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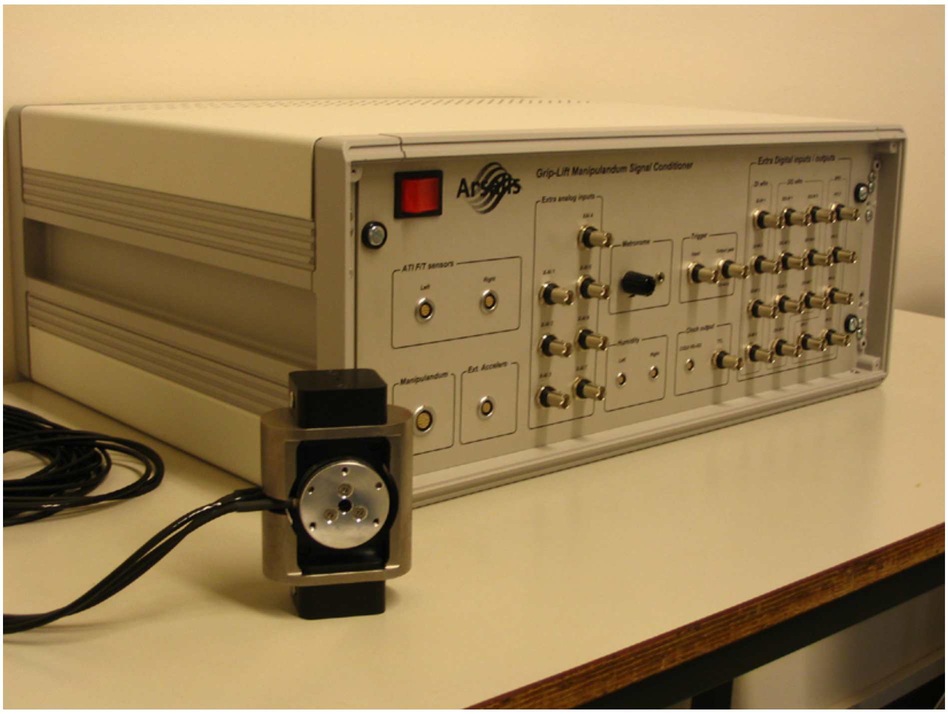
ESAGLM MEv2

Grip-lift manipulandum with capacitive moisture measurement

User's Guide



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CHANGE RECORD

Iss.	Rev.	Date	# Pages	Affected Pages	Description
A	0	April 2007	48	All	First issue.
B	0	07/11/2011	54	All	- Re-format the whole document (MAN) - Text about the High-G accelerometer and Gyroscope was deleted. It was replaced by text about the moisture sensor. - Figure 5 and Figure 6 were updated -Section 5.2 was added in order to describe the MEv2 (moisture sensor) - Section 6.1.2, figure 14 and Table 3 were updated in order to describe the new 19-pin LEMO connector and the connections - Table 4 was updated - Update section 4.1 and add figure of ATI referential. - Add section 8: Parameter calculations for the GLM. - Update section 9: Description of the GLM data acquisition software. - Add list of Figures and list of Tables.
C	0	26/07/2017	vi + 56	2	Update MEv2 and IMU introduction
				10	Update GLM IMU transducers description
				12-13	Update MEv2 transducers description
				16-18	Update GLM IMU inputs to SCU
				23-24	Update Table 6: channel list
				34	Update software setup AI, update figure 21.
				36-38	Update software DO setup text and figure 23.
				61	Added section 9.11: MEv2 Verification Utility.

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1. Introduction

The grip-lift manipulandum is a device designed to study the motor control of the precision grip in humans. The motor control of the precision grip relies on the coordination of the grip force (i.e. the force applied by between the thumb and index fingers on an object) and the load force (i.e. the apparent weight of the object) when manipulating an object in space. The instrumented object manipulated by the subject is called the manipulandum or grip-lift manipulandum (GLM). The experimental setup is designed to be used in altered gravity fields (0 – 2g environments), although it can be used in a conventional gravitational environment (1g) as well. The experimental setup is composed of the grip-lift manipulandum, an environmental accelerometer, a signal conditioner and peripheral devices controlled all together by the data acquisition system. This document presents the requirement specifications for all components of the experimental setup, then describes each component and provides information on how to use the experimental setup.

2. Requirement specifications of the grips-lift setup

2.1. Mechanical requirement specifications

The grip-lift manipulandum is designed to meet the following mechanical specifications:

- basic mass of 200 grams;
- have a set of 3 additional weights allowing for a total mass of 400, 600 and 800 grams; the position of the center of gravity of the loaded manipulandum remains unchanged;
- have a set of additional weights allowing for the position of the center of gravity of the loaded manipulandum to be changed in order to generate an inertial torque around the grip axis varying between 0 and 50 Nmm when the manipulandum is moved;
- have a distance between the thumb and index as close as possible to ca. 30mm, so generating the uniformly distributed around the center of gravity of the manipulandum.

2.2. Instrumentation requirement specifications

The grip-lift manipulandum is to be instrumented with the following transducers:

- two three-dimensional Mini-40 force and torque sensors (ATI Industrial Automation, Apex, NC , USA), one located under the index and one under the thumb of the subject;
- a three-dimensional accelerometer for measuring acceleration of the GLM due to smooth, though potentially rapid, movements;
- a one-dimensional accelerometer for measuring acceleration of the GLM due to shocks in vertical direction;

- a three-dimensional rate gyroscope for measuring the rotational speed of the GLM around its three main axis of symmetry;
- one probe on each force and torque sensor that measure the humidity under each fingerpad
- a set of four micro infrared LED (CODA micro markers) that will allow the GLM's position to be measured in the 3D space.

2.3. Peripheral requirement specifications

Several peripherals are used either to control the experimental protocol or to monitor the experimental variables. The following peripherals are to be integrated with the data acquisition system:

- an external accelerometer is used to measure the three-dimensional environmental gravity field ranging from 0 to 2g;
- a programmable metronome is used to set the movement frequency for cyclic movements;
- buffered digital lines are used to control light emitting diodes (LED) used as the target movement targets;
- the position of the manipulandum in space is measured with a kinematics acquisition system such as the CODA motion system (Charnwood dymamics Ltd, Leicestershire, UK);
- the orientation of the gaze is measured with the Chronos eye tracking system (Chronos Vision GmbH, Berlin, Germany);
- the humidity of the thumb and index fingers, influencing the friction coefficient between the fingers and the GLM, is measured with two isolated capacitive circuits , namely the Moisture Evaluator version 2 circuit (MEv2).

2.4. Signal conditioning and data acquisition requirement specifications

The signals of the manipulandum transducers and the peripheral devices are treated by a signal conditioner connected to a data acquisition system, which is controlled by data acquisition software.

The following specifications are applied to the signal conditioner:

- two ATI interface boards are included for controlling the 2 Mini-40 F/T sensors (ATI Industrial Automation, Apex, NC, USA);
- each analog input is equipped with a Bessel 4-pole low pass filter with a cutoff frequency of 400 Hz;
- one buffered digital input is used to trigger the data acquisition externally;
- buffered digital outputs are used to control the programmable metronome and the target LEDs;
- one digital output is used to trigger each frame of the CODA motion analysis system from the main signal conditioner;

- one digital output is used to provide a gate-type trigger signal for the Chronos eye tracking system;
- an interface board (called the MEv2 Daughter Board) is included for adequately redressing and adjusting (gain & offset) the two-channel finger humidity measures.

The following specifications are applied to the data acquisition system:

- provide enough analog and digital inputs to acquire all the signals;
- provide enough digital outputs for controlling the peripherals;
- be able to trigger data acquisition from an external TTL signal;
- be able to trigger another data acquisition system with a TTL signal;
- provide a specific strobe circuitry to trigger each frame of the CODA motion analysis
- be able to sample all signals at a minimum rate of 1kHz;

2.5. Data acquisition software requirement specifications

A custom software controls the data acquisition system. The software needs to ensure the following functions:

- calibrate the signals from the GLM accelerometers and from the environmental accelerometer;
- set up the data acquisition given the selected peripherals;
- view input signals for monitoring purposes;
- acquire signals according to a selected setup and save acquired traces;
- read and display acquired traces;
- log all major events in a log file.

3. Description of the grip-lift manipulandum

Various design options have been discussed in periodic meetings along the development period. The meeting minutes are included in appendix. The following paragraphs describe the final prototype of the GLM.

3.1. Mechanical description of the grip-lift manipulandum

The grip-lift manipulandum (GLM) is composed of different mechanical parts assembled with screws (Figure 1). The GLM is made of two half shells. These shells are hollow in order for additional transducers to be embedded. Each half shell supports one force and torque transducer and is terminated by a flange allowing for the covers or the additional weights to be mounted onto the GLM. The grip-lift manipulandum is composed of the following parts:

- Two half shells: hollow body structure supporting each ATI Mini 40 F/T sensor, allowing for printed circuit board (PCB) with accelerometers and moisture sensors to be embedded. The half shells are machined in 7075-aluminium; the drawings are presented in appendix.

- Two covers: hollow square cover containing two CODA micro markers and the drive circuitry used to locate the GLM in space. Each cover has a LEMO 4-pin connector to plug the markers into the CODA system. The covers are mounted to the half shell flanges with screws. The covers are machined in 7075-aluminium; the drawings are presented in appendix.

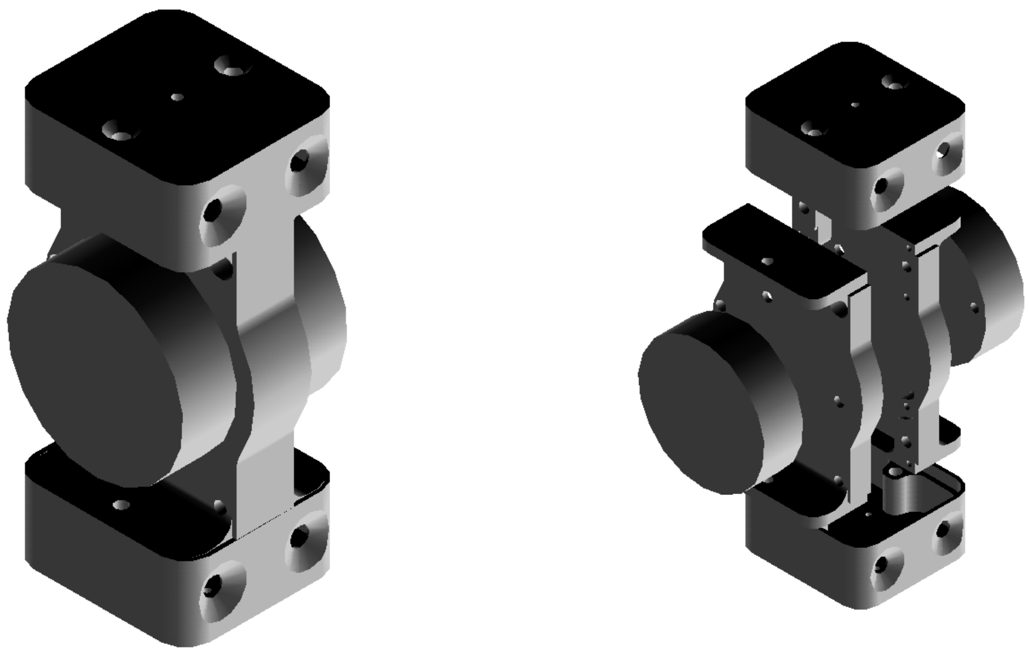


Figure 1. Assembled (left panel) and exploded view (right panel) of the GLM. The two cylinders located at each side of the GLM represent the ATI Mini-40 force and torque transducers.

The overall distance between the grip surfaces, including the two forces and torque sensors, is of 37.5mm. In its minimal configuration, the overall dimensions of the GLM are 91 x 37.5 x 48 mm (height, width, depth). Its basic weight, including all instrumentation as presented below, is of 262 grams with the covers and 194 grams without the covers.

3.2. Mechanical description of the additional weights

Three ranges of additional weights are available for the grip-lift manipulandum. These weights increase the mass of the GLM from a base mass of approx. 200 grams up to 400, 600 and 800 grams. The mini- and small-weights are designed to increase the mass of the GLM but keeping its center of mass in the center of the grip axis (i.e. the axis of the cylindrical force and torque transducers by which the GLM is grasped). The big-weights are designed to generate a (gravitational and) inertial torque around the grip axis when the GLM is manipulated, by off-centering their center of mass from the grip axis.

3.2.1. The mini-weight

The mini-weight is a single weight of approx. 600 grams, which brings the total mass of the GLM to approx. 800 grams (Figure 2). The mini-weight is machined as one single piece of steel in order to concentrate as much mass as possible close to the center of gravity of the GLM. The overall dimensions of the GLM with the mini-weight are 107 x 38.5 x 69 mm (height, width, depth); the drawings are presented in appendix. This design allows an ergonomic grasp of the GLM even for a subject with a small hand, such as a child. The mini weight is mounted between the GLM half shells and the covers, so the GLM can be located in space via the markers built in the covers.

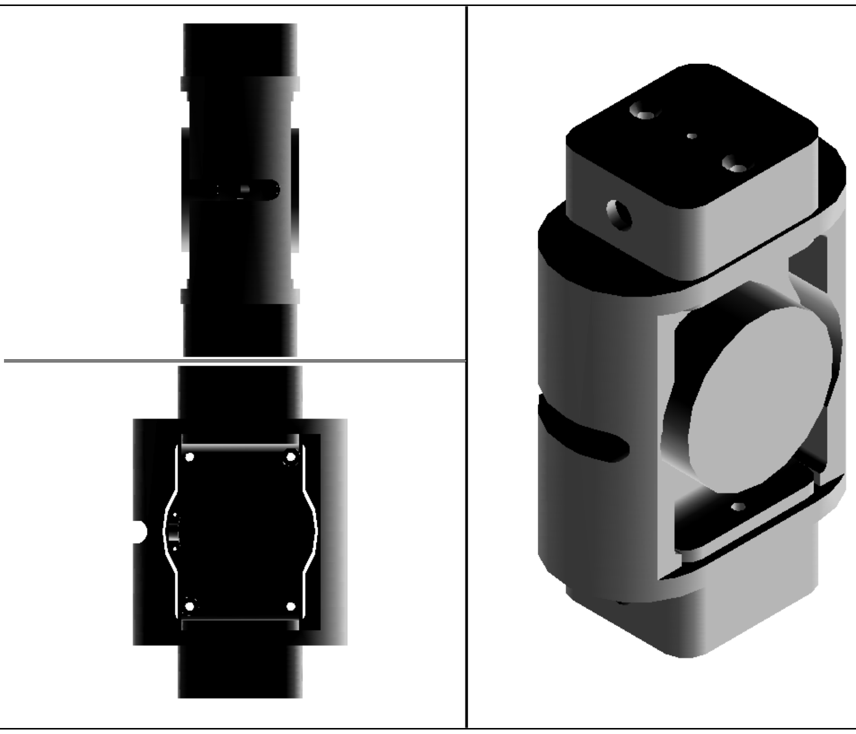


Figure 2. Back view (top left panel), side view (bottom left panel) and isometric view (right panel) of the mini-weight mounted on the GLM.

3.2.2. The small-weights

The small-weights are a range of three weights of approx. 200, 400 and 600 grams, which bring the total mass of the GLM to approx. 400, 600 and 800 grams (Figure 3). The three small-weights have exactly the same visual appearance they can be interchanged without the knowledge of the subject. Moreover, the small-weights feature a double press screw allowing for a quick assembly and disassembly on the GLM. The small weights are composed of different parts described in Table 1. All parts of the small weights are machined in 7075-aluminum, except for the press screw machined in brass to increase its friction coefficient with aluminum. A series of 3 holes are drilled in each corner of the small-weights. These holes are left empty in the 200-gram weight and are filled with high-density (approx. 14900 kg/m³) tungsten carbide rods in the 400- and the 600-gram weights.

Table 1. Description of small weights assemblies.

<table>
<tr><th>Base structure</th><th>Common parts</th><th>Rod inserts</th><th>Total weight*</th></tr>
<tr><td>Small-weight 200 (189.3g)</td><td rowspan="3">2 x press screw (11.5g)
2 x brass nut (23.2g)
4 x big hole covers (1.3g)
8 x small hole covers (0.4g)</td><td>none</td><td>460.9g</td></tr>
<tr><td>Small-weight 400 (217.7g)</td><td>4 x dia.10 x 22 mm rod (25.8g)
8 x dia.6 x 22 mm rod (9.3g)</td><td>666.5g</td></tr>
<tr><td>Small-weight 600 (172.7g)</td><td>4 x dia.14 x 29 mm rod (64.2g)
8 x dia.8 x 29 mm rod (21.0g)</td><td>869.0g</td></tr>
<tr><td colspan="4">* Theoretical weight including the GLM without covers (194g).</td></tr>
</table>

The overall dimensions of the GLM with the small-weight are 97 x 38.5 x 74 mm (height, width, depth); the drawings of all parts are presented in appendix. The design of the small weight also allows an ergonomic grasp of the GLM even for a subject with a small hand, such as a child. The small weights are mounted and dismounted around the GLM without covers by sliding them laterally. Two grooves are machined on the top and bottom surfaces for the CODA mini markers to be glued on each small weight, allowing the GLM to be located in space.

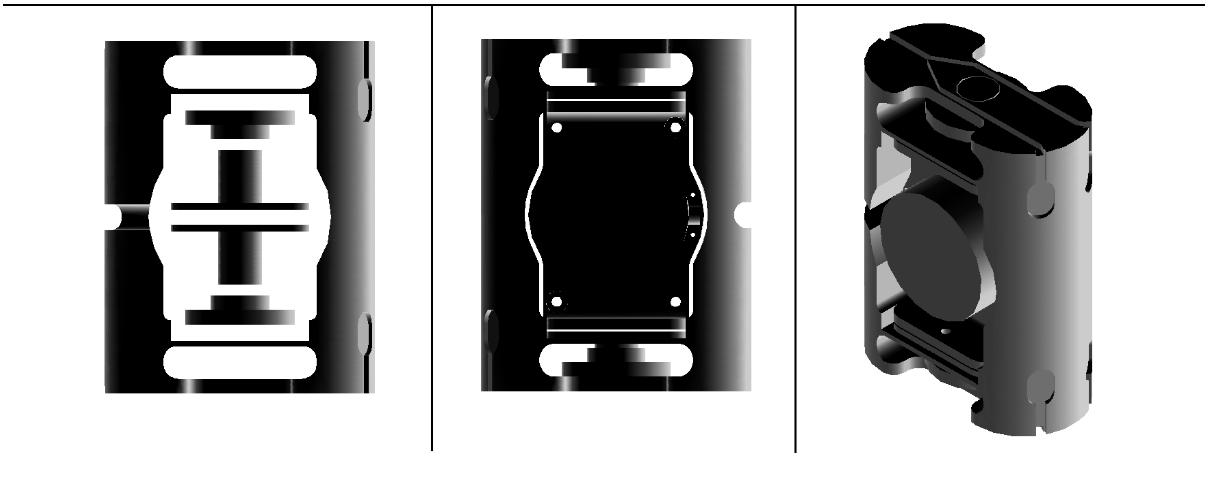


Figure 3. Exploded view (left panel), side view (middle panel), and isometric view (right panel) of the small-weight mounted on the GLM without covers.

3.2.3. The big-weight

The big-weight is a made of a three-arch structure mounted around the GLM without covers, allowing a (gravitational and) inertial torque to be generated around the grip axis when the GLM is manipulated. This weight is designed to generate a torque while keeping the mass of the object as close as possible to its basic mass (Figure 4). Two posted are screwed on the flanges of the half shells; three arches are then mounted on the posts to define a spherical envelope with a 100mm radius. Inertial masses of either 25 or 50 grams can be placed anywhere on the arches to generate a torque around the grip axis. The drawings of all parts are presented in appendix. All parts of the small weights are machined in 7075-aluminum. The big weight is designed so that the GLM can be grasped between the two proximal arches. The big weight is mounted and dismounted around the GLM without covers by (un)fastening two screws from the GLM flanges. The GLM can be located in space by placing CODA mini markers anywhere on the arches of the big weight.

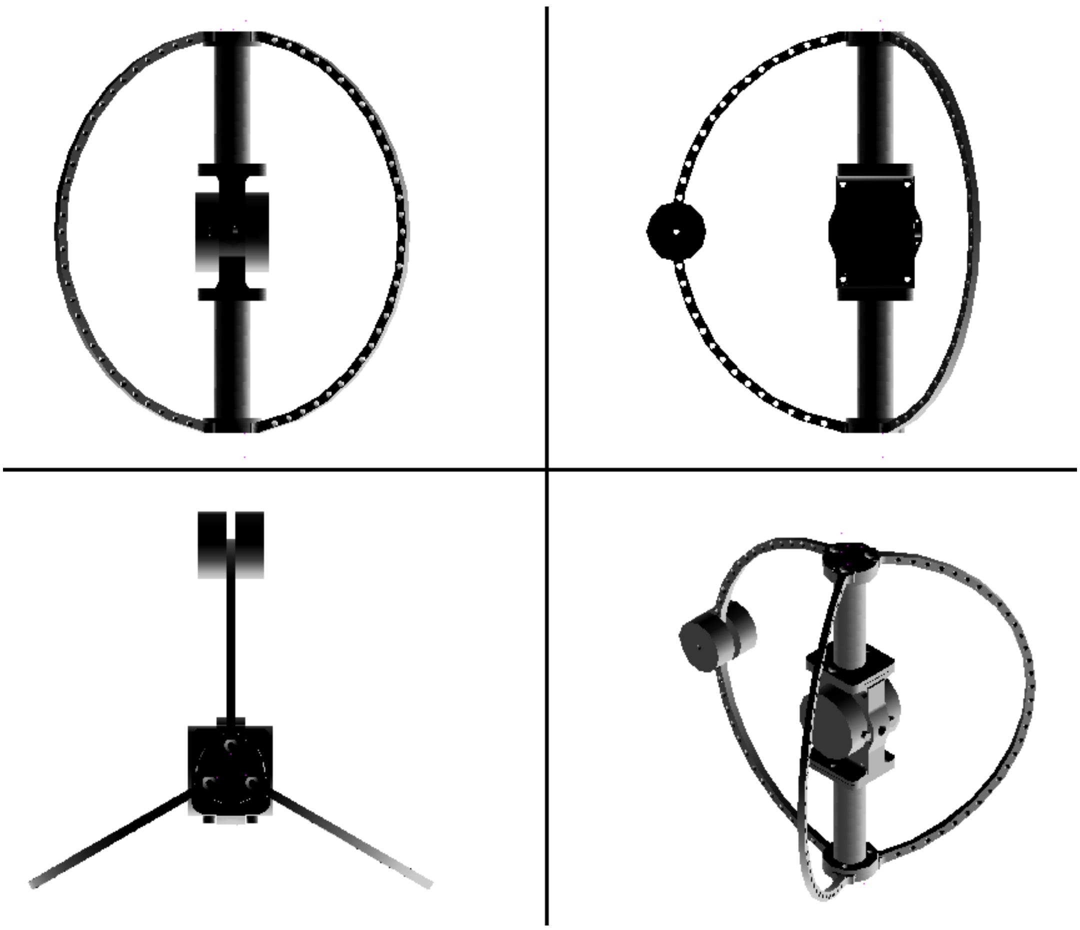


Figure 4. Front view (top left panel), side view (top right panel), top view (bottom left panel) and isometric view (bottom right panel) of the big-weight mounted on the GLM without covers.

3.3. Experimental setup overview

An experimental rack has been built to test the GLM hardware and implement experimental protocols either in a parabolic flight campaign or in a laboratory. An overview of the GLM experimental setup is presented in Figure 5. All transducers are either mounted inside the GLM or on the experimental rack. The GLM transducers and all peripherals, except the CODA markers and the Chronos helmet, are connected to the main signal conditioner. The signal conditioner is fitted in a 19-inch rack mount enclosure; it contains the analog and digital circuitry interfacing the transducers to the data acquisition system. Analog and digital signals are directed to a Compact DAQ (National Instruments) data acquisition system equipped with one 32-channel analog input module and three 8-channel digital input/output modules. Moreover, a dual port RS422 PCI board is fitted in the main PC to receive the signals from two CODA cx1 sensor units. A description of the CODA motion system hardware is presented further in this user guide.

The main personal computer (PC) controls the data acquisition hardware. The main PC runs GLM data acquisition software which controls the main acquisition loop and the CODA software which collects kinematic data. A second signal conditioner and PC are dedicated to the acquisition of the Chronos eye tracking system (not described in this user guide).

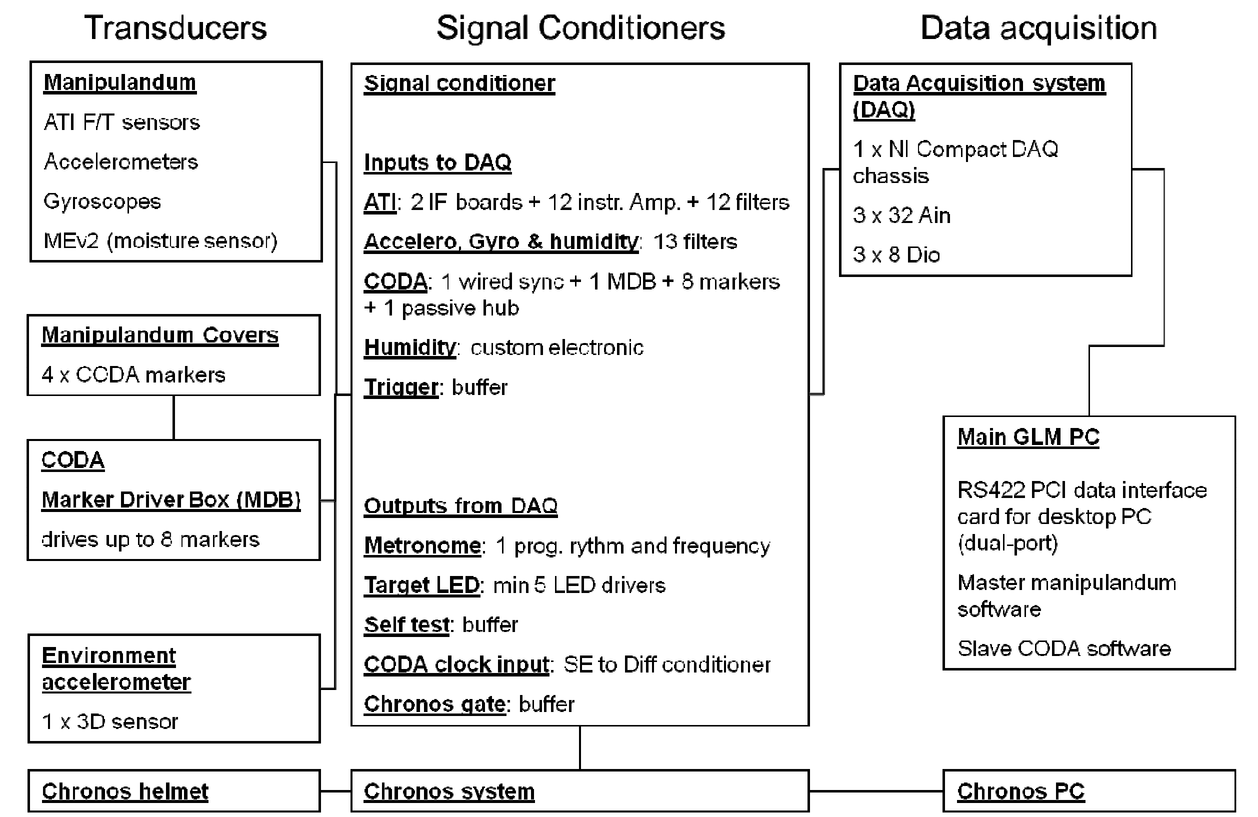
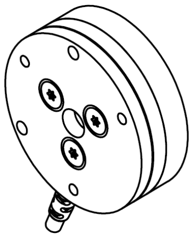


Figure 5. Overview of the GLM experimental setup.

4. Description of the GLM instrumentation

Various transducers are implemented to meet the instrumentation and peripheral specification requirements. The instrumentation is described in the following paragraphs.

4.1. ATI Mini-40 force and torque sensors



The grip-lift manipulandum is equipped with two ATI Mini-40 force and torque transducers. The SI-40-2 calibration has been selected as well as a +/- 5V output range to be used with an ATI-IF-OEM3 power and signal conditioning board. Each sensor delivers 6 channels of force and torque under each contact surface and is delivered with a factory calibration.

The F/T sensors are mounted back to back, with their mounting side fixed to the GLM structure, and such that both cable exits be aligned. This implies that their frames of references are rotated of 30 degrees relative to the GLM frame of reference (see Figure 6). The sensor rotation and the calibration factors of each sensor are taken into account in the data acquisition software in order to compute the applied forces and torques, and especially the load force.

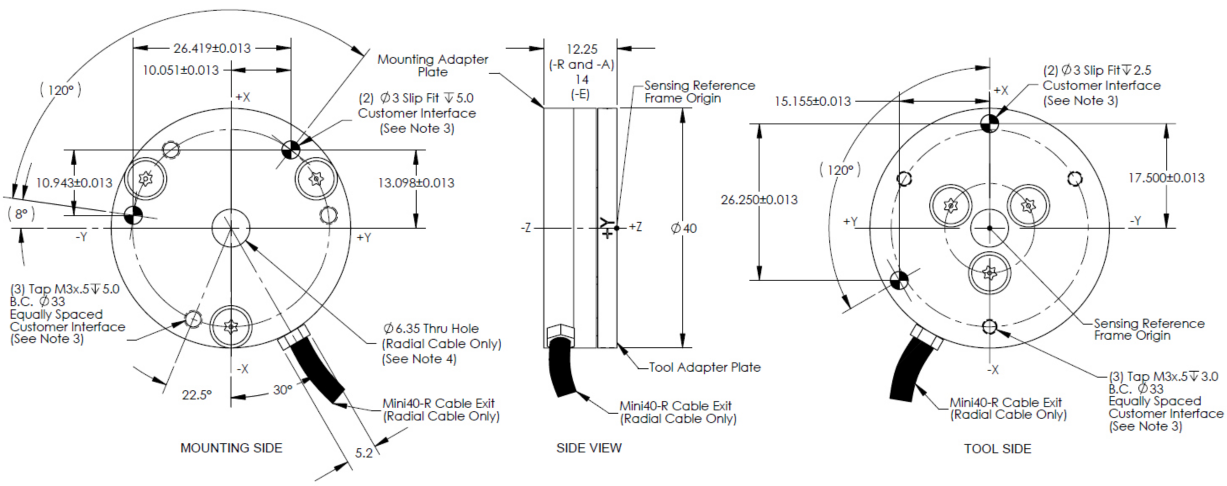


Figure 6. Drawings and reference frame of the MINI-40 force and torques sensor.

4.2. GLM inertial transducers

A printed circuit board (PCB) is fitted to the internal cavity of the half shells of the GLM. The PCB is presented in Figure 7. The PCB features a +/- 3g tridimensional accelerometer (Analog Devices, ref. ADXL335),, two 300°/s bidimensional rate gyroscope (STMicroelectronics, ref. LPY430AL) and one +/- 35g unidimensional accelerometer (Analog Devices, ref. ADXL78) The PCB delivers a buffered output for each transducer to the GLM signal conditioner. The schematic and board layout of the PCB as well as the datasheet of the transducers are presented in appendix.

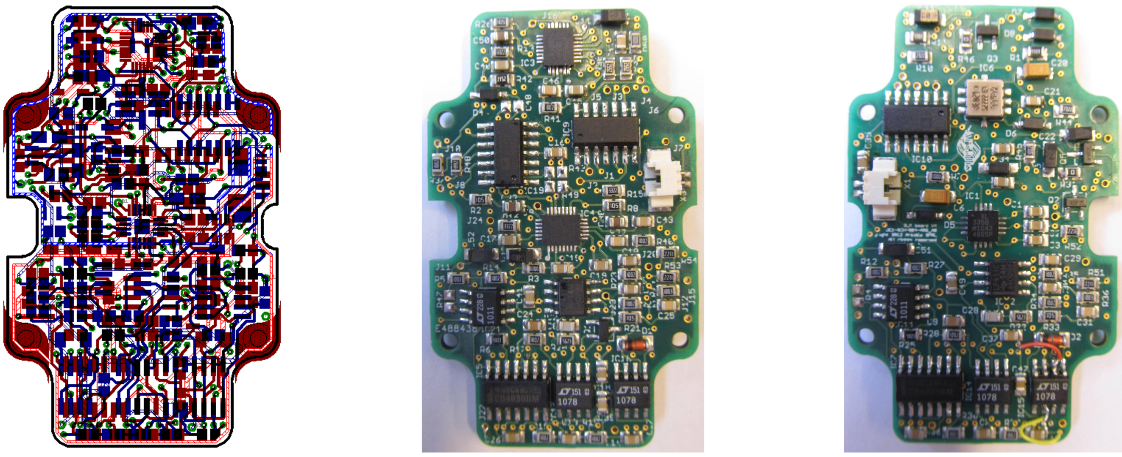


Figure 7. Board layout (left panel), top view (middle panel) and bottom view (right panel) of the PCB fitted inside the GLM.

4.3. CODA markers

A printed circuit board (PCB) is fitted to each cover of the GLM. The PCB contains the driver circuitry for a pair of CODA markers as provided by Charnwood Dynamics (see documentation in appendix). Each cover is equipped with a 4-pin LEMO 00-series connector that receives two markers cables from the CODA marker drive box. The connector pin-out and PCB layout are presented in Figure 8.

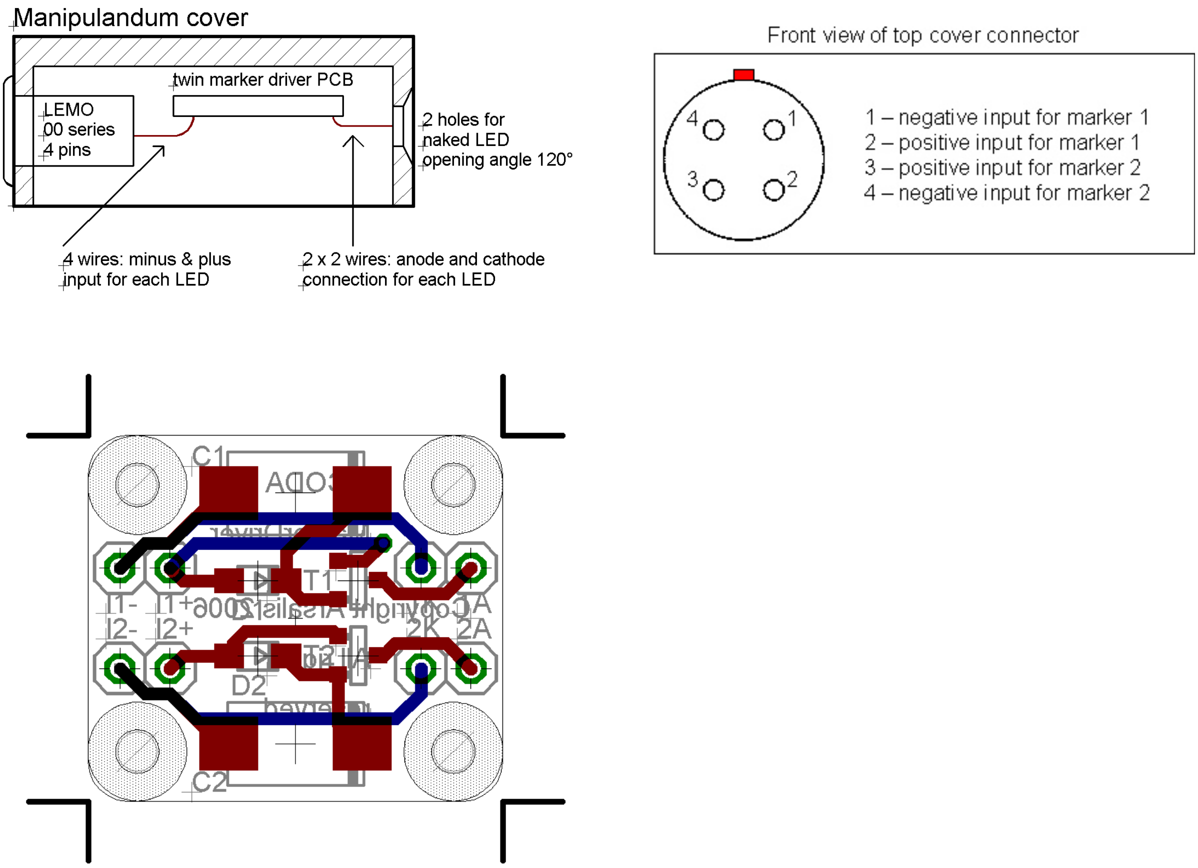


Figure 8. Drawings of cover assembly (top left panel), marker connector pin-out (top right panel), marker driver PCB layout (bottom right panel).

5. Description of the GLM peripherals

5.1. Environmental accelerometer

A tridimensional +/-3g accelerometer (Analog Devices, ref. ADXL330) is used to measure the acceleration of the reference frame as when carrying out experiments in parabolic flights. The accelerometer is mounted on a PCB fitted to an aluminum case specifically realized for this application. The outside faces of the accelerometer case define 3 orthogonal planes so that each direction of the accelerometer can be calibrated by placing the accelerometer on a horizontal support submitted to a 1-g gravitational field. The case is mounted on the experimental setup frame with four M3 screws. The three dimensional accelerometer is powered by the main signal conditioner and delivers a 0-3.6V buffered output for each channel. The case drawings as well as the PCB documentation are presented in appendix.

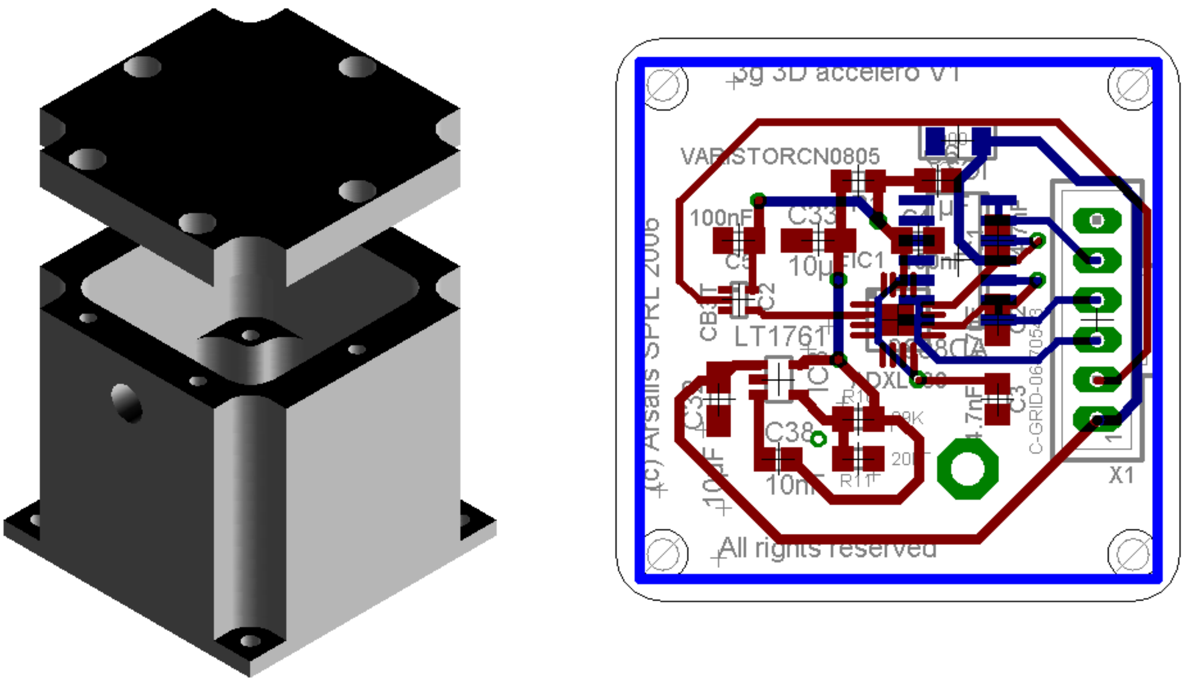


Figure 9. Three-dimensional environmental accelerometer case (isometric view, left panel) and PCB layout (right panel).

5.2. Finger humidity transducers : Moisture Evaluator version 2 (MEv2)

Skin moisture of the thumb and index fingerpads in contact with the GLM is measured with the Moisture-Evaluator version 2 (MEv2). The probe of the MEv2 is a circle printed circuit board (PCB) of 40mm diameter with sensing electrodes located in a 10mm diameter circle around the center of the PCB (see Figure 10). One MEv2 probe is mounted on each ATI F/T sensor. When using the GLM during an experiment, the fingerpads of the subject must cover the whole circle of sensing electrodes for finger moisture to be reliably measured.

The skin moisture level is measured as a change in capacitance at 20 kHz when the finger is in contact with the MEv2 probe on the GLM. The signal output by the GLM is conditioned on a dedicated daughter board in the signal conditioner that scales the output signal according to the factory calibration. The daughter board is also used to control the stimulation output to the Left or the Right moisture probe with a digital line in order to avoid a crosstalk of stimulation while the humidity is measured under one fingerpad. The left and right moisture output signals alternate under the control of the digital signal (Switch_MEv2). The output signal is proportional to the measured capacitance and ranges from 0 to 5V. A very dry skin provides around 2V of output voltage. A very wet skin (saturated) provides around 4.9V of output voltage.

Figure 10. Probe of the MEv2

5.3. The CODA motion system

The CODA motion is a comprehensive system for motion tracking and analysis. It is used to locate the position and orientation of the GLM in 3D. Infrared markers are mounted on the device to be located. Two kinds of markers are used. CODA micro markers are fitted inside the GLM covers to accommodate situations where the GLM is used without additional weights. CODA mini markers are fitted on the small and big additional weights (to accommodate situations where the GLM is loaded) and on the reference frame.

The CODA motion system can be used in various modes. An overview of the CODA motion system implementation selected for its integration with the GLM setup is presented in Figure 11 (see part details in appendix). A passive cx1 MiniHub is used as the main controller for the CODA motion system. The MiniHub is equipped with a wired-strobe module that allows each frame to be clocked by a strobe signal output by the main GLM signal conditioner. The strobe signal is then distributed to the marker drive boxes by a wired strobe adapter unit. The marker drive boxes light each marker in sequence within the time frame of the cx1 sensor unit (i.e. the camera) that is also clocked by the MiniHub.

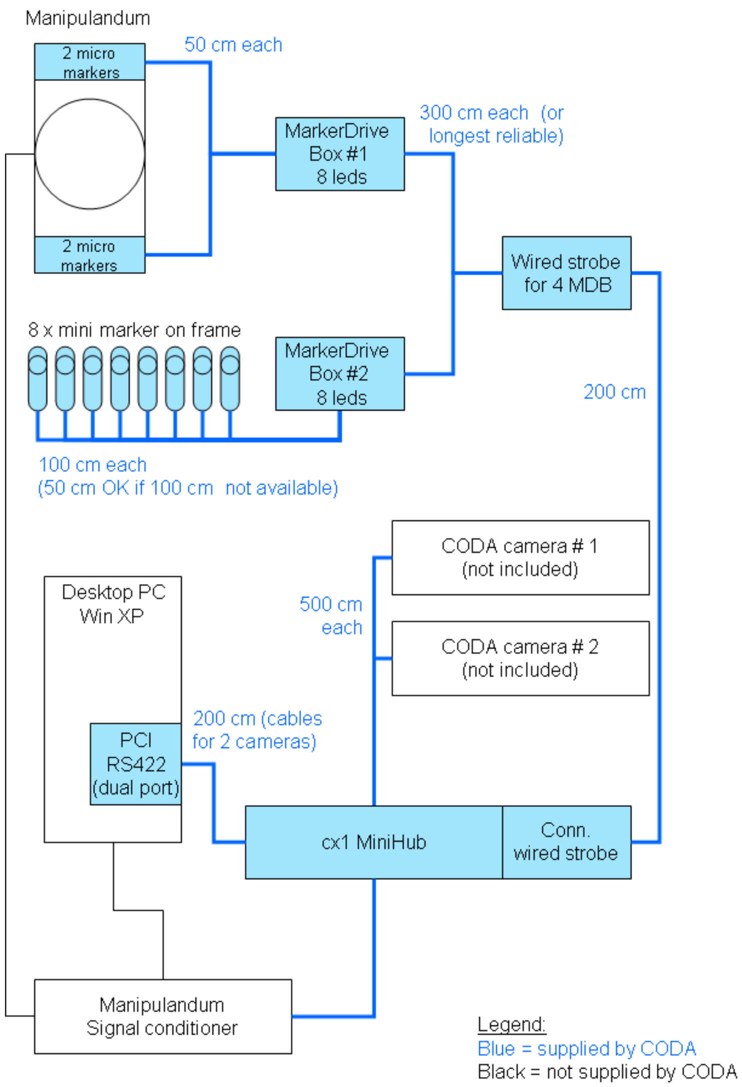


Figure 11. Overview of the CODA motion system elements (blue) integrated in the GLM setup.

6. Description of the GLM signal conditioner

The GLM signal conditioner is an analog and digital interface between the transducers and the data acquisition system that is fitted in a 19" rack enclosure. The front panel of the GLM signal conditioner is presented in Figure 12. The schematic and PCB layout of the GLM signal conditioner are presented in appendix.

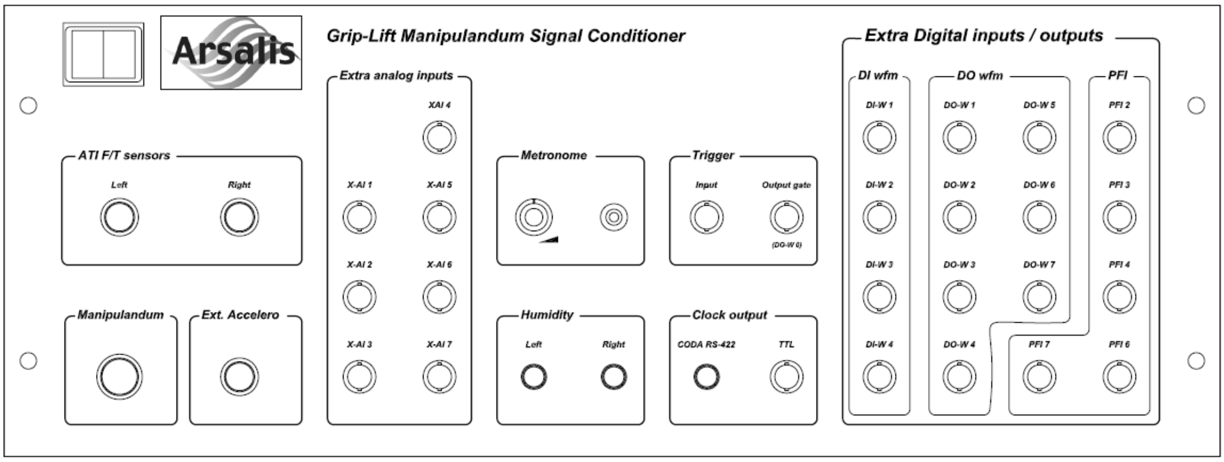


Figure 12. Front panel of the GLM signal conditioner featuring, from left to right, analog inputs (ATI F/T sensors, Manipulandum, Ext. Accelero and Extra analog inputs) and digitally controlled signals (Metronome, Humidity, Trigger, Clock output and Extra digital inputs/outputs).

6.1. Analog inputs

The GLM signal conditioner has 32 analog inputs. Most of the analog inputs are pre-cabled for a specific purpose, a few of them remain available from the front panel for extra channels. Each analog input is specified for a voltage in the range of -5 to +5V, with an over voltage protection up to 220V. Each analog input is equipped with an input buffer, a Bessel 4-pole low pass filter with a cutoff frequency of 400Hz, and an output buffer. The whole signal conditioning chain for each analog input has a unity gain. The filter introduces a frequency independent delay of 800 microseconds.

6.1.1. ATI F/T sensors

Each ATI Mini-40 force and torque sensor is connected to the signal conditioner via a LEMO 8-pin LEMO 1B series connector. Each transducer has its own, matched, interface board, the IF-OEM3 board delivered by ATI along with the transducers. Each pair of sensor and interface board are delivered with their own calibration matrix, therefore sensors and interface boards cannot be unmatched. The left transducer is connected to the cable with a black sleeve; the right transducer is connected to the cable with a red sleeve. The signals of each ATI F/T sensor are listed in Figure 13 and Table 2.

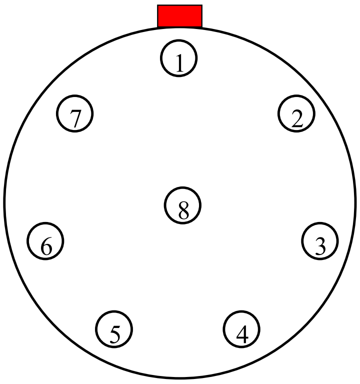


Figure 13. ATI F/T sensors front panel connector, solder side view.

Table 2. ATI F/T sensors signals.

Pin	Signal	Colour	Type	Description
1	P1	Orange	Analog input	Analog input to the IF-0EM3 interface board.
2	P3	Blue	Analog input	Analog input to the IF-0EM3 interface board.
3	P4	Yellow	Analog input	Analog input to the IF-0EM3 interface board.
4	P5	Brown	Analog input	Analog input to the IF-0EM3 interface board.
5	P2	Purple	Analog input	Analog input to the IF-0EM3 interface board.
6	V+	Red	Supply	Positive voltage supply to F/T sensor.
7	V-	Black	Supply	Negative voltage supply to F/T sensor.
8	P0	Green	Analog input	Analog input to the IF-0EM3 interface board.

Each of the 6 signals is directed to its matched interface board. The documentation of the board is presented in appendix. Each IF-OEM3 board is specified with a SI-40 calibration, delivering a differential +/- 5 V output for each of the 6 channels of each sensor (F_x, F_y, F_z, T_x, T_y, T_z). These outputs are connected to the main board of the signal conditioner, buffered and filtered according the above mentioned specification. A buffered, ground referenced, single-ended +/- 5V output is provided for each of the 6 channels of each sensor to the data acquisition system.

6.1.2. Manipulandum

The manipulandum signals are those delivered by the inertial transducers mounted on the manipulandum PCB. These signals are directly connected to the main board of the signal conditioner via a 19-pin LEMO 2B series connector. Two cables that are referred below as cable "A" for IMU signal and cable "B" for MEv2 signals make the connection between the LEMO 19-pins cable connector and the PCB inside the GLM. The manipulandum signals and pin-out are presented in Figure 14 and Table 3.

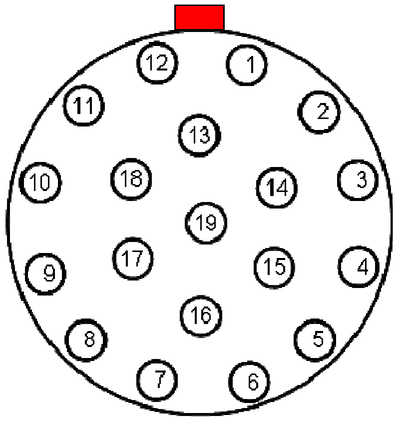


Figure 14. GLM front panel connector, solder side view.

Table 3. Grip-Lift Manipulandum signals.

Pin	Signal	Colour	Cable	Type	Description
1	GLM_IMU_GND	black	A	Supply	Analog ground
2	GLM_IMU_P8V	red	A	Supply	+8V supply to manipulandum
3	Acc/X	purple	A	Analog Input	0-3.6V, range +/-3g, acceleration in X direction
4	Acc/Y	pink	A	Analog Input	0-3.6V, range +/-3g, acceleration in Y direction
5	Acc/Z	green	A	Analog Input	0-3.6V, range +/-3g, acceleration in Z direction
6	Gyro/X	grey	A	Analog Input	0-5V, range +/-300°/s, rate gyroscope around X axis
7	Gyro/Y	white	A	Analog Input	0-5V, range +/-300°/s, rate gyroscope around Y axis
8	Gyro/Z	yellow	A	Analog Input	0-5V, range +/-300°/s, rate gyroscope around Z axis
9	GLM_High_Acc	blue	A	Analog Input	0-5V, range +/-35g, acceleration in X direction
10	GLM_ST	brown	A	Digital output	TTL and CMOS compatible, active low, digital output connected to the transducers, but not used in this application.
11	MEv2L_P_ISO	white	B	Supply	+9V supply to isolated MEv2 Left circuit
12	MEv2L_GND_ISO	black	B	Supply	Ground return of isolated MEv2 Left circuit supply
13	MEv2L_ISO	green	B	Analog Input	MEv2 Left analog measure of humidity
14	MEv2L_SW_ISO	purple	B	Digital output	TTL and CMOS compatible, active low, digital output connected to the transducers, but not used in this application.
15	MEv2R_P_ISO	red	B	Supply	+9V supply to isolated MEv2 Right circuit
16	MEv2R_GND_ISO	blue	B	Supply	Ground return of isolated MEv2 Right circuit supply
17	MEv2R_ISO	grey	B	Analog Input	MEv2 Right analog measure of humidity
18	MEv2R_SW_ISO	yellow	B	Digital output	TTL and CMOS compatible, active low, digital output connected to the transducers, but not used in this application.
19	N/C	N/A			

All analog inputs are buffered and filtered according the above mentioned specification. A buffered, ground referenced, single-ended +/- 5V output is provided for each analog inputs to the data acquisition system. The digital output from the data acquisition system is also buffered.

6.1.3. Ext. Accelero

Three 0-3.6V analog inputs (EnvAcc/X, EnvAcc/Y and EnvAcc/Z), measure the acceleration of the environment in a range of +/-3g. These signals are directly connected to the main board of the signal conditioner via a 6-pin LEMO 1B series connector. All analog inputs are buffered and filtered according the above mentioned specification. A buffered, ground referenced, single-ended +/- 5V output is provided for each of the 3 channels to the data acquisition system. The signals of the external accelerometer are listed in Figure 15 and Table 4.

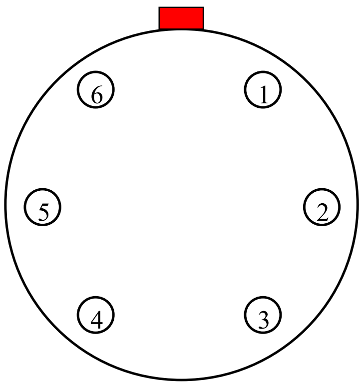


Figure 15. External accelerometer front panel connector, solder side view.

Table 4. External accelerometer signals.

Pin	Signal	Colour	Type	Description
1	ST	White	Digital output	TTL and CMOS compatible, active low, digital output connected to the accelerometer, but not used in this application.
2	E_ACC_Y	Green	Analog input	0-5V, range +/-3g, acceleration in Y direction.
3	E_ACC_Z	Yellow	Analog input	0-5V, range +/-3g, acceleration in Z direction.
4	E_ACC_X	Blue	Analog input	0-5V, range +/-3g, acceleration in X direction.
5	+5V	Red	Supply	+6V supply to external accelerometer.
6	AGND	Black	Supply	Analog ground.

6.1.4. Extra analog inputs

Up to 7 extra analog inputs (X-AI 1 to X-AI 7) can be connected to the front panel via a ground referenced BNC connector. These signals are directly connected to the main board of the signal conditioner. All extra analog inputs are buffered and filtered according the above mentioned specification. A buffered, ground referenced, single-ended +/- 5V output is provided for each of the 7 channels to the data acquisition system.

6.2. Digital inputs/outputs

The GLM signal conditioner has 24 digital inputs/outputs. Most of the digital inputs/outputs are pre-cabled for a specific purpose (metronome, trigger, humidity transducer, clock output). The remaining digital inputs/outputs are available from the front panel for extra channels, although they are either dedicated to waveform inputs or outputs, or to a programmable function. All digital input/outputs are buffered and compatible with both TTL and CMOS.

6.2.1. Metronome

A metronome with manually adjustable volume and software programmable frequency is available from a stereo 3.5 mm jack. The programmed frequency is delivered to 16-Ohm headphones through a headphone amplifier. The datasheet of the amplifier is presented in appendix. The left and right channels of the headphones are driven with the same frequency output.

The output frequency is coded on three digital outputs (Metronome_b0 – Metronome_b2). The three output bits drive a micro controller, which outputs a CMOS-compatible square wave at the programmed frequency. The micro-controller program ensures smooth transitions between frequencies. These metronome control bits are output by the data acquisition software and determine the output frequency at each sample according to Table 5.

Table 5. Metronome frequency control.

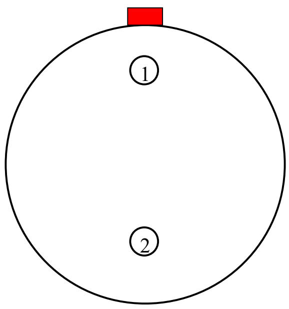
Metronome_b2	Metronome_b1	Metronome_b0	Metronome output
0	0	0	Output frequency of 8000 Hz.
0	0	1	Output frequency of 4000 Hz.
0	1	0	Output frequency of 2000 Hz.
0	1	1	Output frequency of 1000 Hz.
1	0	0	Output frequency of 500 Hz.
1	0	1	Output frequency of 250 Hz.
1	1	0	Output frequency of 125 Hz.
1	1	1	Metronome off.

6.2.2. Trigger

An external trigger can start the data acquisition when connected to the Input BNC. The trigger edge is selected through the data acquisition software. An output trigger is also implemented via a hardware-timed digital output (DO-W0) available from a BNC on the front panel. Both input and trigger are buffered in the signal conditioner.

6.2.3. Clock output

A clock output can be generated by the data acquisition software and is available from the front panel of the signal conditioner both in RS-422 compatible format from a 2-pin LEMO 0B series connector and in CMOS and TTL compatible format from a BNC connector. The clock frequency is programmable via the data acquisition software and the clock edges are synchronous with the main data sampling. The RS-422-compatible output is used to strobe each frame of the CODA motion system in synchrony with the main data acquisition process. The datasheet of the RS-422 clock driver is presented in appendix. The signals of the RS-422-compatible clock output are listed in Figure 16.



Pin	Signal	Colour	Description
1	Out_Clock_Y	Red	Positive differential driver output to the CODA clock output
2	Out_Clock_Z	Black	Negative differential driver output to the CODA clock output

Figure 16. RS-422-compatible clock output front panel connectors, solder side view.

6.2.4. Extra digital inputs/outputs

The digital inputs/outputs not used for a dedicated function as presented above are available to the front panel of the signal conditioner via a BNC connector. The signals are named after the configuration of the digital modules in the data acquisition system; various kinds of inputs/outputs are available:

- Digital input waveforms (DI wfm): input digital lines dedicated to the sampling of digital waveforms.
- Digital output waveforms (DO wfm): output digital lines dedicated to the hardware timed, software controlled outputs.
- Programmable function inputs/outputs (PFI): programmable function digital lines dedicated to either static or timing control inputs/outputs.

7. Description of the GLM data acquisition system

The GLM data acquisition system consists of a Compact DAQ (National Instruments) with analog and digital modules. The Compact DAQ (cDAQ_9172) is a chassis data acquisition system that can receive up to 8 modules (see documentation in appendix). The system is equipped with one 32-channel analog input module (cDAQ_9205) and three 8-channel digital inputs/outputs modules (cDAQ_9401). The Compact DAQ chassis is interface to the data acquisition PC via a USB 2 connector and provides rates of up to 3.2 MSamples/s. In addition to the individual modules the chassis has internal timing circuitry, including two 32-bit counters, which can be addressed by the data acquisition software. The list of channels implemented in the GLM data acquisition system is presented in Table 6.

Table 6. Channel list.

32-channel analog input module (CDAQ_9172) placed in slot 1

Signal	Channel	Description
ATI_L/G0	Ain 00	Analog input for ATI left transducer G0 signal
ATI_L/G1	Ain 01	Analog input for ATI left transducer G1 signal
ATI_L/G2	Ain 02	Analog input for ATI left transducer G2 signal
ATI_L/G3	Ain 03	Analog input for ATI left transducer G3 signal
ATI_L/G4	Ain 04	Analog input for ATI left transducer G4 signal
ATI_L/G5	Ain 05	Analog input for ATI left transducer G5 signal
ATI_R/G0	Ain 06	Analog input for ATI right transducer G0 signal
ATI_R/G1	Ain 07	Analog input for ATI right transducer G1 signal
ATI_R/G2	Ain 08	Analog input for ATI right transducer G2 signal
ATI_R/G3	Ain 09	Analog input for ATI right transducer G3 signal
ATI_R/G4	Ain 10	Analog input for ATI right transducer G4 signal
ATI_R/G5	Ain 11	Analog input for ATI right transducer G5 signal
LowAcc/X	Ain 12	Analog input for X direction of +/-3g accelerometer
LowAcc/Y	Ain 13	Analog input for Y direction of +/-3g accelerometer
LowAcc/Z	Ain 14	Analog input for X direction of +/-3g accelerometer
HighAcc	Ain 15	Analog input for X direction of high-G accelerometer
Humidity-L	Ain 16	Analog input for left fingertip moisture signal
Humidity-R	Ain 17	Analog input for right fingertip moisture signal
<Reserved>	Ain 18	Analog input
RateGyro/X	Ain 19	Analog input for X direction of gyroscope
RateGyro/Y	Ain 20	Analog input for Y direction of gyroscope
RateGyro/Z	Ain 21	Analog input for Z direction of gyroscope
EnvAcc/X	Ain 22	Analog input for X direction of environmental accelerometer
EnvAcc/Y	Ain 23	Analog input for Y direction of environmental accelerometer
EnvAcc/Z	Ain 24	Analog input for Z direction of environmental accelerometer
X-AI1	Ain 25	Analog input for extra analog input 1
X-AI2	Ain 26	Analog input for extra analog input 2
X-AI3	Ain 27	Analog input for extra analog input 3
X-AI4	Ain 28	Analog input for extra analog input 4
X-AI5	Ain 29	Analog input for extra analog input 5
X-AI6	Ain 30	Analog input for extra analog input 6
X-AI7	Ain 31	Analog input for extra analog input 7
Trigger IN	PFI0	Digital trigger input – PFI0

Table 6. Channel list. (continued).

8-channel digital input/output module (CDAQ_9172) placed in slot 2

Signal	Channel	Description
Metronome_b0	Slot2/bit0	Hardware timed digital output
Metronome_b1	Slot2/bit1	Hardware timed digital output
Metronome_b2	Slot2/bit2	Hardware timed digital output
CODA_clock	Slot2/bit3	Hardware timed digital output
DI-W 1	Slot2/bit4	Digital waveform input
DI-W 2	Slot2/bit5	Digital waveform input
DI-W 3	Slot2/bit6	Digital waveform input
DI-W 4	Slot2/bit7	Digital waveform input

8-channel digital input/output module (CDAQ_9172) placed in slot 3

Signal	Channel	Description
Trigger Output gate	Slot3/bit0	Hardware timed digital output
DO-W 1	Slot3/bit1	Hardware timed digital output
DO-W 2	Slot3/bit2	Hardware timed digital output
DO-W 3	Slot3/bit3	Hardware timed digital output
DO-W 4	Slot3/bit4	Hardware timed digital output
DO-W 5	Slot3/bit5	Hardware timed digital output
DO-W 6	Slot3/bit6	Hardware timed digital output
MEv2 switch	Slot3/bit7	Hardware timed digital output

8-channel digital input/output module (CDAQ_9172) placed in slot 5

Signal	Channel	Description
ST	Slot5/bit0	Static digital output
PFI1	Slot5/bit1	Programmable function to implement in software
PFI2	Slot5/bit2	Programmable function to implement in software
PFI3	Slot5/bit3	Programmable function to implement in software
PFI4	Slot5/bit4	Programmable function to implement in software
PFI5	Slot5/bit5	Programmable function to implement in software
PFI6	Slot5/bit6	Programmable function to implement in software
PFI7	Slot5/bit7	Programmable function to implement in software

8. Parameter calculations for the GLM

8.1. Frame of reference

The reference frame of the GLM has its origin at the theoretical center of gravity of the device and its axes are aligned to the GLM geometry. The frame of reference is presented in Figure 17.

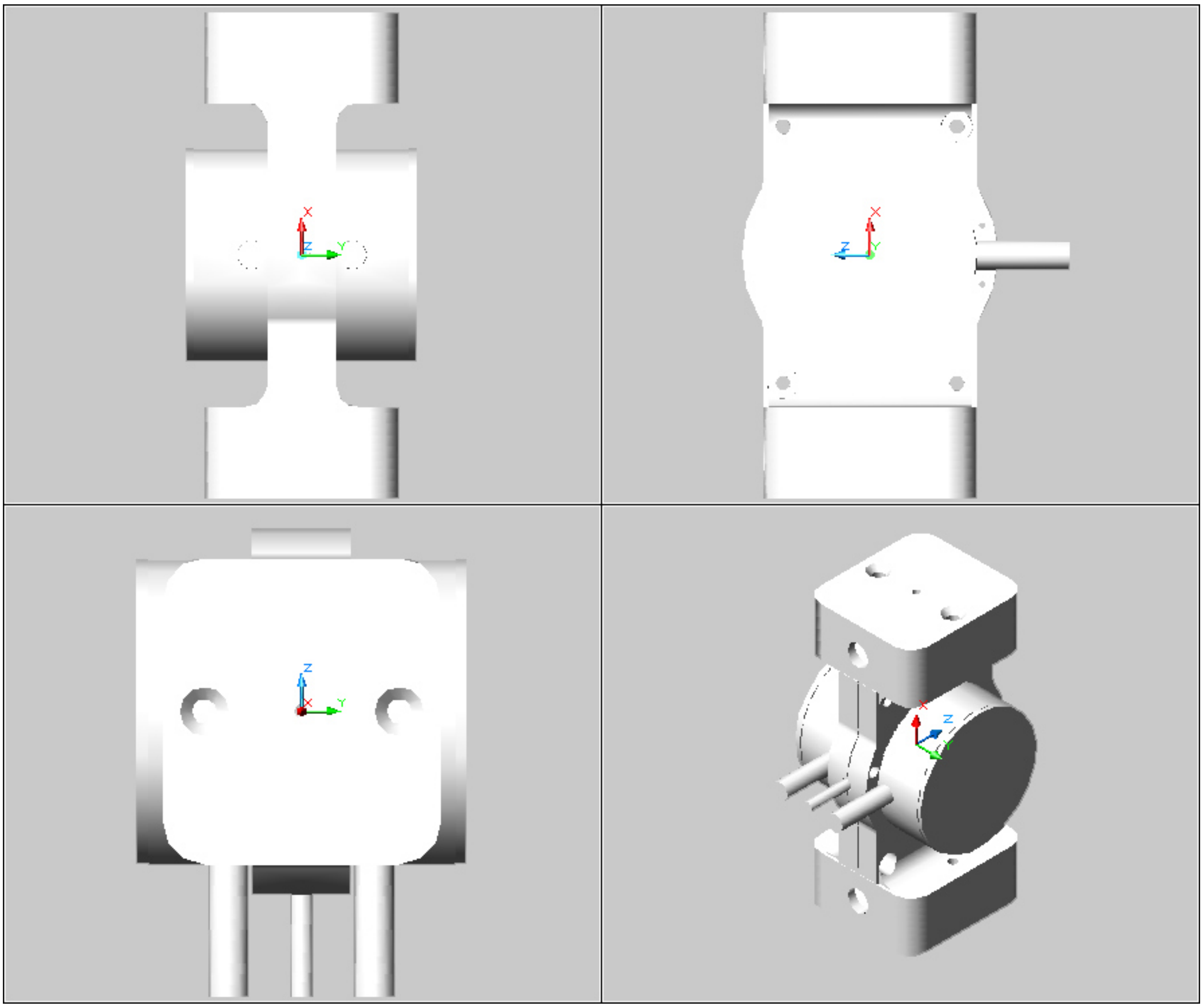


Figure 17. Reference frame of the GLM as shown on front view, i.e. the subject's view (top left panel), left view (top right panel), top view (bottom left panel) and isometric view (bottom right panel).

8.2. Forces and torques from ATI Mini-40 sensors

For each ATI sensor, 6 signals of force and torque are derived from 6 analog inputs that are then used to compute the actual forces and torques, according to a calibration matrix supplied by ATI. The calibration matrix is matched to each pair of sensor and signal conditioning board. The resulting signals are expressed in the frame of reference of each ATI sensor (suffix A) and are labeled F_{XAR}, F_{YAR}, F_{ZAR}, T_{XAR}, T_{YAR} and T_{ZAR} for the right sensor (suffix R) and F_{XAL}, F_{YAL}, F_{ZAL}, T_{XAL}, T_{YAL} and T_{ZAL} for the left sensor (suffix L). These forces and torques are expressed in each sensor's reference frame (see Figure 6) but with each axis reversed since they represent loads applied by the subject rather than reaction loads measured by each sensor. Moreover, each sensor is covered by a surface contact plate of thickness δ (typically 1.55 mm) which offsets the applied force relative to the sensing surface of each sensor. Last, the reference frame of the GLM (suffix G) is rotated by an angle α (typically of 30 degrees) and located and the mid-distance between both sensors, involving a translation ε (typically of 18.75 mm, i.e. 12.25 mm for the ATI Mini40-R sensor thickness plus 6.50 mm for the shell thickness). Therefore, the forces and torques applied on the GLM are computed in the following sequence:

First, determine the coordinates of the centre of pressure on each contact surface, expressed in the reference frame of each ATI sensor; i.e. OP_{XAR} and OP_{YAR} for the right sensor and OP_{XAL} and OP_{YAL} for the left sensor, according to Table 7.

Table 7. Centre of pressure coordinates in each sensor's frame of reference

Parameter	Calculation	Description
OP_{XAR}	$(T_{YAR} - F_{XAR} * \delta) / F_{ZAR}$	X coordinate of the center of pressure on right sensor
OP_{YAR}	$- (T_{XAR} + F_{YAR} * \delta) / F_{ZAR}$	Y coordinate of the center of pressure on right sensor
OP_{XAL}	$(T_{YAL} - F_{XAL} * \delta) / F_{ZAL}$	X coordinate of the center of pressure on left sensor
OP_{YAL}	$- (T_{XAL} + F_{YAL} * \delta) / F_{ZAL}$	Y coordinate of the center of pressure on left sensor

Second, determine the coordinates of the center of pressure on the right (suffix R) and on the left (suffix L) contact surface, expressed in the reference frame of the GLM reference frame (suffix G); i.e. OP_{XGR} and OP_{ZGR} for the right sensor and OP_{XGL} and OP_{ZGL} for the left sensor, according to Table 8.

Table 8. Centre of pressure coordinates in the GLM frame of reference

Parameter	Calculation	Description
OP_{XGR}	$- OP_{YAR} * \cos(\alpha) - OP_{XAR} * \sin(\alpha)$	X coordinate of the center of pressure on right sensor
OP_{ZGR}	$OP_{YAR} * \sin(\alpha) - OP_{XAR} * \cos(\alpha)$	Z coordinate of the center of pressure on right sensor
OP_{XGL}	$OP_{XAL} * \sin(\alpha) + OP_{YAL} * \cos(\alpha)$	X coordinate of the center of pressure on left sensor
OP_{ZGL}	$- OP_{XAL} * \cos(\alpha) + OP_{YAL} * \sin(\alpha)$	Z coordinate of the center of pressure on left sensor

Third, express the force and torque applied on the right (suffix R) and on the left (suffix L) sensor in the reference frame of the GLM (suffix G); i.e. F_{XGR}, F_{YGR}, F_{ZGR}, T_{XGR}, T_{YGR} and T_{ZGR} for the right sensor and F_{XGL}, F_{YGL}, F_{ZGL}, T_{XGL}, T_{YGL} and T_{ZGL} for the left sensor, according to Table 9.

Table 9. Forces and torques in the GLM frame of reference

Parameter	Calculation	Description
F_{XGR}	$- F_{YAR} * \cos(\alpha) - F_{XAR} * \sin(\alpha)$	Force applied in X direction on the right sensor
F_{YGR}	$- F_{ZAR}$	Force applied in Y direction on the right sensor
F_{ZGR}	$F_{YAR} * \sin(\alpha) - F_{XAR} * \cos(\alpha)$	Force applied in Z direction on the right sensor
T_{XGR}	$F_{ZGR} * (\delta + \varepsilon) - F_{YGR} * OP_{ZGR}$	Torque applied around X axis on the right sensor
T_{YGR}	$- T_{ZAR} + F_{XGR} * OP_{ZGR} - F_{ZGR} * OP_{XGR}$	Torque applied around Y axis on the right sensor
T_{ZGR}	$- F_{XGR} * (\delta + \varepsilon) + F_{YGR} * OP_{XGR}$	Torque applied around X axis on the right sensor
F_{XGL}	$F_{XAL} * \sin(\alpha) + F_{YAL} * \cos(\alpha)$	Force applied in X direction on the left sensor
F_{YGL}	F_{ZAL}	Force applied in Y direction on the left sensor
F_{ZGL}	$- F_{XAL} * \cos(\alpha) + F_{YAL} * \sin(\alpha)$	Force applied in Z direction on the left sensor
T_{XGL}	$- F_{ZGL} * (\delta + \varepsilon) - F_{YGL} * OP_{ZGL}$	Torque applied around X axis on the left sensor
T_{YGL}	$T_{ZAL} + F_{XGL} * OP_{ZGL} - F_{ZGL} * OP_{XGL}$	Torque applied around Y axis on the left sensor
T_{ZGL}	$F_{XGL} * (\delta + \varepsilon) + F_{YGL} * OP_{XGL}$	Torque applied around X axis on the left sensor

Fourth, express the total force and torque applied on the GLM left as a result of the loads measured on the right and left sensors, determine the grip force (GF) and the two components of the load force (LF) that tend to make the GLM slip out of the grip, according to Table 10.

Table 10. Forces and torques in the GLM frame of reference

Parameter	Calculation	Description
F_X	$F_{XGL} + F_{XGR}$	Total force applied in X direction on the GLM
F_Y	$F_{YGL} + F_{YGR}$	Total force applied in Y direction on the GLM
F_Z	$F_{ZGL} + F_{ZGR}$	Total force applied in Z direction on the GLM
T_X	$T_{XGL} + T_{XGR}$	Total torque applied around X axis on the GLM
T_Y	$T_{YGL} + T_{YGR}$	Total torque applied around Y axis on the GLM
T_Z	$T_{ZGL} + T_{ZGR}$	Total torque applied around Z axis on the GLM
GF	$(F_{YGL} - F_{YGR}) / 2$	Grip force
LF_V	$- F_X$	Vertical, downward, component of the load force
LF_H	F_Z	Horizontal, forward, component of the load force
LF_T	sqrt $((LF_V)$^2 + (LF_H)^2)	Total tangential load force

9. Description of the GLM data acquisition software

9.1. Software requirements

The GLM data acquisition software is written and compiled with Labview 2011 (National Instruments). It requires a Personal Computer with Windows XP or later, 2GB RAM minimum and at least one USB2 port. In order to drive the NI_cDAQ_9172_chassis (equipped with the NI_cDAQ_9205_32chAin and two NI_cDAQ_9401_8chDIO), the NI-DAQmx driver must also be installed on the PC.

No prior configuration of the NI_cDAQ is required as the GLM software takes care of all configurations.

9.2. Software files

The GLM software files will be installed by default in …/ Program Files/GLM/. The files and folders associated to the GLM application are presented in Figure 18. Files installed in the GLM folder by the installation process are listed below:

- GLM.exe : *the executable file*
- GLM.ini : *main configuration file*
- GLM.aliases : *computer IP address alias*
- GLM ReadMe.txt : *software information file*
- GLM history.txt : *software history file*
- /cDAQ+ATI info/ : *Hardware documentation*
- /GLM Device/ *: folder for the "dcf" file (device config. file)*
- ESAGLM_xxx_xxx.dcf : *the dcf file is provided with each device. The dcf file name is equivalent to the device serial number reported on the front panel. The dcf file is provided by Arsalis and must be installed manually in the /GLM Device/ folder.*
- /GLM Device/Historical Records/… *: folder holding the dcf file history*
- /GLM patterns/ : *folders holding the digital output pattern files*
- /GLM setups/ : *folders holding the setup files*
- /GLM support files/ : *dll and picture files required for the software*

Any other files or subdirectories in the GLM directory are either created by the software itself (e.g. GLM.log) or are added by the auto-update function.

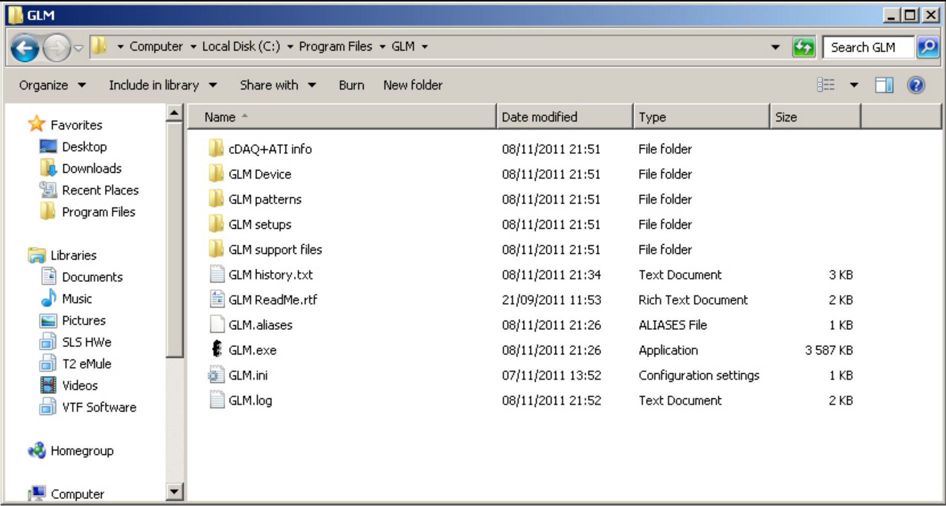


Figure 18. GLM software files.

9.3. Software overview

The main control panel of the GLM-BOX software gives access to three other panels:

- The setup panel to edit the acquisition protocols and calibration values.
- The acquisition panel to acquire and save data.
- The view panel to display pre-acquired data.

All GLM panels have width*height dimensions not larger than 1024*768. All panels have a bottom textual field that informs the user of the running processes or actions required. All major events are recorded in a log file saved as …/program files/GLM/GLM.log. Note that this log file retains the last 1000 entries. When one of the setup, acquisition, view, calibration or scope panel is displayed, the main control panel is hidden.

9.4. Main control panel

The main control panel is presented in Figure 19. This panel mainly provides access to the panels described here above, and has five additional features:

First, the program automatically detects the presence of the GLM device connected to one of the USB port of the PC using the associated *dcf* file. If no device is found or if the device is not recognized (*i.e* the serial number of the NI-cDAQ-9172 does not match the NI_s/n parameter in the *dcf* file, the access to the acquisition panel is disabled and a 'NO Device' message is displayed. The detection of the device is done regularly, so that if the device is connected after the GLM software is launched, the device will be detected without restarting the software. As soon as the device is detected, a 'Device connected' message is displayed onto the main panel and access to the acquisition panel is enabled. Also, the main panel displays the GLM serial number as written in the *dcf* file. This serial number must match the serial number of the GLM Hardware reported on its front panel. If the *dcf* file is missing, the software displays "<ERROR>" instead of a serial number.

Second, the current data acquisition setup can be selected from the list of previously saved setups. The listed setups are created in the "setup" section (see below).

Third, software updates can be downloaded using the Help>Check for update menu.

Finally, a scope panel, to visualize incoming data, and the calibration panel can be launched from the Advanced menu.

Figure 19. Main panel of the GLM software.

9.5. Setup panel

The setup panel of the GLM software allows any data acquisition protocol to be created, modified and edited. All protocols are saved as INI files in …/program files/GLM /GLM setups. To load a previously saved protocol or a blank new setup, click on the 'setup' control in the top part of the panel.

After editing a protocol, click the 'save' control. A 'save as' window is displayed prompting the user to select a new or existing name for the new/modified protocol. The 'Delete' control permanently erases the file for the loaded setup.
The setup panel divides in 8 different tabs:

- The general parameters
- The analog inputs (AI) parameters

- The digital input waveform (DI-W) parameters
- The digital output waveform (DO-W) parameters
- The digital input/output PFI lines (DIO-PFI) parameters
- The counters parameters
- The display parameters
- The calibration parameters

9.5.1. General parameters

The general parameters tab is presented in Figure 20. It has three categories detailed below:

9.5.1.1. Acquisition

In that category, specify the sampling frequency and the number of samples to collect. The sampling frequency applies to the analog input, digital input and digital output. The duration of the acquisition is equal to the number of samples divided by the sampling frequency. Specify the sampling frequency and the number of samples such that the duration is an integer. Also take into account the duration of the digital output waveform file (see the *DO pattern* section for details) when configuring the sample frequency and number of samples to collect.

For CODA users, consider also choosing a sampling frequency that is a multiple of the sampling frequency of the CODA system. This facilitates synchronization of the data with the CODA images.

9.5.1.2. Trigger

The acquisition can be set to start manually or using a digital trigger. In the 'manual' case, once the user presses the start button, the acquisition sets up and starts collecting data as soon it is ready. In the 'triggered' case, once the user press the start button, the acquisition sets up and waits for a TTL signal on the line specified by the 'trigger source' indicator. The trigger source is the PFI0 line of the cDAQ-mod1. The TTL signal that triggers the acquisition start can either be a rising or a falling edge. The latter can be selected in the 'Trigger edge' control. Note that the trigger parameters are hidden when the trigger mode is disabled (manual).

9.5.1.3. Save

Select the directory where all acquisition files will be saved after acquisition. Data are saved as raw data (*txt* file extension) and as calibrated data (*glm* file extension).

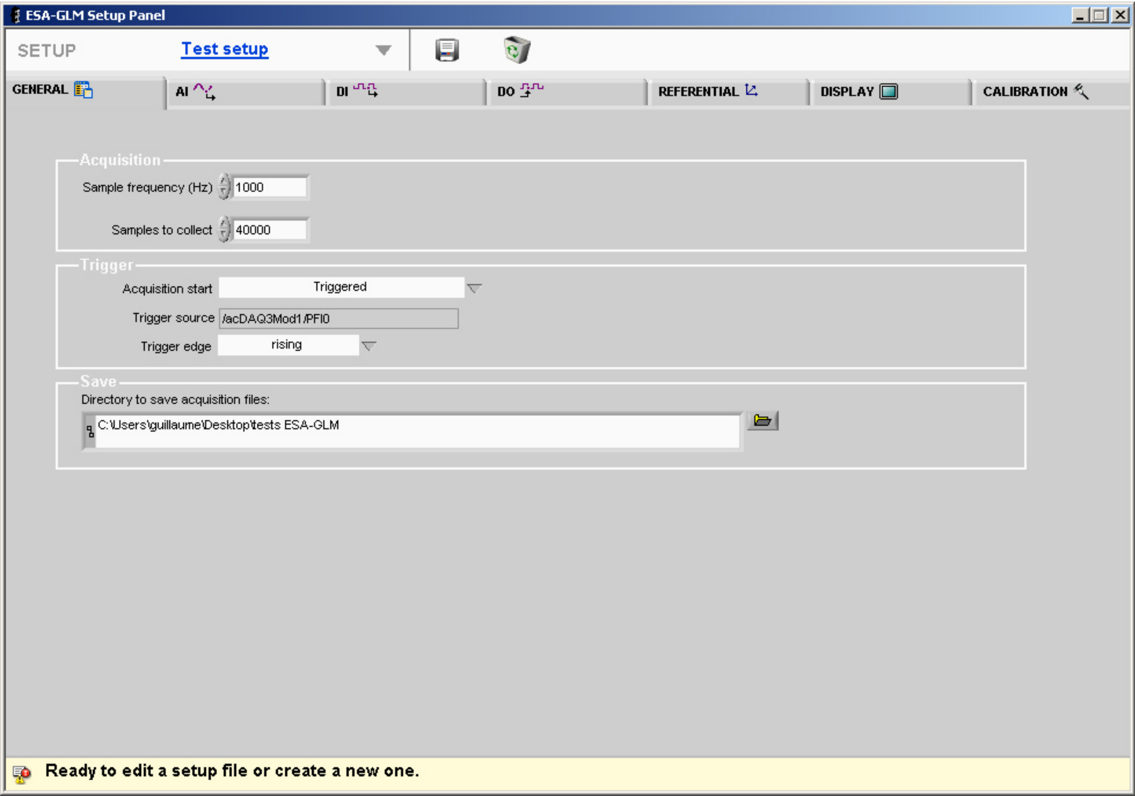


Figure 20. Setup panel (general parameters) of the GLM software.

9.5.2. Analog inputs (AI) parameters

The AI parameters tab is presented in Figure 21. It has three categories detailed below:

9.5.2.1. Inputs range

The 'AI range +/-' control sets the hardware voltage range used during the acquisition. By default the value is set to +/- 5 volts. Except changes made at the hardware level, the default value should always be used. For security, this control is disabled.

9.5.2.2. Labels

Within the 32 analog input channels (analog module-A), AI 00 to AI 24 have predefined labels since these connections are not changeable. For that reason the labels controls for these lines are grayed and disabled. On the contrary AI 25 to AI31, called XAI-1 to XAI-7 refer to the extra analog inputs that can be accessed on the GLM amplifier front panel. The default labels for these extra lines are "NA" (standing for *not applicable*). These labels must be changed to reflect the signal connected to each of the extra analog inputs. Additional labels can be given for the extra analog modules B and C.

9.5.2.3. Tasks

The 'AI task' indicator is displayed for verification of hardware consistency. This corresponds exactly to the hardware task that will be requested for acquiring the analog inputs from the cDAQ board.

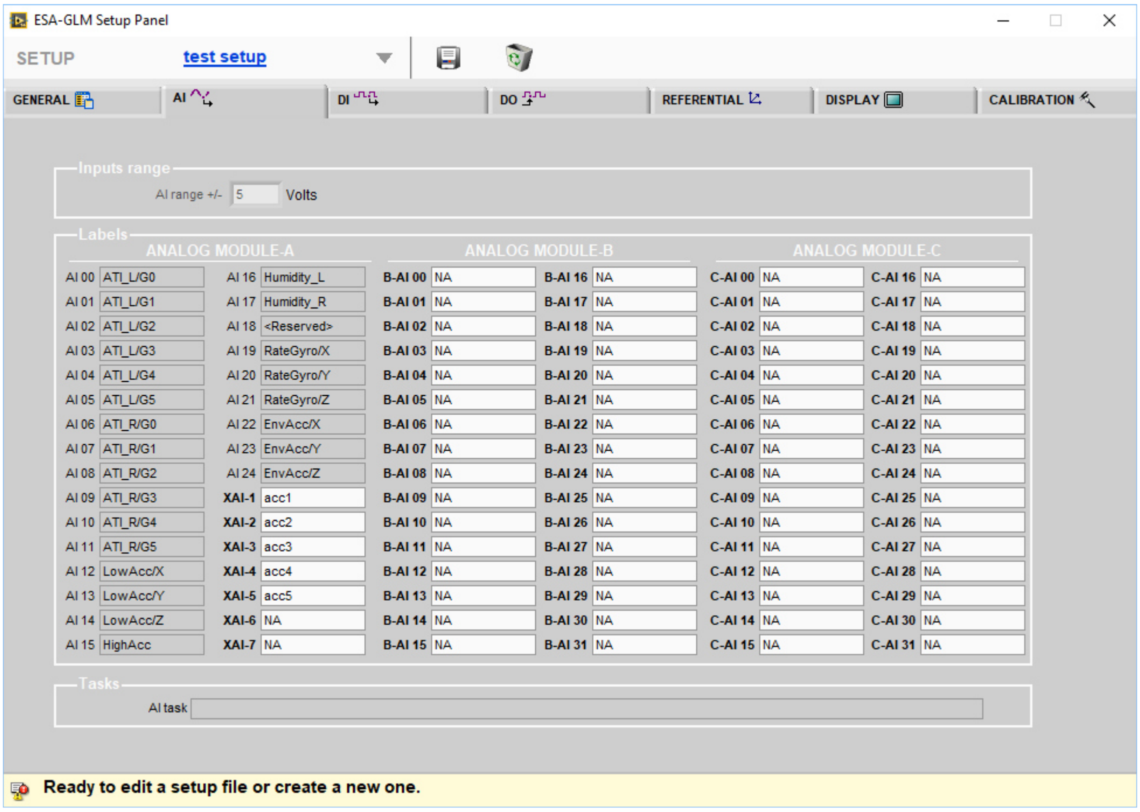


Figure 21. Setup panel (analog inputs parameters) of the GLM software.

9.5.3. Digital inputs waveform (DI) parameters

The DI section of the setup panel has two categories:

9.5.3.1. Labels

Four digital inputs, called DI-W 1 to DI-W 4, are acquired by the GLM system. These DI lines can be accessed on the GLM amplifier front panel. Each one of the DI lines can be assigned a label. The default is "NA" (standing for *not applicable*). These labels must be changed to reflect the digital signal connected to each of these digital input lines.

9.5.3.2. Tasks

The "DI-W task indicator is displayed for verification. This corresponds exactly to the hardware task that will be requested for acquiring the 4 digital inputs from the first of the digital modules placed in the NI-cDAQ chassis.

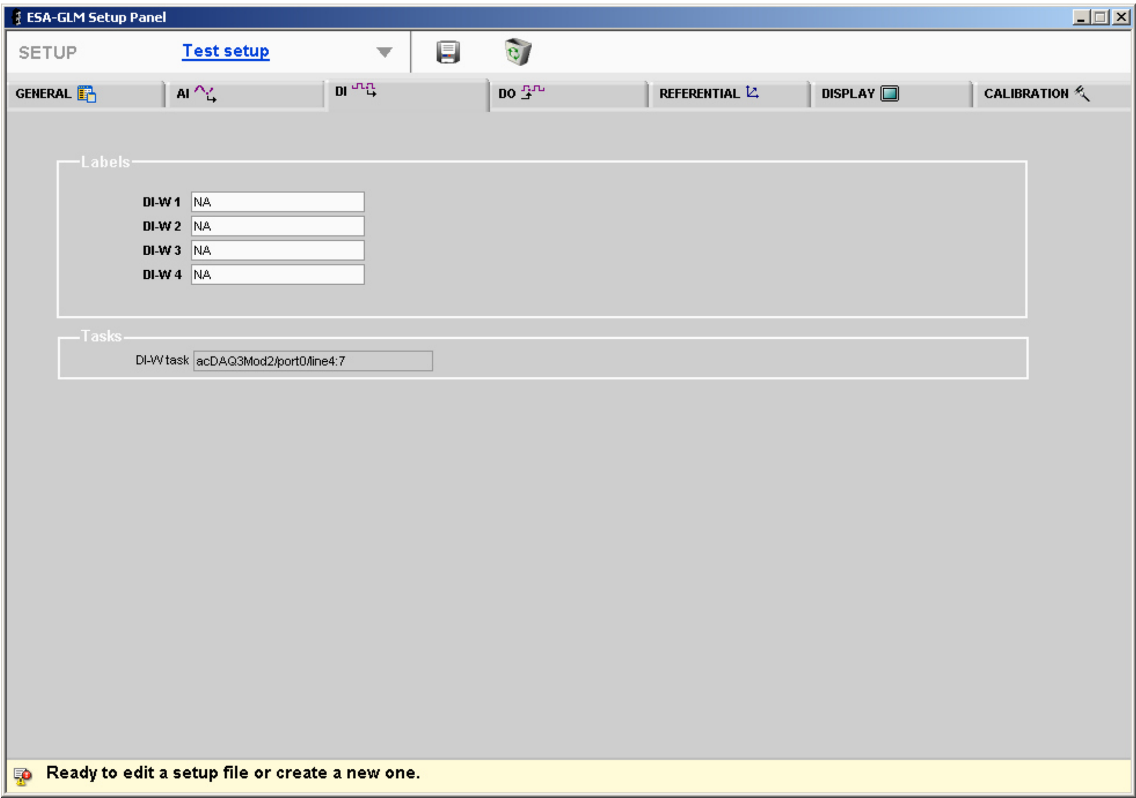


Figure 22. Setup panel (digital inputs parameters) of the GLM software.

9.5.4. Digital outputs (DO) parameters

The DO parameters tab is presented in Figure 23. It has three categories detailed below:

9.5.4.1. DO pattern

In total, 12 bits are set as digital output lines. The lines DO-W 01 to 05 are predefined outputs (Metronome, Coda-clock, Gate_Output). The remaining lines (DO-W 1 and DO-W 7) can be manually configured as digital output waveform or output clock.

The Digital outputs are read from a text file called 'pattern file' and stored in /GLM patterns/ folder. These files give the decimal values at each instant for the 12 lines. The text file can be created from an excel spreadsheet (an example is provided with your system). Note that the DO pattern file can have as many Patterns as desired. Each pair of columns stands for one pattern. During acquisition processes, GLM-BOX software cycles through the patterns defined in the DO pattern file in numerical order.

The DO pattern category holds three controls; the first one is the DO pattern file selection. The second control is the 'DO pattern time resolution (Hz)'. The latter value defines the time unit of each line of the DO pattern file. The sampling rate divided by the time resolution (Hz) must be an integer. Before starting an acquisition, GLM will create a table of values at the sampling rate specified in your setup in order to synchronize all the analog and digital inputs/outputs. Third, the 'Pattern expand' control defines how GLM will deal with the pattern **IF** the duration of the DO pattern does not perfectly match the total duration of the acquisition: the DO pattern can either be treated in loop or be completed with the digital default values.

9.5.4.2. DO channels specifications

Twelve digital lines are set by the GLM system. Six of these lines are predefined and six of them, called DIO-W 1 and DIO-W 6 can be configured by the user. Each one of the DO lines can be assigned a label, a type and a default state. For the predefined channels, the controls are grayed and disabled. For each editable DO channel, the default label is "NA" (standing for *not applicable*). These labels must be changed to reflect the digital signal connected to each of these digital output lines.

For each editable DO channel, the type can be either "DO waveform" or "DO clock". The "DO waveform" refers to values set in the DO pattern file for the channel. Setting the "DO clock" type will ignore the values of the DO pattern file for the channel and create a clock signal on the basis of four editable parameters: the start edge, the delay(pts), the frequency(Hz) and the duty factor. The start edge defines if clock starts with a rising or falling edge. The delay(pts) is the number of points to wait before output the first edge of the clock. The frequency(Hz) is the number of ticks per second to output. The duty factor defines the relative duration of the ticks, it is expressed as a ratio, x:y. For example a duty factor of 1:2 means that the tick will be high or low (depending on the clock edge) half the period (period= 1/frequency). Note that some duty factors cannot be strictly applied. For example: if the sampling frequency of the acquisition is set to 1 kHz, the clock frequency of a DO line is set to 100 Hz, the clock is set to a rising edge and its duty factor to 1:3, then the clock period is 1k/100 = 10 points. A duty factor of 1:3 would request that 3.333 points are high and 6.6666 are low. Because GLM will round the values to integers, the result would be 3 points high and 7 points low. The duty factor specified cannot be strictly applied. On the contrary, a duty factor of 1:2 would work in our example: 5 points high followed by 5 points low. If GLM detects a clock frequency or a duty factor that cannot be strictly applied, an error message will be displayed. If the DO type is set to "waveform", the clock parameters are disabled and ignored.

For each editable DO channel, the default state can be either "high" or "low". This parameter defines the state of the lines prior to starting the DO patterns. All DO lines are set to their default state before configuring that acquisition and after each acquisition.

On the right part of the panel, a 'CHECK' button allows to display the current pattern for each line that will be output during acquisition process (see Figure 24).

9.5.4.3. Tasks

The 'DO-W task' is displayed for verification of hardware consistency. This corresponds exactly to the hardware task that will be requested for writing the digital outputs from the DAQ board.

<u>For CODA users</u>: The 'CODA extra task' is also displayed. This corresponds exactly to the hardware task that will be requested to append extra CODA cycles at the end of the acquisition. The CODA channel is a clock that triggers the CODA slave system. The CODA system is set up to wait for a certain amount of triggers or ticks. If fewer ticks than expected were received, the CODA would hang on indefinitely. To avoid this situation, extra ticks can be done right after the acquisition ends up.

The number of extra CODA cycles can be set in the 'CODA clock extra cycles' control on the right of the 'CODA extra task' indicator.

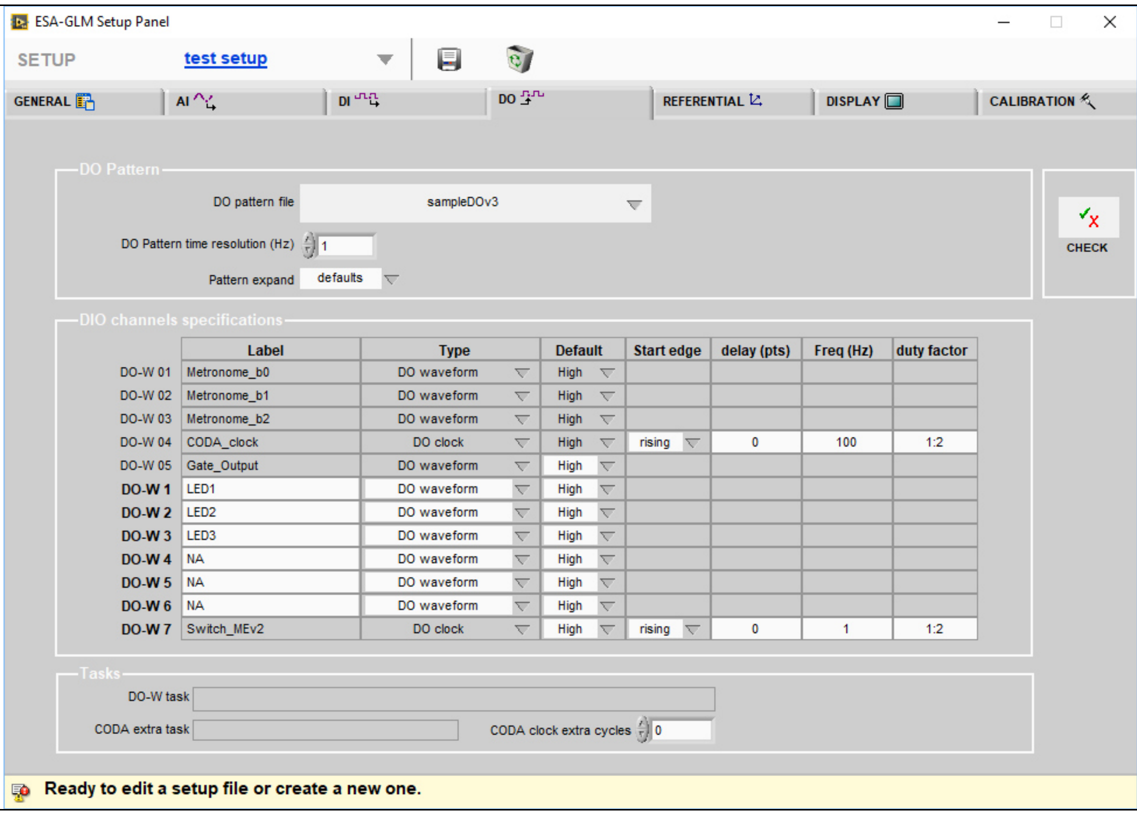


Figure 23. Setup panel (digital outputs parameters) of the GLM software.

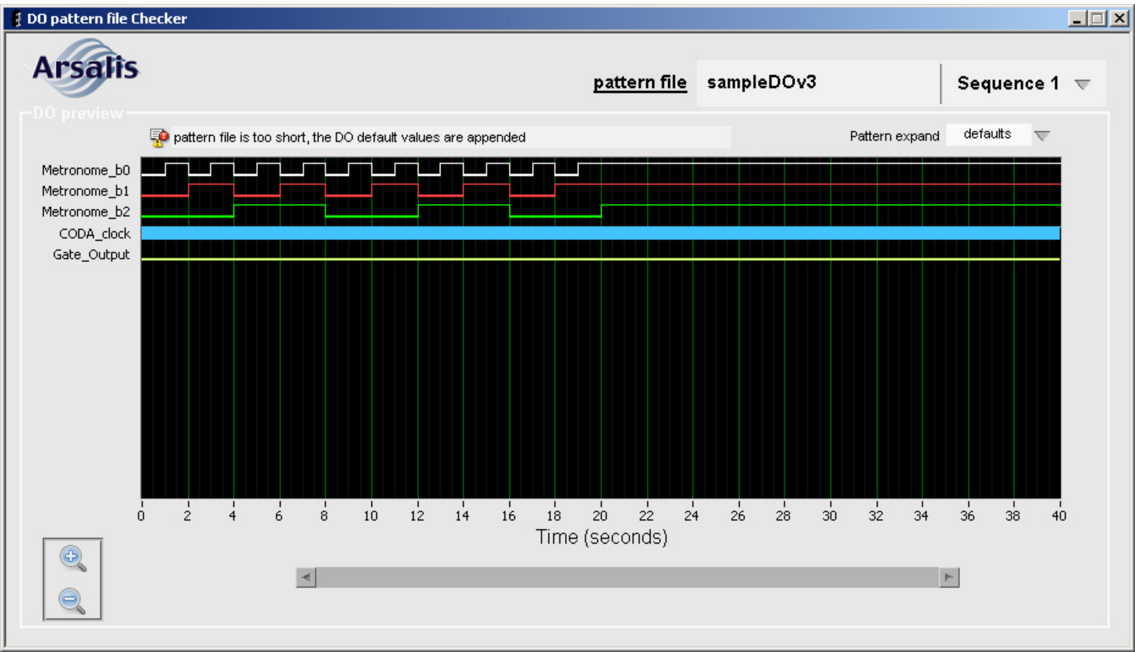


Figure 24. DO Pattern file check of the GLM software.

9.5.5. Referential parameters

The Manipulandum includes two ATI sensors and a 3D-accelerometer. Each one has its own referential. In order to implement these sensors in a common referential, a few settings are needed. Because these settings are dependent on the ATI model and on the GLM hardware selected by Arsalis, some settings cannot be changed manually. Those settings are issued from the *dcf* file.

The referential parameters tab is presented in Figure 25. It has two categories detailed below:

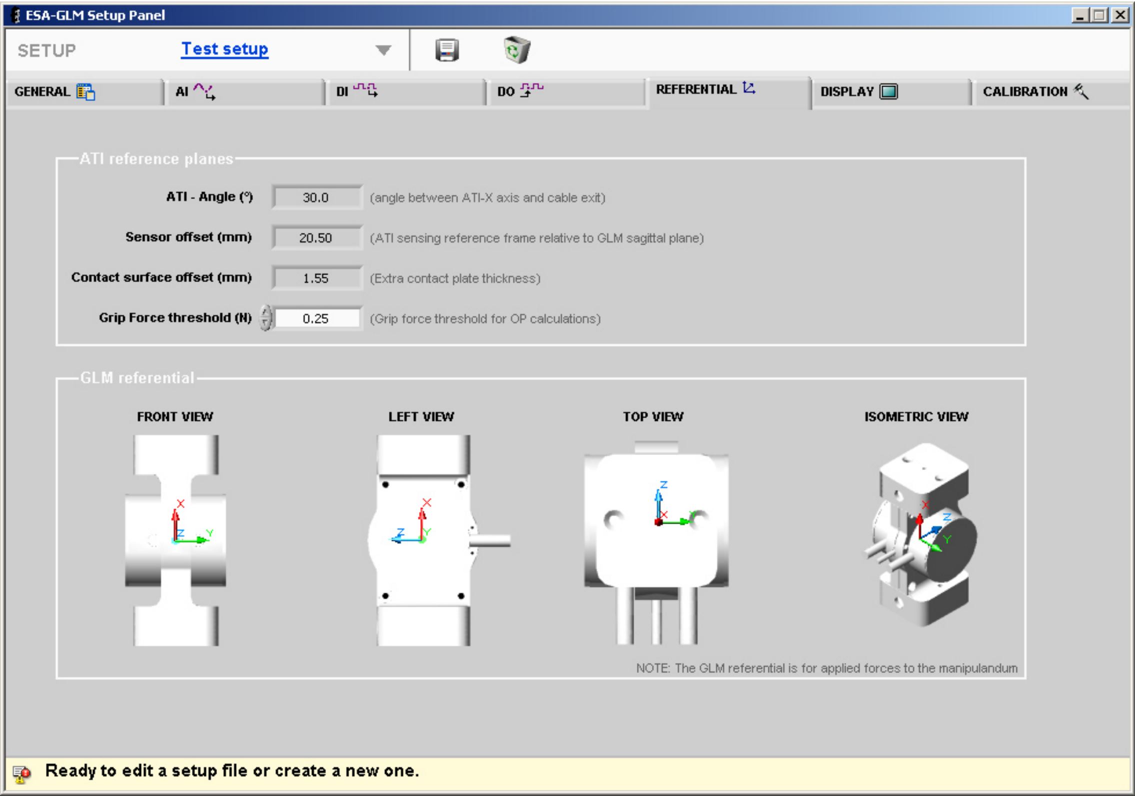


Figure 25. Setup panel (referential parameters) of the GLM-BOX software.

9.5.5.1. ATI reference planes

This section of the setup panel shows the parameters for the ATI forces and torques calculations according to the GLM referential. These parameters are used during conversion of raw data to calibrated data after acquisition. In order these parameters are:

- The 'rotation angle' (in degrees) of the ATI referential X axis relative to the ATI cable exit,

- The ATI sensor reference plane offset (in millimeters relative to the sagittal plane of the manipulandum)
- The contact surface offset (in millimeters relative to the ATI sensor reference plane).
- The Grip force threshold (N) is the minimal force along the z axis for center of pressure measurements (OPs). If the applied force is lower than specified, the center of pressure calculations are set to 'NaN' values.

9.5.5.2. GLM referential

This section of the setup panel displays the 3D-accelerometers referential on which the ATI signals will be aligned after calculations. This referential cannot be modified by the user.

9.5.6. Display parameters

The channels that can be monitored during acquisition are all analog inputs, all digital inputs and all digital outputs that have a defined label. The acquisition panel has three plot windows: a top, middle and bottom plot window. Each one can plot two channels. The display parameters tab is presented in Figure 26. It has one category detailed below:

9.5.6.1. Preferences (for acquisition panel)

In this section, the six channels to display in the acquisition panel and ordinates max/min values can be selected. This selection is the default selection. However, while running the acquisition panel, the user can modify the plot selection and when exiting the acquisition panel, the user selection of plots and max/min values will update the default selection.

The time axis of the plot windows in the acquisition panel can also be set in this section of the setup panel using the "Plots X scale range (s)" control. The default is 10 seconds. The plot windows of the acquisition panel behave as scrolling charts with a "time window" as set in this "plots X scale range (s)". However, if the acquisition duration is shorter than this latter setting, the acquisition plots X scale will be shortened to the smallest value. Also, at the end of the acquisition the X scales of the plots resize to show the full duration of the acquisition.

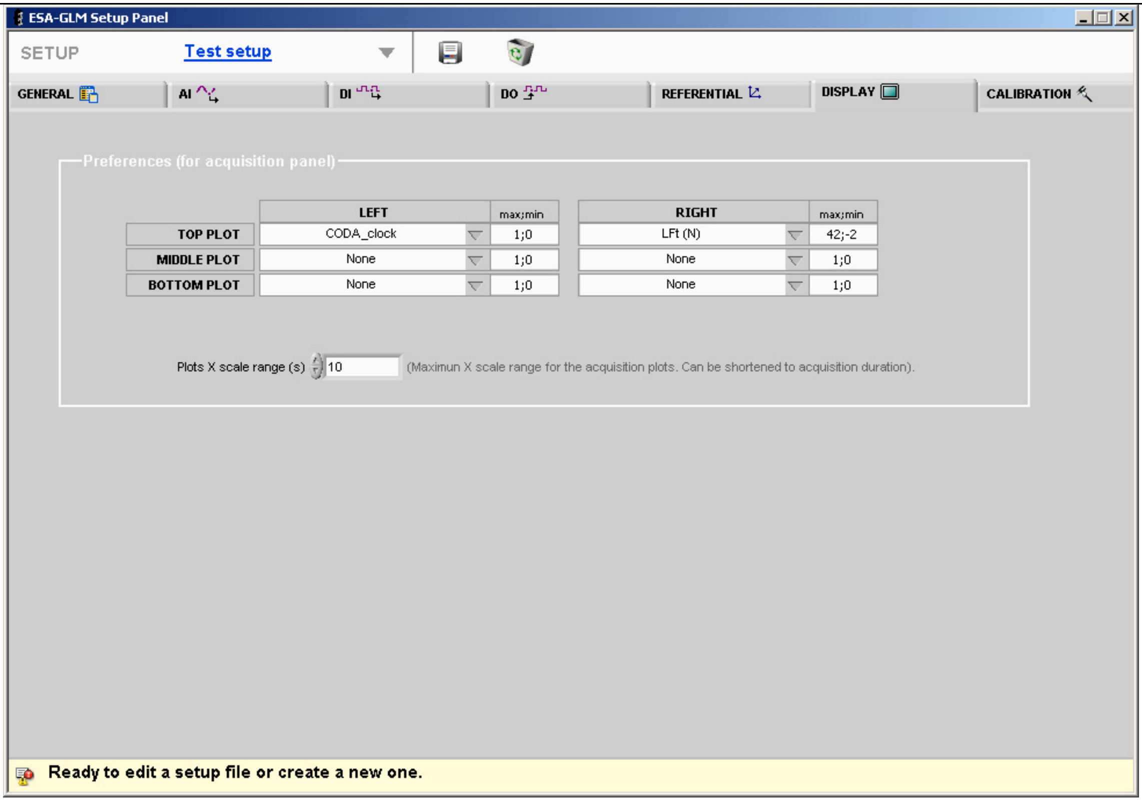


Figure 26. Setup panel (display parameters) of the GLM-BOX software.

9.5.7. Calibration

All calibration data for the GLM system are saved in the *dcf* file. This file contains the latest calibration values for your system. The calibration values are for the ATI transducers, the 3D-accelerometers (LowAcc), the environmental accelerometers (EnvAcc), the Left and Right MEv2 (Humidity_L; Humidity_R) the extra Analog Inputs. The calibration parameters tab is presented in Figure 27. It has two categories detailed below:

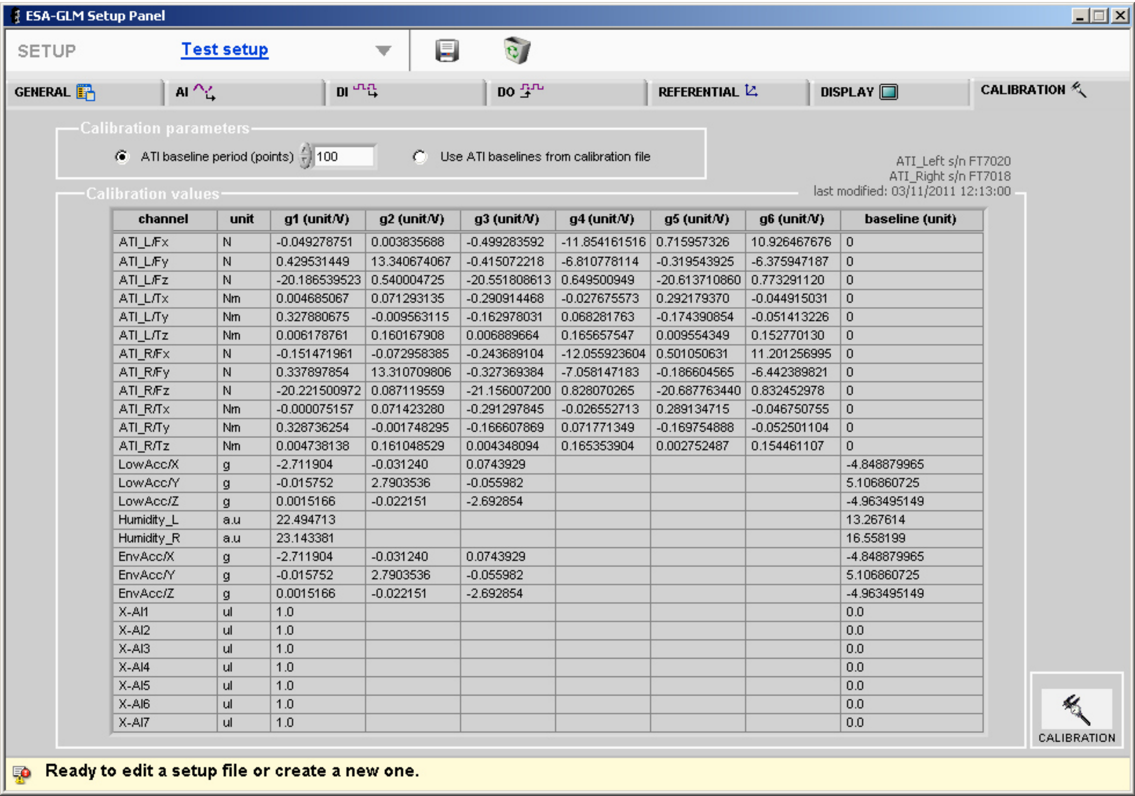
9.5.7.1. Calibration parameters

After an acquisition is done, the GLM software subtracts a "zero" baseline from the ATI data. This baseline can be either:

- The mean value of x points taken at the beginning of the acquisition
  To use this method, select 'ATI baseline period (pts)' and specify the number of points to average. In that case, make sure the manipulandum is in a steady state position and not touched at the beginning of each acquisition period.

- Fixed values specified in the calibration file.

To use this method, select 'use ATI fixed values…'. These fixed values can be set in the Calibration process or determined during preliminary experiments and manually entered in the calibration table (see the next section).



channel	unit	g1 (unit/V)	g2 (unit/V)	g3 (unit/V)	g4 (unit/V)	g5 (unit/V)	g6 (unit/V)	baseline (unit)
ATI_L/Fx	N	-0.049278751	0.003835688	-0.499283592	-11.854161516	0.715957326	10.926467676	0
ATI_L/Fy	N	0.429531449	13.340674067	-0.415072218	-6.810778114	-0.319543925	-6.375947187	0
ATI_L/Fz	N	-20.186539523	0.540004725	-20.551808613	0.649500949	-20.613710860	0.773291120	0
ATI_L/Tx	Nm	0.004685067	0.071293135	-0.290914468	-0.027675573	0.292179370	-0.044915031	0
ATI_L/Ty	Nm	0.327880675	-0.009563115	-0.162978031	0.068281763	-0.174390854	-0.051413226	0
ATI_L/Tz	Nm	0.006178761	0.160167908	0.006889664	0.165657547	0.009554349	0.152770130	0
ATI_R/Fx	N	-0.151471961	-0.072958385	-0.243689104	-12.055923604	0.501050631	11.201256995	0
ATI_R/Fy	N	0.337897854	13.310709806	-0.327369384	-7.058147183	-0.186604565	-6.442389821	0
ATI_R/Fz	N	-20.221500972	0.087119559	-21.156007200	0.828070265	-20.687763440	0.832452978	0
ATI_R/Tx	Nm	-0.000075157	0.071423280	-0.291297845	-0.026552713	0.289134715	-0.046750755	0
ATI_R/Ty	Nm	0.328736254	-0.001748295	-0.166607869	0.071771349	-0.169754888	-0.052501104	0
ATI_R/Tz	Nm	0.004738138	0.161048529	0.004348094	0.165353904	0.002752487	0.154461107	0
LowAcc/X	g	-2.711904	-0.031240	0.0743929				-4.848879965
LowAcc/Y	g	-0.015752	2.7903536	-0.055982				5.106860725
LowAcc/Z	g	0.0015166	-0.022151	-2.692854				-4.963495149
Humidity_L	a.u	22.494713						13.267614
Humidity_R	a.u	23.143381						16.558199
EnvAcc/X	g	-2.711904	-0.031240	0.0743929				-4.848879965
EnvAcc/Y	g	-0.015752	2.7903536	-0.055982				5.106860725
EnvAcc/Z	g	0.0015166	-0.022151	-2.692854				-4.963495149
X-AI1	ul	1.0						0.0
X-AI2	ul	1.0						0.0
X-AI3	ul	1.0						0.0
X-AI4	ul	1.0						0.0
X-AI5	ul	1.0						0.0
X-AI6	ul	1.0						0.0
X-AI7	ul	1.0						0.0

Figure 27. Setup panel (calibration) of the GLM-BOX software.

9.5.7.2. Calibration values

This section displays all calibration values and parameters from the calibration file. The calibration table shows the ATI, accelerometers, MEv2 humidity, XAIs calibration parameters.

- First column presents the channel name.
- The second column presents the unit of the signal after conversion.
- The six following columns present the gain factors (g1 to g6) for the channels.
- The last column presents the baselines (offsets) values.

This table is displayed for information only and allows verification of the calibration factors actually loaded.

Note that the gain factors for the ATI Mini-40 force and torque sensors are pre-established calibration matrices given by ATI. The gain factors for the accelerometers and the MEv2 sensors are established using the calibration procedure included in the GLM software (see paragraph 0).

The 'Calibration' button at the bottom right of the calibration tab opens the *Calibration panel*. All changes that will be made in the calibration panel will be saved in the *dcf* file. When the calibration file is updated, a copy of the preceding calibration values is stored in /GLM Device/Historical Records/ as *YYYYMMDD_ESAGLM_xxx_xxx*.dcf where YYYYMMDD corresponds to the date of creation of the calibration values.

9.6. Calibration panel

The calibration panel is presented has five parts:

- 'Edit parameters' to manually modify some calibration value or parameter.
- 'LowAcc calibration' to calibrate in 6 steps the 3D accelerometers.
- 'EnvAcc calibration' to calibrate in 6 steps the Environmental accelerometers.
- 'ATI baselines" to measure the ATI sensors baselines.
- 'Humidity calibration' to calibrate the MEv2 sensors output.

These sections are detailed below and are presented in Figure 28 to Figure 32.

9.6.1. Edit parameters

This section displays all calibration values and parameters from the selected calibration file. The calibration table shows the ATI, accelerometers and extra analog inputs calibration parameters.

- First column shows the channel name.
- The second column holds the unit of the signal after conversion.
- The six following columns give the gain factors (g1 to g6) for the channels.
- The last column shows the baselines (offsets) values.

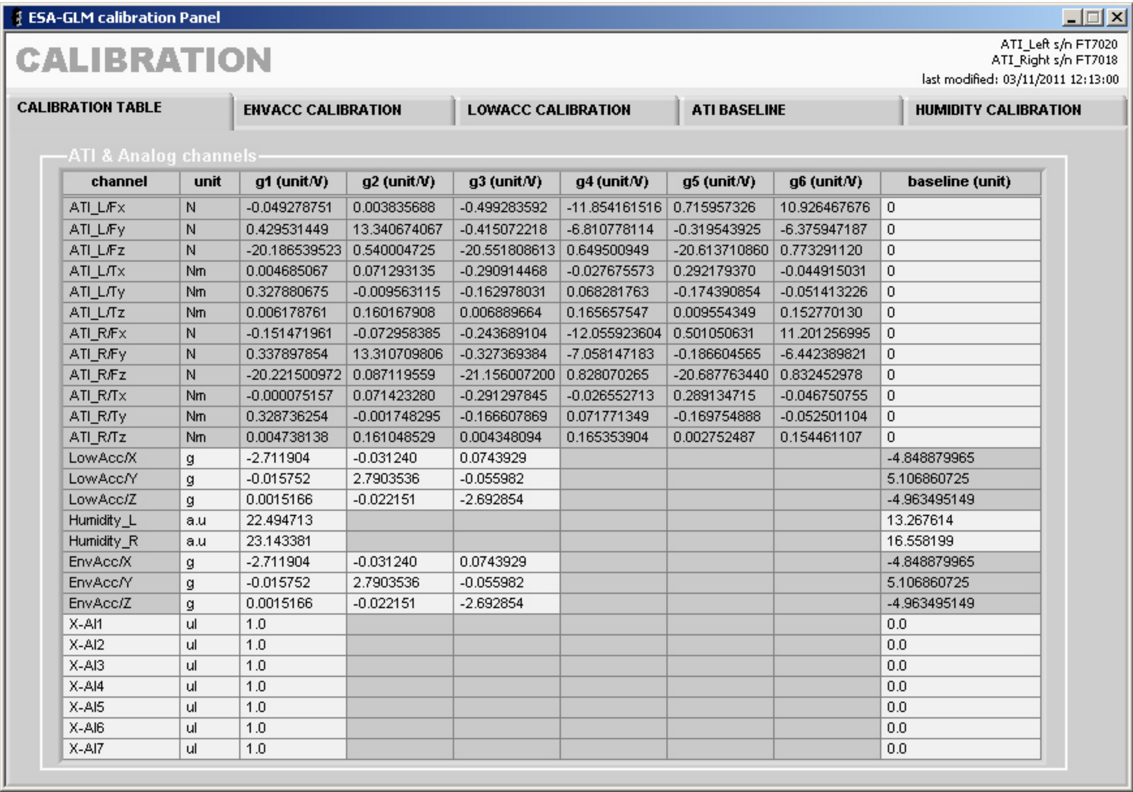
The ATI sensors calibration units and factors (g1 to g6) are provided by ATI. The serial number of each sensor is displayed above the calibration table. These parameters for the ATI sensors cannot be modified. Only the fixed_baselines values can be edited by user or measured from the 'ATI baselines' section of the calibration panel.

The accelerometers are calibrated using the next tabs in the calibration panel. This calibration process uses the gravitation as reference, Therefore their units should always be *g.* The calibration process will output 3 gain factors per channel and a baseline value by solving complex linear equations. This type of calibration provides more accuracy than using simple regressions. As a consequence, the calibration parameters for the accelerometers cannot be manually edited.

The Left and Right finger moisture channels are expressed in Volts or arbitrary units (a.u). These signals can be calibrated in the 'Humidity calibration' section of the panel such that extremes values of skin moisture match the sensors full scale and an arbitrary scale ranging from 0 to 100. Also, the user can manually enter a calibration unit, a factor and a baseline to change the data output of the MEv2 channels.

Note that all the gains are expressed in unit/Volts (*i.e* g/V for the accelerometers) and the baselines are expressed in the channel unit.

After an acquisition, data are saved as raw data (Volts) and as calibrated data. For all the analog inputs listed in the table of the calibration panel, GLM applies the calibration factors for the signals and in all cases, subtracts the baselines from the measures. The result is data expressed in their defined units:
calibrated data= [Volts*gain] – baseline.



channel	unit	g1 (unit/V)	g2 (unit/V)	g3 (unit/V)	g4 (unit/V)	g5 (unit/V)	g6 (unit/V)	baseline (unit)
ATI_L/Fx	N	-0.049278751	0.003835688	-0.499283592	-11.854161516	0.715957326	10.926467676	0
ATI_L/Fy	N	0.429531449	13.340674067	-0.415072218	-6.810778114	-0.319543925	-6.375947187	0
ATI_L/Fz	N	-20.186539523	0.540004725	-20.551808613	0.649500949	-20.613710860	0.773291120	0
ATI_L/Tx	Nm	0.004685067	0.071293135	-0.290914468	-0.027675573	0.292179370	-0.044915031	0
ATI_L/Ty	Nm	0.327880675	-0.009563115	-0.162978031	0.068281763	-0.174390854	-0.051413226	0
ATI_L/Tz	Nm	0.006178761	0.160167908	0.006889664	0.165657547	0.009554349	0.152770130	0
ATI_R/Fx	N	-0.151471961	-0.072958385	-0.243689104	-12.055923604	0.501050631	11.201256995	0
ATI_R/Fy	N	0.337897854	13.310709806	-0.327369384	-7.058147183	-0.186604565	-6.442389821	0
ATI_R/Fz	N	-20.221500972	0.087119559	-21.156007200	0.828070265	-20.687763440	0.832452978	0
ATI_R/Tx	Nm	-0.000075157	0.071423280	-0.291297845	-0.026552713	0.289134715	-0.046750755	0
ATI_R/Ty	Nm	0.328736254	-0.001748295	-0.166607869	0.071771349	-0.169754888	-0.052501104	0
ATI_R/Tz	Nm	0.004738138	0.161048529	0.004348094	0.165353904	0.002752487	0.154461107	0
LowAcc/X	g	-2.711904	-0.031240	0.0743929				-4.848879965
LowAcc/Y	g	-0.015752	2.7903536	-0.055982				5.106860725
LowAcc/Z	g	0.0015166	-0.022151	-2.692854				-4.963495149
Humidity_L	a.u	22.494713						13.267614
Humidity_R	a.u	23.143381						16.558199
EnvAcc/X	g	-2.711904	-0.031240	0.0743929				-4.848879965
EnvAcc/Y	g	-0.015752	2.7903536	-0.055982				5.106860725
EnvAcc/Z	g	0.0015166	-0.022151	-2.692854				-4.963495149
X-AI1	ul	1.0						0.0
X-AI2	ul	1.0						0.0
X-AI3	ul	1.0						0.0
X-AI4	ul	1.0						0.0
X-AI5	ul	1.0						0.0
X-AI6	ul	1.0						0.0
X-AI7	ul	1.0						0.0

Figure 28. Calibration panel (Edit tab) of the GLM software.

9.6.2. EnvAcc calibration

This calibration process applies to the following channels (the referential for the EnvAcc is related to the ZERO-G airplane referential):

EnvAcc/X
EnvAcc/Y
EnvAcc/Z

The calibration process consists in positioning the environmental accelerometer case in six successive positions and acquiring the data in these positions for two seconds. The measures are averaged. A picture displayed on the calibration panel illustrates each position. Each position corresponds to either +g, -g or zero for the channels. Through the six positions, for a given channel, one corresponds to +g, another to –g and four others to zero.

On the same panel, a plot window displays the average values as a function of *g*. The plot refers to the channel that is selected in the ring control below the plot. Arrows on the right and left of channel name allows cycling through the channels. When more than one point exists for a given channel, a linear regression is calculated giving the slope (sensitivity) and the offset. The equation of the linear regression is displayed above the plot. However the calibration matrix factors will be calculated only at the end of the full calibration process. They are not displayed at that level.

A control bar at the bottom of the picture and plot indicators holds three buttons and one indicator. From left to right:

- "Measure" starts the two seconds acquisition of the accelerometers channels. When acquisition is done, the average measures are plotted for each channel and the next picture prompting the user to place the environmental accelerometer case as shown is displayed. The text (step x/6) in the middle of the control bar increments giving the user an indication on the remaining steps in the calibration process.
- "To table". This control is enabled once when the calibration process is complete. All gains and baselines values calculated for the accelerometers are transferred to the calibration table.
- "Reset" clears the plots, empties the buffers and reset the calibration process to step 1/6.

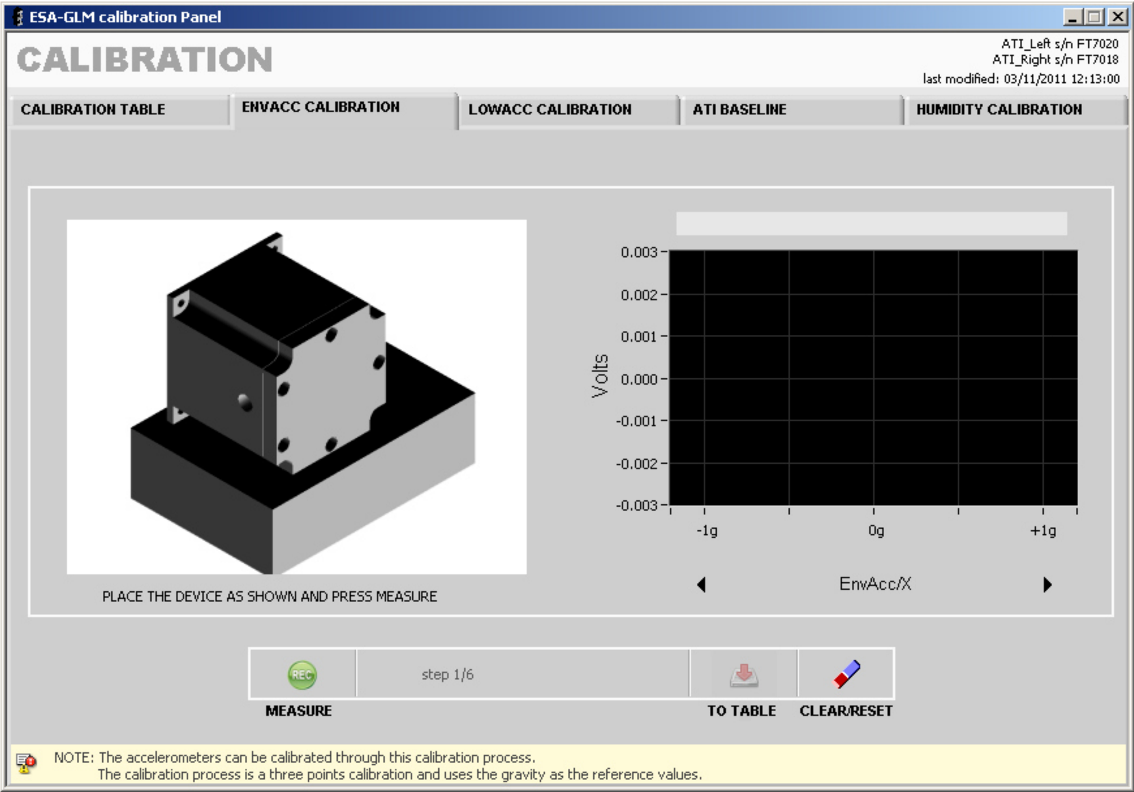


Figure 29. Calibration panel (EnvAcc calibration) of the GLM software.

9.6.3. LowAcc calibration

The accelerometers are located inside the GLM manipulandum. This calibration process applies to the following channels:

LowAcc/X
LowAcc/Y
LowAcc/Z

The calibration process consists in positioning the manipulandum in six successive positions and acquiring the data in these positions for two seconds. The measures are averaged. A picture displayed on the calibration panel illustrates each position. Each position corresponds to either +g, -g or zero for the channels. Through the six positions, for a given channel, one corresponds to +g, another to –g and four others to zero.

On the same panel, a plot window displays the average values as a function of *g*. The plot refers to the channel that is selected in the ring control below the plot. Arrows on the right and left of channel name allows cycling through the channels. When more than one point exists for a given channel, a linear regression is calculated giving the slope (sensitivity) and the offset. The equation of the linear regression is displayed above the plot. The sensitivity should be around 0.3 V/g. However the calibration matrix factors will be calculated only at the end of the full calibration process. They are not displayed at that level.

A control bar at the bottom of the picture and plot indicators holds three buttons and one indicator. From left to right:

- "Measure" starts the two seconds acquisition of the accelerometers channels. When acquisition is done, the average measures are plotted for each channel and the next picture prompting the user to place the manipulandum as shown is displayed (see Table 11). The text (step x/6) in the middle of the control bar increments giving the user an indication on the remaining steps in the calibration process.
- "To table". This control is enabled once when the calibration process is complete. All gains and baselines values calculated for the accelerometers are transferred to the calibration table.
- "Reset" clears the plots, empties the buffers and reset the calibration process to step 1/6.

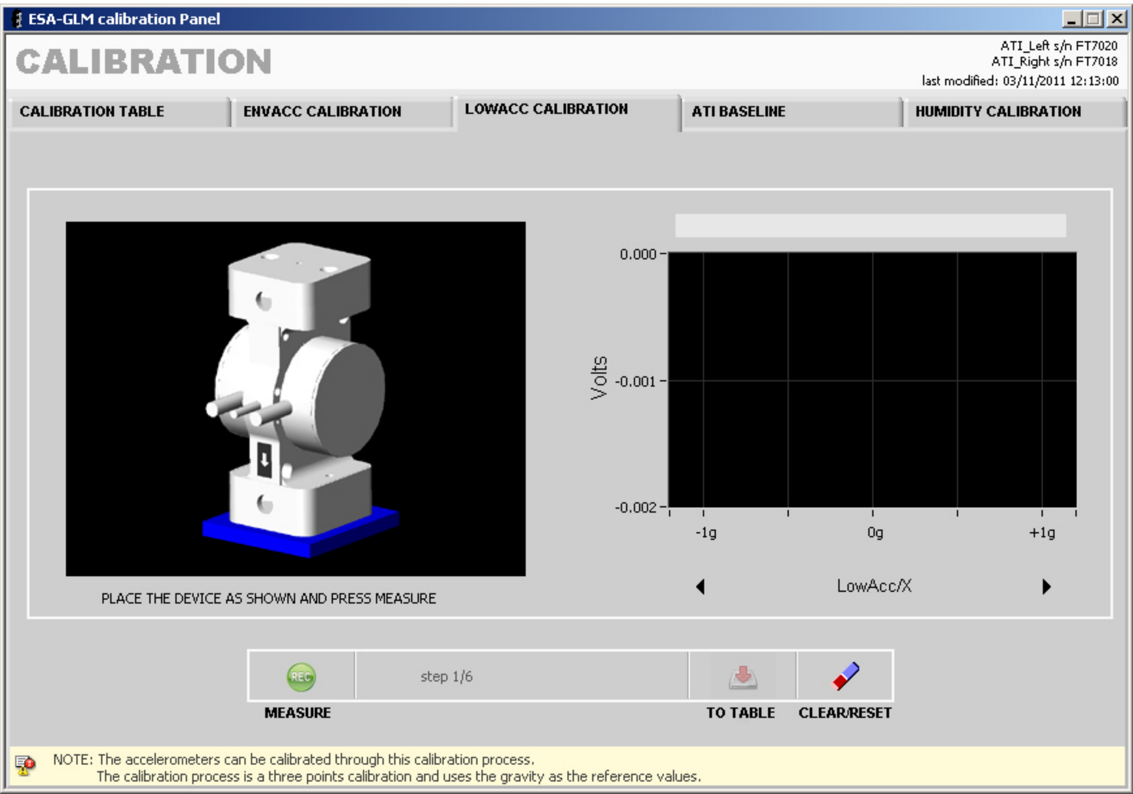
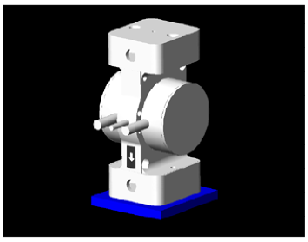
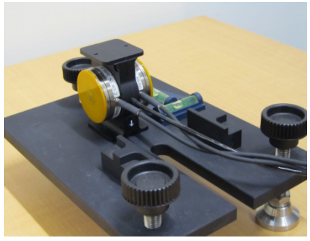
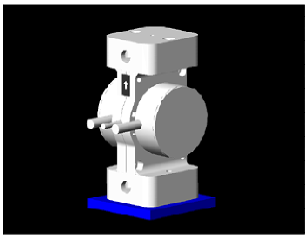
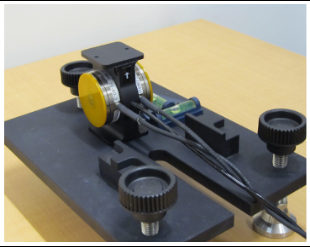
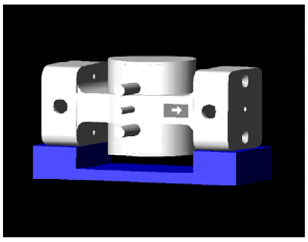
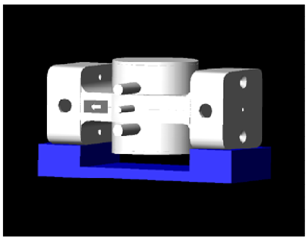
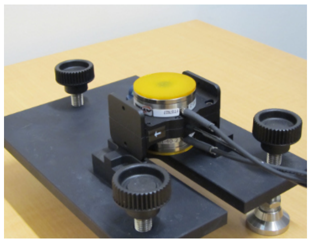
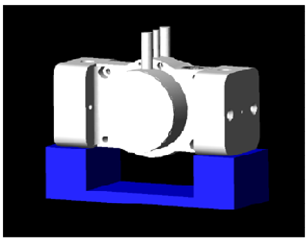
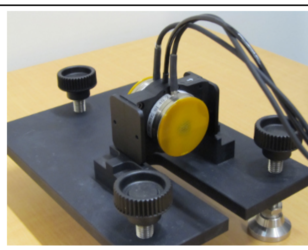
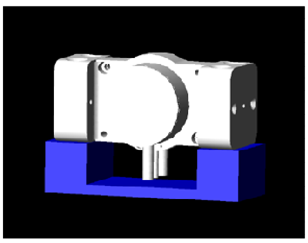
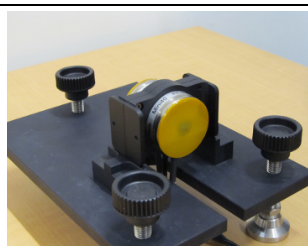


Figure 30. Calibration panel (LowAcc calibration) of the GLM software.

Table 11. Accelerometers calibration pictures in GLM frame of reference

Illustration used in software	referential	Real picture
	X+	
	X-	
	Y+	
	Y-	
	Z+	
	Z-	

9.6.4. ATI baselines measurement

The baseline measurement process consists in positioning the manipulandum straight, untouched and measure the 6 channels average output from both ATI sensors during 2 seconds

A control bar at the bottom of the picture and plot indicators holds three buttons and one indicator. From left to right:

- "Measure" starts the two seconds acquisition of the ATI channels. When acquisition is done, the average measures are transformed in calibrated units using the ATI calibration matrix.
- "To table". This control is enabled once when the calibration process is complete. All baselines values calculated for the ATI sensors are transferred to the calibration table.
- "Reset" clears the tables, empties the buffers and reset the calibration process.

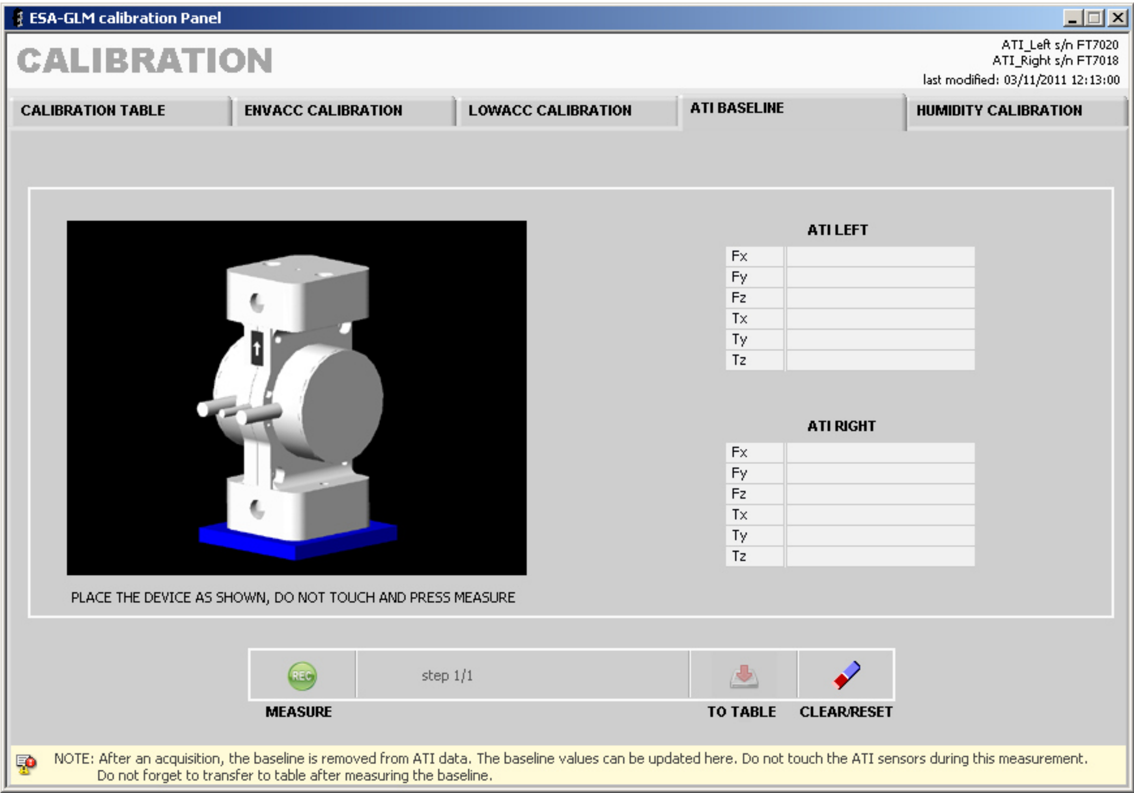


Figure 31. Calibration panel (ATI baseline) of the GLM-BOX software.

9.6.5. Humidity calibration

The humidity calibration process is a two points calibration. First, the user defines the minimum value by leaving the sensors untouched, then the user defines the maximum value by stimulating the MEv2 sensors with 'wet' fingers.

Thus, it is a three steps process:
First step, measure without touching the MEv2 sensors,
Second, humidify the fingers with a solution equivalent to sweat;
Third, measure the MEv2 sensors with 'wet' fingers.

These minimum and maximum vales are arbitrary set to 0 and 100.

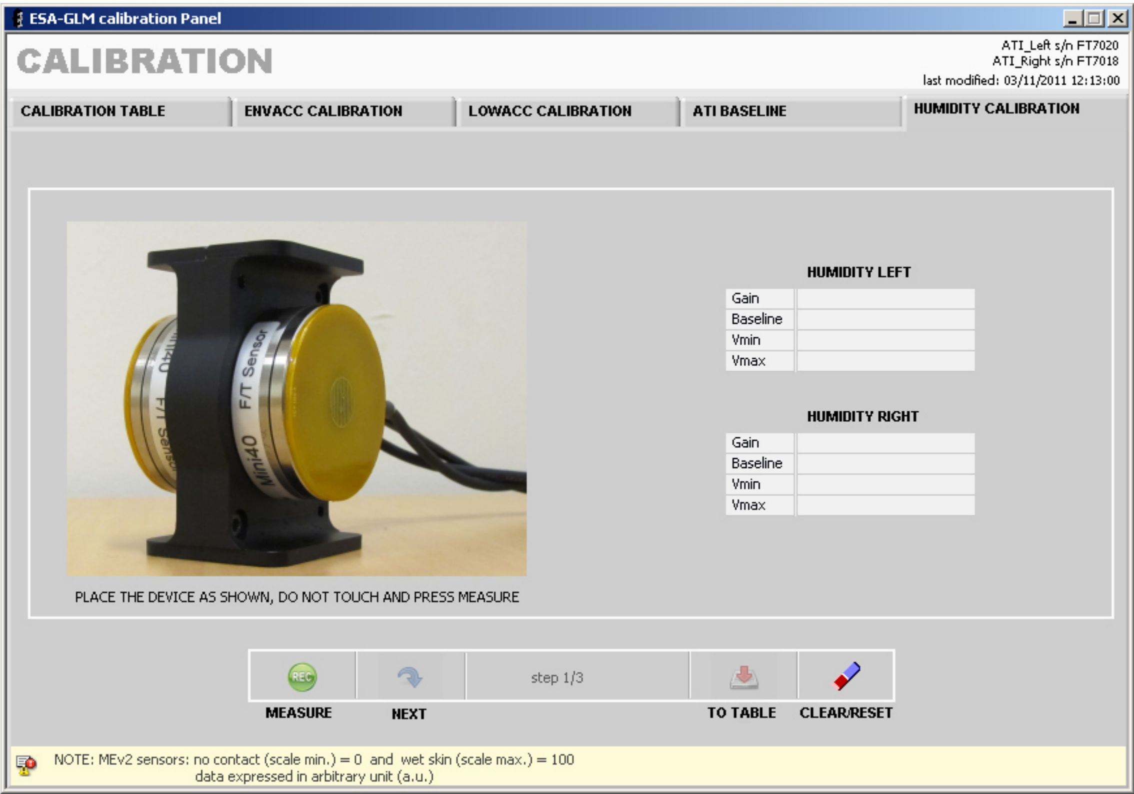


Figure 32. Calibration panel (Humidity calibration) of the GLM software.

A control bar at the bottom of the picture and plot indicators holds three buttons and one indicator. From left to right:

- "Measure" starts the two seconds acquisition of the ATI channels. When acquisition is done, the average measures are transformed in calibrated units using the ATI calibration matrix.
- "Skip" to go to the next step when no measurement is required.

- "To table". This control is enabled once when the calibration process is complete. All gains and baselines values calculated are transferred to the calibration table.
- "Reset" clears the tables, empties the buffers and reset the calibration process to step 1/3.

9.7. Acquisition panel

The 'acquisition panel' is presented in Figure 33 and is described below:

In the top part of the panel:

- Enter the file name for the next acquisition. A three digit number will be added to the file name. This number ensures the file name is unique in the directory where acquisition files must be saved and no overwriting can occur.
- The protocol used for the acquisition is displayed. To select another protocol, go to the main panel by exiting the acquisition panel. To edit or check the protocol, go to the setup panel.
- In the setup panel, the directory where acquisition files are saved has been specified. If this folder cannot be found, a warning message is displayed and the acquisition files will be saved in the default system directory.
- The "START" or "REC" button begins the acquisition. If the acquisition is a triggered acquisition, GLM waits for the trigger signal before collecting the data. The data acquisition is synchronized by using the analog sample clock as the sample clock for the digital inputs/outputs. **The data are automatically saved after the acquisition completes**.
- The "ABORT" button is enabled as soon as the "START" has been pushed. If "ABORT" is pressed before the acquisition completes, the acquisition stops, data are discarded, plots are cleared, no file is saved, the file name is not incremented and GLM gets ready for a new acquisition.
- The "PREVIEW" button is enabled as soon as the acquisition completes and the data have been saved in file. Pressing this button opens a 'VIEW' window where the last acquired data are displayed in calibrated units.

In the bottom right of the panel:

- The elapsed and remaining time of the acquisition is displayed in seconds. The remaining time is calculated using information from the protocol.

In the center of the panel:

The acquisition panel has three plot windows: a top, middle and bottom plot window. Each one can plot two channels. The channels that are displayed are the defaults as set in the setup panel for the current protocol. The channels to display can be modified using the control rings on the top left and right of each plot window.

The Abscissa (time in seconds) is common for all the plot windows and is displayed at the bottom plot window. The abscissa scale range is set in the setup panel.

All plot windows behave as scrolling charts and at the end of the acquisition the abscissa resizes to show the full duration of the acquisition.

On the left and right of each plot window, the ordinates extremes of each plot window are +5 and -5 by default. These values can be edited if needed and will overwrite the defaults for the next time for the current setup.

After the acquisition completes, all the acquired data are saved as raw data in a text file (.txt extension) and as calibrated data in a text file (.glm extension). Both files have the same name, are saved in the same directory and differ only by the extension. Both files are tab separated and can easily be opened with any text editor or Microsoft® Office Excel.

In the glm file, calibrated data are calculated as follow:

- For ATI channels: **Y** = **AX**
  where **Y** is the output **A x Vector**, **A** is the *n*-by-*k* matrix of calibration, **X** is the ATI vector with k elements, n is the number of rows in **A**, and k is the number of columns in **A** and the number of elements in **Vector**. The calculation is:
  $$yi = \sum_{j=0}^{k-1} aij \times j \qquad \text{for } i = 0, 1, 2, \ldots, \text{n-1}$$
  This calculation is done for each sample.
  Subsequently, a baseline is subtracted from each sample of the ATI data. The baseline is either fixed values or the mean values calculated on part of the data set (see the setup section).

- The same calculation is applied to the accelerometers signals. The subtracted baseline is the fixed values calculated in the calibration process for LowAcc and EnvAcc accelerometers (see section 0).

- For the other analog channels: Calibrated data= (Volts*Gain) - baseline

- For all other channels: No calculation is applied.

Both *.txt and *.glm files have channels saved as columns and samples as rows. The first row is the channels labels including their units. In total, the number of rows is *n*+1, where *n* is the number of samples. Extra information is also appended at the end of the first row: creation date, DO pattern name and sequence index, calibration file timestamp.

The first column is the time in seconds, all other columns are the channels or calculations (see labels in first row of files for details).

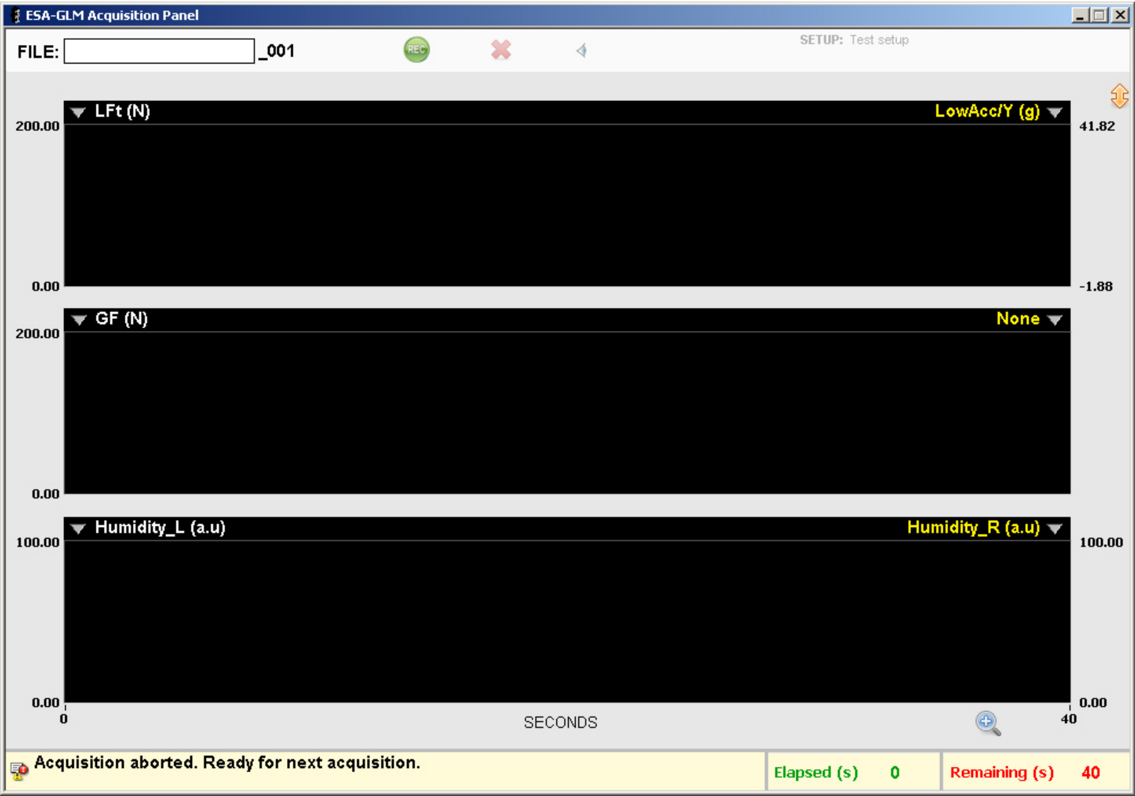


Figure 33. Acquisition panel of the GLM software.

9.8. View panel

The 'view panel' is presented in Figure 34 and is described below:

In the top of the panel, click the 'OPEN' button, a browse window pops up. Select the *.glm file to open. When a file is open, its name and information is displayed in the top right corner of the view panel.

The view panel has three plot windows: a top, middle and bottom plot window. Each one can plot two channels. The channels that are displayed can be selected using the control rings on the top left and right of each plot window. The Abscissa (time in seconds) is common for all the plot windows and is displayed at the bottom plot window. The abscissa scale range is the full duration of the acquisition set. On the left and right of each plot window, the unit of the selected channel is displayed. The ordinates extremes of each plot window adapts to the data that is displayed. However the ordinates extremes can be edited if needed.

At the bottom, a zoom control allows to reduce the time window that is displayed. To zoom: click on the zoom control, select the desired portion of the traces using the mouse on any of the three plot window. The plots are zoomed when the mouse is released. Use the scroll bar on the abscissa at the bottom of the panel to scroll the traces. To return to the full traces view, click the zoom control again.

When the mouse is placed on one of the three graph panel, a tip strip displays the average, min and max values of the plots displayed.

Figure 34**. View panel of the GLM software.**

9.9. Scope panel

The 'scope panel' is presented in Figure 35 and is described below:

The scope panel is used to test the integrity of the setup, analog and digital inputs. In scope mode, the GLM acquires all inputs continuously and plots them immediately. The acquisition frequency is the one specified in the setup. Two plot charts are available in scope mode and each one can display any of the configured analog and digital inputs.

- The scope panel displays the acquisition frequency in the top part of the panel.
- The display can be 'frozen' at any time using the "PAUSE" button.
- The channel selection for each plot can be modified at any time.
- The time scale of the plot charts can be modified at any time.

- The Y scales of each plot can be manually edited or can adapt to the signal input by selecting 'autoscale' on the top right of each plot window.
-

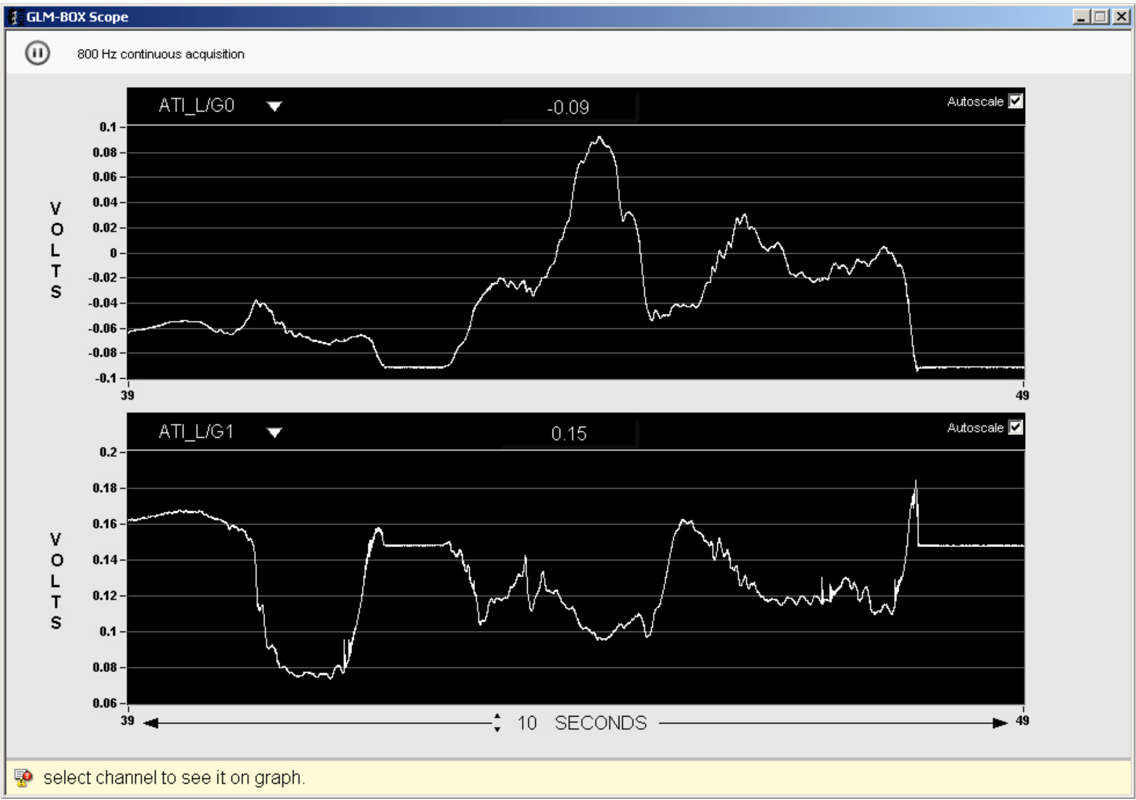


Figure 35. Scope panel of the GLM software.

9.10. Re-calibration panel

The 're-calibration panel' is presented in Figure 36 and is described below:

The Re-calibration panel can be accessed in the *Advanced* menu from the main panel of GLM software. It allows to re-convert a *.txt file (raw acquisition data) into its associated *.glm file (calibrated data) using any GLM calibration (*dcf*) file. This panel is like an *add-on* to the GLM software. This process panel can be interesting in some case where incorrect calibration factors or baselines have been applied to your data the first time.

To re-save *.glm files:

- Browse to the directory where the *.txt files are saved
- Select the calibration file (*dcf* file) to use (current calibration file and Historical records will be listed and can be selected)
- Select the method you want to use to subtract the baselines

- Select the file(s) you want to convert in the files list on the left of the panel. Use CTRL+ or SHIFT+ to select more than one file.
- Press the "RE-CALIBRATE" button to start the process.

All created *.glm files overwrite existing *.glm files in the directory where raw data are opened.

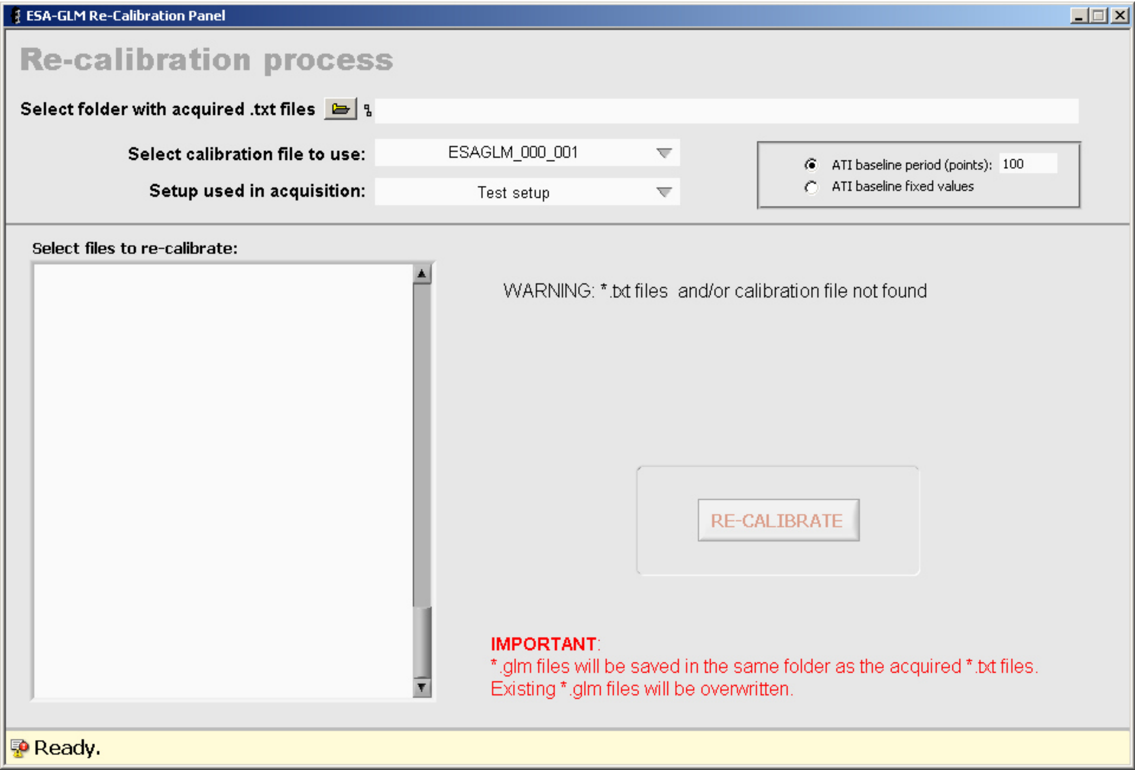


Figure 36. Re-calibration panel of the GLM software.

9.11. MEv2 Verification Utility

The 'MEv2 Verification Utility' is presented in Figure 37 and is described below. The MEv2 verification utility can be accessed in the *Advanced* menu from the main panel of GLM-ESA software. It allows the verification of the MEv2 outputs. The Utility is used to assess the correlation between MEv2 output and corneometer value at different grip force levels.

The top two graphs display the left (thumb finger) and right (index finger) MEv2 readout according to the state of the switch MEv2 digital line which is toggled at the half acquisition period under software control. The bottom display shows the grip force applied on the manipulandum in relation to the target force as selected in its sub-menu in the top-left corner of the display. Two led indicators in the top right corner of the display are lit up when the fingers are correctly placed on the MEv2 sensors. The right part panel shows the signal measures as average and standard deviations.

Press the "START MEv2 MEASURE" to perform a measure on both fingers when the target grip force is reached and maintained. If data are acceptable, press the "Save Results" button to enter the corresponding Corneometer readings and save the data and results in text files.

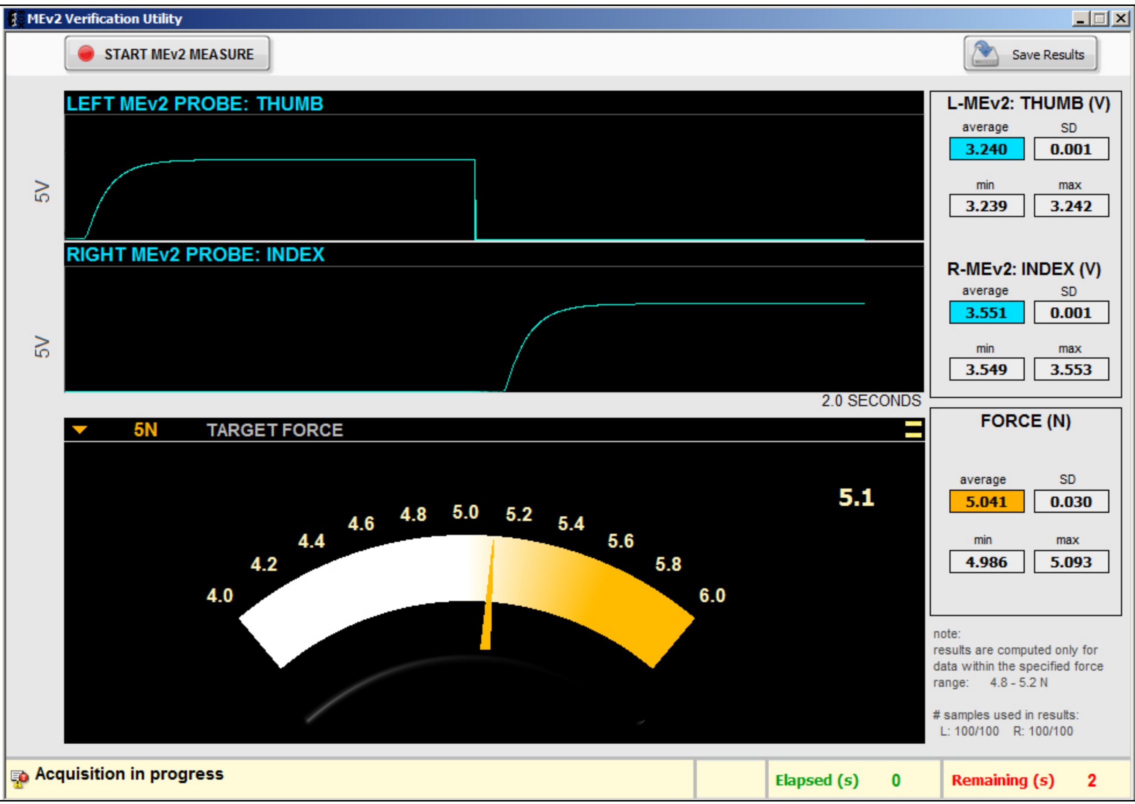


Figure 37. MEv2 Verification Utility panel of the GLM-ESA software.