Shimmer3

Bridge Amplifier+ Expansion Board

User Guide

Revision 1.6

Legal Notices and Disclaimer

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1. Introduction

This document is an accompaniment to the *Shimmer Bridge Amplifier+ Expansion Board.* Its purpose is to aid the user in getting started with *Shimmer Bridge Amplifier+ Expansion Board*.

The *Shimmer Bridge Amplifier+ Module* contains a bridge amplifier, excitation source, and connector enabling force measurement with Shimmer. The expansion board is ideal for all load, weight, force, torque, and pressure measurements through the connection of a user-supplied strain gauge based bridge sensor or load cell. One application area is muscle capacity testing including pinch-grip, lift-bar, and grip-strength.

The Bridge Amplifier circuitry detects variance in resistance values when force is applied to the load cell. The small, lightweight, wearable form factor allows for measurements free from wired constraints to allow for natural range of motion, and measurement outside of a dedicated lab setting.

Additionally, the board has a connector and amplifier for Resistance measurement. For example, this can be used to measure data from a temperature sensor, like the Philips 21091A, or other resistance-based sensors with a range of 1kΩ - 20kΩ.

2. General Information

2.1. Pre-Requisites

- A *Shimmer3* device programmed with appropriate firmware.
  - *LogAndStream* (v0.6.0 or greater) can be used to simultaneously log data to SD card and stream data over Bluetooth.
  - *SDLog* (v0.12.0 or greater) can be used to log data to the SD card.
  - *BtStream* (v0.7.0 or greater) can be used to stream data over Bluetooth.
  - All are available for download from www.shimmersensing.com.
- A *Shimmer Bridge Amplifier+ Expansion Board*.
- A suitable strain gauge load cell or resistance-based sensor.

2.2. Bridge Amplifier+ Expansion Board Specification

- Bridge Amplifier:
  - Gain[1]: 183.7 ± 1% (Normal Channel), 551 (3x Normal) ± 1% (High Gain Channel)
  - Frequency Range[1]: DC..1kHz (Normal Channel), DC..100Hz (High Gain Channel)
  - Common Mode Rejection[1]: higher than 110dB
  - Input Impedance[1]: 50MOhm
  - Input Signal Range: ±7mV, ±2.5mV/V (Normal Channel), 0-4mV, ±1.43mV/V (High Gain Channel)
  - Zero-load Noise: 12mV RMS both outputs, < 1% full-scale (Normal Channel), < 0.5% full-scale (High Gain Channel)
  - Excitation Voltage[2]: 2.8V ± 5%
  - Input Protection: Current limiting, EMI/RF suppression
- Resistance Amplifier
  - Gain[1]: 10.1 +/-2%
  - Pull-up/Input Impedance: 200kOhms to +3.0V
  - Frequency Range[1]: DC..408Hz (2nd Order)
  - Signal Range: 280mV or 20kOhms (1kΩ-20kΩ measurement range recommended)
  - Zero-load Noise: 0.1 mV RMS at output.
- Connections: Two 3.5mm jacks (headphone type) for 4 conductor shielded cable for Bridge Amplifier and Resistance Amplifier,
- Current Consumption: < 100µA (Excitation disabled), 17mA (Excitation enabled[3])
- EEPROM memory: 2048 bytes.

[1] Calculated specification, exact value subject to environmental and component variation.
[2] The Excitation source is software controlled.
[3] This value is load-cell dependant, to estimate use the formula I = 1 + 2.8/(RSGin || RSGout); RSG data is available from the load-cell manufacturer.

3. Hardware Considerations

3.1. Board Layout and Connections

The board layout for the *Bridge Amplifier+ Expansion Board* is illustrated in Figure 3-1, whilst connections for the 3.5 mm jacks on the board and their corresponding functions are listed in Table 3-1 and Table 3-2. For details on the connections for J6 and J7, which connect the board to the *Shimmer3 mainboard*, please refer to the *Shimmer User Manual*, which can be downloaded from the Shimmer website.

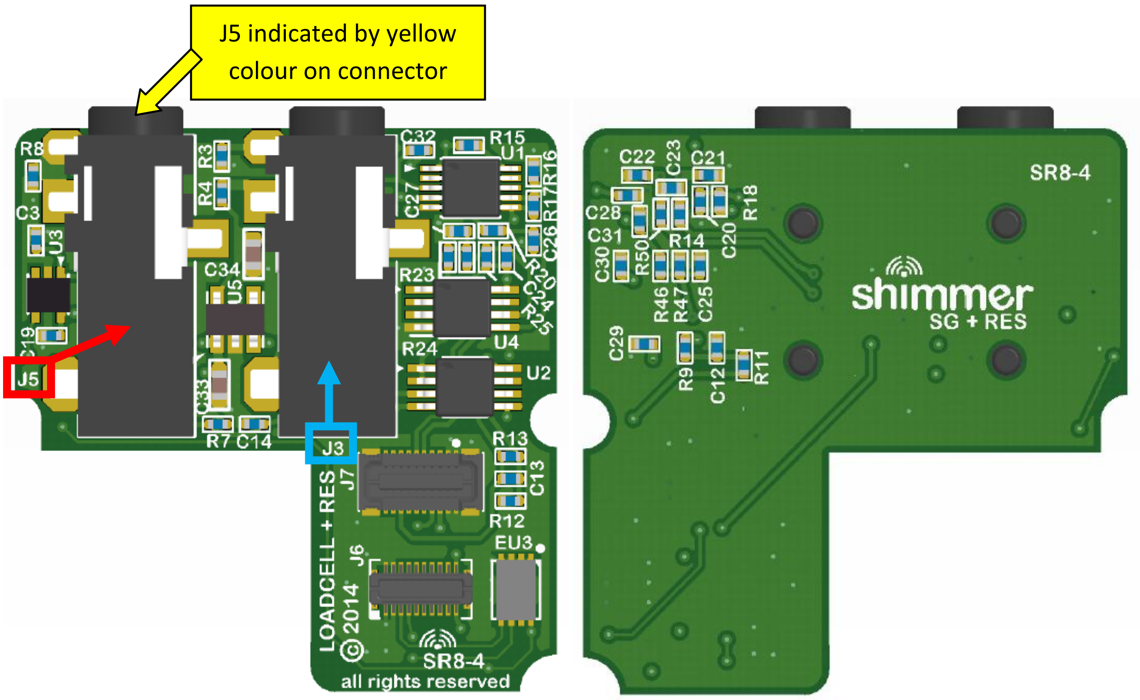

Figure 3-1 Board Layout for Bridge Amplifier+ Expansion Board

The 3.5 mm 4-position jack connectors, J3 and J5, (indicated in Figure 3-1) have four connections each, as labelled in Figure 3-2. Their connections are listed in Table 3-1 and Table 3-2.

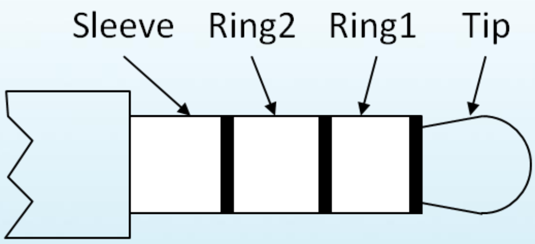

Figure 3-2 Connector labels for 3.5mm 4-position jack

Connector Pin #	Shimmer3 Label	Function / Notes
Sleeve (J3.1)	GND	Ground Connection
Tip (J3.2)	SGP	Signal (Positive)
Ring1 (J3.3)	SGN	Signal (Negative)
Ring2 (J3.4)	PV_SG	2.8V if GPIO_INTERNAL1 is high.

Table 3-1 Shimmer Bridge Amplifier+ Expansion Board connections for J3.

Important Note: Do not insert a two-position 3.5mm plug into the J3 connector as this may cause a short-circuit between PV and GND.

Connector Pin #	Shimmer3 Label	Function / Notes
Sleeve (J5.1)	GND	Ground Connection
Tip (J5.2)	SGN	RDIV1 (Signal)
Ring1 (J5.3)	GND	Ground Connection
Ring2 (J5.4)	GND	Ground Connection

Table 3-2 Shimmer Bridge Amplifier+ Expansion Board connections for J5.

Important Note: The pin-out of the J5 connector is not the same as that for other Shimmer3 expansion boards and is not compatible with Shimmer accessories, such as the Optical Pulse Sensing Probe.

A high quality four-position 3.5mm jack with cable is available for purchase from Shimmer. You can wire this connector to your load cell according to the connections in Table 3-1.

3.2. Output Signals

Table 3-3 below lists the ADC channel of the *Shimmer3* to which each of the output signals from the *Bridge Amplifier+ Expansion Board* is connected.

Signal	ADC channel	Function
Bridge Amplifier Low Gain	A14	bipolar pre-amplification
Bridge Amplifier High Gain	A13	additional 3x gain for unipolar load cells
Resistance Amplifier Output	A1	resistance pre-amplification

Table 3-3 ADC channels for Bridge Amplifier+ Expansion Board output signals

4. Using the Bridge Amplifier+ Module

4.1. Load Cell Calibration: Calculating Load

To convert the output of the Shimmer to a quantifiable unit you require:

- Output specification for the load cell device you are using in mV/V.
- Knowledge of the daughter board gain (Normal or High Gain Channel, see specification overview above).

The calculation procedure is:

1. Measure the ADC output difference (ADC_{DIFF}) between a zero-load reading and the reading of interest in your application. Referencing the actual zero-load reading obviates consideration of DC offset error.
2. Convert the ADC_{DIFF} into an analogue voltage difference (V_{DIFF}) in mV using a ratio

   3000mV / 4095bits = V_{DIFF} (mV)/ ADC_{DIFF} (bits)
   where 4095 is the resolution of the Shimmer 12bit ADC

   V_{DIFF} (mV) / = ADC_{DIFF} (bits) * 3000 mV/4095 bits

3. Divide the voltage by (2.8V x gain) to compute the load-cell output (LC_{OUT}) in mV/V

   LC_{OUT} (mV/V) = V_{DIFF} (mV) / (2.8V * gain)

4. Refer to the load cell calibration report or datasheet to determine the rated output (R_{OUT}) in (mV/V)/lb or (mV/V)/kg.

   LOAD = LC_{OUT} / R_{OUT}

Example Calculation:
The high gain output has a zero-output ADC value of 230. In a grip test using a Futek LMD500 the peak ADC value is 1430. What is the load in lbs?

(1) ADC_{DIFF} = 1430 bits – 230 bits = 1200 bits
(2) V_{DIFF} = 1200 bits * 3000 mV/4095 bits = 879 mV
(3) LC_{OUT} = 879 mV / (2.8V * 551) = 0.570 mV/V
(4) This calibration data for the LMD500 used has a rated output of 2.83mV/V @ 300lbs.
LOAD = 0.570 (mV/V) / (2.83(mV/V) / 300lbs) = 60.42lbs

4.2. Resistance Calibration: Calculating Resistance

For the Resistance amplifier channel, the relationship between the resistance at the input, Rs, and the voltage output, Vo, is as follows:

$$Rs = \frac{(200 * 10^3)Vo}{(10.1)Pv - Vo}$$

where Pv = 3V and Vo should be measured in volts.

5. Firmware Considerations

Note: This section is only of concern to persons wishing to modify the firmware.

Users with firmware development experience who wish to develop custom firmware for the *Bridge Amplifier+ Expansion Board* should follow the example provided in the BtStream application, source code for which is available on the Shimmer GitHub repository at https://github.com/ShimmerResearch/shimmer3/tree/master/apps.

Users should note that the excitation voltage for the load cell connection is enabled via GPIO_INTERNAL1. The amplifier for the Resistance input is enabled via Internal Expansion Power (EXP_RESET_N). See the *Shimmer3 User Manual* for more details on these pins.

6. Hardware Customisation

DISCLAIMER: We recognize the variation in gain and ranges of interest when performing research with load cells. Hardware customization is best discussed with our engineers at the time of order and executed by our factory.

7. Troubleshooting

7.1. Verifying Your Shimmer Bridge Amplifier Works

To verify the excitation output is working, simply activate the bridge amplifier input using software such as '*ShimmerConnect*' or *'Multi Shimmer Sync for Windows'* or *'Multi Shimmer Sync for Android'* and start streaming. Then, measure the excitation voltage using a voltmeter or multi-meter set to measure DC voltage. Place a probe on the PV_SG connection and another on the GND connection, whose locations are shown in Table 3-1. The voltmeter should read 2.8V +/- 5% if the excitation output is working.

To verify that the high gain and low gain channels are working as expected, a known signal, e.g. sine wave of amplitude <=4mV and frequency 0.5-1000Hz, should be input directly to the SIGP and SIGN connections. The bridge amplifier output signals should then be viewed using software as mentioned above.

The low gain channel uses bipolar pre-amplification, so a full replication of the input signal should be visible on the low gain plot. Because the high gain channel is unipolar, a signal which replicates the input signal, but is clipped for all values <0V, should be visible on the high gain output. Also, due to the differences in gain the amplitude of the high gain channel will be approximately 3 times that of the low gain channel.

In summary, if the excitation is functioning correctly and you can view a known signal on both the high gain and low gain channels, then your *Bridge Amplifier* is working. If you are experiencing any problems despite this, your load cell should be investigated.

7.2. Secure connection between Shimmer and expansion board

For any device purchased on or after September 1st, 2014, the *Bridge Amplifier+ Module* is permanently fixed to the *Shimmer3* mainboard. Removal of the expansion board from the mainboard should not be carried out under any circumstances. Doing so will cause damage to one or both of the boards and any necessary repairs will not be covered by warranty.

For devices purchased before September 1st, 2014, it was possible to disconnect the *Bridge Amplifier+ Module* from the *Shimmer3* mainboard. For these devices, Shimmer recommends an adhesive to secure the connection between the *Shimmer3* mainboard and Expansion Boards. The adhesive that is used by Shimmer during assembly is called Superdots (www.superdots.com). We use the Ultra Tak variety. With Superdots applied, the expansion boards can still be removed and swapped out, if required, as the adhesive does not go solid but has a rubbery consistency, allowing it to be removed. However, customers should remember that frequently removing expansion boards is not recommended and can cause damage to the connectors. Superdots also provides some shock absorbtion.

Shimmer fits the Superdots by stretching them around the edges of the Expansion Board. This ensures that the adhesive doesn't prevent the connectors from making a good connection and there is enough adhesive to secure the boards together but not to interfere with the fit. **Note**: Shimmer does not supply Superdots.

8. Appendices

8.1. Assembly

Opening the Bridge Amplifier+ enclosure

Whilst the *Shimmer3* enclosures can be opened to allow users to change the SD card, it is important to note that the plastic enclosures are not designed for regular opening and closing. In particular, it is recommended that the screws not be removed and reinserted on a regular basis as damage to the plastic by over-use of the screw mechanism will occur. Furthermore, the expansion board connectors can be damaged by disconnecting and reconnecting, resulting in the loss of communication with the expansion board.

For any device purchased on or after September 1st, 2014, the *Bridge Amplifier+ Module* will be permanently fixed to the *Shimmer3* mainboard. Removal of the expansion board from the mainboard should not be carried out under any circumstances. Doing so will cause damage to one or both of the boards and any necessary repairs will not be covered by warranty.

For devices purchased before September 1st, 2014, it is possible to disconnect the *Bridge Amplifier+ Module* from the *Shimmer3* mainboard. Please note, however, that this is not recommended.

In either case, if the enclosure must be opened to replace the SD card, care must be taken not to damage the expansion board connection. Please refer to the Shimmer assembly video on our YouTube channel[4].

8.2. Recommended accessories

Philips 21091A Technical Data

Please follow this link[5], register and search for the Philips 21091A skin-surface temperature probe for more information, which is recommended for use with the Resistance Amplifier input of the *Shimmer Bridge Amplifier+ Expansion Board*. This skin temperature probe can be purchased on the Shimmer e-store[6].

The following approximate resistance values have been measured by Shimmer:

Temperature (°C)	Resistance (kΩ)
-18 (approx - freezer)	16.8
10	9.3
26	4.5
37 (approx - body temp)	1.5
80	0.55

Table 8-1 Shimmer Bridge Amplifier+ Expansion Board connections for J5.

The accuracy of the probe is quoted as ± 0.1 °C (25-45 °C), ±0.2 °C (0-60 °C).

[4] http://youtu.be/jcuB4yVEBWI
[5] https://estore.healthcare.philips.com/b2b_store/b2b/z_init.do
[6] http://www.shimmersensing.com/shop/skin-surface-temperature-probe#related-tab

Shimmer performed an in-house calibration of the resistance amplifier output with the Philips 21091A skin-surface temperature probe inserted using Vernier's Direct-Connect Temperature Probe[7]. Shimmer found the relationship between the resistance amplifier channel output and temperature in °C to be logarithmic. To convert the resistance amplifier output from mV to °C based on Shimmer's in-house calibration, apply the following formula:

y = -27.42ln(x) + 56.502

Where y = temperature in °C
Where x = (200*Vo)/((10.1)Pv-Vo)
Where Pv = 3000mV
Where Vo = Uncalibrated output of the resistance amplifier channel

Note: For a more accurate resistance to temperature (°C) conversion users are advised to calibrate the resistance amplifier output against two temperature measurement systems.

8.3. How to Connect a Wheatstone Bridge to the Shimmer Bridge Amplifier

A full bridge arrangement is used for connecting strain gauges and measuring strain. Section 2.2 lists the input signal range.

Based on the deflection of your sensor you will want to choose resistance values to best match with our front end gain:

- Normal channel: ±7mV, ±2.5mV/V
- High Gain channel: 0-4mV, ±1.43mV/V

In general use, you should use the highest resistor values that you can as they lower system power consumption but you need to consider the equivalent resistance of your pressure sensor.

Referring to Table 3-1 and Figure 3-2, the top/bottom of the bridge would go to the PV_SG/GND signals and the output would be SIGP/SIGN.

It is recommended that users review the principles of bridge operation using online resources. The following serves as a good introduction: http://www.sensorland.com/HowPage004.html.

[7] http://www.vernier.com/products/sensors/temperature-sensors/dct-din/

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