

BCI2000 g.USBamp Support

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1 Introduction

g.USBamp is an amplifier/digitizer combination from g.tec medical engineering GmbH / Guger Technologies OEG (<http://www.gtec.at>). This document describes support for this device in BCI2000, which consists of two components: A BCI2000-compatible Source Module (`gUSBamp.exe`) and a command-line tool (`USBampgetinfo`).

2 g.USBamp Hardware

The USBamp consists of 16 independent 24-bit A/D converters that can sample at up to 38.4kHz per channel. Because there is one A/D converter for each channel, one particular sample is digitized at the exact same time for each channel. This is unlike with traditional A/D converter boards that only have one A/D converter. BCI2000 has a feature that can align samples in time (parameter *AlignChannels* in Section *Filtering*). Because this feature is not needed in conjunction with the USBamp, it needs to be turned off (i.e., *AlignChannels* needs to be 0).

3 g.USBamp Source Module

The BCI2000-compatible Source Module `gUSBamp.exe` can be used instead of any other source module. In addition to standard parameters (i.e., *SampleBlockSize*, *SamplingRate*, *SoftwareCh*, *TransmitCh*, *TransmitChList*), it also contains the following parameters:

DeviceIDMaster Serial number of the master device. If you only have one device, this parameter has to equal *DeviceIDs*. If you have more than one device, then this parameter represents the serial number of the device whose SYNC goes to the slaves, i.e., the only device that has a cable connected at SYNC OUT, but none connected to SYNC IN. If only one device is connected, this parameter can be set to *auto*.

DeviceIDs List of serial numbers of all devices. If you have more than one device, this list determines the order of the channels in the data file. If only one device is connected, this parameter can be set to *auto*.

FilterEnabled Choose 1 if you want a pass band filter, and 0 if you don't. The gUSBamp is a DC amplifier and thus you most likely will want a pass band filter.

FilterHighPass High pass frequency for pass band. You need to query the amp for possible values. See description of the USBampgetinfo tool for more info.

FilterLowPass High pass frequency for pass band. See description of the USBampgetinfo tool for more info.

FilterModelOrder Model order for passband filter. See description of the USBampgetinfo tool for more info.

FilterType Type of passband filter. 1=CHEBYSHEV, 2=BUTTERWORTH

NotchEnabled Choose 1 if you want a notch filter, and 0 if you don't.

NotchHighPass Similar to FilterHighPass.

NotchLowPass Similar to FilterLowPass.

NotchModelOrder Similar to FilterModelOrder.

NotchType Similar to FilterType.

SampleBlockSize Samples per channel per digitized block. Together with the sampling rate, this parameter determines how often per second data are collected, processed, and feedback is updated.

SamplingRate The sampling rate of all connected USBamps. If one wants to use a bandpass or a notch filter, there needs to be a filter configuration for that particular sampling rate (see the section on the USBampgetinfo tool). (Guger Technologies can provide you with a new driver configuration file if you need a different filter.)

SignalType Defines the data type of the stored signal samples (int16 or float32). If the data type is int16, signal samples (which are produced by the amplifier in units of μV) are converted back into virtual A/D units (see Data Storage section below). If the data type is float32, the signals are stored in units of μV . In this case, SourceChOffset should

be 0, and SourceChGain should be 1 (since the conversion factor from μV into μV is 1).

SoftwareCh The total number of channels across all USBamp devices.

SoftwareChDevices The number of channels acquired from each device. If there is only one device, this parameter has to equal *SoftwareCh*. For example, '16 8' will acquire channels from the first device listed under *DeviceIDs*, and 8 channels from the second device listed under *DeviceIDs*. Data acquisition always starts at channel 1. The sum of all channels (e.g., 24 in this example) has to equal the value of *SoftwareCh*.

DigitalInput Turn on digital input. If turned on, the last sampled channel on each amplifier will contain sampled values of digital input 0 on the DIGITAL I/O input block on the back of the device. For example, if SoftwareCh is 8, then channels 1-7 will represent analog inputs, and channel 8 will represent the digital input. Thus, if DigitalInput is turned on, *SoftwareCh* and *SoftwareChDevices* may be a maximum of 17.

TransmitCh The number of channels that are transmitted to the BCI2000 Signal Processing module. See the BCI2000 Project Outline for further information.

TransmitChList The list of channels that are transmitted to the BCI2000 Signal Processing module. See the BCI2000 Project Outline for further information.

3.1 Data Storage

Unlike other systems, the USBamp is a DC amplifier system that digitizes at 24 bit. Bandpass and notch filtering is performed on the digitized samples, resulting in floating point signal samples in units of μV . BCI2000 currently supports signed 16 bit integers and floating point numbers for its data storage. If *SignalType* is set to int16, the floating point values have to be converted back into integers before they can be stored and transmitted to Signal Processing. This is done by the following transformation: $sample_{stored}(A/Dunits) = \frac{sample_{acquired}(\mu V)}{SourceChGain}$. (*SourceChOffset* is assumed (and required) to be zero for all channels.) BCI2000 Signal Processing or any offline analysis routine can derive, as with any other BCI2000

source module, sample values in μV by subtracting, from each stored sample, *SourceChOffset* (i.e., zero), and multiplying it with *SourceChGain* for each channel. If *SignalType* is set to float32, data samples are stored in units of μV . In this case *SourceCh* should be a list of 1's (because the conversion factor between data samples into μV is 1.0 for each channel).

4 The USBampgetinfo Command Line Tool

This command line tool displays all connected USBamps, including their serial number and the USB port that they connect to. Further, this tool reads, for the first of the connected amplifiers, all supported bandpass and notch filter configurations. Thus, this tool can be used to determine which filters can be used for a particular sampling frequency within BCI2000. The following is an example screen output:

```
*****
BCI2000 Information Tool for g.USBamp
*****
(C)2004 Gerwin Schalk
      Wadsworth Center
      New York State Department of Health
      Albany, NY, USA
*****
Amp found at USB address 1 (S/N: UA-200X.XX.XX)
Printing info for first amp (USB address 1)

Available bandpass filters
=====
num| hpfr  | lpfreq |  sfr | or | type
=====
000| 0.10 |    0.0 |   32 | 8 | 1
001| 1.00 |    0.0 |   32 | 8 | 1
002| 2.00 |    0.0 |   32 | 8 | 1
003| 5.00 |    0.0 |   32 | 8 | 1
004| 0.00 |   15.0 |   32 | 8 | 1
005| 0.01 |   15.0 |   32 | 8 | 1
006| 0.10 |   15.0 |   32 | 8 | 1
```

007	0.50	15.0	32	8	1
008	2.00	15.0	32	8	1
009	0.10	0.0	64	8	1
010	1.00	0.0	64	8	1
011	2.00	0.0	64	8	1
012	5.00	0.0	64	8	1
013	0.00	30.0	64	8	1
014	0.01	30.0	64	8	1
015	0.10	30.0	64	8	1
016	0.50	30.0	64	8	1
017	2.00	30.0	64	8	1
018	0.10	0.0	128	8	1
019	1.00	0.0	128	8	1
020	2.00	0.0	128	8	1
021	5.00	0.0	128	8	1
022	0.00	30.0	128	8	1
023	0.00	60.0	128	8	1
024	0.01	30.0	128	8	1
025	0.01	60.0	128	8	1
026	0.10	30.0	128	8	1
027	0.10	60.0	128	8	1
028	0.50	30.0	128	8	1
029	0.50	60.0	128	8	1
030	2.00	30.0	128	8	1
031	2.00	60.0	128	8	1
032	0.10	0.0	256	8	1
033	1.00	0.0	256	8	1
034	2.00	0.0	256	8	1
035	5.00	0.0	256	8	1
036	0.00	30.0	256	8	1
037	0.00	60.0	256	8	1
038	0.00	100.0	256	8	1
039	0.01	30.0	256	6	1
040	0.01	60.0	256	8	1
041	0.01	100.0	256	8	1
042	0.10	30.0	256	8	1
043	0.10	60.0	256	8	1
044	0.10	100.0	256	8	1

045	0.50	30.0	256	8	1
046	0.50	60.0	256	8	1
047	0.50	100.0	256	8	1
048	2.00	30.0	256	8	1
049	2.00	60.0	256	8	1
050	2.00	100.0	256	8	1
051	5.00	30.0	256	8	1
052	5.00	60.0	256	8	1
053	5.00	100.0	256	8	1
054	0.10	0.0	512	8	1
055	1.00	0.0	512	8	1
056	2.00	0.0	512	8	1
057	5.00	0.0	512	8	1
058	0.00	30.0	512	8	1
059	0.00	60.0	512	8	1
060	0.00	100.0	512	8	1
061	0.00	200.0	512	8	1
062	0.01	30.0	512	6	1
063	0.01	60.0	512	6	1
064	0.01	100.0	512	6	1
065	0.01	200.0	512	8	1
066	0.10	30.0	512	8	1
067	0.10	60.0	512	8	1
068	0.10	100.0	512	8	1
069	0.10	200.0	512	8	1
070	0.50	30.0	512	8	1
071	0.50	60.0	512	8	1
072	0.50	100.0	512	8	1
073	0.50	200.0	512	8	1
074	2.00	30.0	512	8	1
075	2.00	60.0	512	8	1
076	2.00	100.0	512	8	1
077	2.00	200.0	512	8	1
078	5.00	30.0	512	8	1
079	5.00	60.0	512	8	1
080	5.00	100.0	512	8	1
081	5.00	200.0	512	8	1
082	0.10	0.0	600	8	1

083	1.00	0.0	600	8	1
084	2.00	0.0	600	8	1
085	5.00	0.0	600	8	1
086	0.00	30.0	600	8	1
087	0.00	60.0	600	8	1
088	0.00	100.0	600	8	1
089	0.00	200.0	600	8	1
090	0.00	250.0	600	8	1
091	0.01	60.0	600	6	1
092	0.01	100.0	600	6	1
093	0.01	200.0	600	6	1
094	0.01	250.0	600	8	1
095	0.10	60.0	600	8	1
096	0.10	100.0	600	8	1
097	0.10	200.0	600	8	1
098	0.10	250.0	600	8	1
099	0.50	30.0	600	8	1
100	0.50	60.0	600	8	1
101	0.50	100.0	600	8	1
102	0.50	200.0	600	8	1
103	0.50	250.0	600	8	1
104	2.00	30.0	600	8	1
105	2.00	60.0	600	8	1
106	2.00	100.0	600	8	1
107	2.00	200.0	600	8	1
108	2.00	250.0	600	8	1
109	5.00	30.0	600	8	1
110	5.00	60.0	600	8	1
111	5.00	100.0	600	8	1
112	5.00	200.0	600	8	1
113	5.00	250.0	600	8	1
114	0.10	0.0	1200	8	1
115	1.00	0.0	1200	8	1
116	2.00	0.0	1200	8	1
117	5.00	0.0	1200	8	1
118	0.00	30.0	1200	8	1
119	0.00	60.0	1200	8	1
120	0.00	100.0	1200	8	1

121	0.00		200.0		1200		8		1
122	0.00		250.0		1200		8		1
123	0.00		500.0		1200		8		1
124	0.01		100.0		1200		6		1
125	0.01		200.0		1200		6		1
126	0.01		250.0		1200		6		1
127	0.01		500.0		1200		6		1
128	0.10		100.0		1200		6		1
129	0.10		200.0		1200		8		1
130	0.10		250.0		1200		8		1
131	0.10		500.0		1200		8		1
132	0.50		100.0		1200		8		1
133	0.50		200.0		1200		8		1
134	0.50		250.0		1200		8		1
135	0.50		500.0		1200		8		1
136	2.00		100.0		1200		8		1
137	2.00		200.0		1200		8		1
138	2.00		250.0		1200		8		1
139	2.00		500.0		1200		8		1
140	5.00		100.0		1200		8		1
141	5.00		200.0		1200		8		1
142	5.00		250.0		1200		8		1
143	5.00		500.0		1200		8		1
144	0.10		0.0		2400		8		1
145	1.00		0.0		2400		8		1
146	2.00		0.0		2400		8		1
147	5.00		0.0		2400		8		1
148	0.00		30.0		2400		8		1
149	0.00		60.0		2400		8		1
150	0.00		100.0		2400		8		1
151	0.00		200.0		2400		8		1
152	0.00		250.0		2400		8		1
153	0.00		500.0		2400		8		1
154	0.00		1000.0		2400		8		1
155	0.01		200.0		2400		4		1
156	0.01		250.0		2400		6		1
157	0.01		500.0		2400		6		1
158	0.01		1000.0		2400		6		1

159	0.10		200.0		2400		6		1
160	0.10		250.0		2400		6		1
161	0.10		500.0		2400		8		1
162	0.10		1000.0		2400		8		1
163	0.50		200.0		2400		8		1
164	0.50		250.0		2400		8		1
165	0.50		500.0		2400		8		1
166	0.50		1000.0		2400		8		1
167	2.00		200.0		2400		8		1
168	2.00		250.0		2400		8		1
169	2.00		500.0		2400		8		1
170	2.00		1000.0		2400		8		1
171	5.00		200.0		2400		8		1
172	5.00		250.0		2400		8		1
173	5.00		500.0		2400		8		1
174	5.00		1000.0		2400		8		1
175	0.10		0.0		4800		6		1
176	1.00		0.0		4800		8		1
177	2.00		0.0		4800		8		1
178	5.00		0.0		4800		8		1
179	0.00		30.0		4800		8		1
180	0.00		60.0		4800		8		1
181	0.00		100.0		4800		8		1
182	0.00		200.0		4800		8		1
183	0.00		250.0		4800		8		1
184	0.00		500.0		4800		8		1
185	0.00		1000.0		4800		8		1
186	0.00		2000.0		4800		8		1
187	0.01		500.0		4800		6		1
188	0.01		1000.0		4800		6		1
189	0.01		2000.0		4800		6		1
190	0.10		500.0		4800		6		1
191	0.10		1000.0		4800		6		1
192	0.10		2000.0		4800		8		1
193	0.50		500.0		4800		8		1
194	0.50		1000.0		4800		8		1
195	0.50		2000.0		4800		8		1
196	2.00		500.0		4800		8		1

197	2.00		1000.0		4800		8		1
198	2.00		2000.0		4800		8		1
199	5.00		500.0		4800		8		1
200	5.00		1000.0		4800		8		1
201	5.00		2000.0		4800		8		1

Available notch filters

```
=====
num| hpfr  | lpfreq |  sfr | or | type
=====
```

000	48.00		52.0		128		4		1
001	58.00		62.0		128		4		1
002	48.00		52.0		256		4		1
003	58.00		62.0		256		4		1
004	48.00		52.0		512		4		1
005	58.00		62.0		512		4		1
006	48.00		52.0		600		4		1
007	58.00		62.0		600		4		1
008	48.00		52.0		1200		4		1
009	58.00		62.0		1200		4		1
010	48.00		52.0		2400		4		1
011	58.00		62.0		2400		4		1
012	48.00		52.0		4800		4		1
013	58.00		62.0		4800		4		1