator (115v, 60Hz, beige case)
Z-LITE-Z	Fiber Optic Illuminator (230v, 80Hz, black case)
500186	Bifurcated Light Guide with lenses
Z-LITE-186	Z-Lite Illuminator and bifurcated light guide

4-Channel Transducer Amplifier

Transducers available separately

Transbridge (TBM4M) is a four-channel analog transducer manifold, specifically designed to amplify output voltage signals from pressure, force, displacement, and temperature transducers as well as a wide variety of other signal sources. Analog output signals are available from each channel for input to a data acquisition system for digital signal processing in a computer.

Each channel contains a regulated 10-volt power supply (+5 and -5 volts with respect to signal ground) to provide DC power to transducers, and a precision differential amplifier with selectable voltage amplification and variable position adjustment control.

Transducers can be connected to Transbridge via any of the 8-pin connectors on the front panel. Four spare 8-pin DIN plugs are provided with each instrument to allow you to rewire cables of other manufacturers' transducers and connect them to Transbridge. Each Transbridge channel may be used in either Full Bridge or the Half Bridge mode independently. For transducer types other than resistive bridges, such as active transistor circuits, magnetic, photocell or piezoelectric devices, the instrument's differential amplifiers may still be used effectively for signal amplification in differential (full bridge) and single-ended (half bridge) modes.

SYS-TBM4M	Transbridge Transducer Amplifier

Specify line voltage

OPTIONAL ACCESSORIES

13024	Single Rack Mount Kit
13025	Dual Rack Mount Kit
500184	BNC-to-BNC cable, 10 ft
3161	8-pin DIN plug
3718	Package of 4, 8-pin DIN (startup kit)

TRANSBRIDGE SPECIFICATIONS

CHANNELS	4
VOLTAGE AMPLIFICATION	x1, x10, x100, x1000
VOLTAGE OFFSET ADJUSTMENT	> ± 50 mV
NOISE 10Hz, G=100)	.4uV p-p (0.1 to
LINEARITY G=1; +/-.01% of FSR, G-=1000	+/-.001% of FSR
OUTPUT VOLTAGE SWING	± 10 V
MAXIMUM OUTPUT CURRENT	2 mA
INPUT IMPEDANCE, EACH INPUT	10^{10} ohms
TRANSDUCER EXCITATION	10 V DC (±5 V) approx.
BANDWIDTH, SMALL SIGNAL	1 MHz (x1), 80 KHz (x10), 10 KHz (x100), 1.0 KHz (x1000)
DIMENSIONS	8.5x5.12x10 in. (21.6x13x25.44 cm)
SHIPPING WEIGHT	11 lb (5 kg)

TRANSDUCERS

FORT10-100	Force Transducer, Dual Range (10 g and 100 g)
FORT10g	Force Transducer (10 g)
FORT25	Force Transducer (25 g)
FORT100	Force Transducer (100 g)
FORT250	Force Transducer (250 g)
FORT1000	Force Transducer (1000 g)
FORT5000	Force Transducer (5000 g)
3491	Probe Extension Cable

Caution: Extension cable may diminish signal-to-noise ratio.

FORCE TRANSDUCERS

These rigid-lever force transducers transform applied force into proportional voltage. Using balanced strain gauges, FORT transducers produce linear output voltage vs. applied force input with very little deflection.

To use, clamp the handle of the FORT transducer in a horizontal position and apply the forces to be measured to a rivet or hook mounted in the hole at the end of the flat sensing leaf.

FORT100	Force Transducer (100 g)
FORT250	Force Transducer (250 g)
FORT1000	Force Transducer (1000 g)
FORT5000	Force Transducer (5000 g)

FORT SPECIFICATIONS

	FORT100	FORT250	FORT1000	FORT5000
FORCE RANGES, FULL SCALE	100 grams	250 grams	1000 grams	5000 grams
OUTPUT SENSITIVITY (± 10%)	7 µV/V/g	3 µV/V/g	0.84 µV/V/g	0.38 µV/V/g
INPUT & OUTPUT RESISTANCE	350 Ω	350 Ω	350 Ω	350 Ω
RESOLUTION	0.01% of full scale force	0.01% of full scale force	0.01% of full scale force	0.1% of full scale force
RESONANT FREQUENCY	300 Hz	300 Hz	300 Hz	60 Hz
LINEARITY ERROR	Less than 0.1% of full scale	Less than 0.1% of full scale	Less than 0.1% of full scale	Less than 0.1% of full scale
MAX. OPERATING VOLTAGE	10 V AC or DC	10 V AC or DC	10 V AC or DC	10 V AC or DC
MAXIMUM APPLIED FORCE	3× rated full scale force	3× rated full scale force	3× rated full scale force	3× rated full scale force
DRIFT	thermally compensated	thermally compensated	thermally compensated	thermally compensated
DIMENSIONS	0.3 inch diam × 4 in. (7.6 mm diam × 10.2 mm)	0.3 inch diam × 4 in. (7.6 mm diam × 10.2 mm)	0.3 inch diam × 4 in. (7.6 mm diam × 10.2 mm)	0.3 inch diam × 4 in. (7.6 mm diam × 10.2 mm)
WEIGHT (excluding cable)	0.3 oz (8 g)	0.3 oz (8 g)	0.3 oz (8 g)	0.3 oz (8 g)

10g & 25 Force Transducers

	FORT10g	FORT25
FORCE RANGE, FULL SCALE	0-10 grams	0-25 grams
OUTPUT SENSITIVITY	10 mV/gm, nominal	3 mV/gm, nominal
INPUT & OUTPUT RESISTANCE	1500 Ω	1500 Ω
RESOLUTION	< 1mg	< 2mg
RESONANT FREQUENCY	450 Hz	450 Hz
LINEARITY ERROR	<0.2% of full scale	<0.2% of full scale
MAXIMUM OPERATING VOLTAGE	10 V DC (-5V ~ +5V or 0 ~ 10V)	10 V DC (-5V ~ +5V or 0 ~ 10V)
MAXIMUM APPLIED FORCE	2× rated full scale force	3× rated full scale force
DRIFT	<30 mg/hr	<50 mg/hr
DIMENSIONS	40 x 22 x 19 mm Handle 88 mm	40 x 22 x 19 mm Handle 109 mm
WEIGHT	100 gram	100 gram

These 10-gram and 25-gram force transducers are reliable tools for high precision force measurement. Using balanced semiconductor strain gauges, both produce linear output voltage *vs.* applied force input with very little deflection. The rigid lever force transducer transforms the applied force into a proportional voltage. Featuring a temperature-compensated full-bridge configuration with four high sensitivity semiconductor strain gauges. These transducers have broad dynamic measuring range and very high sensitivity.

To use, clamp the handle of the FORT10 or FORT25 transducer in a horizontal position and apply the forces to be measured to a rivet or hook mounted in the hole at the end of the flat sensing leaf.

Measure hydrostatic pressure in small vessels and oocytes

MODEL 900A MICROPRESSURE SYSTEM

- ***Simultaneously measures electric potential and pressure***
- ***Preset internal microelectrode pressure***
- ***Air-filled system — no debubbling***

Model 900A is designed to measure hydrostatic pressure in small vessels and cells. Pressure ranges of -200 to +400 mm Hg can be measured with stability and accuracy. The system's sensing element is an electrolyte-filled glass microelectrode with a tip diameter range of 2 to 5 microns.

Pressures of electrolyte solutions are measured by maintaining a salt concentration gradient at the tip of the sensing electrode in dynamic equilibrium by applying an equal air pressure inside the microelectrode. The pressure reading appears on the front panel display and via the BNC recorder output.

Because the piezoelectric pressure controller uses external pressure and vacuum sources, pressures lower than -200 to greater than +400 mm Hg can be quickly and accurately measured at the microelectrode tip.

The open pressure chamber is almost immune to vibrations and movements and, unless they are extremely large, the open system is unaffected by leaks. The pressure controller is contained in a small, lightweight enclosure that can easily be mounted near the micropipette to help reduce dead space. It includes an amplifier, a piezoelectric valve and a pressure transducer. The user supplies fluid-filled microelectrodes, +500 mm Hg pressure source and a -300 mm Hg vacuum source.

Measuring electric potential and pressure simultaneously lets you use potential recording as an additional cue for locating the electrode where visibility is limited, or correlate pressure and potential when this is meaningful.

The unique "Set Pressure" mode lets you preset the internal pressure of the microelectrode — select a positive pressure for flushing the tip, or a negative pressure for pulling solution into the tip. By disconnecting the microelectrode holder and attaching the tubing to a manometer, you can check the calibration against a standard.

A built-in alarm sounds to indicate maximum pressure. The alarm also sounds when the tip is blocked or electrical continuity is broken (*e.g.*, the microelectrode comes out of the solution, too little filling solution to cover the Ag/AgCl pellet, disconnected ground reference, *etc.*).

The piezoelectric pressure controller regulates internal pipette pressure by controlling air flow into and out of a small pressure chamber. A vacuum source is connected on the outlet side of the chamber, and a piezoelectric valve meters air entering the pressurized chamber. The residual volume of the pressure chamber includes the micropipette, the connecting tubing and the pressure transducer on the outlet side of the piezoelectric valve. The 900A accurately controls and adjusts the pressure in the chamber to match pressures applied externally to the microelectrode tip.

The response time of the piezoelectric valve is 0.5 ms from fully closed to fully open. Overall system response time depends largely on the amount of residual volume in the tubing. When this volume is small, the system responds very rapidly (typically 10 milliseconds).

The lightweight pressure controller pod may be mounted close to the microelectrode using small-bore tubing, to minimize system dead space.

Microelectrode holders MEH6RF and MEH6SF for 1.0 mm O.D. capillary glass included. (1.2, 1.5 and 2.0 mm also available — please specify when ordering.)

SYS-900A	Micropressure System

System price includes a one-day technical training session at WPI in Sarasota, Florida.

Specify line voltage

OPTIONAL ACCESSORIES

900AP	Replacement Probe
CAL900A	Pressure Calibration Chamber
3491	Probe Extension Cable
2933	Rack Mount Kit
5332	Replacement Liquid Trap
MEH6RF	Micropipette Holder (1.0, 1.2, 1.5 or 2.0 mm — Specify O.D.)
MEH6SF	Micropipette Holder (1.0, 1.2, 1.5 or 2.0 mm — Specify O.D.)
TIPTW900A	Prepulled Micropipette for 900A (1 mm thin-wall, 2 µTip) (pkg of 10)
900APP	Replacement Pressure Pod
SYS-PM015D	Pressure Manometer (15 psi)