UPGRADE REVISION JULY 2001

MODEL UCSD-16/32BA

ISOLATED BIOELECTRIC AMPLIFIER CUSTOM DESIGNED AND BUILT FOR RESEARCH FOR THE UNIVERSITY of CALIFORNIA at SAN DIEGO.

This system is battery powered for safety, AC isolation and reduced artifact. Sockets, switches and connectors use gold contacts for reliability. The BIOAMP features low-distortion/low-noise, hi 50/60~ rejection amplifiers with the best specs of any EEG/EMG BIOAMP available, foreign or domestic. In most cases this eliminates the requirement for shielded "SCREEN ROOM" environments, even in the presence of low-signal potentials. Optical and magnetic output coupling provides complete isolation from AC voltages and ground. Constructed as a portable battery-powered system, this BIOAMP conforms to AAMI/ANSI standard ES-1, 2.1 "ELECTRONIC MEDICAL APPARATUS WITH ISOLATED PATIENT CONNECTIONS". Additionally, ISO-GND lead current is automatically limited to 10 µA. System is factory expandable up to 132+ channels.

ISOLATED INPUTS

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EEG/EMG: TRUE DIFFERENTIAL; >1 Giga Ohms impedance. With a total of 32 active channels, this system is designed for connection to an SAI HEADBOX with a built-in digital impedance meter; and then for use with loose-lead electrodes and

/or an E-CAP. **Note that the headbox-to-bioamp cable *must be kept separated* from any radiating sources of interference such as AC power cords.**

CLAMPS: Input diff amps are overload-protected to +/- 625 V.

DIFFERENTIAL AMPLIFIERS

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DATA FILTERS; BUTTERWORTH TYPES

2-pole response, -12 dB/oct; -3 dB points.

HP: 0.01-0.1-1-10 Hz; common control of channels 1-30

HP: 0.01-0.1-1-10 Hz; separate control on each channel 31-32.

2-pole response, -12 dB/oct; -3 dB points,

LP: 15-30-100-1000 Hz; common control of channels 1-30

LP: 15-30-100-1000 Hz; separate control on each channel 31-32

GAIN: 5-10-20-50 x1000; common control of channels 1-30.

GAIN: 5-10-20-50 x1000; separate control on each channel 31-32

CENTERING: Automatically compensates for up to +/- 180 mV of offset due to electrodes.

BASELINE NOISE: **Noise referred-to-input (RTI) using BIOAMP cal-cable & CALIBRATOR @ OFF:**

0.68 µVpp, @ a BW of 0.01-100 Hz, measured with RMS VM, 10-10M Hz avgd/conv.

1.34 µVpp, @ a BW of 0.01-1000 Hz, measured with RMS VM, 10-10M Hz avgd/conv.

FOR NOISE TESTS SET GAIN AT x20000; AVGD/CONV INDICATES THE READINGS WERE TAKEN ON AN RMS METER, AVERAGED OVER 10 SECONDS AND THEN CONVERTED TO PP (multiply by 2.828)

CMRR: COMMON MODE REJECTION RATIO is ~106 dB, a 200000:1 reduction in 50/60 Hz noise; designed to eliminate data-distorting 50/60 Hz notch filters.

CROSSTALK: Worst case between channels at full output is better than 80db (10000:1)

CAL/TEST SIGNALS
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The following test signals are used in conjunction with a ***calibrator cable*** to confirm gain accuracy and overall operation: 16 Hz SINEWAVES at 20/100 µVpp (2%) and a 0V level (at OFF) used for checking base-noise levels of the BIOAMP.

Additionally, a 10 µV/200 ms PULSE is available, enabled locally by a push switch *and* externally by a TTl(+5V) command. Repetitive pulses, free-running at ONE pulse per second, can also be commanded by a front-panel switch.

LED MONITORS
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POWER: Indicates when power switch is on connecting battery to the power supplies.

FAIL: Will indicate when the BIOAMP has shut itself down; this due to multiple input overloads or opens, internal electronic failures or a battery voltage < +/- 5.60 V, any of which can produce distorted data signals unknown to the operator.

LOW-BATTERY : Will indicate if voltage is < +/- 5.75 V indicating a recharge is due within ~1/2 hr**;** this LED will *flash* when batteries are overloaded due to multiple *open inputs*.

ELECTRODE: MONITOR A LED for each channel will flag high DC levels-- indicative of a poor electrode connection, a lead-off or a problem within the BIOAMP.

REF: Indicates the intensity at which an ELECTRODE MONITOR must glow to indicate signal blocking-- a situation requiring electrode maintenance.

CONTROL INPUTS
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CAL COMMAND : A 0.1-10ms TTL pulse applied to this input will *trigger* one CAL-TEST pulse; this **input** is available at the **output** cable and on a front-panel BNC connector.

ISOLATED OUTPUTS
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ANALOG : Single-ended; optically/magnetically isolated from inputs; +/2.5V out of Sub-D connectors with limiting set at ~ +/-3.0V; output impedance ~200 ohms. An adaptor cable or BNC breakout box is supplied to interface to the user receiving device. Outputs will drive unshielded flat cables up to about 40 feet long without noise or oscillation; ***note that this output cable must be kept separated from radiating sources of interference such as AC power cords.***

STATUS: A consolidated TTL output "STATUS" line remotely flags: LEAD-OFF, LOW BATTERY, FAIL and POWER OFF; therefore when this line is low (0V / LED off), *one or more of these events has occurred.* This isolated TTL line is current limited @ 2 mA for direct-driving a STATUS LED indicator if desired.

POWER
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Uses +/-6V / 7.2A CIRCULATING / RECHARGEABLE batteries; draw is ~124ma.
The LOW-BATTERY indicator is calibrated to come on at 5.75 V and will allow the operator at least 30 minutes to change-out the battery. Run time before battery change-out is ~36 hrs. FUSES: two 1 A FAST-BLOW.

ALWAYS STORE BATTERIES FULLY CHARGED TO MAXIMIZE LIFE SPAN

THE CALIBRATOR TEST-SIGNALS ARE USED TO FUNCTIONALLY TEST THE BIOAMP AND THE ADC + COMPUTER SYSTEM; THESE TESTS SHOULD BE PERFORMED AFTER INITIAL INSTALLATION AND PRIOR TO RECORDING IMPORTANT DATA.

Internally generated test-signals are used in conjunction with a ***calibrator cable*** to confirm gain accuracy and overall BIOAMP performance**;** signal parameters are selected by adjusting the **CALIBRATOR** signal rotary switch making them available at the **CALIBRATION SOURCE** jack on the BIOAMP and on the HEADBOX (if used).

In all cases a CALIBRATOR CABLE *must be used for testing* and two types are available:

A **HEADBOX** cable is used when overall ***end-to-end system testing*** is desired, simulating system inputs (normally an E-CAP) and producing predictable CALIBRATOR test-signal outputs.

A **BIOAMP** cable is used to ***test the BIOAMP alone,*** without the HEADBOX connected. This BIOAMP test will determine if the failure is in the headbox and / or its cabling-- or due to the BIOAMP itself when the the system fails to function properly with the ***end-to-end*** HEADBOX calibrator test-cable

The following CALIBRATOR test-signals (2%) are generated by this BIOAMP:

0 µV OFF position on CALIBRATOR test-signal switch. (NOISE TESTING)
20 µVpp Sinewave at 16 Hz
100 µVpp Sinewave at 16 Hz
10 µVpk Pulse at 200 msec pulse-width; also free-running at 1pps.

There are two methods of producing the CAL-PULSE test-signal**:**

SINGLE PULSE: Enable by switching to REMOTE / MANUAL; then press the MANUAL button for a single CAL-PULSE; the red LED will indicate when a pulse is generated. This pulse can also be commanded with a TTL trigger (~1-10ms) injected back to the bioamp via the output cable. (see BIOAMP OUTPUT CONNECTOR PINOUTS manual sheet).

PULSE TRAIN: Enabled by switching to INTERNAL / AUTO; the pulse will now automatically occur at the specified interval.

If the amplified CALIBRATOR test-signal output signals appear distorted or noisy, perform additional tests found on the page entitled: “DETERMINING THE BIOAMP BASE-NOISE”.

Determine the bioamp ***baseline noise levels*** using an RMS responding VM connected ***direct*** to the outputs at the rear of the bioamp; note that this VM ***must have an AC grounded low-side input;*** if this ground is found to be missing or a floating DVM is used, ***make this connection*** and then proceed**.**

Connect-up the BIOAMP cal-test cable and select OFF on the CALIBRATOR switch; set the GAIN to **x20000** and bandwidth to **0.01 to 100 Hz** and turn-on POWER.

TOTAL BASELINE NOISE SPEC FOR UCSD-32 IS: 4.8 mV rms

An increase >x2 in noise level of ALL channels implicates the environment; an individual channel-- the BIOAMP itself.

Because the *battery-powered* SAI BIOAMP will usually prove to be OK, the system may have to be repositioned or moved to an alternate location for successful operation—a situation not uncommon.

Also see section titled: DATA INTERFERENCE PROBLEMS

GUIDE-LINES FOR COMBATING EXCESSIVE 50/60 Hz DATA NOISE

Call it 50/60 cycle/Hertz, RFI (radio-frequency interference), EMI (electro-magnetic interference) or just plain data noise, external influences degrading the performance of a bioelectric amplifier when working with micro-volt data signals can be difficult to solve-- especially when the problem originates from outside your sphere of influence. When encountering system problems, always reseat cable connectors and check cables for damage.

Since all SAI bioamps are battery powered, 50/60 Hz is not generated by this device. However it can be ***induced*** into the inputs and amplified to the outputs; for example ***induction*** will occur by running the headbox cable alongside an AC power cord; 50/60 Hz can also be induced into the ***output*** cable. Another mistake is leaving the headbox IMPEDANCE METER "ON" causing 30Hz data noise spikes.

The most common data-signal noise source is 50/60 Hz from the AC/mains. Typical situations include: defective (hi-resistance) or non-existent **AC/MAINs power grounds; AC power cords** placed near (less than 1-2 ft) the bioamp, its headbox or output cables and/or the source of the data signal (subject); **high-powered AC** devices such as space heaters, soldering irons, TV's, PC's, X-rays, E-C's; MRI's near the bioamp and related components; **fluorescent lighting** and *especially* those on **dimmer-type controls**-- even in the low and off positions; radio transmitters / antennas on land and on ships at sea, close to your facility, can cause periodic interference that may be next to unresolvable.

When excessive pickup occurs on a specific channel of a bioelectric amplifier, an electrode failure is fairly obvious and easy to correct; however noise problems which occur on ***all*** channels can be disconcerting and correcting this condition will be difficult unless a logical investigation is performed.

An SAI bioamp failure affecting the CMR of ***one channel*** is a possibility since this type of failure would be caused by the input diff-amp, a device subject to the outside world and thus subject to spike damage. (CMR is common-mode rejection, the ability of a bioamp to reject 50/60 Hz from the environment)

An SAI bioamp failure affecting the CMR of ***all channels*** is unlikely since this type of failure would cause it to stay in the FAIL mode-- a situation usually requiring major repair; therefore the user would not see an output of any kind.

Listed below are six primary reasons for an ***all channels 50/60 Hz*** problem:

1. The partial or total failure of the REFERENCE electrode connection due to the electrode or its wire; in an SAI bioamp, ***all*** MONITOR indicators will be on making the diagnosis easy.

2. Lighting fixtures and especially any control device used to vary light levels.

3. Bioamp and headbox cables running too close to AC power cords or AC powered devices.

4. Electronic devices radiating excessive 50/60 Hz due to failure, non-compliance or just heavy-draw (devices such as X-rays and e-cautery).

5. Facility/building AC/MAINS isolation transformers and AC/MAINS wiring inadequacies.

6. The absence of a proper AC power ground connection to the ***bioamp analog output-common***, a connection normally supplied by the signal-receiving device such as an ADC/computer, tape recorder, chart recorder etc; note that if a battery powered device such as a laptop/ADC is used, an external AC power ground connection ***to the ADC INPUT COMMON must be made.***

Working in a building that has grounding and other wiring failures may be difficult to solve; making a separate ground connection via a grounding rod may or may not solve the problem. For example, if another area in your building has wires crossed-up or defective appliances, it may cause excessive current to flow into ground-- and you now have big trouble because you would first have to ***correct someone else's problem*** to correct yours. Ultimately, however, the bioamp system may have to be moved to an alternate location for successful low-noise operation—a situation not uncommon.

PERFORM THE FOLLOWING TESTS :

Connect-up the BIOAMP cal-test cable and select OFF on the CALIBRATOR switch; set each GAIN to **X20000** and bandwidth to **0.01 to 100 Hz;** turn-on POWER and with an RMS voltmeter read the noise levels of several channels at the bioamp output connectors. These readings should not exceed the bioamp stand-alone ***baseline noise spec*** by a factor of ~x2 which figures to be **9.6mV rms.**

If excessive noise is proven to emanate from the bioamp system, attempt to minimize noise pick-up by repositioning the bioamp, (the headbox and their cables if applicable), turning-off neon lights and surrounding AC powered devices etc. The headbox or its cabling can also cause noise pickup if damaged and visual checks should be made at this time. If noise levels are excessive using the output cable, its routing should be repositioned for minimal pickup.

Unshielded headbox and E-CAP cabling (antennas) can pick-up excessive 50/60 Hz and RFI/EMI noise; adding a shield with a GND drain-wire and connecting it to the headbox cabinet (***only)*** can minimize this effect**.** Aluminum foil wrapped around strip cables, covered with mylar box-tape works well. This shield will also work for output cables which run near, but not on AC power cables. Connect the output cable drain-wire first to the bioamp box; then disconnect and tie it to the AC power ground; after taking noise readings, determine which termination works best and make the connection permanent.

Another situation which may occur is working in an area which is on a AC isolation system (transformer) such as medical facilities. If this is the case, SAI can supply a grounding system which will tie the bioamp cabinet to power ground or water pipe ground to minimize 50/60 Hz noise pickup. Because the bioamp and headbox cabinets are normally connected to the system battery-common (which is the ISO-GND)
via a 10Kohm resistor, this additional ground connection would normally bypass the isolation barrier. However, this is a special ground cable with an automatic safety self-resettable breaker built-in which opens-up if currents >10 µa flows, effectively maintaining the isolation of the BIOAMP system.

Various tests can be made to ascertain that ***your*** AC power socket is properly configured. The ***first check*** should be made using a neon-lamp test plug; this is available at hardware stores and also at RADIO SHACK (# 22-101 "AC OUTLET TESTER" --125v, in the USA). This device has a series of neon lamps, and depending on the sequence in which they glow, will indicate how the AC socket is configured.

However this device may not indicate a ***poor*** ground and if this tester passes the socket, continue to the next step.

The next check that should be made is to measure for any AC voltage at the AC power socket ***between the ground (green) and the neutral (white);*** these two points are normally tied together and grounded by the power company via a ground rod, usually down the side of the step-down transformer power pole, ***and*** at your building AC power distribution / meter panel (fuses / breakers). We find the normal reading at our lab bench sockets, ground to neutral, is a steady 10- 200 mVac using a FLUKE RMS DVM; when the ground to this bench is disconnected, it increases to several volts (fluctuating) due to the fact that the DVM leads are essentially open. We do not recommend using an ohmmeter here to check for this neutral/GND connection (would read 0 ohms) because any voltage that may appear here could damage your meter and of course this is a dangerous situation should you get yourself connected across any potential.

BACKGROUND INFORMATION

A BIOAMP/HEADBOX combination with the calibration signal patched into the headbox was set-up on a lab test-bench with a 5ft headbox to bioamp cable (unshielded) stretched-out. The resultant cal-signal outputs with various induced AC power defects were recorded on a GOULD chart recorder.

FIVE SITUATIONS WERE RECORDED:

1. The lab bench had proper AC power and grounds;
2. The bench AC ground was opened;
3. An isolation transformer was used between the AC power source and the lab bench with the AC ground passed thru (normal ground-connection configuration for an "isolation transformer")
4. The pass-thru iso-trans ground is disconnected;
5. Same as 4 except the headbox is moved close to bioamp; note that when the ground is missing, the distortion and AC pickup decreases when the headbox is near bioamp.

After these tests, it was concluded that a solid solution to AC/MAINS power/ground problems when the user is reluctant or unable to make corrections-- is to obtain an **isolation transformer** or a **power-line conditioner** ***with isolation*** and use it to power the receiving devices (PC's, recorders, scopes, etc.)

Try the iso-transformer or conditioner first with its pass-thru ground connection intact; then if AC pick-up is still a problem, the building ground is probably defective. For this situation break the ground connection at the iso-trans or conditioner ***output*** (isolator plug/socket adaptor -or- cut the ground wire); then run a wire from the receiving device (ADC etc) ground ***direct*** to a iron or copper water pipe; note that we did ***just this*** here in an SAI lab and with the iso-transformer and water-pipe ground and the data signals ***looked better than ever.***

Iso-transformers and AC line conditioners are available from, among others**:** computer stores, ALLIED, NEWARK, (none at RADIO SHACK here in San Diego). Again, note that ***line-conditioners are not isolators unless stated.***

And finally, if noise problems are caused by a large power-draw radiating device, ***separation or overall shielding of one or both are the only practical solutions.***

MFHB WIRING ASSIGNMENTS

CUSTOMER: UCSD
MODEL: UCSD 16/32BA

PIN #	WIRE #	CABLE A TO BIOAMP	ECAP CONN ( ) PIN #	CABLE B TO BIOAMP	ECAP CONN ( ) PIN #	CABLE C TO BIOAMP	ECAP CONN ( ) PIN #	CABLE D TO BIOAMP	ECAP CONN ( ) PIN #	CABLE E TO BIOAMP	ECAP CONN ( ) PIN #	CABLE F TO BIOAMP	ECAP CONN ( ) PIN #
1	1	CH 1-		CH 13 -		CH 25 -		PS COM					
14	2	CH 1 +	1 (A)	CH 13 +	7 (A)	CH 25 +	3 (B)	PS COM					
2	3	CH 2 -		CH 14 -		CH 26 -		+5V					
15	4	CH 2 +	14 (A)	CH 14 +	20 (A)	CH 26 +	16 (B)	+5V					
3	5	CH 3 -		CH 15 -		CH 27 -		PS COM					
16	6	CH 3 +	2 (A)	CH 15 +	8 (A)	CH 27 +	4 (B)	-5V					
4	7	CH 4 -		CH 16 -		CH 28 -		PULSE SIG					
17	8	CH 4 +	15 (A)	CH 16 +	21 (A)	CH 28 +	17 (B)	HI CAL					
5	9	CH 5 -		CH 17 -		CH 29 -		LO CAL					
18	10	CH 5 +	3 (A)	CH 17 +	9 (A)	CH 29 +	5 (B)	CAL COM					
6	11	CH 6 -		CH 18 -		CH 30 -		CAL COM					
19	12	CH 6 +	16 (A)	CH 18 +	22 (A)	CH 30 +	18 (B)						
7	13	CH 7 -		CH 19 -		CH 31 -							
20	14	CH 7 +	4 (A)	CH 19 +	10 (A)	CH 31 +	6 (B)						
8	15	CH 8 -		CH 20 -		CH 32 -							
21	16	CH 8 +	17 (A)	CH 20 +	23 (A)	CH 32 +	19 (B)						
9	17	CH 9 -		CH 21 -									
22	18	CH 9 +	5 (A)	CH 21 +	1 (B)								
10	19	CH 10 -		CH 22 -									
23	20	CH 10 +	18 (A)	CH 22 +	14 (B)								
11	21	CH 11 -		CH 23 -									
24	22	CH 11 +	6 (A)	CH 23 +	2 (B)								
12	23	CH 12 -		CH 24 -									
25	24	CH 12 +	19 (A)	CH 24 +	15 (B)								
13	25	N/C		ISO GND	13 (A)	ISO GND	13 (B)						
				REF	25 (A)	REF	25 (B)						

CHANNEL ALLOCATION & ELECTRO-CAP WIRING

Rev 7.26.01

Form UCSD-32

To order your E-CAP: specify which electrodes you desire connected to each BIOAMP channel by filling in the "Electrode" column. Include this form with your purchase order to Electro-Cap.

"A" E-CAP 25P FEMALE

CH#	PIN#	ELECTRODE
1	- 1	=
2	- 14	=
3	- 2	=
4	- 15	=
5	- 3	=
6	- 16	=
7	- 4	=
8	- 17	=
9	- 5	=
10	- 18	=
11	- 6	=
12	- 19	=
13	- 7	=
14	- 20	=
15	- 8	=
16	- 21	=
17	- 9	=
18	- 22	=
19	- 10	=
20	- 23	=
REF -	**25**	=
I-GND	**13**	=

"B" E-CAP 25P FEMALE

CH#	PIN#	ELECTRODE
21	- 1	=
22	- 14	=
23	- 2	=
24	- 15	=
25	- 3	=
26	- 16	=
27	- 4	=
28	- 17	=
29	- 5	=
30	- 18	=
31	- 6	=
32	- 19	=
.REF -	**25**	=
.I-GND	**13**	=
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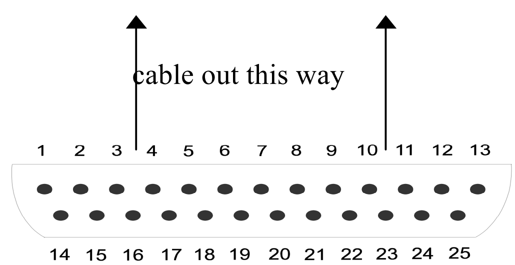
When specifying A1/M1 &/or A2/M2 as REF, they will be supplied as drop connectors: mating connector set with ~ 4" wire length. ISO-GND can also be specified as a drop, or if not-- indicate location in E-CAP.

Pg1 & Pg2 (retina-potential detection) if required, can also be drops **or** electrodes in the CAP (specify). If bipolar artifact signals (EOG, EMG, ECG etc) are required, channels will have to be reserved as these are direct inputs to the BIOAMP via an input headbox-- not normally thru the E-CAP; indicate **"RESERVED"** for these special channels.

THE E-CAP CABLE LENGTH IS: **SIZE: S M L**

E-CAP CABLE CONNECTORS: **Two** 25-P FEMALE SUB- D's: **A & B;** use this PIN# configuration looking at the wire-insertion **back-side** of the cable connector



SAI prefers to supply the E-CAP with the BIOAMP to facilitate a final TURN-KEY checkout of the BIOAMP system; otherwise an operable system at turn-on cannot be guaranteed. We can also rewire an existing E-CAP to the required configuration.

UCSD32UPEC